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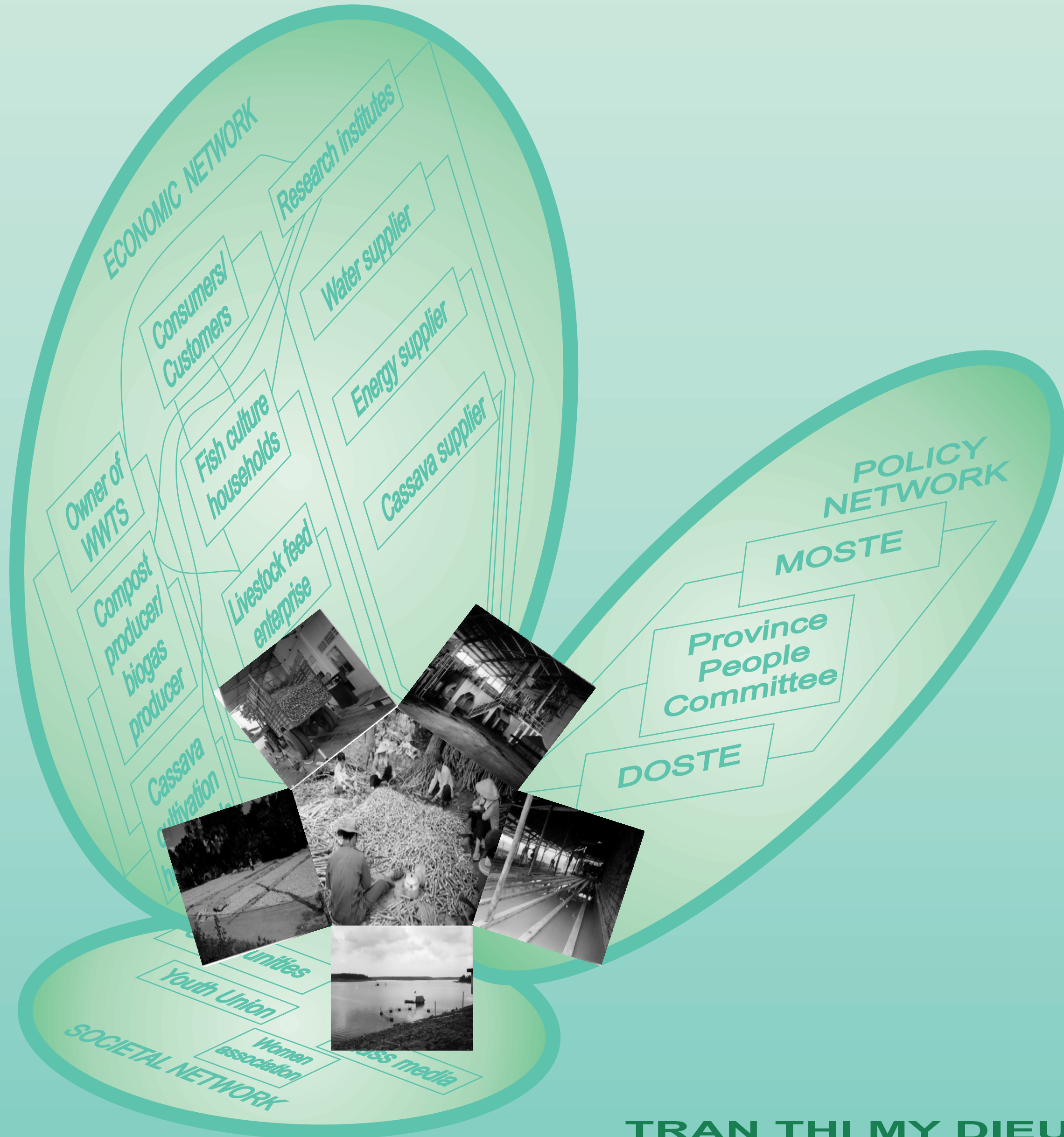
With several decades of experiences on environmental protection behind us, Vietnam recognizes that with the end-of-pipe approach, we have been treating environmental symptoms instead of the disease. It is of course important to have technological (end-of-pipe) solutions to overcome existing pollution problems and to deal with accidental pollution event. But it is essential and more environmental friendly as well as economically to prevent wastes form being generated or to reuse their valuable materials. Working towards more sustainable development of (agro-) food processing industry in vietnam, this book provides a methodology to analyze and assess possibilities and approaches to move existing (food processing) industrial systems towards zero waste industrial ecosystems. A major part of this book is dedicated to the application of the developed methodology on existing food processing industrial system in vietnam. The case studies analyze how and to what extent the existing food processing industry in vietnam could be transformed into more environmental sound direction. Based on theoretical elaboration and supporting empirical evidence, the book reflects on the applicability of Industrial Ecology Concepts in Vietnam.

BIEN HOA I - INDUSTRIAL ZONE

GREENING FOOD PROCESSING INDUSTRY IN VIETNAM
PUTTING INDUSTRIAL ECOLOGY TO WORK
TRAN THI MY DIEU

GREENING FOOD PROCESSING INDUSTRY IN VIETNAM

PUTTING INDUSTRIAL ECOLOGY TO WORK



TRAN THI MY DIEU

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Greening Food Processing Industry in Vietnam:
Putting Industrial Ecology to Work

Promotors:

Prof.dr.ir. A. P. J. Mol	Professor of Environmental Policy Environmental Policy Group, WUR
Prof.dr.ir. W. H. Rulkens	Professor of Environmental Technology Sub-department of Environmental Technology, WUR

Promotion committees:

Prof.dr.ir. M.A.J.S. van Boekel	Wageningen University
Prof.dr. P. van Beek	Wageningen University
Dr.ir. C. S. A. van Koppen	Wageningen University
Dr. Nguyen Trung Viet	Vanlang University, Vietnam

Greening Food Processing Industry in Vietnam:
Putting Industrial Ecology to Work

Tran Thi my Dieu

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Preface

The food processing industry is a large, rapidly growing sector in Vietnam and plays a vital role in its country's economic development. However, its development currently seems to go hand-in-hand with environmental deterioration. Up to now, most research and development activities, regulations and policy measures related to environmental management of (food processing) industry in Vietnam have mainly been focussing on what to do with wastes and emissions after they had been created. However, with several decades of experiences on environmental protection behind us, Vietnam recognizes that with the end-of-pipe approach, we have been treating environmental symptoms instead of the diseases. It is of course important to have technological (end-of-pipe) solutions to overcome existing pollution problems and to deal with accidental pollution events. But it is essential and more environmental friendly as well as economically to prevent wastes from being generated or to reuse their valuable materials. Working towards more sustainable development of (agro-) food processing industry in Vietnam, this book provides a methodology to analyze and assess possibilities and approaches to move existing (food processing) industrial systems towards zero waste industrial ecosystems. A major part of this book is dedicated to the application of the developed methodology on existing food processing industrial systems in Vietnam. The case studies analyze how and to what extent the existing food processing industry in Vietnam could be transformed into more environmentally sound direction. Based on theoretical elaboration and supporting empirical evidence, the book reflects on the applicability of Industrial Ecology Concepts in Vietnam.

This book is realized with the help of many people for which I am very grateful. It profits especially from the expertise, experiences and ideas of my promotors: Prof. Dr. Ir. Arthur P. J. Mol, Chair of Environmental Policy Group, Department of Social Sciences and Prof. Dr. Ir. Wim Rulkens, Head of Sub-Department of Environmental Technology, Wageningen University. I greatly appreciate the valuable advice, guidance and encouragement of my promoters from the beginning till the end of my research. Without their critical and detailed comments on design, analysis and writing, this dissertation would not have been what it has become now. There are no words to entirely express my thankfulness to all what my promoters have done to enrich my knowledge and teach me how to conduct scientific research.

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Special thanks go to Phan Van Het and Hoang Hung (Dong Nai DOSTE), Md. Doan Thi Toi, Le Van Khoa and Tran Phuc Tue (Ho Chi Minh City DOSTE), Mr. Hoang (Tay Ninh

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It was my pleasure to work within the Environmental Policy Group of Wageningen University. I owe many thanks to Peter Oosterveer, Gert Spaargaren, Loes Maas, Kris van Koppen, Bas van Vliet, Hans Bruyninckx and Astrid Hendriksen for their interesting lectures and excursions, from which I learned a lot. Special thanks go to Corry Rothuizen and Willy Baak for all the arrangements that they had to make for me. I acknowledge Susan Martens, Er Ah Choy, Victor Sabandeja, Synara Sanchez, Zhang Lei, Peter Ho, Liu Yi, Feng Yecheng, Luciana Melchert, Ajchara Wattanapinyo, Orathai Chavalparit, Sander van den Burg and Stein Nanke for their cordiality and friendship. My gratitude to all members of Loes Maas' family and Joost van Buuren for their hospitality and kindness to all Vietnamese students is beyond words.

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I am proud to be a daughter of my father, Tran Van Ghe and my mother, Pham Thi Ngoc Bich. Without their love, understanding and encouragement over the years, I would never have come to this academic point. Many thanks to my younger brothers, Tran Quoc Truong and Tran Quoc Tri, my elder sister, Tran Thi My Hien, her husband, Phan Thien and her son, Kelvin, and my aunt, Tran Thi Thu Thao for their affection towards me.

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Wageningen March, 2003.

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ABBREVIATIONS

BOD	Biochemical Oxygen Demand
CENTEMA	Center for Environmental Technology and Management, Vietnam
CN^-	Cyanide
CO_2	Carbon Dioxide
COD	Chemical Oxygen Demand
DIZA	Dong Nai Industrial Zone Authority
DO	Diesel Fuel Oil
DOSTE	Department of Science, Technology and Environment
EIA	Environmental Impact Assessment
EIP	Eco-Industrial Park
EMT	Ecological Modernization Theory
EOP	End-of-Pipe
EPA	Environmental Protection Agency of the United Nation
EPZ	Export Processing Zone
FAO	Food and Agriculture Organization of the United Nation
FO	Fossil Fuel Oil
GDP	Gross Domestic Product
HCMC	Ho Chi Minh City
HEPZA	Ho Chi Minh City Export Processing Zone and Industrial Zone Authority
HRT	Hydraulic Retention Time
IE	Industrial Ecology
IET	Industrial Ecology Theory
IHWTP	Industrial Hazardous Waste Treatment Plant
IIDCs	Industrial Zone Infrastructure Development Companies
IZ	Industrial Zone
JICA	Japan International Cooperation Agency
LEP	Law on Environmental Protection
MARD	Ministry of Agriculture and Rural Development
MOSTE	Ministry of Science, Technology and Environment
NEA	The National Environmental Agency of Vietnam
NGOs	Non-Government Organizations
$N\text{-}NH_3$	Ammonium Nitrogen
$N\text{-}NO_3^-$	Nitrate Nitrogen
N-Org	Organic Nitrogen
OECD	Organization of Economic Cooperation and Development
PCs	People Committees
$P\text{-}PO_4^{3-}$	Phosphate
SKERs	South Key Economic Regions
SO_4^{2-}	Sulfate
SS	Suspended Solid
TDS	Total Dissolved Solid
UASB	Up-flow Anaerobic Sludge Blanket
ULI	Urban Land Institute
UNEP	United Nations Environmental Program
UNIDO	United Nations Industrial Development Organization
US EPA	United State Asian Environmental Partnership
VAT	Value Added Tax
Vinacafe	Vietnam National Coffee Corporation
Vinamilk	Vietnam Dairy Products Company
Vinasugar 2	Vietnam Sugar and Sugar Corporation 2
VSS	Volatile Suspended Solid
WHO	World Health Organization
WWTS	Wastewater Treatment System

CHAPTER 1

INTRODUCTION

1.1 DEVELOPMENT OF FOOD PROCESSING INDUSTRY IN VIET NAM

Thanks to the economic reform policy, Vietnam has managed to clear off the stagnation in production and business operation of the period 1986-1990, step by step overcoming the difficulties that hamper further development and gradually moving into an accelerated industrialization and modernization process (Hao, 2003). The industrial sector has made a considerable contribution to national development. The gross industrial output of 1995 was 103.37 thousand billion VND (equivalent to 9.48 billion USD), of 1998 it was 150.68 thousand billion VND (equivalent to 11.60 billion USD) and of 2000 it was estimated to be approximately 200 thousand billion VND (equivalent to 14.23 billion USD) (Hao, 2003)[1]. During the period of 1996-2000, the annual industrial gross output (at constant 1994 prices) was 13.56% (General Statistical Office of Vietnam, 2001). The industrial production of some key economic areas reached an even higher economic growth in 2000, such as Ho Chi Minh City (16.5%), Hai Phong (19.7%), Da Nang (20.8%) and Dong Nai (29.1%) (German Chamber of Commerce, 2002).

Though the emphasis in industrial development before *Doi Moi*[2] had traditionally been on heavy industry, now with the increasing importance of a market-economy system, the light industry with consumer products such as food processing is becoming more dominant (Minot, 1998; Frijns et al., 2000; Dung, 2002). The food processing industrial sector is a large and rapidly growing industry and plays an important role in Vietnam's economic development, for several reasons. First, food processing industries process agricultural raw materials to provide new products for human life and simultaneously help to raise income of farmers, who used to be poorer than non-farmers. Second, food processing companies normally generate more employment than other manufacturing sectors as it is relatively labor-intensive. Thus, if located in rural areas, they create jobs for villagers, where poverty is often concentrated. Finally, the food processing industrial sector increases the added value of agricultural products before exportation and thus it contributes to economic development. In a study on food processing industry in Vietnam during the last decade, Dung (2002) indicated that in 1997, the value added in the food processing industrial sector is estimated to be about 2.0 billion USD. This represents about 8.8 percent of the gross domestic product (GDP) and 35.5 percent of industrial added value. Furthermore, the contribution of food processing industry to the GDP appears to be growing (Box 1.1). These values indicate how important the role of food processing industry is in economic and industrial development in Vietnam. This is becoming even more relevant from now onwards, as it is Vietnam's development strategy to become one of the top agricultural countries in the world by the year 2010[3]. Main products of

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[1] Exchange rates were 1 USD = 10,900 VND (1994); 1 USD = 12,983 VND (1998) and 1 USD = 14,050 (2000).

[2] This term was coined in 1986 for a transition from the centrally planned command economy to a "market economy with socialist direction".

[3] Vietnamese government continues to highlight the role and important position of agricultural and rural economy in the national economy of Vietnam in the process of industrialisation and modernisation of the country because: (1) rural area is the living and working place of 70-80% of the population; (2) agricultural and rural economy continues to contribute considerably to the GDP of the country; (3) agriculture is an important source for foreign exchange, (4) agriculture ensures food security for the country, (5) agriculture has a large market for industry, (6) stability in rural areas play a decisive role in stabilising the socio-economic conditions of the country.

food processing industry consist of tapioca starch, cane sugar, coffee, milk, beverage, canned fruits, seafood, tea, vegetable oil, fish sauce, milling rice and maize, etc.

Box 1.1 Contribution of food processing industry to the GDP (gross domestic product) in Vietnam

	Gross domestic product	Industrial value added	Food processing value added	Food processing as percentage of GDP (%)	Food processing as percentage of industry (%)
1991	31,286	6,042	2,100	6.7	34.8
1992	33,991	6,921	2,346	6.9	33.9
1993	36,735	7,766	2,602	7.1	33.5
1994	39,982	8,771	2,994	7.5	34.1
1995	43,797	9,998	3,460	7.9	34.6
1996	47,888	11,448	4,000	8.4	34.9
1997	52,198	12,960	4,600	8.8	35.5
Annual growth	8.9%	13.6%	14.0%		

Source: Minot, 1998.

Vietnam is ranked 16th in terms of cassava production in the world (Box 1.2). Cassava plays an important socio-economic role as a secondary crop in Vietnam (Kim et al., 2003). Preliminary statistical data in the year 2000 show that Vietnam has 234,900 ha of cultivation area of cassava[4] with average yields of 8.67 tons/ha/year. During the coming years, the cassava planting area in Vietnam will not increase, but remains within the range of 200,000 to 300,000 ha. Nevertheless cassava yields will increase by the adoption of new cassava varieties and more intensive cultural practices (Bien et al., 2003; Kim et al., 2003).

Box 1.2 Total world cassava production of each country

No.	Countries	Cassava production (tons/year)		
		1999	2000	2001
1	Nigeria	32,697,000	33,854,000	33,854,000
2	Brazil	20,864,340	23,335,974	24,087,730
3	Thailand	16,506,625	19,064,000	18,283,000
4	Indonesia	16,438,100	16,089,100	16,158,000
5	Congo, Dem republic of	16,500,000	15,959,000	15,435,700
6	Ghana	7,845,440	8,107,000	8,512,000
7	India	6,700,000	7,000,000	7,000,000
8	Tanzania, United Rep of	7,181,500	5,757,968	5,650,000
9	Mozambique	5,352,760	5,361,974	5,361,974
10	Uganda	4,875,000	4,966,000	5,265,000
11	China	3,750,720	3,800,933	3,850,900
12	Angola	3,129,734	3,300,000	3,300,000
13	Benin	2,062,616	2,800,000	2,800,000
14	Paraguay	3,694,400	2,719,410	3,853,720
15	Madagascar	2,435,000	2,228,000	2,228,000
16	**Vietnam**	**1,800,500**	**1,986,300**	**2,050,300**
17	Colombia	1,761,550	1,791,867	1,982,351
18	Philippines	1,890,315	1,770,800	1,652,040
19	Ivory Coast	1,600,000	1,673,000	1,900,000
20	Cameroon	1,984,132	1,500,000	1,700,000
	World	**171,917,962**	**176,784,378**	**178,860,310**

Source: Food Market Exchange, 2003a.

[4] Cassava cultivation areas in Vietnam can be divided into three regions: (1) in the South, cassava cultivation areas concentrated in Tay Ninh, Binh Phuoc, Dong Nai, Binh Thuan and Dac Lac; (2) in the Central, there are in Gia Lai, Quang Ngai, Binh Dinh and Quang Nam; (3) in the North, there are in Phu Tho and Ha Tay.

In Vietnam, nowadays, cassava is predominantly used as raw material for tapioca production, both at household-scale (or small-scale)[5] and large-scale production levels. Increase in demand of tapioca starch in domestic and international markets for food processing and other non-food industries has induced a dramatic increase of investment by small and large-scale tapioca production firms (IFPRI, 1998 and Goletti et al., 2001). Tapioca processing industry is considered to be one of the largest food processing industrial sectors in Vietnam (Hien et al., 1999). By November 2002, tapioca producers in Vietnam produced annually about 500,000 tons tapioca starch, equivalent to 1.6 millions tons of fresh cassava roots (Vina Econet, 2003)[6]. It is expected that within the next two years, the production of tapioca starch in Vietnam will increase, as several new factories will be put into operation (Box 1.3).

Box 1.3 Tapioca production companies in Vietnam

Name	Province	Capacity (tons starch/day)
VEDAN	Dong Nai	200
VEDAN	Binh Phuoc	300
Tan Chau-Singapore	Tay Ninh	100
Tay Ninh Tapioca	Tay Ninh	120
Song Be-Singapore	Binh Phuoc	100
An Giang	An Giang	50
Phu Yen	Phu Yen	50
Ve-Thai	Gia Lai	50
Quang Ngai	Quang Ngai	50
Da Nang	Da Nang	50
Heng Chang Tapioca*	Tay Ninh	100
Vietnam Tapioca*	Tay Ninh	100
AW Group*	Binh Phuoc	70
Nuoc Trong*	Tay Ninh	60
Bang Na-Binh Thuan*	Binh Phuoc	50
Dac Lac*	Dac Lac	50
Korea Tay Ninh**	Tay Ninh	100
Quang Binh**	Quang Binh	100
Nghe An**	Nghe An	60
Thanh Hoa**	Thanh Hoa	60
Hue**	Hue	120

* have just been finished the construction by the end of 2002
** in stage of investment application

Source: Food Market Exchange, (2003b).

Vietnam's domestic sugar industry is primarily based on sugarcane. In ten years (1990-1999), the sugarcane production area has increased with a factor of nearly 2.7, from 131 thousand ha to 350.8 thousand ha, of which 201.9 thousand ha are in use by cane sugar processing companies (MARD, 2002a). The Government is strongly promoting expansion in the sugar processing sector, as part of a nation-wide effort to expand overall food processing capacity (for instance, of beverages, dairy products, confectionery, bakery, fruit and other food processing) (FAO, 2002). By the end of 2000, Vietnam had 44 large-scale cane sugar companies (with an average capacity of 1,780 tons sugarcane/day) and a large number of small-scale production units (with capacities under 100 tons sugarcane/day) and a total sugar output of 1 million tons (MARD, 2002a). Though the international competitiveness of Vietnam's cane sugar is at a poor level, the sugar industry has still a bright prospect as it is estimated that the domestic demand will increase up to 1.0 to 1.1 million tons in 2005 and between 1.2 to 1.3 million tons in 2010 (Duc, 2002).

[5] Currently, there are about 13 tapioca producing villages in Vietnam. Each village has about 30 up to 700 tapioca producing households.

[6] The remaining 400,000 tons are directly used as human food and animal feed.

Coffee was planted for the first time in Vietnam in 1857 with an initial area of less than thousands ha (MARD, 2002b). Until 1975, total area under coffee still remained at around 20,000 ha with a production between 5,000 and 7,000 tons of green coffee per year (Nhan, 2001). However, in the last few years, coffee production in Vietnam has increased rapidly. The total coffee area in 2001 was 500,000 ha, mainly under Robusta coffee, with an annual production of over 700,000 tons (Nhan, 2001). Thus, after 25 years, Vietnam's coffee industry had its area increased 25 times and its production a 100 times. Today, Vietnam is the world's second-largest coffee grower and the largest grower of Robusta coffee (Lam, 2002). In order to improve coffee quality, Vietnamese government promotes the careful and slow expansion of Arabica coffee plantations with the ultimate goal for 2010 of having a stable production at 600,000 tons/year, consisting of 70% Robusta and 30% Arabica (Enden, 2002). Parallel with the production development, Vietnam's coffee export volume has strongly increased as well, from 176.4 thousand tons in 1994 to 488 thousand tons in 1999 (equivalent to 2.77 times) (MARD, 2002b) and around 850 thousand tons in 2002 (Incomebank Bullentin, 2002). Vietnamese coffee is now exported to more than 50 countries in the world, especially to the US, EU countries (Vinacafe, 2002) (German, Sweden, Great Britain, France, the Netherlands, Spain, Italy, etc.) and Asian countries (Japan, Singapore, China, Philippines, Malaysia and Indonesia). As presented in Vietnam Economic Newspaper (September 17, 2002), coffee export from Vietnam to other countries during the first seven months of 2002 was 430,657 tons valuing 165,132,000 USD in value (see breakdown by countries in Box 1.4). In order to raise competitiveness in the world coffee market in the coming years, Vietnam's coffee industry will have to continue investing in processing technology to improve quality, reduce production costs and cover the domestic and international demand (MARD, 2002b).

Box 1.4 Coffee export in the first seven months of 2002 by countries

Countries	Value ($ 1,000)	Countries	Value ($ 1,000)
Australia	2,772	Japan	12,276
Belgium	7,008	Korea	6,330
Cambodia	8	Malaysia	1,554
Canada	1,160	Philippines	5,368
China	2,270	Singapore	3,801
Denmark	231	Spain	9,536
Finland	197	Sweden	30
France	6,582	Switzerland	9,263
Germany	24,314	Taiwan	414
Holland	7,844	Thailand	46
Hong Kong	181	The U.K	10,197
Indonesia	1,122	The U.S	19,911
Italy	10,607	Russia	31
		Total	**165,132**

Source: Vietnam Economic Newspaper, September 17, 2002.

Over the last years, the milk processing industry has rapidly grown at the average rate of 29.3% per year (Hao, 2003). Since this is a relatively young industry, the introduced technologies are advanced and the equipment is new. Consequently, the products have reached the international standard and can be exported. At this moment, Vietnam Dairy Products Company (Vinamilk), the country's leading milk processor, which is holding 75-90 percent of the domestic market share (Vina Econet, 2002), has more than 90 products including sweetened condensed milk, powder milk for babies, children and adults, nutritious cereal powder, biscuits, UHT milk, Soya milk, ice-cream, yogurt, cheese and fruit juices (Vinamilk, 2002). Total annual output of Vinamilk in 1999 is summarized in Box 1.5. In the first six months of 2002, Vinamilk exported for 135 million USD, against 127.5 million USD in the first six month of 2001 (Vietnam News, 2002). However, this industrial sector is facing a difficulty of insufficient dairy cattle (Tuyen and Giao, 2003). Though the diary population of the whole country at present is about 35 thousand heads (Vu and Cai, 2003), this can only respond to 10% of the fresh milk demand of processing industry (Hao, 2003). Therefore, the main objective of Vietnam's dairy development plan in the period of 2002 to 2010, which was set up by the Government[7], is to increase the milk production to meet the local demand on dairy products with targets of 100,000 and 200,000 heads of dairy cattle in 2005 and 2010, respectively (Tuyen and Giao, 2003). Meanwhile, annual total milk production of 2005 and 2010 is planned to be 165,000 and 350,000 tones, respectively.

Box 1.5 Annual output of Vinamilk in 1999

The total annual output of Vinamilk in 1999 was roughly 420 million cans of sweetened condensed milk, 65 million liters of pasteurized fresh milk, 37.2 million liters of yogurt, 6 million liters of ice-cream, 20,000 tons of milk powder, 48 million liters of Soya milk and yogurt, and 2 million liters of fruit juice.

Source: Australian Trade Commission, 2002 and APFood, 2003.

Favorable conditions in terms of weather and soil facilitate the generation of various kinds of fruits and vegetables in Vietnam, such as banana, longan, dragon, pineapple, mango, litchi, mushroom, ginger, citrus, etc. There are now 17 main vegetable and fruit processors in Vietnam, including 12 canning factories with a total design capacity of 70,000 tons/year and 5 factories for frozen products with total design capacity of 20,000 tons/year (MARD, 2002c). However, at present, only about 5-7% of vegetables and fruits are processed, therefore foreign investors are now boosting investment in processing industry of Vietnam. Fruit/vegetable juice and bottled water, which use available domestic resources, are rapidly expanding, as consumers become more health conscious. Other soft drinks are also becoming more prevalent across the country with the continuing development of the Vietnamese economy and rapid urbanization. Euro-monitor expects the soft drink market in Vietnam to experience strong rising annual growth rates, resulting in an overall increase of 59% in volume terms, to 708 million liters in 2006 (Euromonitor International, 2002).

Discussion on development orientation of food processing industries in Vietnam, Dr. Do Huu Hao, Director of Industrial Strategies and Policies Research Institute of Vietnam Nam stated that (Hao, 2003: 22):

> *"In 2010, the total percentage of processed agricultural products will be at least 70%, responding to domestic demand and basically replacing imported agricultural products. Export turnover will be USD 9 billion... Sugar production will increase to 1.6 million tons. 90% coffee and tea production will be industrially processed... The yield of domestically produced milk will be 500,000 tons, responding to 56% of domestic consumption demand. The processing yield of 4-5 million tons of feed for animals will be ensured... Around 10 million tons of vegetables and 10 million tons of fruits will be processed to respond to domestic demand and export requirements. By 2010, the industry will be able to produce 2.5 billion liters of beer and 1 billion liters of refreshment..."*

According to Hao (2003), the first priority of the overall orientation towards the year 2010 is invest in and develop processing industries, especially agro-processing industries which are closely linked with the development of agro-forestry-fishery material sources (for instance

[7] Decision No. 167/QD/2001/TTg on policies for dairy cattle development.

milk is linked with dairy development zones; sugar linked with sugarcane growing zones; vegetable oil is linked with zones cultivating coconut, sesame and soya beans; fishery processing linked with aquaculture and capture areas, etc). Thus, industrialization seems to be an irreversible trend in Vietnam for the coming decade, especially in the industrial heartland (South Vietnam Economic Studies Center, 1996) including Ho Chi Minh City (HCMC) - Dong Nai - Binh Duong - Ba Ria - Vung Tau – apart of Tay Ninh and Long An. These regions form an economic development quadrangle with HCMC as a nucleus and Thu Dau Mot, Bien Hoa and Vung Tau as 3 satellites, together the so-called South Key Economic Regions (SKERs) of Vietnam. The SKERs have a large potential for agro-industrial development in the Mekong Delta, rich fishery resources along the coast, oil and gas resources in Vung Tau. They have also relatively long experiences in market economy. Because of these conditions, the economic development in this area has been the fastest in the country, attracting major foreign investment[8]. In the coming years, according to governmental authorities, industrial investments related to agricultural products (such as sugar, tapioca, dairy, beverage, seafood, caned fruits, etc.) should be the first development priority in the SKERs (South Vietnam Economic Studies Center, 1996).

1.2 ENVIRONMENTAL POLLUTION OF FOOD PROCESSING INDUSTRY

Rapid growth of industry in Vietnam is putting stress on natural resources and the environment (UNIDO, 2003). Water and air pollution, degradation of land resources, soil erosion, over-exploitation of natural resources and threats to the ecosystem are among the most challenges. Besides mismanagement, important reasons for the rapid increase of environmental pollution are the limitations in the level of technology applied in industrial production processes and wastes treatment (Hung, 1997).

Industrial production activities have impacts on the natural environment through the entire cycle of raw materials exploration and extraction, transformation into products, and use and disposal of products by the final consumers. All these activities generate wastes. Neither enterprises nor consumers want to store wastes in their own yards. Therefore, they have to find places and methods to get rid of it, and frequently the natural environment is serving as the recipient of all kinds of wastes, among which industrial wastes with high toxicity and loading of contaminants. This explains why industrial wastes (including wastewater, solid wastes and air pollution) are one of the major causes of severe environmental deterioration in Vietnam. Though the process of industrialisation undoubtedly has raised the level of welfare in Vietnam, several authors indicate that the current development processes produce serious environmental deterioration (Chi, 1993; Nhan and Nga, 1993; Thanh, 1993; Work Bank, 1995; CENTEMA and SONADEZI, 1997a and 1997b; An, 1997; Quy, 1997; Triet et al., 1999; Sy, 2000; and Dang, 2001).

Besides the most notable polluters in the heavy industrial sector (such as power plants, iron and steel mills, pulp and paper factories, cement plants, chemical plants and fertiliser companies), food processing companies are considered to be one of the major polluters in the light industrial sector involving companies in the food processing, textile and dyeing,

[8] In the year 2000, Vietnam counted 68 industrial zones (IZs), export processing zones (EPZs) and high-tech zones (HTZs), of which 38 are located in SKERs (Nhue et al., 2001). Up till 2001, they have nearly attracted 1,140 domestic and foreign enterprises with a total investment capital of about 9 billion USD (Tam, 2001). Among the industrial sectors, which contribute to establishment of IZs, food processing industry is one of the majors. Factories producing cane sugar, milk, confectionery, beverage, wine, seafood, coffee, tapioca, etc. are present in many existing IZs and Export Processing Zones (EPZs) such as Tan Thuan EPZ (Ho Chi Minh City), Bien Hoa 1 IZ, Bien Hoa 2 IZ (Dong Nai province), Song Than IZ, Vietnam-Singapore IZ (Binh Duong province), etc.

electroplating and leather tanning sub-setors (c.f. Fryer, 1995; Frijns et al., 2000). The growth of tapioca processing industry has resulted in heavy water pollution as it generates large amounts of wastewater with very high organic concentrations. According to Hien et al. (1999), in order to produce 1 ton of starch, a tapioca-processing factory discharges about 12 m^3 of wastewater containing 11,000-13,500 mg O_2/L in terms of COD, 4,200-7,600 mg SS/L and pH 4.5-5.0. Studies of Mai et al. (2001) and Oanh et al. (2001) on large-scale tapioca processing companies give similar characteristics of tapioca wastewater with total COD in the range of 7,000-41,406 mg/L, BOD_5 of 6,200-23,077 mg/L, and CN^- of 19-28 mg/L[9]. In a study at three villages including Cat Que, Duong Lieu and Minh Khai, where 6,000 processors support a population of 30,000 residents with starch processing and associated products (such as noodles, maltose, candy, and pigs, which are fed on cassava fibrous residues), Peters et al. (2000) found that processing 1 ton cassava roots generates about 10.7 m^3 of wastewater containing 6,125 mg O_2/L (COD) and 1466 mg SS/L. These values indicate the heavy pollution this wastewater causes to the receiving water body. Pollution of wells, springs and rivers in especially the provinces of Binh Phuoc, Ha Noi and Dong Nai is the most visible sign of devastating environmental side-effects of tapioca processing. An incident at Song Be-Singapore Tapioca Company, as reported by Lao Dong newspaper (December 19, 1997), is an obvious evidence of the potentially serious environmental impact of tapioca wastewater. Tapioca wastewater from a broken pond of the wastewater treatment system of the company ran into Tham Rot Spring and destroyed the flora and killed fish. Around 300 kg of fish died from the polluted spring (Khoa and Boot, 1998). Residents living in tapioca processing villages in Ha Noi agreed that the drinking water during the off-season was much cleaner[10] (Peters et al., 2000). Deterioration of the environmental quality at Tra Co Village, Dong Nai Province (see Chapter 5) is an other example of adverse environmental impacts from tapioca wastewater. Solid waste from tapioca starch processing comprises root skins, hard roots and fibrous residues. It is estimated that about 3 kg of solid waste (outer skin, fibrous residues) are generated per 1 kg of starch produced (Hien et al., 1999), equivalent to 20% of raw cassava used (Nandy et al., 1995). Several kinds of wastewater from cane sugar, soft-drink, milk, seafood processing, canned food factories, slaughterhouses, etc., which contain 500-8,000 mg O_2/L in terms of COD, 400-6,500 mg O_2/L as BOD_5 and a pH in the range of 4.9-5.1, also contribute to the deterioration of surface water resources[11]. With a significant large number of enterprises, food-processing industries have been attributed as one of the major environmental pollution sources in Vietnam, including wastewater, solid wastes and polluted air. Hardly any treatment plants are available and functioning properly, and even new industries have not installed waste treatment facilities (Workbank, 1995; Mol and Frijns, 1998; Triet et al., 1999). Reports of the South Vietnam Economic Studies Center (1996) and JICA (1999) show that most of the waterways receiving industrial wastewater are severely polluted and consequently do not meet the standards for producing drinking water, recreation, aquatic protection, agriculture and industrial use. Though there is only a very limited systematic monitoring of environmental quality and seldom industrial emissions to air and water are registered and published, the consequences of industrial pollution indicated by the limited data can still provide us with an impression on the seriousness of the state of the

[9] Mai et al. (2001) studied the effect of the organic loading rate on treatment efficiency for tapioca processing waste using an UASB with wastewater from VEDAN company. Total COD and BOD_5 of the tapioca wastewater from the centrifuge process were in the range of 7,00-14,243 mg/L and 6,200-13,200 mg/L, respectively. A study of Oanh et al. (2001) on removing suspended solids from tapioca processing wastewater in upflow anaerobic filter (UAF) with tapioca wastewater from Tay Ninh Tapioca Company showed a total COD and BOD_5 of wastewater in the range of 14,262-41,406 mg/L and 7,125-23,077 mg/L, respectively.

[10] The seasonal tapioca production in these villages (Duong Lieu, Cat Que and Minh Khai), from November to March to accommodate the harvest season, further contributes to the concentration of waste in a small area during a short period of time.

[11] Data gathered from various processing factories in Vietnam. See also Chapter 7.

environment. The canals running through the low-lying urban areas of Ho Chi Minh City, the Sai Gon River downstream of Ben Than, the Dong Nai River downstream of Hoa An, and the Thi Vai River are heavily polluted[12]. Some of these waterways are polluted so heavy that they do no longer offer practical benefits for use except probably as means of transport.

It is known that a lot of wastes generated from industrial activities may still contain valuable components, but these are wasted due to a variety of reasons:

- Enterprises do not know how to recover these valuable components;
- The economic benefit of reuse and recovery is low;
- Due to the absence of waste exchange or a waste exchange information centre, nobody knows who might be interested in reusing residue components;
- There is an absence of legislation and incentives to encourage reuse and recycling activities and resource conservation;
- Low costs and fines for waste discharge/disposal make enterprises uninterested in the amount of wastes generated.

1.3 ENVIRONMENTAL PROTECTION APPROACHES: from End-of-Pipe to Industrial Ecology

1.3.1 End-of-Pipe Treatment in Vietnam: dominance and shortcomings

With several decades of environmental research and experiences behind us, we have begun to recognize that we have been treating environmental symptoms (discharged wastewater, disposed solid wastes, polluted air, etc.) in stead of the diseases (causes of waste generation) for too long. The problem of pollution lies not within individual rivers, air-sheds, or hazardous waste sites, but within the relationship between industrial activities on one hand and environmental policy and management on the other. Until today, much of the current thinking on environmental protection in Vietnam focus mainly on what to do with wastes and emissions after they have been created. End-of-pipe treatment approaches have become increasingly popular in Vietnam since the establishment of the Law on Environmental Protection (1993) and other legislation related to the environment. Promulgation of national environmental standards of different kinds of industrial wastes and pollution (such as solid waste, wastewater, soil pollution, air pollution, noise and vibration, toxic materials, and hazardous wastes) compels industrial producers to seek for treatment methods to meet these standards.

To some extent, there is no doubt that end-of-pipe treatment has played and will play a major role in the reduction of pollution. Central wastewater treatment plants of Bien Hoa 2 industrial zone, Vietnam-Singapore industrial zone, Linh Trung industrial zone, and several industrial production companies are obvious evidences of this. However, it is also visible that

[12] Personal experiences as research member of several projects, such as "Improvement of Environmental Water Quality in Ho Chi Minh City – Project Phase 1 in Tau Hu-Ben Nghe Basin"; Researches on "Preliminary survey and assessment of environmental quality of Bien Hoa 1 Industrial Zone" and "Planning on Water and Wastewater Management for Bien Hoa 1 Industrial Zone"; EIA report of project on "Establishment of Nhon Trach 5 Industrial Zone", EIA report of project on "Establishment of Textile Industrial Zone in Nhon Trach, Dong Nai", EIA report of project "Establishment of My Xuan A Industrial Zone". In addition, an article on Environment in Southern Economic Zones at SOS level (VISTA, 2003) presented that around 300 industrial plants in the key southern economic zones pump out an estimated 200 tons of fumes every day and release 200,000 m^3 of wastewater, day and night, into the Sai Gon – Dong Nai river system, pushing the environmental situation to SOS levels.

although the end-of-pipe treatment approach has been implemented from the early 1990s onwards, environmental quality in Vietnam is still worse. This continuing deterioration is not only caused by the applied treatment technologies or the continuing industrial growth. It is also a consequence of improper implementation of the end-of-pipe approach. Requesting polluters to meet strict discharge standards, while there is a lack of resources, knowledge and experience for monitoring leads to improper operation of waste treatment systems. For instance, instead of continuous operation, waste treatment systems are more than incidentally operated only during the environmental inspection period and effluents are frequently diluted with fresh water to meet the standards.

1.3.2 Developed Countries: from end-of-pipe to industrial ecology

These shortcomings in end-of-pipe approaches in Vietnam can also be found in the international literature on environmental protection. In most of the industrialized countries environmental protection also started with the introduction of end-of-pipe waste treatment systems. But in most of these countries sooner or later alternative approaches were developed and introduced to meet some of the disadvantages, shortcomings and inefficiencies of end-of-pipe treatment systems. The development and introduction of alternatives did not result in the end of end-of-pipe treatment systems, but the later lost its monopoly position. Often different approaches are prioritized, for instance in a way exemplified in Fig. 1.1. The environmental protection methods or approaches towards the top are usually preferred, as they are more (economic and environmentally) effective and efficient in reducing the amount of wastes and therefore reduce present and future threats to human health and the environment.

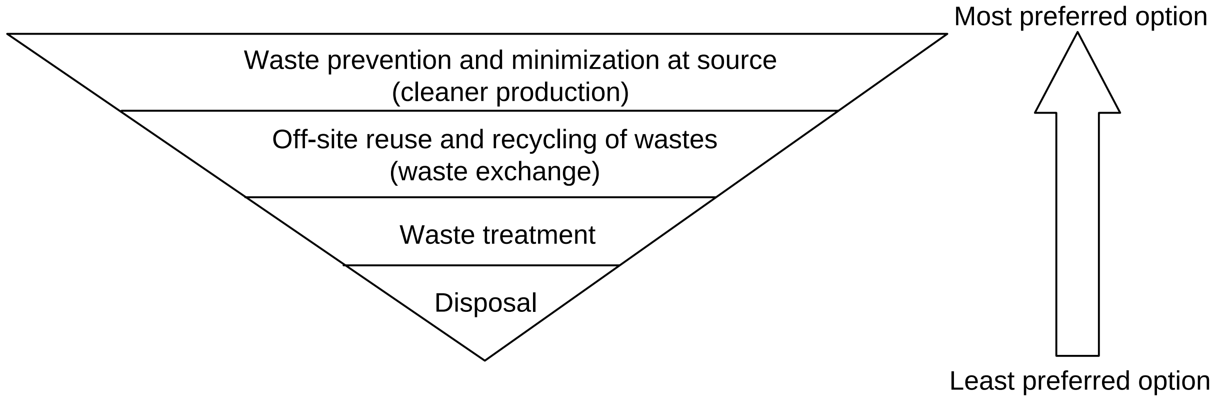

Fig. 1.1 Waste management hierarchy (modified from the European model, 1997).

Waste prevention and minimization at the source is often the most preferred strategy, as no waste means no pollution and no cost involved in its management. Producers can eliminate the generation of wastes from their production processes via various approaches: good housekeeping (European Comission, 1997; Ramjeawon, 2000; Henningsson et al., 2001; Hyde et al., 2001), changing to other raw material inputs (Jorgenson and Wilcoxen, 1990; Chaan-Ming, 1995; Vigneswaran et al., 1999), adopting new technologies (EUROPEN, 1997), changing the composition of their products, etc.

When waste prevention and minimization at source can no longer be carried out, waste materials should be reused in other production processes as secondary raw materials for production of new products. Generally, these offsite reuse and recycling (or waste exchange) options create economic benefits as less energy is consumed for producing new products from recycled materials, and it spares the environment from further abuse and degradation as less virgin material is used (EPA, 1996).

Even when both approaches are first applied there is often still some residual waste material left. Preferably, this left-over waste has to be treated first and the remaining has to be disposed properly to prevent environmental risks, pest problems, and endangering human health and safety. In both literature and practices from industrialized countries, one can find that each of these approaches plays an important role in environmental protection. Often the combination and integration of some or all these approaches is seen as the best or only strategy to overcome continuing environmental deterioration.

More recently, in developed nations the integration of the various environmental protection approaches has been studied and incidentally implemented under the notion of industrial ecology. The idea of industrial ecology has been described in different ways in the literature (as will be shown in chapter 2), all contributors to the concept emphasise the ideas of *reduce, reuse, recycle* to advance sustainable industrial systems. The idea is to create a model of a zero waste industrial system. Industrial ecology intends to do that by learning from the principles and functioning of the natural environment, in which all system components are integrated and no waste is produced (Lambert and Boons, 2002). Practical applications of the idea of industrial ecology can be found in developed countries such as Denmark, Canada, USA, The Netherlands, France and Sweden.

1.3.3 Industrial Ecology in Vietnam?

These industrial ecosystem practices, projects and experiences have several rather specific characteristics and limitations up until today. First, the industrial ecology concept has been applied especially in developed countries, with their advanced technological systems, organisational schemes and institutional structures. Second, the functioning industrial ecosystem projects usually exclude agro-industrial sectors[13]. Third, these projects, practices and experiences are often developed especially for large-scale industrial production units (for instance eco-industrial parks) and hardly ever for small- and medium- scale enterprises or for stand-alone large firms. Fourth, most of the more academic industrial ecology projects and practices have a strong focus on technologies and material flows, while questions of organization, managements and the role of various actors in putting industrial ecology models to work have received little attention.

Here we approach the central theme of this study. In guiding the rapid agro-industrial development of Vietnam into more sustainable directions the idea of industrial ecology seems tempting. From the existing literature and the experiences in industrialized countries we can clearly envision various advantages of an environmental protection strategy that is successfully based on the notion of industrial ecology in stead of one based on only end-of-pipe treatment. It is this potential that I want to investigate in this study. However, the short characterisation of the current experiences implies that the application of the idea of industrial ecology to agro-industrial food processing in Vietnam is far from a run race. In applying the notion of industrial ecology to agro-industrial development in Vietnam I will enter virgin ground regarding four issues. First, the model of industrial ecology cannot just be replaced from the developed world to industrialising countries such as Vietnam, because of the differences in existing institutions, technological possibilities and socio-economic conditions. Vietnam can of course learn from the existing experiences of industrial ecosystems but will have to adapt it to the country's conditions. Second, the focus on agro-industrial production will involve a closer interaction with a sector that has up till now remained out of the scope of industrial ecology studies: agriculture. Third, although Vietnam has a growing number of

[13] For extended information about the experiences with industrial ecosystem projects and practices, see appendix 1.

industrial zones in which large scale (agro-)industries are geographically concentrated, a major part of agro-industrial production take place in large stand-alone firms and in small and medium sized companies. Finally, for Vietnam it is essential that implementation issues are given full consideration in developing any environmental protection model. In using the idea of industrial ecology for agro-industrial development in Vietnam, this study will not remain restricted to issues of technology and material flow optimalization. It will also have to pay attention to actors and institutions that play a role in (hampering) implementation.

1.4 RESEARCH OBJECTIVES

The core objective of this research is to analyze and assess possibilities and the potential for greening food processing industries in Vietnam, based on the combination and integration of existing pollution treatment and prevention approaches

More specifically, this study seeks to fulfil the following sub-objectives:

- to develop a methodology for analysing and designing pollution prevention models for agro-food industries, integrating physical-technological and socio-institutional models;

- to assess the applicability of the developed methodology by applying it on different case studies in the Vietnamese food processing industry;

- to design zero waste industrial ecosystems for these cases and assess the role of actors and institutions in moving towards such systems in contemporary Vietnam;

- to assess the relevance of the Industrial Ecology Concepts for Vietnam

1.5 STRUCTURE OF THESIS

The thesis is divided in to eight chapters. This chapter, chapter 1, has presented an overview of food-processing industrial development in Vietnam, its environmental implications, research objectives and this paragraph will outline the structure of the thesis. In chapter 2, histories and aspects of the major pollution prevention approaches are described. Their strengthens and weaknesses are analyzed. Discussions focus on end of pipe treatment, cleaner production, industrial ecology concept and ecological modernization theory. It appears that all these theoretical approaches aim at pollution reduction and environmental improvement, but the focuses differ from each other. Therefore, integrating these approaches into a broader perspective, to which they should be subordinated, could be a promising approach for pushing industrial systems toward more sustainable ones. Using the various theoretical ideas introduced in chapter 2, chapter 3 moves one step further to develop a methodology on how to come to an integrated model of pollution prevention for an industrial system. A systematic methodology to develop a physical-technological model to move an existing industrial system towards a zero waste industrial ecosystem in four basic steps is elaborated in detail followed by a feasibility analysis in terms of actors and institutions. A selection of research strategy and research units as well as methods of data collection and analysis is also explained and briefly described in this chapter. Before dealing with case studies to test the developed methodology, chapter 4 gives a brief review on environmental management of industry in Vietnam. Roles of actors of current state environmental management organizations and environmental legislation relating to end-of-pipe treatment, cleaner production, waste reuse and recycling, industrial ecology and ecological modernization, are the main discussion objects in this chapter.

The chapters 5 to 7 comprise the empirical part of this study to test the approach and its suitability for greening food processing industries in Vietnam using an integration of the physical-technological model and a triad network analysis. Each of these chapters begins with a general introduction to the specific type of food processing industry, the studied area and its environmental implications, followed by a study on the material balance, a zero waste industrial ecosystem development, actors and institution analysis and some concluding remarks. Chapter 5 is devoted to a study on tapioca industry at household-scale tapioca production units in Tra Co Village, Dong Nai Province. The second case study presented in chapter 6 is within the same industrial sector as the previous case study, but cover the large scale Tan Chau-Singapore Company in Tay Ninh Province. The third case study on a group of food processing factories in Bien Hoa 1 IZ is presented in Chapter 7. The final chapter comprises the conclusions.

CHAPTER 2

POLLUTION PREVENTION APPROACHES: Theory

2.1 INTRODUCTION

It has been a maxim of many years standing that the goals of industry are incompatible with the preservation and enhancement of the environment (Graedel and Allenby, 1995). It is unclear whether the maxim was ever true in the past, but this certainly no question that it is untrue today. The more demand to provide a suitable life quality for Earth's citizens will not involve less, but more industrial activities and contribute to serious environmental problems. Thus, providing a sustainable world will require close attention to industry – environment interactions. The disregard for the protection of the environment can not be justified by the benefits of economic development. Therefore, the question on 'how to protect and improve the environmental quality' has rose many decades ago.

Since the beginning of the environmental movement in the early 1960s, both government regulatory agencies and industry have focused their pollution reduction efforts on controlling effluents at the point where they enter the environment (Chiu and Peters, 1994), end-of-pipe measures were added into industrial processes (Khan et al., 2001). However, the advent of strict environmental legislation in recent years, combined with the ineffectiveness and relatively high cost of several end-of-pipe treatment technologies have, in many instances, resulted in making this approach inadequate to deal with the magnitude and complexity of environmental degradation. The limitations of end-of-pipe treatment made environmental decision-makers consider replacement of end-of-pipe treatment by other alternative methods of pollution control. Consequently, during the last decade, environmental researchers began focussing on cleaner production/waste minimization and even a new academic discipline, industrial ecology, was born with the mission to design zero-emission industrial processes (Aryes and Simonis, 1994; Graedel and Allenby, 1995; Ayres and Ayres, 1996; Allenby, 1999). These pollution prevention approaches have contributed significantly to reducing pollution, improving environmental performance, raising profitability and enhancing competitiveness. Though several successes on environmental protection have been achieved by applying these approaches, environmentalists recognize that their practical sphere is limited due to lack of understanding on core dynamics, mechanism, institutions and actors that could move the unsustainable industrial system into a more environmentally sound direction. The emergence of ecological modernization theory, especially from the late 1980s onwards, plays an important role in fulfilling gaps in those approaches, which emphasize strongly on physical transformation in the environmental reform of industrial system.

This chapter gives an overview on histories and aspects of the major pollution prevention approaches and analyzes their strengths and weaknesses. The end-of-pipe approach (section 2.2) is the point of departure for the discussion as it has the longest history of practical implementation in environmental protection. Section 2.3 deals with cleaner production and specifies on cleaner production measures and its benefits and constraints. The usefulness of the idea and concept of industrial ecology in improvement of environmental performance at larger scales, rather than only within a boundary of one industrial production unit, is described in section 2.4. Limitations of the industrial ecology concept are also analyzed in this section. By briefly introducing the history and core features of ecological modernization theory, section 2.5 tries to elaborate on the important role of this theory in contributing to the implementation of industrial ecology. Finally, section 2.6 draws some conclusions on these existing pollution prevention approaches.

2.2 END OF PIPE TREATMENT

2.2.1 Introduction to End-of-Pipe Treatment

Along with rapid industrialization, which has resulted in the rise of pollution, there is a growing concern about the quality of the living environment. To comply with requirements of good quality of the living environment, industries are forced to treat their wastes before discharge. Because the treatment is applied after generating the waste, this type of treatment is called ‘end-of-pipe’ treatment (Jorgenson and Wilcoxen, 1990; Sakurai, 1995; Luken and Freij, 1995; Hartl and Kort, 1997; Vigneswaran et al., 1999; Hilson, 2000). Many treatment technologies attempt to reduce the risk posed by pollutants using various strategies such as limiting the dispersal of the contaminant (e.g. landfilling), reducing toxic effects by dilution (e.g. smokestacks), or transferring contaminants from one medium to another (e.g air-stripping of contaminated water) (Huesemann, 2001). A great number of treatment plants applying biological, physio-chemical or chemical processes to treat different kinds of industrial wastewater, solid wastes and air pollutants are in use in most countries all over the world. Though the end-of-pipe treatment approach is being seriously questioned, this is still one of the most used pollution treatment methods to handle unavoidable wastes and emission of pollutants from industrial production processes. Strengths and weaknesses of this approach are discussed in the next paragraph.

2.2.2 Strengths and Weaknesses of End-of-Pipe Treatment

Strengths. Most industrial activities necessarily generate wastes and/or byproducts. For instance, it is impossible to make cheese, for instance, without having the part of the milk that is not used become “waste” or a “by-product” (Erkman, 1997). Obviously, even using the best precautions, some pollution will still occur during manufacturing and needs to be treated properly before discharging into the environment. In those cases, end-of-pipe treatment is the only suitable environmental protection solution. Excellent examples on practical applications of cleaner production for textile, paper and electroplating industries are available from reports of Cheung (1995), Chaan-Ming (1995), Chandark et al. (1995), Roestamsjah et al. (1995), Oka (1995), Lee (1995), Nataagiin (1995), Bajracharya (1995), Hwa (1995), Tapaneeyangkul (1995). These example projects showed that by applying cleaner production measures, wastes generation could be reduced, however, all of them still have to install wastewater treatment plants for complete removal of contaminants. In some cases, we have to admit that use of end-of-pipe treatment method requires less capital investment, less development and less disruption (Bahat, 1996; Howes et al., 1997; Hilson, 2000) than the outright replacement of existing capacity with new structures and equipment (Duchin et al., 1995; Sakris and Cordeiro, 2001). Fast and less costly solutions make end-of-pipe treatment methods to be more attractive for a firm with a strict budget and limited funds, which, from the perspective of environmental performance, is aiming only at investing the necessary to meet legislative compliance. This can be illustrated by the case of power plants. Though retrofitting power plants with scrubbers for removing sulfur from flue gas virtually always increase the cost of production due to additional requirements on equipment, energy, maintenance and other inputs, this is still considered widely a preferable solution in the short-term (Duchin et al., 1995).

Weaknesses. Although end-of-pipe pollution control strategies have resulted in reducing negative environmental consequences of processing facilities, they focus on the symptoms and not the basic causes of environmental problems (Khan et al., 2001). The classical end-of-pipe strategy for treatment of pollution has proven to be quite useful but not adequate to make an efficient use of limited resources (Erkman, 2001). End-of-pipe pollution control causes greater consumption of material and energy, more capital expenditure and more work hours compared to measures taken at source (Dimitroff-Regatschnig and Schnitzer, 1998). Therefore, these technologies usually add to manufacturing costs without adding to production, which makes them more expensive (Pargal and Wheeler, 1996). Their use often creates new environmental problems such as the need to dispose of wastes from treatment facilities and is likely to erode the competitiveness of local industries. This is the reason why in many developing countries waste is often dumped into the nearby environment without being treated (Sakurai, 1995).

To some extent, the respective effectiveness of end-of-pipe approach in solving environmental problems is highly questionable. In recent years, the more sustainable industries of the world have identified that many conventional end-of-pipe systems are not only costly to operate and maintain, but also ineffective at remediating environmental damage (Hilson, 2000b). The use of an end-of-pipe treatment system has then been recognized only to help putting a firm’s operations in line with regulatory demands. Reducing toxic effects, for instance emitting flue gas through sufficient high smokestacks, will certainly reduce the risk of localized obvious acute toxicity, but is likely to increase the probability of more widespread subtle chronic effects that are currently unknown or difficult to monitor. Similarly, it is uncertain whether transfer of a pollutant from one medium to another will actually reduce the overall risks (Huesemann, 2001). Though chemical and biological treatment technologies are certainly effective to limit or reverse contaminant dispersal, it is important to realize that many of these technologies also have undesirable side-effects (Barton et al., 1996; Page et al., 1998). For example, incineration might generate flue gases that contain minute quantities of dioxins that are highly toxic. In addition, ashes containing toxic metals are generated and have to be dealt with (Heusemann, 2001). To some extent, even bioremediation, a low impact technology relying on native bacteria to metabolize pollutants, can cause the formation of intermediates that are more toxic than the original contaminants, e.g. carcinogenic vinyl chloride during chlorinated solvent bioremediation (Baker and Herson, 1994).

The implementation of end-of-pipe treatment methods depends heavily on how serious pressure is from environmental authorities to control industrial pollution in firms. In environmental policy, command-and-control approaches have been adopted to provide incentives for polluters to introduce and operate pollution treatment facilities in most countries. Though various instruments of command-and-control approaches have been successful in dealing with environmental problems initially (Huber, 1991), it is increasingly recognized that these policy approaches face many drawbacks such as economic inefficiency, environmental ineffectiveness, no incentive for innovation and even democratic illegitimacy (Tietenberg, 1988; Eckerskey, 1995). In a study on pollution regulation and abatement efforts of China, Wang (2002) found that in China pollution charge rates were generally very low and not effective in terms of providing incentives for firms to invest in end-of-pipe treatment. As a result about 90% of the major water polluters violated the discharge standards in 1993. In addition, strict enforcement to comply with discharge standards might lead to improper implementation of end-of-pipe treatment system. For instance, instead of complete treatment, water polluters can just dilute contaminants by adding fresh water to wastewater in order to meet the legal concentration standards. By doing so, the enterprises themselves avoid penalties from state environmental agencies and reduce cost of waste treatment, but this hampers the environment and increases scarcity of natural resources.

With all limitations as discussed above, end-of-pipe approach is arguably proactive, has low performance and is more costly but less sustainable than other environmental protection approaches.

2.3 CLEANER PRODUCTION

2.3.1 Introduction to Cleaner Production

Cleaner production (CP) differs from end-of-pipe treatment in that it minimizes wastes and emissions by reducing them at the sources. There is no clear distinction between the term 'cleaner production' and 'waste minimization'. Both aim at reducing the pollution problem by dealing with it during the manufacturing process itself. Therefore, discussion will not focus only on 'cleaner production', but includes 'waste minimization'.

Various definitions of cleaner production are described by several authors, such as OECD (1995a), EBerkel et al. (1997), Frijns et al. (1997), UNEP (1997), Baas (1998a) and Visvanathan (1998). In general, cleaner production can be defined as the continuous application of an integrated preventive environmental strategy to production processes in order to prevent wastes and emissions at the source, to conserve energy and raw materials, to eliminate the use of toxic materials and to improve working conditions. Cleaner production contributes to optimalization of the use of resources, thus environmental benefits may be achieved in conjunction with financial and economic benefits and technological improvement. Thanks to systematic avoidance of wastes and pollutants, process losses and costs of waste treatment and disposal are reduced, while process efficiency and product quality is increased. Earlier experiences have proven that the following measures were successful in achieving cleaner production: (1) improved housekeeping around the existing processes, (2) recycling, recovery and reuse materials/by-products/wastes, (3) changing input materials, (4) changing production process and (5) changing product. The appropriate technology depends on the type of industry and its size and location.

Good housekeeping implies that managers and employees of an enterprise are diligent in ensuring that they comply with all environmental regulations. In seeking ways, the generated wastes and the resources used are kept to a minimum. Good housekeeping measures can often be implemented at little or no cost. The following steps in good housekeeping can lead to significant waste minimization. Starting with the improved management of raw material and products inventory, reduction in raw material and product loss and provision of training to the employees can be effective means to improve housekeeping. For instance, by introducing trays to collect the dripping blood from each individual bag of frozen meat during defrosting, a meat processing company saved significantly, in terms of resource efficiency for one of the more expensive ingredients as well as in terms of effluent loading (BOD) on treatment facilities. Approximately 30 tons of blood per year were incorporated in the production, reducing the requirement for additional water as well (Henningsson et al., 2001). In case of beer production, precise adjustment of bottle fillers or installation of a metal sheet under the fillers can minimize losses of beer during filling stage (European Commission, 1997). The second, step scheduling of the process in view of equipment cleaning can reduce waste generation. For example, preparing light paints before dark ones or arranging fabric requiring similar dyeing and finishing process in sequential order will make cleaning of vats unnecessary before starting a new batch. Using the generated wastewater from bottle washing to wash the casks will reduce water supply demand. Thirdly, an improvement in monitoring and operating all phases of the production process is necessary to ensure an optimal control of the material flow within the system.

Recycling, recovery and reuse of materials is the next most preferable method of cleaner production. In many cases, waste material generated in manufacturing processes can be reused either onsite, in the original process with or without treatment to remove impurities, or offsite, in other plants. For instance, organic solvents used in cleaning and pharmaceutical manufacturing processes are often collected, distilled and reused in the original process (Chiu and Peters, 1994). In the finishing stage of textile and clothing manufacture, the amount of paint discharged with wastewater can be reduced by internal recycling. It is possible to apply the recycled paint in processes where a lower quality is acceptable. Also, less current colors can be mixed to darker or black colors (European Commission, 1997). Some more examples of recovery of materials/by-products/wastes worth mentioning: milk powder recovery in milk powder production, dye in textile industry, copper in electroplating, paint and water in car painting industry, cutting oil in machine workshop, etc. If onsite recycling is not feasible, offsite recycling will be the next evaluation and selection. A clear evidence of offsite recycling and recovery is using putrescible and biodegradable wastes, wherever possible for animal feedstock or soil conditioners and fertilizers. In a study on waste minimization in palm oil industry, Vigneswaran et al. (1999) found many possibilities to recover and reuse generated wastes. These include use of palm oil waste as animal feed, recovered fiber as fuel for production of steam in boilers, sludge as fertilizer and recovery of methane through anaerobic digestion.

Changing input materials is other cleaner production measure to reduce generation of pollutants from used raw materials. A straightforward example is available from electric utilities, namely switching from high sulphur to low sulphur coal in order to comply with restriction on sulphur dioxide emissions (Jorgenson and Wilcoxen, 1990). In printing, water based inks can be a substitute for chemical solvent based inks to minimize waste in solvents and to prevent air pollution due to the evaporation of solvents (Vigneswaran et al., 1999). Similarly, the water based film developing system can be replaced by a dry systems in electronic components and powder paints can be used instead of organic solvent based paints in painting the electrical light components. In a study on the application of cleaner production in a bleaching and dyeing factory in Hong Kong, Chaan-Ming (1995) found that replacement of current chemicals including Detergent, Acetic acid and Stabicol A by Hostapal EF-X, Formic acid, and Stabilizer SG-X, respectively, reduced effluent COD to 6% without adversely affecting the production quality.

Production process change plays an important role in reducing waste volume and strength. This includes equipment modification by small changes in existing equipment and technology change by replacement of technology and processing both in order to minimize waste and emissions during production processes. Some examples are: alteration in washing/cleaning procedure such as using counter current washing, replacement of single-pass processes by closed loop processes, use of mechanical means to transport waste (e.g. from poultry farm) instead of using water, etc. Modifying the technology used to produce a product is one of the most effective methods of preventing pollution. By doing so, a company can prevent pollution and increase production productivity, improve product quality and reduce costs for raw materials, utilities, waste handling, etc. However, because technology changes generally involve greater investments than procedural changes and usually take longer time to implement, they are commonly investigated after procedural changes have been implemented.

Changing products can be applied if their substitution can lead to waste minimization such as replacement of non-rechargeable batteries by rechargeable ones, use of ammonia instead of chlorofluoro-carbon in refrigerators, producing biodegradable plastic bags to replace conventional plastic bags, etc. Product changes include changes in final or intermediate products to reduce waste generation and other environmental loads arising elsewhere in the life cycle. The approach here is usually product-specific and therefore commercially sensitive. Eco-labeling is an attempt to identify consumer products, which genuinely have improved environmental performance without revealing commercially sensitive information (Clift, 1994; Kirkwood and Longley, 1995).

Cleaner production is considered in Agenda 21 as environmentally sound production processes and products that "protect the environment, are less polluting, use all resources in a more sustainable manner, recycle more of their wastes and products, and handle residual wastes in a more acceptable manner" (OECD, 1995a). However, it is important to remember that cleaner production programs are in themselves no guarantee of continuity in environmental progress (Zwetsloot, 1995). The most important factor for the promotion of cleaner production is the stringent enforcement of environmental regulations (Sakurai, 1995). According to Chiu and Peters (1995), mandatory direct regulations for pollution prevention is probably the most effective means of achieving reductions in the quantity and toxicity of pollutants generated in the industrial section. Besides, financial incentives (both providing grants and loans, and levying fees and taxes) and voluntary compliance programs (including technical assistance, technical information exchange, research and demonstration program) will encourage the implementation of cleaner production (Chiu and Peters, 1994).

2.3.2 Benefits of Cleaner Production

Cleaner production is now recognized as a cost-effective complement to pollution abatement in meeting environmental standards. Many articles in the *Journal of Cleaner Production* reporting successful case studies on cleaner production and waste minimization are available (Overcash, 1986; Luken and Freij, 1995; Sakurai, 1995; Dimitroff-Regatschnig and Schnitzer, 1998; Vigneswaran et al., 1999; Khan et al., 2001; Hyde et al., 2001; Hennigsson et al., 2001). These articles reflect practical evidences on benefits of cleaner production applications in many Asian countries such as Thailand, China, Hongkong, Singapore, etc. (Table 2.1). Experiences of factories applying cleaner production measures in the world show that adopting a cleaner production program as a way of doing business can yield a number of significant benefits for them. The major benefits are increase of production efficiency (quantity of product per unit of raw material), improvement of the environmental quality and product quality and the reduction in generation and discharge of pollutants. In addition, a cleaner production program offers benefits in economic terms with respect to potential future liability, on competitive advantage and on positive public image.

As pollutants are reduced, the proportion of raw material being converted to desired end products increases. Thus, cleaner production leads directly to increase production capacity and yield. Economic savings from reduced raw material use in food and drink companies have been revealed by for instance research of Hyde et al. (2000) and Henningsson et al. (2001). Henningsson et al. (2001) reported that the East Anglian Waste Minimization in the Food and Drink Industry Project started in 1997 in 13 independent food and drink companies. The savings in raw materials for companies within the project were far higher than for any other category, representing 67% of total savings. This was consistent with the Environmental Technology Best Practice Program case study of the Hillsdown Holdings group's waste minimization project, where 65% of the savings generated by five food manufacturing companies came from more efficient raw material use (Hyde et al., 2000). This confirms the importance for food and drink companies to look for waste reduction at source rather than end-of-pipe solutions.

Table 2.1 Benefits from practical applications of cleaner production measures

Projects	Cleaner production measures	Achievement	Benefits of CP	Reference
Tapioca Starch Industry (Thailand)	- Reuse of root wash water after sedimentation - Reuse tapioca wastewater for Torula yeast production	Over COD reduction of about 73%, while produce 0.5 kg yeast/kg COD removed (yeast contains about 50% protein)	Reduction of waste and treatment cost	Vigneswaran et al., 1999
Palm Oil Industry (Thailand)	- Reuse turbine cooling water - Use of floating valve in the press station and oil clarification room to stop overflow - Modification at clarification process to recover oil		- Prevent loss of water - Increase production efficiency	Vigneswaran et al., 1999
Cheese making manufacture	Collection of whey and reuse in cattle food production		Reduction of waste and treatment cost	European Commission, 1997
Electroplating factory (China)	Recovery and recycling heavy metal (nickel and chrome) by equipment modification	- Recovered 5.23 kg Ni/day (about 87.8% Ni lost if not recovered) - Recovered 2.059 kg Cr/day (96.5% Cr lost if not recovered)	- Reduction of raw material use - Reduction of waste and treatment cost due to recovery	Cheung, P. S., 1995
Paper manufacturing factory (China)	- Recovery fiber and additives from white water and treated water by equipment modification - Recover waste heat from steam in generating electricity by equipment modification	- Water cost savings (about 500,000 NTD/moth) - Energy savings (about 6 million NTD/month)	Prevent loss of water and energy	Cheung, P. S., 1995
Siam Paper Industry in Thailand	Installing a settling cone not only reduce the extent of waste treatment but also permitted the wastewater recycling	Use 100% waste paper as raw material and recycling 15,000 m^3/day of treated wastewater. This leads to a saving of 73% of the annual operating cost	- Reduction of raw material use - Reduction of waste and treatment cost	Vigneswaran et al., 1999
Dyeing and finishing factory (China)	- Use countercurrent washing processes to reduce water consumption - Install heat exchanger to recover waste heat - Onsite recover and reuse of soda and chemicals - Change hard metallic rollers by synthetic material roller to eliminate heavy metal in generated sludge - Computerized dyestuff handling devices to prevent wastage of dyestuffs	By applying these cleaner production measures, the factory achieve operating profit of 10.7% in compared to 2.3% in case of no cleaner production	- Reduction of water use - Prevent loss of energy - Reduction of raw material use (dyestuffs and line) - Reduction of waste and treatment cost	Cheung, P. S., 1995
Bleaching, Dyeing and Printing factory (Hong Kong)	- Installing chemical feeding system to reduce wastage of dyestuffs and extra pollution; - Recovery and reuse caustic soda - Arrangement for bathes of fabric requiring similar dyeing and finishing processes in sequential order - Counter-flow water rinsing to conserve water use and reduce wastewater volume	Decrease the equipment and operation cost by 53% and 61%, respectively, compared to the requisite of end-of-pipe treatment.	- Reduction of raw materials use - Prevent loss of water - Reduction of waste and treatment cost	Chaan-Ming, L., 1995

Through cleaner production, the amount of waste and emissions that needs to be treated is reduced. This reduces both the pollution loads in the environment and treatment costs. Perhaps the greatest long-term economic incentive for applying cleaner production is reduction of potential future liability and risk. If a waste is generated in relatively small quantities, the risks of a company being forced into a site cleanup or into adopting other measures could be reduced. In addition, by reducing production cost (from saving raw materials, water and energy), increasing productivity and reducing the threat of future liability, a company can increase its market share, revenues and profitability. Cleaner production provides a company with the unique opportunity to meet regulatory requirements, to realize economic benefits and project itself favorably in terms of public opinion. Improvement of the environmental quality by minimization of wastes and emissions will strongly enhance public perception of a company as a good corporate citizen.

2.3.3 Barriers and Constraints of Cleaner Production

The benefits discussed above encourage industrial production units to consider cleaner production measures. However, a number of factors may inhibit actually putting such measures into effect. Various authors have analyzed barriers and constraints which persist and slow the progress towards cleaner production (OECD, 1995a; Sakurai, 1995; Berkel, 1996; Frijns et al., 1997; Anoymous, 1998; Frijns, 2001). These constraints and barriers fall mainly into three categories including technical, environmental management and legislative, and economic barriers.

Technical barriers. Technical barriers impede the ability of a company to develop, evaluate and implement a cleaner production program. These barriers include lack of in-house expertise in pollution prevention and the absence of readily available cleaner production technologies that can be adopted directly (Chiu and Peters, 1994). In addition, attitudes about changing established industrial production processes or practical operations may be negative and such attitudes tend to block new ways of pollution minimization. Cleaner production choices often cannot completely substitute end-of-pipe solutions. They are frequently criticized as strategies which hardly help industrial units in complying with the law (OECD, 1995a). This brings us to an explanation why instead of investing in cleaner production, industrial units continue to spend on compliance-trigged end-of-pipe facilities.

During a study on the feasibility of cleaner production application to a bleaching and dyeing factory, Hong Kong, Chaan-Ming (1995) received feedback from the factory that they thought it might not have sufficient know how and manpower to guide and supervise workers to exercise better housekeeping practices. Chandark (1995) obtained similar remarks from his case studies on pulp and paper factories; all process personnel, although qualified in pulp and paper technology, lacks knowledge in techniques of waste minimization and cleaner production. The environmental performance of regional small-scale gold mining operations illustrates effectively how technological and information gaps have hindered cleaner production in the industry (Hilson, 2000b). Although cyanide has been the leach reagent of choice for the extraction of precious metals for over 100 years (Mosher and Figueroa, 1996), in many South American countries such as Brazil, Columbia and Venezuela, most small artisanal mines opt to use toxic mercury instead of cyanide and in spite of the well-documented environmental problems and health risks associated with its use (Akagi et al., 1995; Malm et al., 1995; Porcella et al., 1997; Hilson, 2000a and 2000b). Many small-scale gold and silver refining processes, primitive panhandlers in countries like Brazil and China continue to use mercury very carelessly, allowing mercury to escape undetected into the air, freshwater and soils (Hilson, 2000a).

Other industrial units do believe that all possible improvements have already been realized. Hence they tend to prefer the compliance-oriented one-time effort of setting up pollution control facilities and be done with the issue of environmentally sound production. Some of the pollution control systems at site represent billion dollar investments and the people employed have specialized skills and knowledge to operate the system (OECD, 1995b). Changes in the conventional technologies could make workers and managers obsolete and would require investment by companies in training programs, an added difficulty for a firm with a limited budget (Hilson, 2000a). Besides, pollutant generators may be reluctant to take risks with new, unproved technologies or to compromise other business goals and practices. It is also possible they distrust alternative technical processes or simply are uninterested in changing their habitual ways of doing business.

Environmental Management and Legislative Barriers. These barriers are attributed to limited awareness of pollution management issues at the decision-making level and shortcomings of environmental legislation.

From the side of limited awareness on pollution management, appropriate evidence is drawn from research of Hwa (1995) in Singapore and Phuong (2002) in Vietnam. In analyzing negative points of the implementation of cleaner production, they indicated that 'from the government site, there is no incentive policy to encourage the investment in cleaner production. The existing environmental regulations focus only on end-of-pipe technologies. In addition, low resource pricing and non-existing pollution fees are among the major regulatory constraints to promote cleaner production' (Phuong, 2002:85). Criticizing gaps of India environmental regulatory framework, Chandak (1995) stated that there is little institutional impetus provided for the adoption of cleaner technologies and waste minimization techniques. By doing research on textile industry, Chaan-Ming (1995) found that one constraint to implement cleaner production in Hong Kong is ad hoc way of management of the factory. Its management is busy handling the day-by-day operation of the factory without planning for environmental regulation compliance and cleaner production. Corruption is another factor that acts against the promotion of cleaner production (Cheung, 1995). If a factory operator can solve the problems by paying a small bride, why should he invest in pollution control or even cleaner production?

Absence of strict environmental regulations is one of the legislative barriers preventing the implementation of cleaner production practices. Logically, if environmental protection is not of national concern, why should industrial enterprises invest in cleaner technologies and implement cleaner production practices. With limited governmental pressure on industries to perform at high environmental performance levels, and with most governments unfamiliar with such concepts as "waste minimization", "cleaner production" and "pollution prevention", enterprises have little reason, at least from a regulatory point of view, to install end-of-pipe facilities, let alone the implementation of cleaner production. According to Hilson (2000a, 2000b), "loose" environmental legislation is not perceived as being a major problem, but is a major obstacle for governmental and environmental groups, international organizations, and independent agencies seeking to solve industrial environmental problems. This does not mean that stringent environmental legislation would always help to put cleaner production into effect. Though stringent regulations and enormous penalties for noncompliance are incentives for firms to pursue paths of pollution prevention and cleaner production (Hilson, 2000a), these may also become barriers. Because changing environmental regulations may turn pre-existing cleaner technologies, which are recognized as being effective pollution prevention apparatuses one year, to be very well obsolete in the following years. In other words, the use of command-and-control instrument alone deems to hamper the implementation of a cleaner production program.

Economic barriers. According to Frijns (2001), the main constraint on the implementation of cleaner production measures is financial in nature. Even though practices of cleaner production measures lead to cost savings, the unavailability of capital for production process improvement often becomes a significant obstacle to implementing those practices. Analysis of economic barriers on cleaner production implementation in case of mining industry, Hilson (2000b) concludes that due to shortage of financial incentives, many mines in the Americas will be unable to implement the cleaner technologies needed to improve environmental performance. Major companies may have sufficient capital to upgrade inefficient processes, but small and medium size firms often do not (Chiu and Peters, 1994). The implementation of more advanced cleaner production measures that require production technology changes and high initial investments are not likely to happen overnight, especially not in the small scale industrial sector (Frijns, 2001). To some extent, application of cleaner production measures arguably have higher short-term costs, not only due to investments in technology, but also due to the necessary revamping of organizational processes and the higher risk accompanying process modification. Short-term financial performance will be more negatively related to pollution prevention efficiencies than to end-of-pipe treatment efficiency (Sarkis and Corderiro, 2001). In addition, low disposal and treatment fees impeding cleaner production activities is also considered as a kind of economic constraint.

2.4 INDUSTRIAL ECOLOGY

2.4.1 Introduction to Industrial Ecology Concepts

The idea of **industrial ecology** (IE) has taken root in the past few years, especially since the well-known article by Frosch and Gallopous in a special issue of *Scientific American* (Frosch and Gallopoulos, 1989). It encompasses the transformation of the traditional model of industrial activity into a more integrated model – an industrial ecosystem, in which waste from one process can serve as raw material for the other ones. Afterward, many concepts concerning IE have appeared. IE is defined by Tibbs (1992) as designing industrial infrastructures as if they were a series of interlocking ecosystems interfacing with the natural global ecosystem. IE goes even further than this definition because it is an attempt to model the industrial system after the natural ecosystems that demonstrate resources efficient operation (UNEP, 1997). According to Karamanos (1995), IE is a new and innovative strategy for sustainable industry involving design of industrial systems in a way to minimize waste and maximize the cycling of materials and energy. Karamanos touches upon aspects of waste minimization and materials and energy recycling but does not include reduction in the consumption of resources, one of the aims of IE (Krrishnamohan and Herat, 2000). In addition, the concepts of integrating industry with the natural system nor the need for industry to mimic the natural system are emphasized in this definition. Hileman (1992) stated that IE studies how we humans can continue rearranging earth, but in such a way it protects our own health, the health of natural ecosystems, and the health of future generations of plants, animals and humans. It encompasses manufacturing, agriculture, energy production, and transportation. Nearly all of those things we do to provide ourselves with food and make life easier and more pleasant than it would be without them. With this definition, Hileman considers IE as a study to “rearrange the earth”. He stresses the need for sustainable development where the interests not only emphasize on the present and future generations of human race but include that of plants and animals. IE is a novel approach to achieve sustainable development. It aims to optimize the consumption of natural resources and energy and minimize the generation of waste. This means that the ideas of IE imply all other pollution prevention approaches including end-of-pipe treatment and cleaner production measures. In industrial ecology textbooks, many of the instruments of cleaner production return. However, it should be kept in mind that most of cleaner production instruments are directed to single companies or to companies that are linked together in a product chain. In some cases, environmental scientists want to go beyond that perspective, so they do not look at industry from a single company or product chain perspective, but they envisage industrial production as an ecosystem of organisms, exchanging information, energy and materials with each other and with their environment. Erkman and Ramaswamy (2001) state that cleaner production equals pollution prevention practices at the company level, while industrial ecology means pollution prevention practices at the system level. In other words, the concept of IE essentially calls for an integrated approach towards the environmental effects of industrial process as a whole, rather than aiming at the reduction of the effects of separate industrial processes (Boons and Baas, 1997). Nevertheless, IE is still in its infancy and does not have a widely accepted definition (Krrishnamohan and Heart, 2000). Erkman (1997) concluded that whatever the definitions may be, all authors more or less agree on at least three key elements of the IE perspectives:

1. It is a systemic, comprehensive, integrated view of all the components of the industrial economy and their relations with the biosphere.
2. It emphasizes the biophysical substratum of human activities, i.e. the complex patterns of material flows within and outside the industrial system, in contrast with current approaches, which mostly consider the economy in terms of abstract monetary units, or alternatively energy flows.
3. It considers technological dynamics, i. e. the long-term evolution (technical trajectories) of clusters of key technologies as a crucial (but not exclusive) element for the transition from the actual unsustainable industrial system to a viable industrial ecosystem.

The basis of IE is provided by the phenomenon of **industrial metabolism**, which stands for the whole integrated collection of physical processes that convert raw materials and energy, plus labor, into finished products and wastes in a (more or less) steady-state condition (Ayres and Simonis, 1994). IE goes further. The idea is first to understand how the industrial system works, how it is regulated, and its interaction with the biosphere. Then on the basis of what we know about ecosystems, to determine how it could be restructured to make it compatible with the way natural ecosystems function (Erkman, 1997). By doing so, industrial enterprises can be assembled into **industrial ecosystems.** Such systems consist of a number of industrial enterprises acting synergistically and, for the most part, with each utilizing products and potential wastes from other members of the system (Frosch and Gallopoulos, 1989; Manahan, 1999).

As basic knowledge on industrial metabolism and industrial ecosystems is essential to understand and apply the principles of industrial ecology, sections 2.4.2 and 2.4.3 are devoted to the concepts of industrial metabolism and industrial ecosystem. The role of the IE approach in environmental protection is discussed in section 2.4.4.

2.4.2 Industrial Metabolism

Industrial metabolism follows the flows of materials and energy from their initial sources through an industrial system, to the consumer, and to their ultimate disposal (Erkman, 1997; Manahan, 1999). Industrial metabolism provides a conceptual framework for the transformation of our current production and consumption system toward sustainable development (Côté and Hall, 1995). The basic idea is to analyze the flows of materials and identify and assess all possible emission sources and other environmental effects connected to those flows (Anderberg, 1998). This section considers in some detail the topic of industrial metabolism with discussions on industrial metabolism and biological analogies and material cycle.

Industrial Metabolism and Biological Analogies

The concept of metabolism is as old as the history of biological sciences. It is employed to describe the internal processes of a living organism. Biological metabolism is defined as biochemical processes that involve the alteration of biomolecules. Manahan (1999:43) has pointed at a similarity between biological metabolism and industrial metabolism: 'metabolic processes can be divided into the two major categories of anabolism (synthesis) and catabolism (degradation). An industrial ecosystem likewise synthesizes substances, thus performing anabolism, and it degrades substances, thereby performing in a manner analogous to biological catabolism'. In a biological system, metabolism occurs in individual cells, in an individual organ and in the organism as a whole. Similarly, "industrial metabolism can be examined as individual unit operations within an industrial operation, at factory level, at industry level, and globally" (Manahan, 1999:47). Though there are some differences between a living organism and an industrial production unit (Table 2.2), Ayres (1994) argues that the concept of industrial metabolism is applicable to manufacturing enterprises or firms. He also emphasizes that the key to regional analysis is the existence of a well-defined geographical border or boundary across which physical flows of materials and energy can be monitored.

Table 2.2 Differences between living organisms and firms

Living organisms	Firms
Biological organisms reproduce themselves	Firms produce products or services
Organisms are highly specialized and can not change their behavior except over a long period (evolution)	Firms need not be specialized and can change from one product or business to another. A manufacturing firm converts material inputs, including fuels or electric energy, into marketable products and waste materials.

Source: Ayres, 1994.

According to Manahan (1999:44), "biological metabolism system is self-regulating. At the level of the individual organism, internal regulation is accomplished by biological regulatory mechanisms. At the ecosystem level, regulation occurs through the competition among organisms for available resources". An industrial ecosystem is also self-regulating. However, in this case, the regulatory mechanism is the economic system, which is operated under the laws of "supply and demand". A comparison of the metabolisms of natural ecosystems with that of industrial systems is highlighted in Table 2.3.

Table 2.3 Metabolic characteristics of natural ecosystems and industrial systems

Characteristic	Natural ecosystems	Current industrial systems
Basic unit	Organism	Firm
Material pathways	Closed loops	Largely one way
Recycling	Essentially complete	Often very low
Material fate	Tend to concentrate, such as atmospheric CO_2 converted to biomass by photosynthesis	Dissipative to produce materials too dilute to use, but concentrated enough to pollute
Reproduction	A major function of organisms is reproduction	Production of goods and service is the prime objective, not reproduction per se

Source: Manahan, 1999.

In the natural ecosystem, the biological cycling of materials is maintained by three groups: producers, consumers and decomposers. The producers can be plants and some bacteria, which are capable to produce their own food by photosynthetic or chemical-biological processes. The consumers can be animals that obtain energy and protein by grazing or eating other animals and plants. The decomposers can be fungi and bacteria, which are able to convert organic matters of producers and consumers into food for the producers. Thus, the decomposers also play the role of recyclers. With the sun as the energy source, nature is capable of sustaining the producer-consumer-decomposer cycle indefinitely. The smallest self-sufficient entity that is an ecosystem (Husar, 1994a).

In industrial systems, the producing activities include energy production and other manufacturing to produce goods. The consumers can be other enterprises, humans (markets) and their domestic animals. Decomposing or recycling activities consist of treatment or recovery and recycling of wastes. However, whereas the natural ecosystem relies on its decomposers for a complete recycling of its elements, the industrial system currently lacks such efficient decomposers and recyclers (Husar, 1994a). Thus, unwanted materials (including wastes and non-products) are released into the environment. In this sense, the industrial system is a less closed system. To meet the criteria of an industrial ecosystem, the byproducts and wastes must be utilized and processed within the system (Manahan, 1999).

Material Cycle

Material flow and energy flow are two key aspects of industrial metabolism (Manahan, 1999). In the current industrial system, there are two types of material utilization. The first one is called a linear metabolism system, in which input is unrelated to output (Fig. 2.1). The production, use and disposal of products occur without reuse, or recovery, of energy or materials (Carr, 1998; Lowenthal and Kastenberg, 1998 Krrishnamohan and Heart, 2000). The second one is characterized by maximum internal cycling of materials, but there is still a need for virgin material input and waste continues to be generated and disposed of outside the economic system (Fig. 2.2). According to Manahan (1999), based on as complete knowledge as possible of a system of industrial metabolism, it is possible to optimize the industrial system for maximum efficient production, minimum waste and minimum environmental pollution by internalization of the material cycle (closing). This means that the material cycle is closed as far as possible in away that materials need not be shipped long distance to be used. That means that local markets have to be developed for potential waste materials or such materials need to be locally upgraded to higher value products.

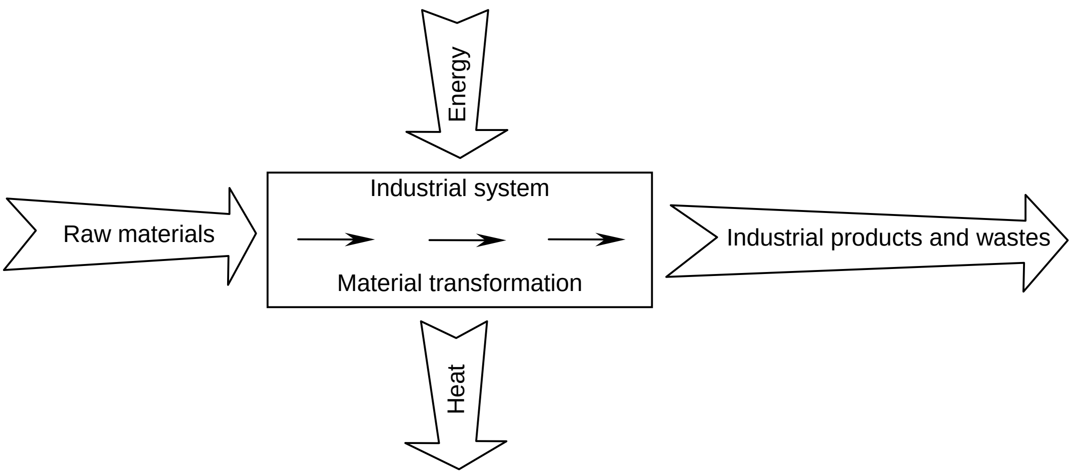

Fig. 2.1 Type 1 of the industrial system (modified from Lowenthal and Kastenberg, 1998 and Krrishnamohan and Heart, 2000).

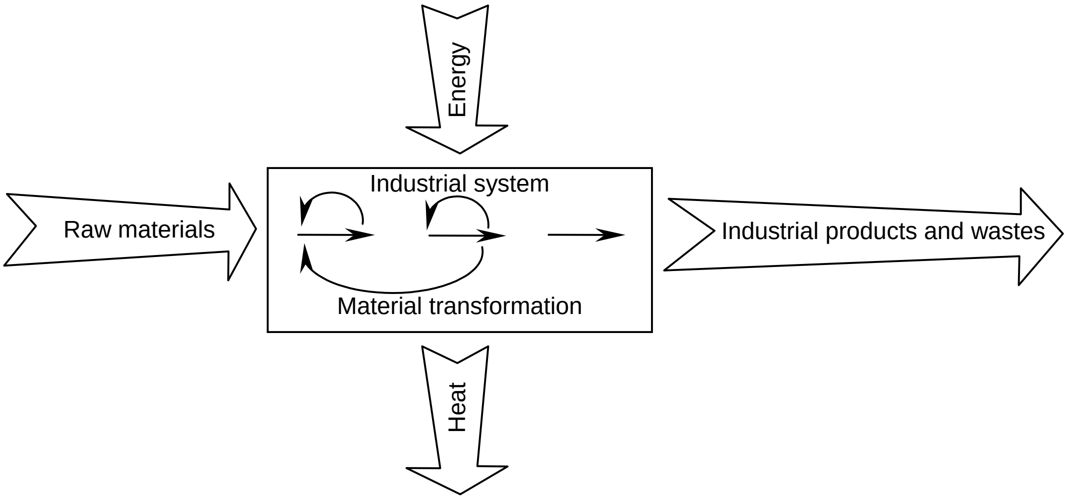

Fig. 2.2 Type 2 of the industrial system (modified from Lowenthal and Kastenberg, 1998 and Krrishnamohan and Heart, 2000).

System integration is another move of the second type to close or internalize the material cycle. This refers to the systematic correlation of all aspects of an industrial production system to attain maximum efficiency and profit. This approach facilitates material and energy flows, exchange and recycling in between various firms in the industrial ecosystem. Meat packaging plants are excellent examples of efficient system integration. Lower grade proportion and scraps of meat can be used in sausage production, lard is used to make soap, cattle hides are available to produce leather and bone meal is a raw material for fertilizer production.

2.4.3 Industrial Ecosystem

Major Components of Industrial Ecosystem

Frosch and Gallopoulos (1989) first introduced a simple definition of an industrial ecosystem focusing on the relations among companies in direct waste/byproduct exchange. Connections with a natural ecosystem have also been made, both at interface level between man-made ecosystems with the natural global ecosystem (Tibbs, 1992) as well as the application of the principles of natural systems to man-made systems (Kirchner, 1995). Industrial ecosystem can be defined as including all types of production, processing and consumption, for instance agricultural production as well as purely industrial operation (Manahan, 1999). The four major components of an industrial ecosystem are primary materials and energy producers, materials processing and manufacturing sector, waste processing sector and consumer sector (Fig. 2.3). The primary material and energy producers may consist of one or several enterprises providing the basic materials that sustain the industrial ecosystem. Throughout the various steps of extraction, concentration, separation, refining, processing, preparation and finishing, virgin materials are converted into finished materials and energy and wastes may be generated. The finished materials from the primary material producers are fabricated to make products in the material processing and manufacturing sector. This sector shows several opportunities for recycling such as process recycled streams (materials are recycled in the manufacturing operation itself) and external recycle streams (materials are recycled from other manufacturers or from post consumer products). In the consumer sector, products are sold or leased to the consumers who use them. In all cases, the end of useful lifetime of the product is reached and it is either (1) discarded or (2) recycled. Finally, the waste-processing sector consists of enterprises that deal specially with the collection, separation, and processing of recyclable materials and wastes.

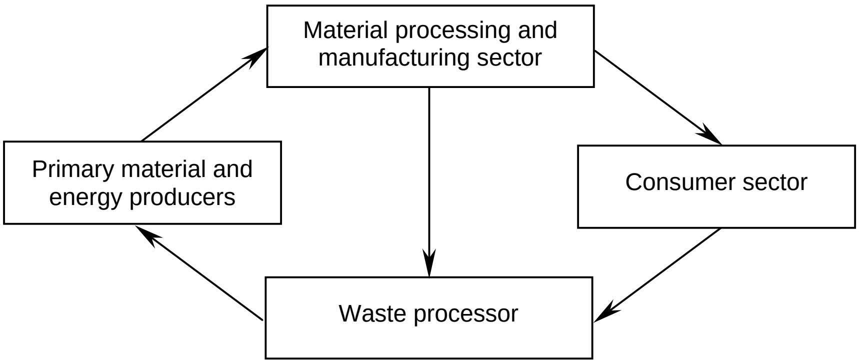

Fig. 2.3 The major components of an industrial ecosystem (modified from Manahan, 1999).

Types of Industrial Ecosystem

An industrial ecosystem will utilize waste material and waste energy between the actors in the system, perhaps also including the non-industrial sector, e.g households, in the system boundaries. In this way, the virgin material, and possibly also virgin energy, inputs as well as the waste and emission outputs of the system as a whole are reduced because waste is used to substitute the virgin material and energy sources. This recycling system differs from the recycling of an isolated product flow in that many different material and energy flows and many different actors are studied (Korhonen et al., 2001). Boons and Baas (1997) clarify different types of industrial ecosystem by drawing different boundaries around a product life cycle, a material life cycle, an geographical area, an industrial sector and miscellaneous. They argue that the criterion for drawing the boundary around an industrial ecosystem is either geographical or based on the product/material chain. These types of industrial ecosystems can be described as follows:

- *Product life cycle*. From this perspective, the boundary of an industrial ecosystem is drawn around the economic actors (both producers and consumers) connected to a specific product.
- *Material life cycle*. Similar to the product life cycle approach, the boundary is now drawn around actors dealing with a specific material. Good examples are cases of steel, plastics and platinum production as described by Frosch and Gallopoulos (1989).
- *Geographical area.* Due to increasing geographical separation between the production and consumption of the (end)product, drawing the boundary in this way usually excludes the consumption of end-products from the system. In this case, the Burnside Industrial Park in Halifax (Canada) and the Industrial Symbiosis approach in Kalunborg (Denmark) are suitable examples.
- *Industrial sector.* From this perspective, a group of companies performing similar activities can form an industrial ecosystem. Therefore, the elaboration in practice is less related to physical compounds. Instead, this can contribute to the application of industrial ecology by developing overall environmental approaches.
- *Miscellaneous.* The concept of industrial ecology do not seem to be concerned with a specific boundary, instead they deal with companies that have found a buyer for a byproducts of their production process. These situations have in many cases developed into bilateral relations.

It can be found in literature that the most focus point commonly used for the industrial ecosystem approach has been an eco-industrial park (EIP) or a local/regional industrial ecosystem with the often-cited example in the industrial district at Kalundborg in Denmark (Lowe and Evans, 1995; Côté and Hall, 1995; Gertler and Ehrenfeld, 1996; Ehrenfeld and Gertler, 1997; Côté and Smolenaars, 1997; Sagar and Frosch, 1997; Cote and Cohen-Rosenthal, 1998; Korhonen et al., 1999, Manahan, 1999). Lowe (1997) stated that the story of Kalundborg has become the premier case illustrating industry can coexist in a more benign manner while generating bottom-line benefits. Several EIP projects appeared in many developed countries in the world after Kalundborg such as:

- Burnside industrial park, Nova Scotia, Canada (Côté et al., 1994; Smolenaars, 1996; UNEP, 1997; Côté and Cohen-Rosenthal, 1998);
- The INES (Industrial Ecosystem) project was started in 1994 in the port of Rotterdam region, the Netherlands (Baas, 1998b; van Koppen and Mol, 2002);
- The Houston Ship Channel in Texas, USA (Lowe and Evans, 1995; Manahan, 1999; van Koppen and Mol, 2002, Lambert and Boons, 2002);
- Port industrial district, Ontario, Canada (UNEP, 1997);
- Brownsville (Texas), Baltimore (Maryland), Cape Charle (Virginia), Chattanooga (Tennessee), United States (Rosenthal, 1996; UNEP, 1997);
- Sophie Esterel, Chalon-sur-Saône, Réseau Haute Saône, France (UNEP, 1997);
- Linkoping, Sweden (UNEP, 1997).

In addition to these examples, every time two or more concerns have a symbiotic relationship in which wastes from one are utilized by another, they can be regarded as a partial constitution of an industrial ecosystem, of which hundreds exist throughout the world. Schwarz and Steininger (1997) gave an interesting example on the case of Styria, where more than 50 concerns are collaborating in a material and energy web that had developed in the province. A large variety of materials was utilized and recycled including used lubricating oil, solvents, scrap iron and other metals, paper and gypsum, a byproduct from power plant desulfurization with limestone. An interesting aspect of the Styria industrial ecosystem is that it did not develop as part of a master plan, but was motivated by the profits from selling byproducts and is also possible the lower prices. Thus, both Kalundborg and Styria industrial ecosystem, as well as perhaps hundreds of others not documented, developed spontaneously, primarily through bilateral agreements and symbiotic relationship between firms (Manahan, 1999).

2.4.4 Strengths and Weaknesses of Industrial Ecology Approach

Strengths. By creating linkages among firms or industrial sectors and move them forward together, industrial ecology overcomes the shortcoming of end-of-pipe treatment, cleaner production and waste minimization approaches, which deal only with individual firms. Industrial ecology strives to optimize resource flows rather than just preventing pollution and to promote sustainability rather than only reduce risk (Olderburg and Geiser, 1997). Practical limitation of other pollution prevention approaches to achieve zero emissions from every production process lead to the need of broader loop-closing aspect of industrial ecology. Industrial ecology offers a bridge between the specific innovations occurring in cleaner production and the attainment of an industrial system supplying human needs within the constraint of global and local carrying capacity (Lowe and Evans, 1995). Brattebø (1996) identifies cleaner production and environmental management as process-oriented while industrial ecology is a system-oriented and covers a longer time frame and the whole array of manufacturing.

Weaknesses. Many articles on industrial ecology focus largely on the physical flows of substance and the physical transformation processes (Ayres and Simonis, 1994; Lowe and Evans, 1995; Nemerow, 1995; Ayres and Ayres, 1996; Ayres, 1996; Rosenthal, 1996; Lowe, 1997; Baas, 1998b; Lowenthal and Kastenberg, 1998; Carr, 1998; Chertow, 1999, Lambert and Boons, 2002; etc.). Most case studies on industrial ecology at national level (Ayres et al., 1994; Husar, 1994b; Lohn et al., 1994; Ayres and Ayres, 1994, Wernick and Ausubel, 1995; Korhonen et al., 2001), regional level (Stigliani and Anderberg, 1994; Brunner et al., 1994; Schwarz and Steininger, 1997; Korhonen, 2001; Holderbeke and Timmermans, 2002) and at industrial sector (Ayres and Simonis, 2994; Nemerow, 1995; Sagar and Frosch, 1997) have paid attention to material flows such as toxic heavy metals, chemicals, air pollutants in order to seek suitable solutions to reduce pollution. I do share the ideas of Baas (1998) that major weaknesses of these approaches are: (1) they do not address issues of co-ordination (mechanism) within and between organisms and (2) almost ignore the institutional structures within which organizations operate. These may be markets for raw materials, commodities, products, service, labor, capital and insurance. These may be legislative, addressing issue of competition, fiscal incentives, environmental regulations and liability. They may also be cultural, social, historical or ethical. Industrial ecology should include the ‘competition between species’ and ‘population dynamics’ without getting trapped in oversimplifications of socio-biology. According to Van Koppen and Mol (2001:138), ‘if we want to bring industrial ecology perspectives from the design table more into practice, it seems essential to further develop an actor and socio-institutional perspective of these kind of industrial transformation’. This gap can be filled by ecological modernization theory as discussed in the next section. Furthermore should be mentioned that Lowe (1997) is correct in stating that network of material flows creating wastes/byproduct exchanges faces the following challenges and risks:

- Companies using each other’s residual products as inputs face the risk of losing a critical supply or market if a plant closes down or changes its product mix;
- Proprietary information could become available to competitor;
- Uneven quality of byproduct materials could cause damage to equipment or quality of products;
- Exchange of by-products could lock in continued reliance on toxic materials;
- Recycling wastes from one firm to another often involves some “downgrading” of the quality of the material being recycled. Even with good recycling, most industrial materials will eventually become waste. Thus, industrial waste recycling may delay, but does not prevent materials from becoming wastes (Oldenburg and Geiser, 1997);
- Possible innovations in regulation to enable an eco-industrial park development may not be allowed by regulatory agencies.

2.5 ECOLOGICAL MODERNIZATION

2.5.1 Three Stages of Ecological Modernization Theory

Historically, economic growth and environmental protection have been seen to be mutually antagonistic, but theory of ecological modernization as discussed by Simonis (1989), Spaargaren and Mol (1991), Weale (1992) and Hajer (1996) suggest that economic and environmental goals can be integrated within a framework of industrial modernity. The perspective of ecological modernization is said to offer a constructive approach to deal with environmental problems, with a central role assigned to science, technology and the state (Mol and Spaargaren, 1993). Even in its relatively short history, the Ecological Modernization Theory (EMT) has gained much attention and has become popular, especially in the West-European countries (Mol, 1995; Mol, 1997; Mol and Spaargaren, 1998). The theory has developed with considerable diversity and debate, not only by national background and theoretical foundation, but also chronologically (Mol and Sonnenfeld, 2000). According to Mol (2000), the emergence of the ecological modernization theory can be distinguished in three stages: (1) starting with Joseph Huber and Martin Jänicke in the early 1980s; (2) continuing from the late 1980s to mid-1990s and (3) recently, from mid of 1990s onward. Distinguishing these three stages of development and maturation of this school of thought is believed very useful for further understanding, identifying and applying the core features of the theory.

The concept of ecological modernization was first developed through the work of the German social scientists Joseph Huber and Martin Jänicke (Gibbs, 2000; Mol, 2000). Mol (1995) argued that Joseph Huber should be acknowledged as the father of Ecological Modernization Theory due to his theoretical contributions to the environment and society debate from the 1980s onwards. In Huber’s view, ecological modernization offers us the only way out of ecological crisis through more industrialization, albeit with changed production and consumption (Gibbs, 2000). Huber identifies two central projects which constitute the heart of the ecological transformation or the ecological restructuring of processes of production and consumption (Mol, 1995). The first project emphasizes on technological transformations and changes. For Hubber, technical developments occur largely autonomously and act to determine change in industrial systems and their relations with the social and natural environment. In some accounts of Huber’s approach, the state should play no role in the switch to ecological modernization, as it will only hinder the development and diffusion of cleaner technologies. He strongly emphasizes on the role of technical innovation especially in the sphere of industrial production (Mol, 2000), while neglecting the social context within which these occur (Gibbs, 2000). This overly technical view was criticized by Mol and Spaargaren (1993), who argued that it is difficult to imagine an ecological switchover without state intervention at various levels. In the second project, the concept of ecological modernization involving the project to ‘economize ecology’ aims to get economic actors to systematically take environmental considerations into accounts in their participation in economic processes of production and consumption (Mol, 1995). Generally, the first contributions by Joseph Huber, were characterized by a heavy emphasis on the role of technological innovations in environmental reform; a critical attitude towards the (bureaucratic) state and a relatively favorable one towards the market; a system-theoretical perspective with a relatively under-developed notion of human agency; and an orientation at the nation-state level (Mol, 2000; Mol and Sonnenfeld, 2000).

From the late 1980s, several authors contributed to develop the theory of ecological modernization such as Simonis (1989), Jänicke (1991) from Germany; Spaargaren and Mol (1991; 1992), Mol and Spaargaren (1993), Mol (1995), Hajer (1995) from the Netherlands; Weale (1992), Murphy and Gouldson, (1995) from the UK. In this period, the ecological modernization theorists were less strong on technological innovation, they had a more balanced view of state and market dynamics in ecological transformation processes, paid more attention to the institutional and cultural dynamics of ecological modernization and to consumption processes (Mol and Sonnenfeld, 2000; Mol, 2000). From mid 1990s onward, studies of ecological modernization have expanded to non-West-European nation states such as developing countries, Central and East European nation-states but also for instance to the USA (Mol and Sonnenfeld, 2000; Mol, 2000; Phuong, 2002). More recently, empirical studies have been carried out in Kenya (Frijns et al., 1997), Vietnam (Frijns et al., 2000; Phuong, 2002) and Southeast Asia (Sonnenfeld, 2000). Increasing attention has been paid to the global dynamics of ecological modernization (Mol, 2001). Christoff (1996) has distinguished a *weak* and a *strong* version in the theory of ecological modernization from mid-1980s onward (Table 2.4). Hajer (1995) equaled the strong ecological modernization with reflexive ecological modernization, whereby political and economic development proceed on the basis of critical self-awareness involving public scrutiny and democratic control, while weak ecological modernization involves a lifeline for capitalist economies threatened by ecological crisis.

Table 2.4 Characteristics of weak and strong ecological modernization

Weak ecological modernization	Strong ecological modernization
Technological solutions to environmental problems	Broad changes to institutional and economic structure of society incorporating ecological concerns
Technocratic/corporatist styles of policy making by scientific, economic and political elite	Made in an open and democratic way with participation and involvement
Restricted to developed nations who use ecological modernization to consolidate their global economic advantages	Concerned with the international dimension of the environment and development
Imposes a single, closed-ended framework on political and economic development	A more open-ended approach with no single view, but multiple possibilities with ecological modernization providing orientation

Source: Gibbs, 2000.

Though there are some temporal and theoretical differences as described above, the perspective of ecological modernization is said to offer a constructive approach to deal with environmental problems (Mol and Spaargaren, 1993). The concept of ecological modernization can be used (1) as a theoretical concept to analyze those changes to the central institutions in modern society deemed necessary to solve the ecological crisis and (2) to describe a more pragmatic political program to redirect environmental policymaking. Three central projects form the heart of ecological modernization consisting of (Gouldson and Murphy, 1996):

- The restructuring of production and consumption towards ecological goals. This involves the development and diffusion of cleaner production technologies and decoupling economic development from the relevant resource inputs, resource use and emissions;
- ‘Economizing ecology’ by placing an economic value on nature and introducing structural tax reform;
- Integrating environmental policy goals into other policy areas.

2.5.2 The Core Features of Ecological Modernization Theory

The core features of the EM theory include technological innovation, economic reform, political modernization and social movement. These core features are derived from analyzing innovative best practices in industrialized, especially European countries. This gives a certain bias to the theory.

Technological Innovation

Whereas counter-productivity and risk society theorists stress the all-negative influence on nature of modern scientific and technological projects, the EM theory emphasizes on the benefits of transformations of technological trajectories for environmental reform (Mol, 1995). In analyzing contemporary processes of environmental reform in the chemical industry, Mol (1995) found that science and modern technology are key factors in the process of ecological restructuring. Environmental technology or technological contributions to the solution of environmental problems, can no longer be equated with or restricted to first generation end-of-pipe (EOP) artifacts as dominant in the 1970s (Mol, 1995). EOP technologies are replaced by or combined with 'environmentally integrated' or 'inherently better' technology (van Weenen, 1990). In the long run, it is better to deal with ecological effects in the design of products rather than dealing with waste streams that already exist (Boons and Baas, 1997). The EM theory does not reject the role of end-of-pipe technologies, but it emphasizes that industry should seek solutions to pollution problems through the exploration of cleaner technologies and production techniques Murphy and Gouldson (2000). From empirical examination of environmental regulation and industrial innovation in case of England and Wales, Murphy and Gouldson (2000:39) received response from one inspector that:

> *"We would always encourage companies to improve the way they are carrying on the process to meet whatever emission standards we require. But if they can't do that, then they may have to fit abatement technologies. But the preferred way is to have them minimize at source and have the minimum of abatement equipment necessary"*

That is why cleaner production is often put forward to interpret the notion of technological innovation in the EM theory (Cohen, 1997; Mol, 1999; Frijns et al., 2000). Environmental reform should be based on interpreting pollution reduction by means of enhancing economic competitiveness rather than as an externality requiring the installation of end-of-pipe technologies (Cohen, 1997). Use of both products and product waste streams need to be optimized (Frosch, 1992). At all stages of production and consumption, actors must shape activities to minimize both resource use and waste generation via criteria of ecological rationality. This is one of the mechanism put forward within the project of EM (Andersen, 1994). As seen by Spaargaren and Mol (1991) and others, ecological modernization involves the invention, innovation and diffusion of cleaner technologies that demonstrate improved environmental and economic performance. There is a technological imperative in ecological modernization and technologies hold the key to decoupling economic development from environmental impact (Gouldson and Murphy, 1996). At the macroeconomic scale, Jänikce et al. (1989) suggested that economic development is often associated with reductions in the environmental intensity of each unit of GDP as a consequence of structural change and technological advance. At microeconomic scale, Lorenzen et al. (1994), Murphy and Gouldson (1995, 2000), Gouldson and Murphy (1996, 1997) and Gibbs (2000) suggested that the development and diffusion of clean technologies bring concomitant economic and environmental benefits. By doing so, instead of seeing environmental protection as a burden on the economy, the ecological modernists see it as a potential source for future growth (Weale, 1992).

Economic Reform

The EM theory emphasizes the role of economic, market dynamics and actors in the ecological restructuring, together with regulators and civil society. According to Mol (1995), 'The market is considered to be a more efficient and effective mechanism for coordinating the tackling of some environmental problems than the state. Market forces, innovative entrepreneurs, consumers, insurance companies, creditors and commissioners, among others, will emerge as new important forces in and social carries of the ongoing process of socio-ecological transformation'. The idea of looking at an economy ecologically and more specifically describing the flows of materials and energy through the economy as a metabolic system was introduced by Ayres (1989, 1992). It is important that the economic and material linkages within societies are identified, understood, and modified to reduce the withdrawals of energy and materials from the natural stock and the disposal of wastes back into the environment (Ayres, 1991). A sustainable industrial society can no longer separate economic imperatives from ecological ones. To do so, it is not only important to look beyond the simple closed-cycle rubric to identify complex paths that reduce the demand on the environment as a sink and source (Ehrenfeld, 1997), but also to create the same strong linkages among different actors. According to the EM theory, the state and economic agents such as producers, consumers, customers, credit institution, insurance companies, etc. play important roles as social carriers of ecological restructuring and reform (Mol, 1995). Economic actors and entrepreneurs were identified as most important in achieving the transformation associated with ecological modernization. Economic actors can systematically take environmental considerations into account in their participation in economic processes of production and consumption by eco-taxes, redirection of insurance conditions towards environmental care, increasing demand for ecologically sound products on the market, introduction of the environment as a factor in economic competition and of environmental audits as a precondition for commercial loans and economic investments (Mol, 1995). But in order to do so, they often have to be triggered, pushed or challenged by regulators, environmental NGOs or citizen-consumers. While economic actors and mechanisms alone will not automatically protect the environment (hence the correction of market failure), they play a major part in articulating, communicating, strengthening, institutionalizing and extending environmental interests in time and place.

Political Modernization

The EM theory suggests that policy for economic development and environmental protection can be combined with synergistic effect (Gouldson and Murphy, 1996). Practical experiences of developed countries have revealed that rather than perceiving the goals of environmental protection to be a brake on development, the EM theory promotes the application of stringent environmental policy as a positive influence on economic efficiency and technological innovation. It is argued that policy must be based on its central tenet that there is no necessary conflict between environmental protection and economic growth and that they may in fact be mutually supportive. For instance, Weale (1992) examined the Dutch National Environmental Policy Plan that its interventionist approach and the way attempting to stimulate innovation through the setting of strict environmental targets established it as an example of a policy consistent with the EM theory. Ecological modernists emphasize the role of government to promote innovation in environmental technology (Cohen, 1997). Critically, innovative and strict environmental regulation by government is seen as a way of driving the innovation process in industry to the end (Murphy and Gouldson, 2000). But the traditional central role of the nation-state in environmental reform is also changing. The role of the state is believed to move from top-down hierarchical command-and-control to more decentralized, flexible and consensual styles. The state also moves from a centralized to a decentralized style, creating more opportunities for non-state actor to take over traditional tasks of the nation-state (Beck, 1994). Governmental institutions cannot rationally formulate policies without knowing which environmental problems pose great risks. Policymakers currently lack critical information on how materials flow through the economy and about the relative dangers of different materials, products, and waste streams (Weinberg et al., 1994). Dealing with such issues, the EM theory provide a new concept that is termed as “modernization of conventional politics” (Mol, 1995; Spaargaren, 1997). Political modernization advocates a new steering concept and mechanism based on the assumption that steering power is not only available to the government, but also to other actors in the society. Steering powers are embedded in interactions between authorities, institutions and citizens, that all have capacities to make rational choices. In all, Mol (1995) concludes that the role of the state in environmental policy will have to change from curative and reactive to preventive, from closed to participate policy making, from centralized to decentralized wherever possible.

The integration of environmental policy goals into other policy areas of government is recognized as important to achieve effective environmental protection (Gouldson and Murphy, 1996). “Economization of ecology” introduced by Mol (1995) implies the introduction of economic concepts, mechanism and principles into environmental policy. Spaargaren and Mol (1991) identify the “economizing” of the environment by placing an economic value on nature to go alongside the values placed upon labor and capital as the other factors of production. Indeed, some authors go further than this to propose a widespread realignment of fiscal structures so that they create environmentally benign and labor-intensive development paths (Gouldson and Murphy, 1996). Transfer of responsibilities, incentives and tasks from the state to the market will advance and accelerate the ecological transformation process, mainly because the market is considered to be a more efficient and effective mechanism for coordinating the tackling of environmental problems than the state (Buttel, 2000a; Buttel, 2000b).

Social Movement

Another core feature of the EM theory deals with the modification of the ideology, strategy and position of social movements in the process of ecological transformation from 1970s onwards. Within policies/politics and culture/ideologies, some notable environmental-informed transformations took place in the 1970s and early 1980s (van Koppen and Mol, 2002). Comparing the ideologies of the major environmental organizations in the 1970s with those in the 1990s, one can hardly miss the differences concerning the causes of and the solutions for environmental problems, as put forward by both representatives of environmental NGOs and the social scientists studying the environmental movement (Mol, 2000). The position of environmental NGOs in environmental and broader social struggles has changed considerably. While in the 1970 and early 1980s, the environmental movement could be seen as part of a broader movement for social change regarding many developments in Western societies, they can increasingly be interpreted as one-issue movement. Rather than acting simply as an outside commentator, environmental NGOs increasingly participate in direct negotiations with state representative and economic agents, and contribute to the development of concrete proposals for environmental reform (Phuong, 2002).

2.5.3 Ecological Modernization and Industrial Ecology: Difference and Supplementation

Though there are temporal, geographical and authorial differences, the Ecological Modernization Theory (EMT) and the Industrial Ecology Theory (IET) have similarities at overcoming or minimizing environmental problems by redirecting industrial production and consumption processes in a more environmentally sound direction. An interesting aspect is that the differences on school of thought of these theories, as described right in this section, can supplement “gaps” of each other. The IET is a theory on physical transformation of material and energy flow, while the EMT does not focused on physical improvement per definition, but rather on social and institutional transformations (Mol and Sonnenfeld, 2000). The IET pays strong attention to the industrial system and material and energy flows to optimize them, while the EMT focuses on a broader set of actors and institutions that affect the process of industrial restructuring and environmental reform. The IET mainly studies the way material and energy flows pass through production processes in order to seek for suitable solutions to improve their production efficiency and increase the environmental performance. By contrast, the EMT analyzed how traditional curative and repair options are replaced by preventive socio-technological approaches incorporating environmental considerations from the design stage of technological and organizational innovations (Mol and Sonnenfeld, 2000). The EMT focuses on the way, in which substance-flows-management can and should be organized in a more efficient way (Spaargaren, 2000). The EMT aims at analyzing strategies to overcome environmental problems by considering technical and social interventions in production and consumption systems rather than only looking at simple co-operation of industrial enterprises in physical model of industrial ecology. By emphasizing on actors and socio-institutional perspectives of industrial transformations, the EMT perspectives supplement for "gaps" of the IET and together with the IET, it is a powerful tool to analyze how the unsustainable industrial system can and should move into more environmentally sound directions.

2.6 CONCLUSIONS

Histories, aspects, strengths and weaknesses of the three existing pollution prevention approaches, end-of-pipe treatment, cleaner production/waste minimization and industrial ecology, were introduced and discussed in this chapter. It appears that all these approaches aim at pollution reduction and environmental improvement, but the focuses differ from each other. Rather than waiting to treat wastes after being generated as the end-of-pipe approach does, cleaner production measures prefer to prevent and reduce pollution at source. Rather than concentrating application within a boundary of individual industrial production unit as done by cleaner production, industrial ecology enlarge its implementation by a network within an industrial sector, a region, a nation and even at global level. However, this strict focus on the physical model is also the main weakness of industrial ecology. Overcoming the shortcoming of paying attention to physical transformation, only ecological modernization theory emphasizes all technical, economic, political and social aspects of an industrial system. Due to the differences in focus, the different approaches have different influences on environmental protection practices. Though cleaner production could help to overcome weaknesses of end-of-pipe treatment, it is not always feasible and sometimes it is difficult to realize complete removal of pollutants without end-of-pipe treatment. Similarly, network creation following the ideas of industrial ecology could increase environmental performance much better than the narrow scale application of cleaner production, nor is this method always applicable, especially with a project in a relatively big area due to difficulties in finding suitable feed-back loops and putting them to work. Therefore, integrating these approaches into broader perspective, to which they should be subordinated, would be a promising approach for pushing industrial systems toward more sustainable ones. Something that needs more thoughts and discussion as will be done in the next chapter, where the further development of pollution prevention methodology is described.

CHAPTER 3

POLLUTION PREVENTION METHODOLOGY

3.1 INTRODUCTION

As introduced in chapter 2, there are many different ways to get rid of wastes and achieve zero (or close to zero) waste industrial systems. Each approach has its strengths and weaknesses and its application often works under specific conditions and time-space constellations. Integration of different approaches can overcome the weaknesses and shortcomings of individual approaches. Lowe (1997) rightly states that the idea or concept of industrial ecosystem more or less takes together a large range of intra-plant innovations and approaches, and inter-plant collaboration in improving environmental and economic performance, both of individual companies and collective industrial systems. This chapter aims at developing a methodology how to come to an integrated model of pollution prevention for industrial systems, using the various theoretical ideas as introduced in chapter 2.

The starting point to develop such a methodology is formed by the material and energy flows in industrial systems. The material and energy flows that cannot be used in the industrial system cause emissions, waste and exhaustion of natural resources. Any methodology consequently starts with analyzing these flows, followed by analyzing the various possibilities to reduce the emissions, waste and natural resource use from these industrial systems. In section 3.2 of this chapter, I will develop a systematic methodology on how to analyze various options to approach a zero waste industrial ecosystem by prevention of waste, minimization of waste, reuse and recycling within one company and within a wider network of companies and waste treatment option (or end-of-pipe solutions).

Often studies – also within the industrial ecology school-of-thought - remain restricted to such material flow analyses and suggestions of primarily technological options and solutions. Such studies run the risk of identifying technologically feasible options and solutions, which prove to be unworkable, unfeasible and undesirable in practice. We should not be too surprised that such studies find limited application in real life. Often factors related to economic costs and benefits, organizational fit, preferences, knowledge and information gaps, institutional capacities, pressures and incentives from state and non-states actors, among others, that are of key importance to the actual implementation of zero waste options and ideas in industrial systems. Consequently, also within the industrial ecology tradition several authors have recently stressed the necessity of paying more attention on the social, economic and policy relations and networks that parallel substance flow (Chiu and Peters, 1994; Luken and Freij, 1995; Nava, 1996; Yakowitz, 1997; Jackson and Clift, 1998; van Koppen and Mol, 2002; etc.). Actors, such as government authorities, industries, workers, consumers and customers, public interest group, bilateral and multilateral cooperation organizations, banks and insurance companies and the institutions in which they are embedded are of central importance in both understanding the causes of waste generation in industrial systems and (re)designing supportive, regulatory and incentive arrangements that help implementing zero waste options (Luken and Freij, 1995; Tamayo, 1996; Alves, 1996; Macia, 1996; Kanbour, 1996; Tu, 1998). The rationale for developing a methodology for analyzing and evaluating existing actors and institutions that constrain and enable the environmental reform of industrial systems in section 3.3 of this chapter lies exactly in the need for implementing favorable technological options.

3.2 METHODOLOGY TOWARDS PHYSICAL-TECHNOLOGICAL MODELS

A systematic methodology to develop a physical-technological model for an industrial system to move towards a zero waste industrial ecosystem consists of four basic steps.

The first step is the analysis of the material and energy flows that run through the industrial systems and partly end up in waste. Without insight in the process flow data and the main points and causes of waste generation in the industrial processes no physical-technological model can be constructed.

The second step focuses on the prevention of the waste generation: what is the maximum feasible prevention/reduction of all pollutants being generated at production sites. The identification and design of measures and options of prevention is often related to cleaner production studies.

The third step concentrates on identifying, analyzing and designing potential external recovery, recycling and re-use options. For wastes, which cannot be recovered internally (within the original production units), recycling and reuse in other plants or economic activities play a vital role in solving the industrial waste problems (Wei and Huang, 2001). This option ranks in the environmental management hierarchy often as the second most preferable method, following prevention of wastes. It is considered advantageous because, among others, natural resources are conserved, treatment and disposal is avoided, and the need for raw materials is reduced, thereby lowering costs (Chiu and Peters, 1994). Besides, many businesses benefit from the proximity or co-location of functions that are closely related to, or rely upon, the production process (ULI, 1988). The creation of a (waste) material flow network or waste exchange practices is part of this third step.

Finally, the last step entails the identification of remaining wastes that need to be treated properly before discharging into the environment. End-of-pipe treatment technologies are usually helpful for a complete removal of remaining contaminants.

Together, these four steps form a systematic methodology that leads us towards a physical-technological model for (close to) zero waste industrial ecosystems. The four steps will be elaborated and operationalized separately in the next paragraphs.

3.2.1 Step 1- Analyzing Material Flows

The central element of this methodological step should be to assess production processes that cause environmental problems in order to be able to redesign those in the next steps so environmental impacts can be minimized. This assessment will start with an inventory of the process flow data to identify the flows of material and energy and the sources of waste generation, followed by the determination of the causes of waste generation.

Inventory of the Process Flow Data

The analysis of energy and material flows usually starts at individual enterprises and production units. Inventory of the process flow data of each industrial enterprise has to determine the type and amount of materials, natural resources and energy used, the products that have been produced, the wastes being generated and the emissions to air, surface and ground water and soil. Such an analysis study is important for the identification of all possible sources of waste generation or excessive material and energy consumption in the enterprise.

Each production process generally comprises a number of operation units. First, one has to go through the whole production process to obtain an overview on where inputs take place and are processed and where products and non-products come out. Then, following the created general understanding of the entire production process, a division into suitable operation units is necessary and important for further detailed studies. For every operation unit, the associated inputs and outputs, transformations, and mass balances are identified. The process flow data can be constructed by connecting the results of studies of individual operation units. The complete data of the process flow shows the relations between the sources of waste streams and emissions and the manufacturing process. It can be used to check all operation units for waste generation and result in a comprehensive list of all waste sources. Mass balances of materials and energy within the process are an important tool and exercise for further evaluation of the possible causes and points of waste generation.

Determining Causes of Waste Generation

The analysis of the material and energy balance contributes to the understanding of the relative importance of different causes of waste generation and energy consumption. As there in general is a lack of detailed data, especially in countries such as Vietnam, the compilation of the material and energy balance is often difficult, time-consuming and costly. For the purpose of prevention and reduction of wastes at source (the next methodological step), it is often possible to limit the compilation of material and energy balances to the most important material flows and/or processes from an environmental point of view. That is: the flows and processes, which have the largest contributions to waste generation and to environmental impacts. However, the obtained data should be sufficient to evaluate the causes of waste generation within the industrial system, both in technological terms as in organizational/procedural terms. This analysis should be able to answers of the following questions:

- Which input materials have impact on the quantity and characteristics of wastes?
- Which technological factors do affect the quantity and characteristics of wastes?
- Do practical operations have impact on the quantity and characteristics of wastes?
- Does the procedure of waste handling affect the potential of waste recycling and reuse?
- Do product specifications have an impact on the quantity and characteristics of wastes?

3.2.2 Step 2 - Prevention and Minimization of the Generation of Wastes

All data collected in the first step are used as guidelines and inspiration to select appropriate possibilities for prevention and minimization of waste generation within individual industrial enterprises of the industrial system. In this line, different cleaner production measures are assessed and designed to deal with waste problems following two main approaches.

Prevention of the Generation of Wastes

Prevention of waste generation aims at preventing wastes from being generated. Options to prevent waste generation can arise by answering the following questions:

- How could good housekeeping be obtained?
- Which kind of materials would be suitable for substitution of current ones?
- What kinds of modification of the production process would be feasible?

- How could the product be modified?

Potential options are identified from available information, which is based on theoretical analyses, previous work experiences, scientific literature, available case studies, parallel ideas from other industrial sectors or available practical demonstration projects of similar industries, both within the country or internationally.

Minimization of (the Environmental Impacts of) Waste

Minimization of waste and minimization of the potential environmental impacts of waste deals with the wastes, that have been generated by a producer. Based on the information of the quantity, characteristics and the current waste handling methods, the aim is to find out whether the current handling of wastes causes environmental problems and is economically inefficient and what are the possible strategies and options to improve the environmental and economic performance regarding waste. Except for offsite recycling and reuse, and final waste treatment before discharge, which will be discussed in the steps 3 and 4, possibilities for recycling and reuse with or without pre-treatment of the wastes within the production process are assessed and evaluated.

From the various experiences in industrial processes as presented in the literature, different techniques and options can be identified for waste prevention and minimization. These are summarized in Fig. 3.1.

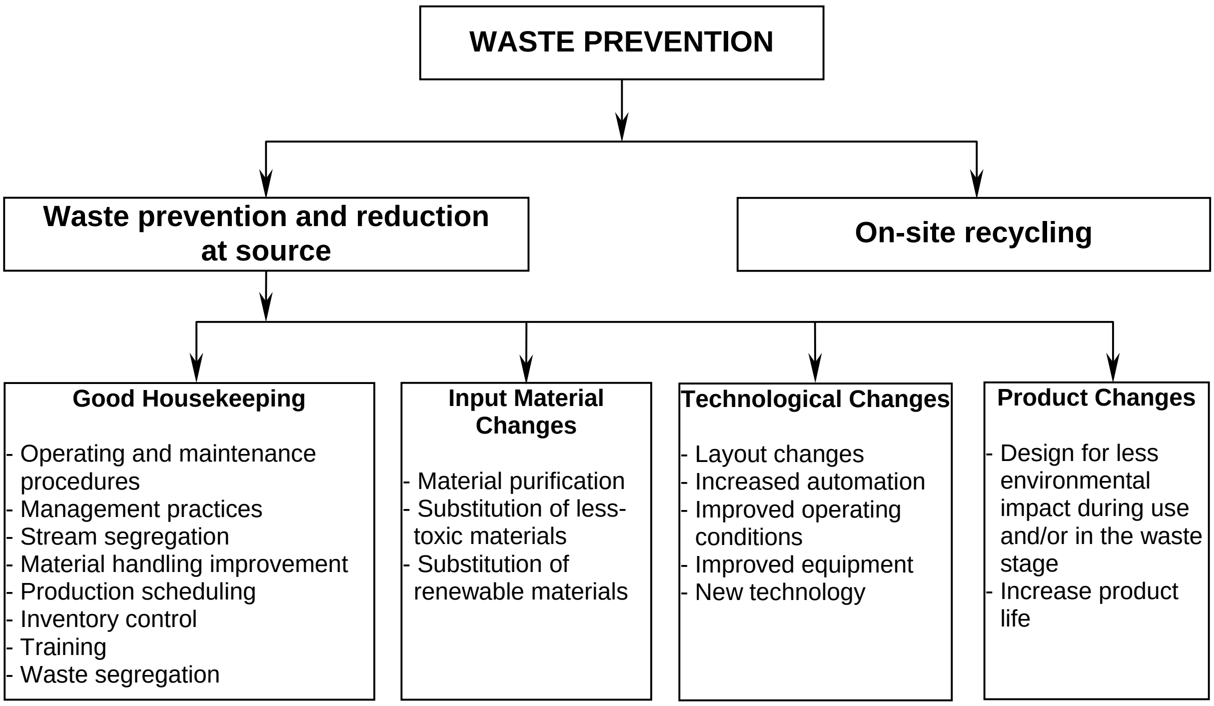

Fig. 3.1 Techniques and options for waste prevention (USEPA, 1992; Chiu and Peters, 1994; Clift and Longley, 1995; Dimitroff-Regatschnig and Schnitzer, 1998; Quoc, 1999; Lambert and Boons, 2002).

Depending on the specific process circumstances and the socio-economic conditions several alternatives for prevention and minimization of waste generation are usually combined to come to an optimum set of option for waste prevention. The assessment of individual and combinations of options should result in an integration of various alternatives into a practical and feasible model. The feasible options are often selected based on criteria of environmental protection, available technology and knowledge base within the company or the direct social environment, contribution to product quality and economic efficiency.

3.2.3 Step 3 – Material Flow Network Creation

This third module in the methodology consists of an assessment of all potential strategies and activities for offsite recycling and reuse or waste/material exchange. It is worth reminding that the aim of the physical-technological model is to push an industrial system to a zero waste system. Therefore, creation of a material flow network, in this case, will only focus on waste (or non-product) materials and energy, which can not be avoided from individual industrial enterprises analyzed in step 2. The central elements of the methodology in this step should be to assess waste materials and energy handling methods that cause environmental problems after the former steps have been installed, to identify and evaluate future potential options for offsite recycling and reuse, and to create a material flow network in order to minimize environmental impacts and maximize resource conservation.

Assessment of the Current Waste Materials and Energy Handling Methods

It is again important to identify amount, characteristics and current handling methods of waste materials and energy. The outcome of this investigation forms the foundation to evaluate:

- the success and failure of the current waste handling methods for offsite recycling and reuse or waste exchange;
- impacts on the environment and the economic efficiency of the current handling methods.

The expectation of this evaluation is to identify the strong and weak points in the current handling methods, which can help us to decide how to create the final material flow network.

Information on the current waste handling methods can be obtained via monitoring data, documentation and literature. But more often, especially in developing countries such as Vietnam, this information has to be collected by interviewing those actors involved in collection, transportation, recovery and final disposal of wastes. Besides, field visits serve as an important tool to collect data and information when these are not available from interviewees or literature. Similar, impacts on the environment could be obtained by interviewing victims that have suffered from adverse effects of the current related activities, to be confirmed by measurements on environmental quality (including surface water, ground water, air environment and soil). In depth semi-structured interviews with a limited amount of informants are used as a method to collect information for evaluating environmental impacts and economic effects resulting from current waste handling methods as well as future potential options.

Network Creation

In general, offsite recycling and reuse of non-product materials falls into two categories: (1) direct reuse in other plants and (2) indirect reuse via processing the non-products to obtain materials that can be reused in other plants or activities (e.g. compost or irrigation water). The key point is to match the supply side of waste generators and the demand side of potential end-users. Therefore, a waste stream must be characterized (composition and generation rate) before options can be assessed for offsite reuse. The basic recycling options vary depending on the end-users for the recycled materials. In most cases, the recycler markets the recycled material (Chiu and Peters, 1994). Offsite recycling and reuse can occur between a pair of companies that organize themselves into an elegant system of material exchange, where market values define their new relationship. But a material flow network can be developed by broadening this relationship with other companies that are involved in non-product processing or use. Concretely, in order to be able to create a material flow network, it is important to address the following information:

- Material and energy inputs and outputs of both the industrial enterprises, which generate waste materials and the industrial enterprises or other units, which are capable of processing or using these waste materials, with or without pretreatment. Concretely, it is important to address:
  + composition and nature of flows of waste and renewable materials and energy (consistency and purity over time);
  + amounts of waste materials and energy;
  + distribution of these waste materials and energy over time (steady, periodic, episodic, or irregular).
- Potential customers (including industrial enterprises and other units, for instance watershed, crop fields, etc.) to utilize waste materials and energy. The following information must be identified hierarchically:
  + potential matches of waste materials and energy with requirements of existing businesses;
  + pretreatment or processing of waste materials and energy needed to reach specific quality requirements of the wastes and energy before recycling;
  + volume of waste materials and energy required by potential customers;
  + the potential of collecting and pooling (if necessary) of these waste materials and energy for flow network creation.

Information obtained from such an analysis will allow us to establish the network of offsite waste materials and energy exchange and assess its contribution to designing a zero waste industrial system. The existing industrial relations, structures, dependencies and geographies can help to identify possible candidates for creating a material exchange network. Therefore, it is important to survey the existing industrial enterprises, their relations with other industries and other industrial units in the neighborhood of the site (or even in the larger community) in order to determine their primary inputs, potential outputs (especially non-product materials) and to evaluate whether they are potential participants in an exchange network. Such an analysis does not only suggest customers that could benefit from the existing industrial enterprises, but can also result in identifying new business niches. Generally, in order to create a material flow network, one can start with an industrial enterprise, or groups of enterprises, that have to handle waste materials and energy, link it materially with existing businesses and then identify new critical businesses that enable an increased exchange efficiency. This survey will indicate any obvious exchange opportunities and highlights 'missing pieces', which if present, would enhance the environmental performance of the network.

In developing and constructing a material flow network, one should keep in mind that 'an industrial ecosystem is a dynamic entity, the participant's market conditions will change in coming years, causing them to introduce new products, and cease the production of others. New materials will be introduced; old familiar ones will disappear. Companies will come and go too. So this challenges of 'niche filling' and of recruiting firms with particular product and/or byproducts will never end' (Lowe, 1997: 62). In embedding the network in effective community, regional or state waste exchange programs the supply and demand sides of the market of waste materials and energy is broadened making it less dependent on individual enterprises and their performance. This helps in bringing greater resilience to the pattern of trades by maintaining varieties of suppliers and customers, especially in case of rapidly changing business conditions.

3.2.4 Step 4 – Waste Treatment

This final methodological step orients at the remaining wastes, after step 2 and step 3 have successfully been constructed. End-of-pipe treatment technology will be a major option in this final step. To be able to select proper waste treatment technology, it should be noted that knowing the characteristics and the net amount of the waste (actually generated mass minus the mass that is reduced via the material flow network) is important. The treatment technology should be selected based on the following considerations:

- characteristics and amount of the waste;
- environmental standards or pollution reduction requirements;
- available treatment technologies;
- environmental characteristics of treatment technologies, i.e. resource conservation, material use (for instance, biological technologies are preferable), but also removal percentages and reuse options (e.g. biogas, sludge).
- economic efficiency.

The characteristics and amount of waste and requirements of pollution reduction are the keys to seek for proper treatment technologies. Experiences from the existing waste treatment systems should be taken as points of departure, as they are practical evidences of failure or success of applied techniques.

3.2.5 Integration

Following these last three steps one can develop a physical-technological model of a (close to) zero waste industrial (eco)system as illustrated in Fig. 3.2. In the most simple case, the anchor that generates the waste materials in need of treatment is only one industrial enterprise (which is visualized in Fig. 3.2). However, if the anchor is a group of industrial enterprises with similar manufacturing processes or even a group of enterprises with different manufacturing processes, the various methodological steps in developing a zero waste industrial ecosystem will be completely the same.

Important is that the methodological steps in developing the physical-technological model are integrated. That means, for instance, step 2, “prevention and minimization of the generation of wastes”, should be applied not only to the anchor (original waste generators), but also to other niches (waste recyclers) to avoid generation of other kinds of waste due to waste processing units. The natural environment compartments such as surface water, soil or atmosphere, which serve as a receiving body of effluents from the final waste treatment system, have to be included in the system to increase the natural resource conservation efficiency, especially in case of water use.

The mass balances of material and energy inputs and outputs have to start from the anchor. Selected niche companies and treatment systems must be able to reuse and remove waste material and energy completely. That means, capacities of niche companies must be equal or higher than the requirements for handling wastes.

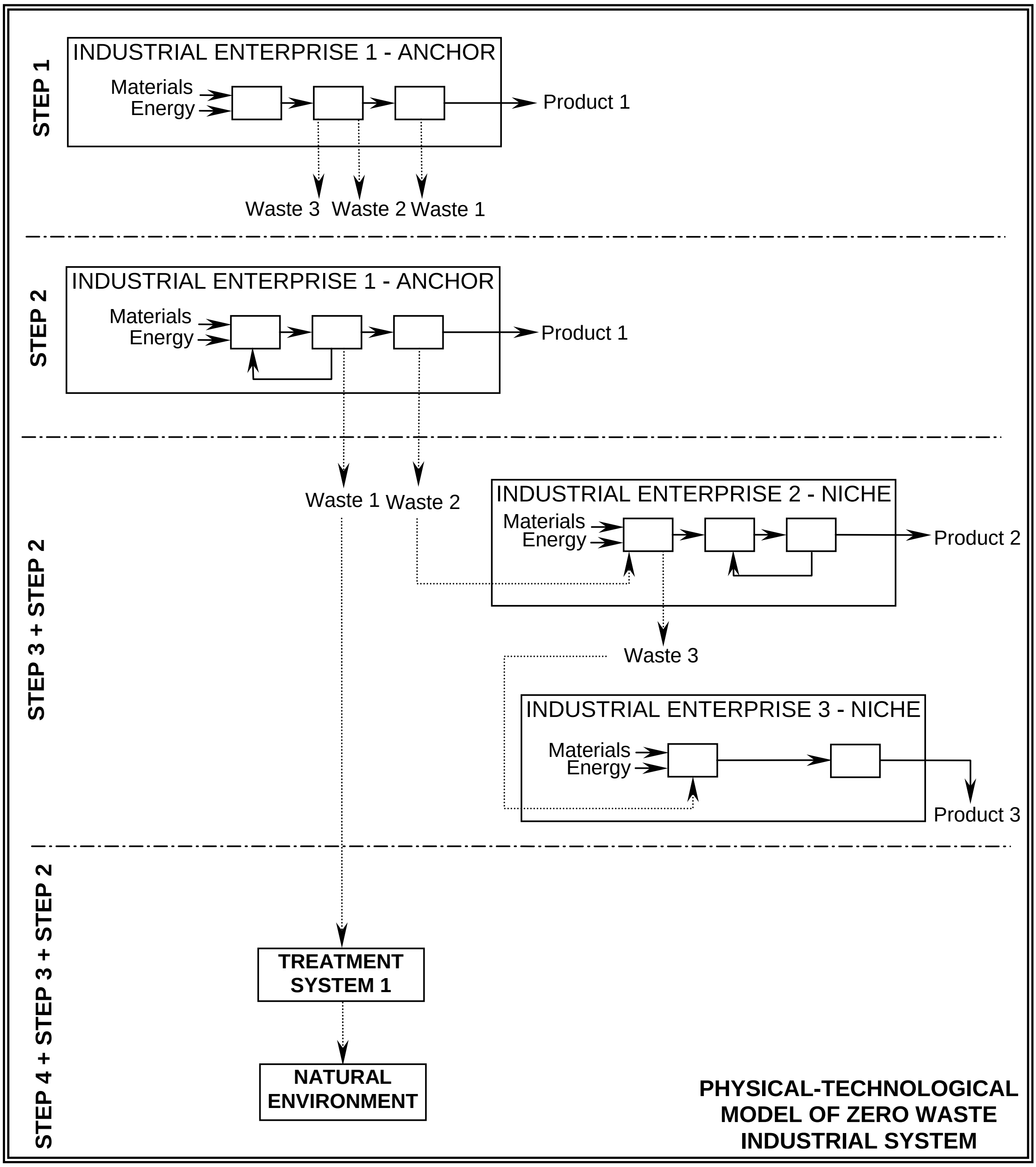

Fig. 3.2 Four basic steps of the methodology towards physical-technological model of a zero waste industrial ecosystem.

Technical options to approach a zero waste industrial ecosystem will be selected based on the considerations of environmental protection target, available technology and economic (or financial) feasibility.

3.3 COMPLEMENTING PHYSICAL-TECHNOLOGICAL MODELS: ACTORS AND INSTITUTIONS

The developed physical-technological model of a zero waste industrial ecosystem is a theoretical system. It is based on theoretical ideas of industrial ecology without analyzing the feasibility in terms of actors and institutions that could trigger, facilitate, enforce or sustain implementation of the various options. Actual application of the physical-technological model might face severe difficulties and barriers since the industrial system as a whole and the various constituting subsystems might have conflicting interest, they are often confronted with a lack of coordination, meet financial problem and are not isolated entity but related to and embedded in complex social-economic conditions. No matter how innovative, original and closed the designed industrial system is in terms of its substance flows, this does not guarantee any success in terms of application and implementation of the whole model or even of few parts. To transform the developed physical-technological model for an industrial system from the design table to reality, it is essential that the complex social, economic and political relations and institutions between the industrial system and the actors outside are analyzed in depth. Only by understanding the existing relations of the industrial systems with, among others, government agencies, other economic entities and social actors, we are able to (i) identify the existing barriers that hamper the implementation and introduction of some or all of the alternatives of the physical-technological model, and (ii) to design the necessary transformations and changes in these social, political and economic relations and institutions in order to facilitate, support and enhance the possibilities of implementing some or all of the physical-technological options.

To understand how different actors influence (in terms of both hampering and supporting) the process of moving existing conventional industrial systems towards zero waste industrial ecosystems, we are in need of an analytical tool that provides us with the concepts to analyze existing interactions and relations between actors within and outside the industrial system, as well as the institutions that govern and structure these interactions and relations. Network analyses and models that relate industrial firms to the societal, economic, and policy environment are useful for this purpose, because, as van Koppen and Mol (2002: 142) state,

> *'Network models have the advantage of combining both the structural properties of institutions and the interactions between actors constructing a network. Networks can be characterized as social systems in which actors engage in more or less permanent, institutionalized interactions'.*

There is broad and well-established literature on network analysis, to which various disciplines have contributed. Within the political and policy sciences, network models have emerged strongly in academics especially since the late 1980s, when the conventional analytical-rational policy models as well as the neo-corporatist and neo-Marxist analysis became less influential. Within economics, business administration and business management network models witnessed a strong push when new and more flexible business relations were identified in the era of post-Fordism. More recently, with the growing interest of scholars to globalization processes more transnational network models became more popular, of which the work of Castells is perhaps the most influential. While the majority of these network perspectives, tools and studies are not or marginally related to environmental issues, some do focus on environment-informed transformation in economic sectors.

Most of the network studies in the field of the environment construct their concepts and analytical tools on an ad hoc basis, following directly from one or a limited number of empirical studies. Consequently, these network models and concepts often have a limited use in empirical studies. The triad-network model, as developed by Mol (1995), is a more theory-based conceptualization. It encompasses a policy, an economic and a societal network and is suitable for analyzing what role actors and institutions from different perspectives (political, economic, social) play in the construction and functioning of industrial systems, how these actors and institutions (can) influence the greening of industrial systems, how they trigger or hamper change and improvements in environmental management, etc. As such the triad-network model helps us in understanding and analyzing the relation between the developed physical-technological model on the one hand and the institutions and actors constituting the economic, social and policy environment on the other hand. Each of the three interdependent networks constitutes a combination of a specific analytical perspective, distinctive institutional arrangements and a restricted number of interacting (collective) actors, which are considered to be most important regarding that perspective. The three mentioned networks will be elaborated shortly and be applied to industrial systems.

Economic network. Economic networks basically focus on economic interactions via economic rules and resources between economic agents in and around industrial parks, industrial chains, or industrial sectors that form the object and unit of analysis (van Koppen and Mol, 2001). Economic network studies analyze: (i) the relationships between firms in a product chain by looking at the vertical interactions from input suppliers to producers and final consumers; (ii) the relationships between competing firms in the same (sub-) sector and interaction, among others via branch organization; (iii) the interactions between firms and other economic agents (such as bank, insurance companies, infrastructure companies) and research institutes and (iv) regional relations and interactions in restricted geographical areas.

In this research, the central actor of the economic network study is a specific food-processing industrial enterprise (see chapter 6) or a group of food processing enterprises (see chapter 5 and chapter 7). In the vertical interactions, other actors involved in the network may include farmers, supplying firms, industrial enterprises benefiting from non-product materials, customers and consumers. The horizontal interactions consist of industrial enterprises producing the same products, which are located in the same region or outside that. Are joint efforts, institutional arrangements or agreements made for these enterprises in the same sector? Do these arrangements involve only economic or social issues (such as price agreements, marketing services, training etc.) or are environmental services or technologies included; or can these environmental service in the future be included and what would it mean for the horizontal relations between these actors? Other actors such as environmental research centers, environmental utility companies, banks, tax agencies, etc. are also included in the economic network. We have to analyze the existing economic and market interactions, arrangements and institutional organization, and ask if environment plays any role in that; or how we can rearrange the interactions and institutional arrangements so that environmental protection can be included.

Policy network. Policy networks concentrate on industry-government relations from a political-administrative perspective (Mol, 1995). All policy incentives and arrangements in supporting or regulating industrial sectors belong to the rules and resources, which are structured and negotiated within this network. It is therefore important to identify the relevant actors and institutions, which determine industrial and environmental policy, including their positions, strategies, resources and interactions (Vliet and Frijns, 1995). Applied to this research, policy network studies should clarify the relationships and interactions between the industrial enterprise(s), and local and central environmental management agencies and authorities. Important in analyzing these interactions and arrangements is the distinction between formal or even legal relations, 'rules of the game' and resources on one hand, and the informal, in-official rules of the game and applied resource exchanges on the other. The legislation related to environment (including relevant laws, regulations, circulars, decrees, guidelines, standards, etc.), which can, should and sometimes have influenced environmental innovation in firms and industrial systems, is part of the formal policy network. And so are the resources available for local environmental authorities in terms of for instance monitoring equipment and manpower for control and enforcement. Analyzing the formal structure and relations between environmental authorities and industrial actors is often less telling than analyzing the actual practices, interdependencies, and institutional arrangements that are at work in greening (or the failures to green) industrial production locations and products.

Societal network. Societal networks aim at identifying relations between the industrial park, chain or sector in question and civil society organizations and arrangements associated with what is usually called ‘the life world’, both directly and indirectly via state agencies (van Koppen and Mol, 2001). Societal network studies focus on the relationships between the industrial enterprise(s) on one hand, and local communities and local and national social organizations such as Youth Union, Women’s Association, mass media and NGOs on the other. These social network studies try to analyze the nature of these relationships, the interdependencies between the actors, the resources being used in interaction patterns and the mechanisms at work. Focal point is if environmental consideration plays any role in these interaction patterns, how the existing relations can give environmental interest a better position 'on board' and how this can then influence, stimulate and support the adaptation of options from the physical-technological model. While social network studies in industrialized societies in Europe and the US often centre environmental NGOs as core actors, in countries such as Vietnam these actors are non-existent. Consequently, Vietnamese societal network studies in environmental reform take a different mode than their European equivalents. The studies of O'Rourke (2000), Woltjer (2001) and Phuong (2002) are good examples of Vietnamese societal network studies on the greening of industry.

As an example of the relations among actors from the three network perspectives the networks surrounding Tan Chau-Singapore Company (Tay Ninh Province, Vietnam), one of the case studies in this research, is presented in Fig. 3.3. It should be remembered that in reality the actors and institutional arrangements found in the three different networks are interdependent and closely interact (Mol, 1995). The overall network analysis, which is derived from three perspectives (economic, policy and societal), helps us to understand how industrial enterprises, economic actors, governmental authorities and social actors play a role in the (successful or failing) implementation of the various options of the physical-technological model.

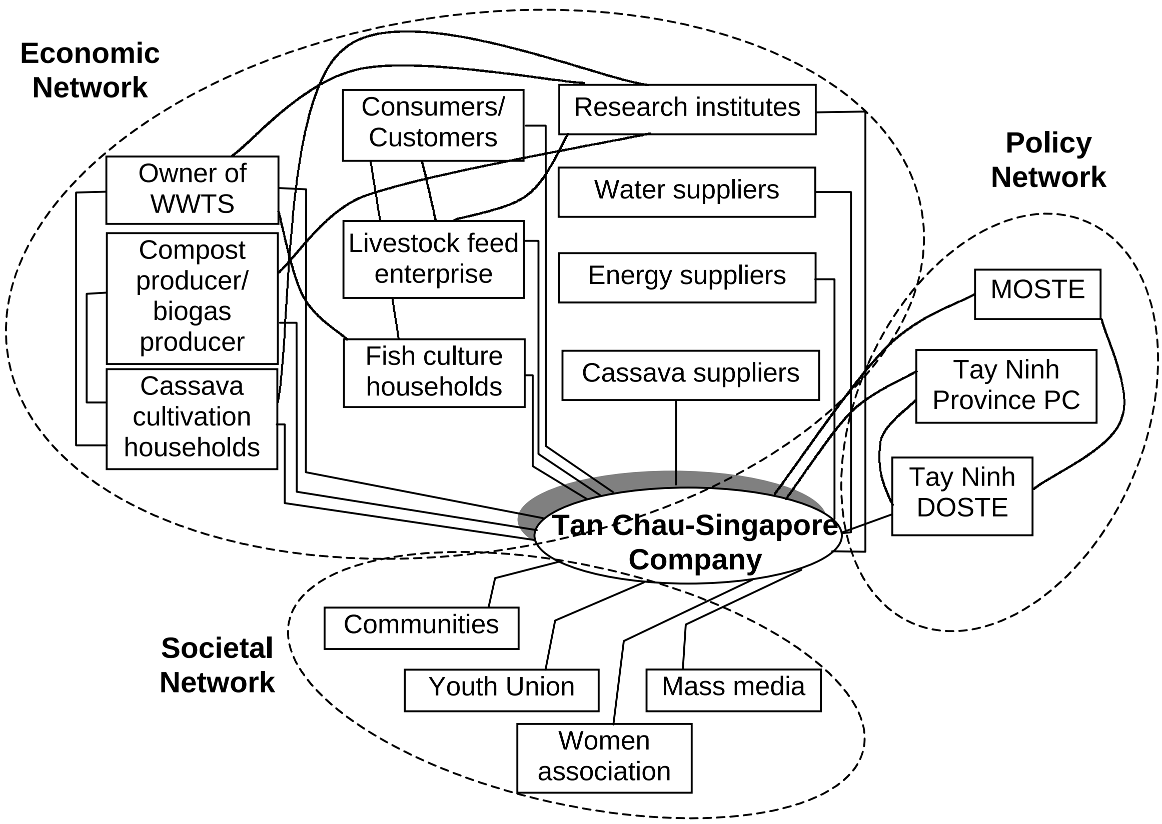

Fig. 3.3 Networks of Tan Chau-Singapore Company (see chapter 6).

In complementing the development of physical-technological models with a network analysis the purpose is to move beyond theoretical and utopian options for zero waste industrial ecosystems. The goals are to connect technological and economically feasible options with an assessment on the social, political and practical feasible to implement these options in real life practices and situations. The network analysis thus engages in two steps: (i) an analysis of the existing actors and institutional (policy, economic and social) arrangements and how these currently facilitate and hamper further implementation of physical-technological options; (ii) an analysis on what changes should and can take place in terms of institutional arrangements and actor relations to improve the implementation of physical-technological options towards zero waste industrial ecosystems.

3.4 RESEARCH STRATEGY AND RESEARCH UNITS

3.4.1 Research Strategy

In order to test the approach and its suitability for greening food processing industries in Vietnam using an integration of the physical-technological model and a triad network analysis, case study research strategy is most suited, for various reasons. First, substance flow optimization requires the use of process flow analysis and mass balance methods for data collection. Only experimental research can give exact information on material flow of the existing industrial system. As this consumes significant amounts of time, it does not allow conducting large number of research units. Using relatively *small numbers* of cases is the first and most important characteristic of the case study research strategy. In this study, cases include individual enterprises and a group of enterprises.

Second, in order to obtain data to develop the physical-technological model, it is required to carry out in *depth* studies rather than *superficial* ones. Requirements on understanding the existing production processes, waste handling methods, interactions of different actors participating in the networks, their institutional arrangements, etc. result in measurements at site and more *labor-intensive* face-to-face interviews with open, semi-structured questions.

Third, influences of geography/location, scale, technological differences and socio-economic conditions on the greening of industrial systems and thus on the outcome of the study, even in case of similar industries, require *onsite study/observation* and do not allow for mathematical modeling, large sampling or anonymous questionnaires.

3.4.2 Selection and Description of Research Units

In selecting case studies to 'test' the developed methodology for designing zero waste industrial systems we have to balance between the diversity of industrial system situations that are found in industrializing Vietnam on one hand, and the practical limitations of labor-intensive research on each individual case study on the other. The latter does not allow for more than three extensive case studies. The former forces to take at least into account differences between:

- Small/household-scale enterprises and large-scale companies (partly related to domestic markets and international markets);
- One enterprise and a group of enterprises;
- A group of enterprises from one industrial sector and a group of enterprises from different industrial sectors (but still within the broad category of food processing industries);

- Enterprises located within and outside industrial zones, as industrial zones (or parks) have specific advantages in industrial ecology design.

These comparisons are important and necessary because, for instance, technological solutions for large-scale companies equipped with more advanced production process, might be not feasible for small-scale enterprises due to lack of investment, knowledge and skills, manpower, etc. A material flow network of a group of similar industrial enterprises will have different characteristics than a material flow network of a group of different industrial enterprises. In addition, differences in actors and institutional arrangements involved in environmental management of enterprises located inside and outside industrial zones will result in distinct facilitating networks for the two categories.

As presented in chapter 1, this research mainly focuses on food processing industries, which have high potentials on environmental impacts and contribute significantly to Vietnam economic development. Based on the brief introduction about development of food processing industries in Vietnam and its environmental implications (chapter 1), three case studies have been selected that together fulfil the various criteria selected above. The first case study (chapter 5) consists of a group of tapioca producing households in Tra Co Village, Dong Nai Province. These enterprises represent the characteristics of household (small) scale enterprise and are all in the same industrial sector. The second case study is within the same industrial sector: a large-scale tapioca producing plant called Tan Chau-Singapore Company in Tay Ninh Province (chapter 6). These case studies help us to understand the possibilities and difficulties in developing, applying and implementing the zero waste industrial ecosystem model in different scales of the same type of industry. The third case study focuses on a group of six different food processing enterprises located in Bien Hoa 1 industrial zone, Dong Nai Province (chapter 7). It is comparable to the case study on Tra Co Village in the sense that a group of companies are studied, but differs in terms of scale of the enterprises and industrial sectors. This case study also explores the potentials of industrial zones, compared to enterprises located outside industrial zones. The following description gives brief overviews on the studied sites.

Case Study at Tra Co Tapioca Processing Village

In Vietnam, tapioca producing units can be family (household) scale with only 3 employees, medium scale factory with about 15 employees, or large-scale factories with more than 30 employees. Household- and large-scale units are most prominent. That is the rationale behind the selection of case studies at Tra Co Village and Tan Chau-Singapore Company. In the South Key Economic Regions (SKERs) of Vietnam, Tra Co Village is a typical traditional tapioca production village. Environmental problems caused by tapioca production in this area are serious, but interestingly Tra Co Village is the only place where tapioca wastewater is partly and successfully reused in fish culture. At the period of conducting the case study, there were 65 tapioca production households in Tra Co Village.

The family (household)-scale tapioca producing units are concentrated in 13 districts in Vietnam (Table 3.1). However, in three provinces (Ho Chi Minh City, Dong Nai and Tay Ninh) a number of households are situated close together and form a village or a group of tapioca producing units. Tra Co Village (Dong Nai Province) was selected after reviewing three possible sites in the three provinces. In Tra Co Village, after observing the tapioca production process of different households, the household of Mr. Nguyen Van Thinh was selected for in depth study on material balances, for various reasons. First, the production capacity of this household is in the normal range of household units in Tra Co Village (about 7 tons cassava roots/household/day). Second, the production equipment, production area and number of workers represent the typical characteristics of a household-scale tapioca production unit in the village. Third, the householder and his workers were willing to help in mass measurements and sampling at each stage of the production process.

In each of the three selected villages, five tapioca production households were selected to observe the manufacturing technology and waste handling methods that have sensitive similarities and differences. These households' production processes differ in fresh roots' handling stage, roots' rinsing methods, starch extraction stage (different settling steps), final products (wet or dry starch) and used machines. In this way, it is possible to compare and analyze the reasons behind better or worse production efficiency and environmental performance and to generate options for prevention and minimization of wastes.

Table 3.1 Number of districts where family-scale tapioca producing units are located

City/Province	Number of district
Dong Nai Province	2
Ho Chi Minh City	1
Tay Ninh Province	2
Binh Dinh Province	2
Quang Ngai Province	1
Quang Nam – Da Nang Province	2
Ha Tay Province	2
Ha Bac Province	1
Total in Vietnam	13

Source: Khoa, 1998.

Case Study at Tan Chau-Singapore Company

Large-scale tapioca companies have been established in the South of Vietnam since 1990, they aim at satisfying the demand of raw material for monosodium glutamate, textile, paper industries, etc. These companies are Vietnam-Singapore Co., Ltd. and Tay Ninh Tapioca Company in Tay Ninh Province, Song Be-Singapore Tapioca Co. Ltd., VEDAN Tapioca Company in Binh Phuoc Province, VEDAN Tapioca Company in Dong Nai Province. Among these companies, Tan Chau-Singapore Company was selected for in dept case study, for various reasons. First, the current production technology of the company is similar to the other companies but the operational procedures were modified to reduce water consumption. Second, this is one of two existing large-scale tapioca companies that contribute considerably to industrial development in Tay Ninh Province. Third, Tan Chau-Singapore Company management board was willing to assist in all onsite measurements and interviews and showed willingness to increase the environmental performance of the company.

Case Study of Food Processing Companies in Bien Hoa 1 Industrial Zone

Among 68 industrial zones and export processing zones in Vietnam (Nhue, 2001), Bien Hoa 1 is the oldest industrial zone. It represents a "bad practice industrial zone" and contributes significantly to environmental deterioration, especially surface water of Dong Nai River and the air quality in Bien Hoa City, Dong Nai Province. It is located on an area of 551 ha about 6 km from the city centre of Bien Hoa City and 30 km from Ho Chi Minh City. Beside other industrial enterprises, the existing food processing companies in Bien Hoa 1 IZ are typical for Vietnam, producing cane refined sugar, milk products, coffee, soft-drink, cakes and candies and ice. The current situation of these companies illustrates the difficulties in applying advanced technologies to solve environmental problems of existing enterprises in Vietnam: less advanced technology, strong emphasis on end-of-pipe treatment, poor environmental awareness, no environmental management systems etc. A group of six food processing companies in Bien Hoa 1 IZ have been selected for conducting the case study. All data related to production processes and environmental implications of these enterprises were collected through site observations, direct interviews and inventory sheets (similar to enterprise manifest).

3.5 METHODS OF DATA COLLECTION AND ANALYSIS

3.5.1 Primary Data Collection

Two major types of primary date were collected for the case studies:

- Data to develop the physical-technological models;
- Data with respect to actors and institutional framework analysis.

Data to develop the physical-technological model relate mainly to material and energy flows within research units and related components of the model. These data were obtained by executing detailed studies at the selected enterprises. Characteristics and amounts of the inputs and outputs of the studied processes were determined at each operational unit by site sampling, measurements and laboratory analysis. Depending on specific practical conditions of each case study, measurement methods differed as described in detail in the corresponding chapters. Direct interviews and questionnaire/inventory sheets were also applied to supplement information related to the production activities of the enterprises. The content of the inventory sheet is presented in appendix 2.

Environmental impacts due to improper disposal or recovery of non-product materials were also identified by carrying out measurements on environmental quality within affected areas. Current waste handling methods were obtained by interviewing villagers, enterprise managers and workers and through site observations.

Data on the role and practices of current actors participating in the three networks were collected by semi-structured, open-ended interviews with a selected number of key informants. These include enterprise managers and employees (of Tan Chau-Singapore Company and 6 food-processing enterprises in Bien Hoa 1 IZ), households (of Tra Co Village), managers of Bien Hoa 1 IZ Infrastructure Company, government officers from DOSTEs of Dong Nai, Tay Ninh, Ho Chi Minh City, and from the National Environmental Agency, environmental experts, community members, etc. The list of interviewees is presented in appendix 3.

3.5.2 Secondary Data Collection

Annual environmental reports or booklets from provincial DOSTEs, environmental impact assessment (EIA) reports and other scientific reports from environmental centers and research institutes were a major data source, which provided insight in the socio-economic, environmental and technological profile of studied sites. Information from different sources was cross-checked to ensure reliability. Besides, international literature was very helpful, especially to select cleaner production measures and waste exchange alternatives.

CHAPTER 4

INDUSTRIAL ENVIRONMENTAL MANAGEMENT IN VIETNAM

This chapter deals with the existing environmental policy framework that enterprises are embedded in. The organizational structure and the role the different actors play in environmental management are described in section 4.1. The second section presents the current environmental legislation, with a special focus on the regulatory and policy documents concerning end-of-pipe treatment, waste reuse and recycling, cleaner production, industrial ecology and ecological modernization. The main conclusions on the existing environmental management structure in Vietnam are drawn in the final section.

4.1 GOVERNMENTAL ENVIRONMENTAL ORGANIZATIONS AND ACTORS

Environmental policy and management with respect to industry in Vietnam can be divided into four main levels: (1) national level, (2) provincial level, (3) district level and (4) industrial production units. The general organization chart of industrial environmental management in Vietnam (in 2002) is visualized in Fig. 4.1.

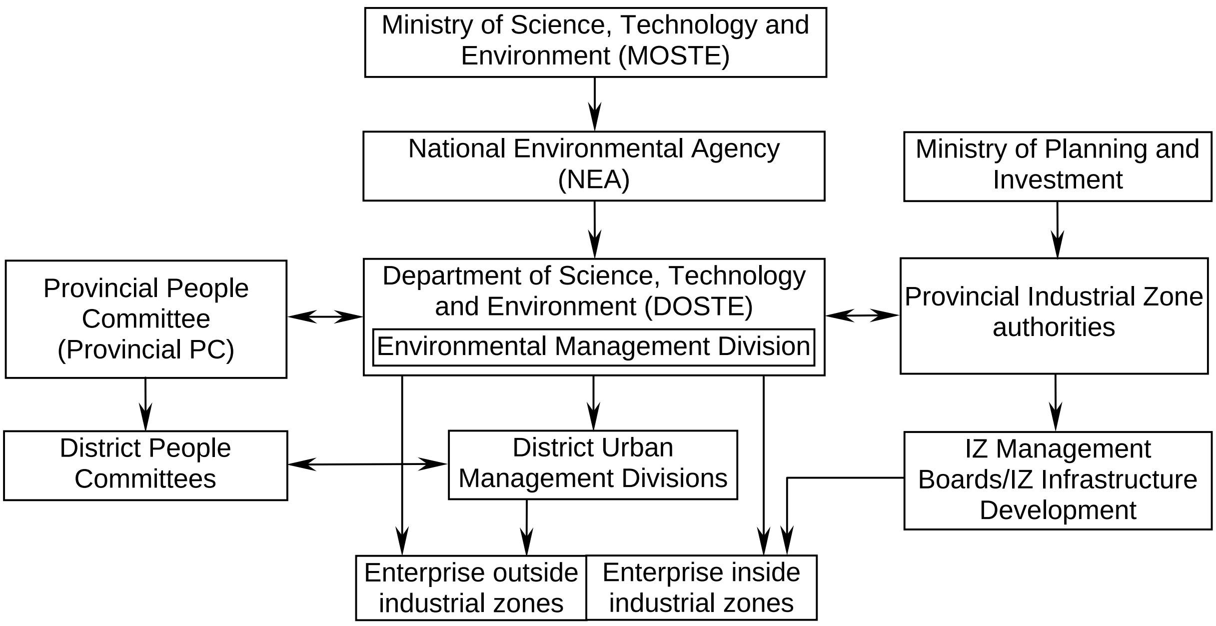

Fig. 4.1 General organization flowchart of environmental management of industry in Vietnam (gathered from different sources).

4.1.1 National Level

At national level, state organizations in charges of environmental management are mainly the Ministry of Science, Technology and Environment (MOSTE) and the National Environmental Agency (NEA) belonging to MOSTE. Recently (in October 2002), the Vietnamese government has decided to split MOSTE into the Ministry of Environment and Resources (MER) and the Ministry of Science and Technology. However this will hardly change the role of MOSTE, now MER, and NEA in the environmental management of industry. But it will take time to put the new organizational structure to work. As most of the research in this study has been carried out before October 2002, the term MOSTE is preferred throughout the text. The main responsibilities of MOSTE are in the areas of scientific research; technological development; standardization of equipment; industrial property rights and environmental protection (Phuong, 2002). With respect to environmental protection, MOSTE has the overall responsibility for the environmental sector and serves as a focal point of all environment-related activities (Thanh, 1993). NEA, being part of MOSTE, was established under the Decision No. 545-QD/TCCB dated 7 October 1993 by Minister of MOSTE in order to coordinate and be responsible for the state management of environmental protection activities throughout the country. Responsibilities and authorities of NEA can be summarized as follows[14]:

- Composing legislative documents on environmental management and proposing integrated environmental protection solutions for sustainable development of the country;
- Carrying out state inspections to individuals and organizations on compliance of environmental protection legislation;
- Organizing and implementing the National Planning on Environment and Sustainable Development and the National Action Plans on environmental protection[15];
- Appraising environmental impact assessment reports;
- Developing and managing environmental monitoring systems for the whole country and periodically assessing the national environmental status to indicate urgent environmental problems that need to be solved;
- Managing environmental pollution and industrial wastes, especially from energy, transportation and heavy industrial sectors in the whole country;
- Solving environmental incidents;
- Organizing training and activities related to environmental protection at provincial, local and community level;
- Managing environmental information and databases.

By 1999, the NEA had 9 divisions with 79 staff (NEA, 2003). These divisions include environmental impact assessment (EIA) appraisal, pollution control, inspection, policy, natural conservation, training and awareness, monitoring, international relations, and information and database.

4.1.2 Provincial Level

At provincial level, the Departments of Science, Technology and Environment (DOSTEs), which are now called the Departments of Environment and Resources (DERs), are responsible for the environmental policy management with respect to enterprises within the provinces. The DOSTEs link to the provincial People's Committees (PCs) in political, administrative and financial aspects. The scope of state management in environmental protection of DOSTE includes:

- Promulgating and organizing the implementation of statutory instruments environmental protection and promulgating environmental standard system;
- Developing and guiding the implementation of strategy and policy of environmental protection, plan to prevent, control and remedy environmental degradation, environmental pollution and environmental incidents;

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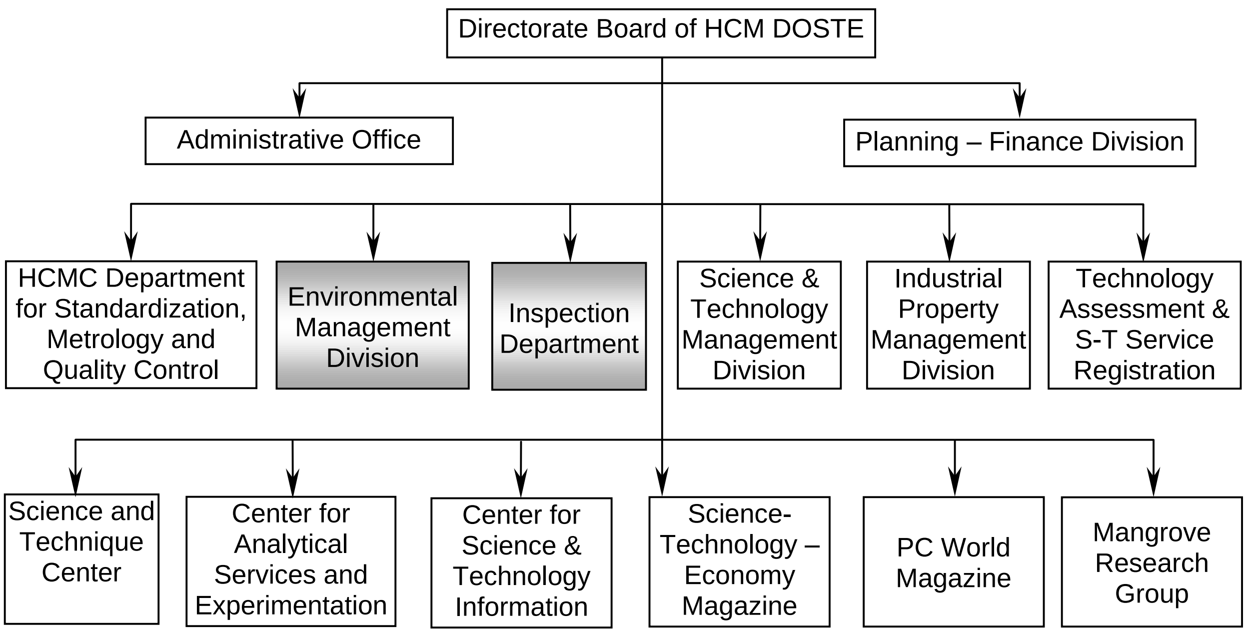
[14] In the Regulation on Organization and Activities of the National Environmental Agency, which was promulgated together with to the Decision No. 545-QD/TCCB dated October 7, 1993 by the Minister of MOTSE.

[15] In the Dispatch No. 187-CT dated June 12, 1991 by Chairman of the Ministry Council.

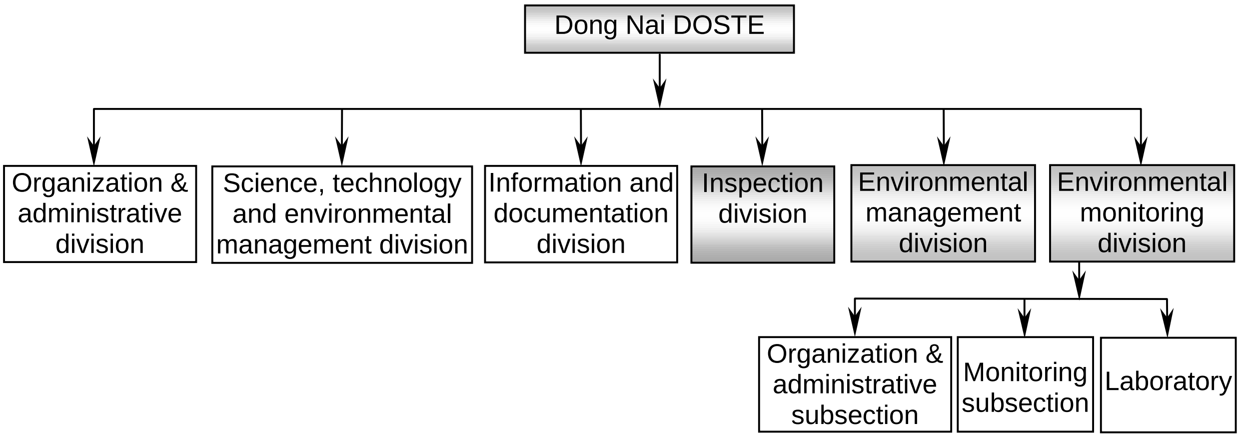
- Establishing and managing environmental protection facilities and facilities related to environmental protection;
- Organizing, establishing and managing monitoring systems, periodically assessing the status of the environment, forecasting environmental changes;
- Appraising EIA reports on projects and on production or business establishments;
- Issuing, revoking, certificates of compliance with environmental standards;
- Supervising, inspecting and checking the compliance to environmental protection legislation, setting disputes or complaints concerning environmental protection or business establishments;
- Training cadres in environmental science and management, education, propagation and disseminating knowledge and legislation in environmental protection;
- Organizing research and development activities and application of scientific and technological advances in the field of environmental protection;
- Developing international relations in the field of environmental protection.

Figure 4.2 shows that there is a difference in the administrative organizational structure of provincial DOSTEs. However, all DOSTEs have an Environmental Management Division and an Inspection Division. The Environmental Management Division in collaboration with Inspection or Monitoring Division is responsible for implementing the Law on Environmental Protection (LEP), issuing and revoking environmental licenses for each enterprise in the city/province, carrying out inspections of environmental performances of enterprises, solving complaints and environmental incidents. The number of staff in the Environmental Management Divisions differ between different provincial DOSTEs, for instance 5 in case of Tay Ninh Province, 6 in case of Dong Nai Province, 17 in case of Ho Chi Minh City. Normally, one to two staff members are responsible for the environmental issues of several districts. Environmental protection activities and problems from districts are reported monthly through meetings between the Environmental Management Division and District Urban Management Divisions.

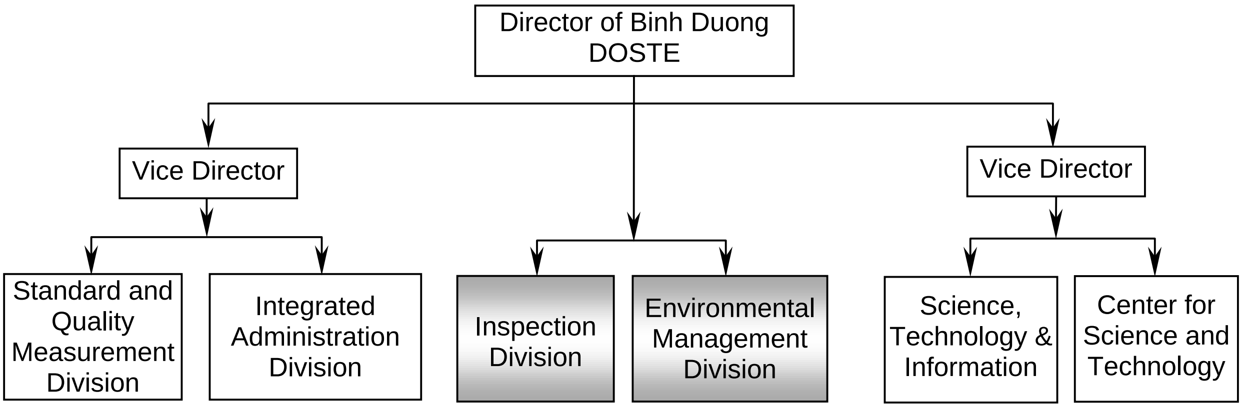


(a) Current organization chart of HCMC DOSTE[16].

[16] Interview with Mr. Le Van Khoa, Vice Head of Environmental Management Division of HCMC DOSTE.



(b) Current organization structure of Dong Nai DOSTE[17].

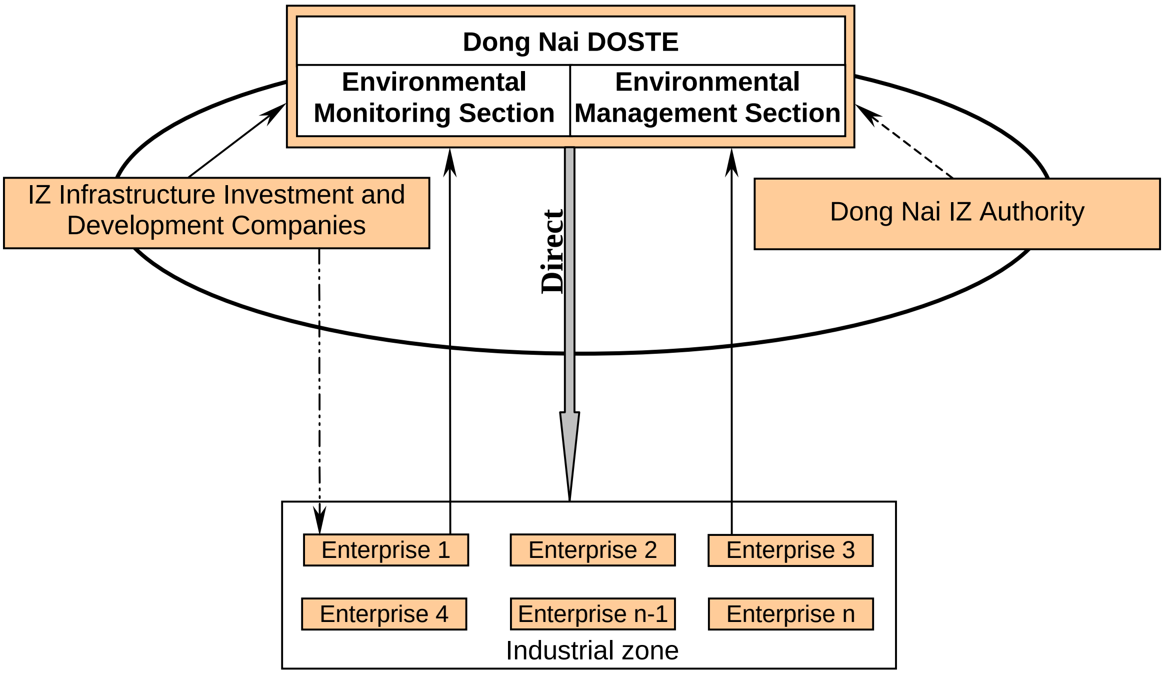


(c) Current organization chart of Binh Duong DOSTE.

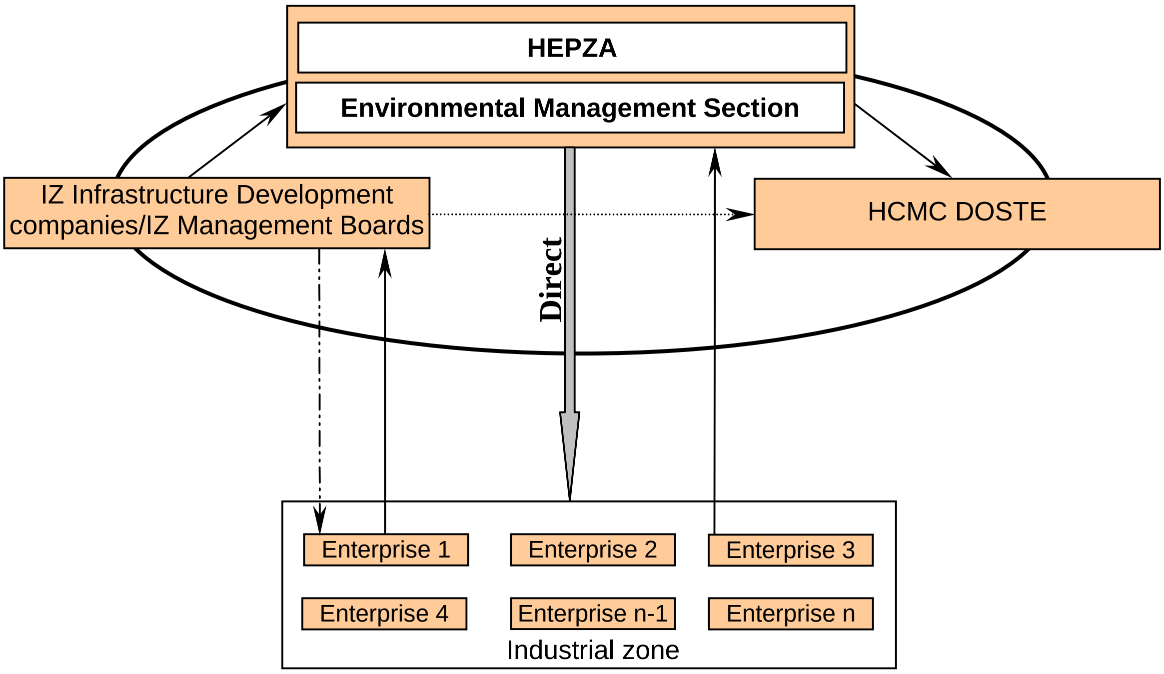
Fig. 4.2 Current organization structures of DOSTEs.

For enterprises located inside industrial zones (IZs) and export processing zones (EPZs), provincial IZs/EPZs Authorities also have tasks and responsibilities in environmental management of these enterprises. However, the actual roles of the provincial IZs/EPZs Authorities are not uniform throughout the whole country (see Fig. 4.3). While in Dong Nai Province, Dong Nai Industrial Zone Authority (DIZA) seems to play no role, in Ho Chi Minh City, HCM Export Processing Zone and Industrial Zone Authority (HEPZA) is direct responsible for the management of the environmental performance of enterprises in IZs and EPZs. It is difficult for DIZA to grasp the environmental situations at enterprises in IZs because all periodical environmental reports from enterprises are submitted to Dong Nai DOSTE[18]. DIZA does not have a right nor sufficient capacity to carry out environmental inspection independently. Their only role in environmental management is at encouragement level and reminding enterprises to execute environmental protection. Though according to Decision No. 162 BKH/KCN, DIZA has the right to retrieve investment licenses of enterprises, which are not in compliance with environmental regulations, this has not been implemented yet, also because it may influence the attraction of investment into IZs. In addition, the tasks of DIZA with respect to environmental management of IZs are still not defined clearly in any official documents.

[17] Interview with Mr. Phan Van Het, Vice Director of Dong Nai DOSTE.
[18] Interview with Mr. Phan Van Yen, Head of Planning and Environmental Department of DIZA.



(a) Actors in charge of environmental management of enterprise inside IZs in Dong Nai Province.



(b) Actors in charge of environmental management of enterprise inside IZs and EPZs in Ho Chi Minh City.

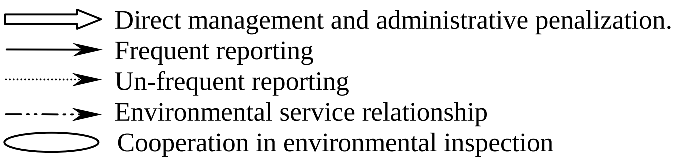


Fig. 4.3 Typical current actors in charge of environmental management of enterprises inside IZs and EPZs.

In case of Ho Chi Minh City (HCMC), HEPZA has contributed significantly to the management of environmental performance of enterprises in IZs and EPZs. This led HCMC

DOSTE to a decision to compile a Draft Statute on State Management for HCMC EPZs and IZs Environmental Protection and submitted it to HCMC PC to make a decision (May, 2002)[19]. The Draft Statute was accepted and promulgated by HCM PC on 8 July 2002. Article 38 of this statute indicates that "HEPZA is responsible to HCMC DOSTE for state management of EPZs and IZs environmental protection". In concrete, HEPZA is responsible for:

- Inspection of the implementation of environmental protection regulations as presented in approved feasibility studies of investment projects;
- Guiding, receiving, considering and issuing registration of environmental licenses for investments in IZs;
- Conducting the environmental monitoring program during infrastructure construction and IZ operation phases. HEPZA has to organize acceptance test for waste treatment systems of enterprises located in IZ and report to HCMC DOSTE;
- Discovering and solving violations on environmental protection;
- Co-operating with HCMC DOSTE, central and local agencies to implement inspection of environment in the management sphere of HEPZA;
- Receiving and solving disputes, complaints, denouncements about environmental pollution caused by activities of enterprises located in IZs and EPZs. HEPZA has to co-operate with HCMC DOSTE, if necessary, to solve these problems;
- Developing regulation and inspecting the separation, collection, transportation and treatment of wastes generated within the IZ. HEPZA has to co-operate with involved organizations to treat municipal solid wastes and industrial solid wastes following Local Statutes on Wastes Treatment and Management;
- Monitoring hazardous wastes management following Decision No. 155/1999/QD-TTg dated 16 July 1999 by the Prime Minister and International Agreements, which Vietnam has participated in;
- Co-operating with other organizations to propagate law, policies and planning on environmental protection and organize education programs to enhance environmental knowledge of staff and workers of enterprises belonging to HEPZA's jurisdiction;
- Executing periodical and incidental reporting following guidance of HCMC DOSTE. Proposing, commending and rewarding persons or teams, who have good achievements in environmental protection and management.

Because this Statute has just been promulgated and applied last year (2002), it is yet too early to assess whether this division of tasks between HEPZA and HCMC DOSTE works well, without conflicting of interest and competition.

4.1.3 District Level

At district level, District Urban Management Divisions, which belong to District PCs, are responsible to DOSTEs for implementing DOSTEs' instructions, handling complaints, resolving disputes, dealing with environmental problems from enterprises (including household production units) and reporting environmental protection activities to DOSTEs. In addition, the District Urban Managment Divisions always perform in collaboration with DOSTEs to carry out environmental monitoring programs at enterprises within their management areas. However, in the specific case of Ho Chi Minh City, direct management of enterprises located inside IZs and EPZs is done by the environmental management section of IIDCs or IZ Management Boards and in some cases by HEPZA. For instance, Tan Thuan

[19] Interview with Mr. Le Van Khoa, Deputy of Environmental Management Division of HCMC DOSTE.

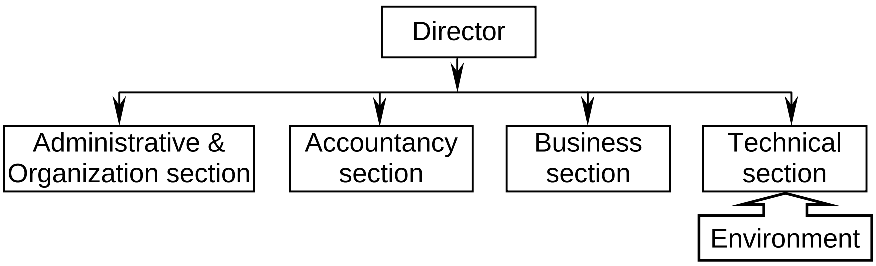
Industrial Promotion Company (IPC) is involved in the investment for construction, infrastructure business exploitation and consulting of both Tan Thuan EPZ and Hiep Phuoc Industrial Park[20]. Therefore Tan Thuan IPC has the tasks and responsibilities on environmental management of both zones. Similarly, besides the role of infrastructural development, SEPZONE Linh Trung plays the role of EPZ Management Board and directly governs environmental protection activities of Linh Trung EPZ[21]. In the case of Le Minh Xuan IZ, the IZ Environmental Management Board has tasks and responsibilities for environmental management activities of the zone[22]. While in the case of Tan Tao IZ, the environmental management is the responsibility of Tan Tao IIDC (called ITACO). In general, the IZ Environmental Management Section of IIDC consists of a water supply subsection, a sewer system subsection (management of sewer network and central wastewater treatment plant) and an environmental management subsection. They have to carry out periodic monitoring (four times a year) and report to both IIDC and HEPZA. In addition, they collaborate with HEPZA and DOSTE in environmental inspections at enterprises in IZ.

4.1.4 Enterprise Level

In order to evaluate the role of actors in charge of environmental management at enterprise level, a survey of 48 enterprises/companies located in Bien Hoa 1 IZ, which represents the oldest IZ in Vietnam and Bien Hoa 2 IZ, which represents a new developed IZ, was conducted. These companies are large-scale, both state and private owned companies. It is recognized that only some companies conduct environmental protection activities voluntarily. Most companies just face inspection of DOSTE. Similar to several enterprises in various parts of the world, Vietnamese firms also show to:

- Lack of awareness on environmental pollution;
- Lack of manpower with environmental professional skills;
- Financial limitations on environmental investments.

Most surveyed enterprises do not have a separate environmental management section. Environmental management of enterprises is an additional task of the technical section, administrative section, product quality inspection section, or enterprise management board. Typical positions of environmental management section in the organization structure of enterprises are described in Fig. 4.4 and Table 4.1. Most environmental managers of enterprises have not been trained on environmental knowledge or have only participated in some short training courses. Besides, they are responsible for other important tasks at the enterprises such as production technology, labor safety, administration, etc. Therefore they normally pay little attention to environmental activities.



(a) Organization structure of Bien Hoa Chemical Factory (Bien Hoa 1 IZ), where environmental management is task of technical section[23].

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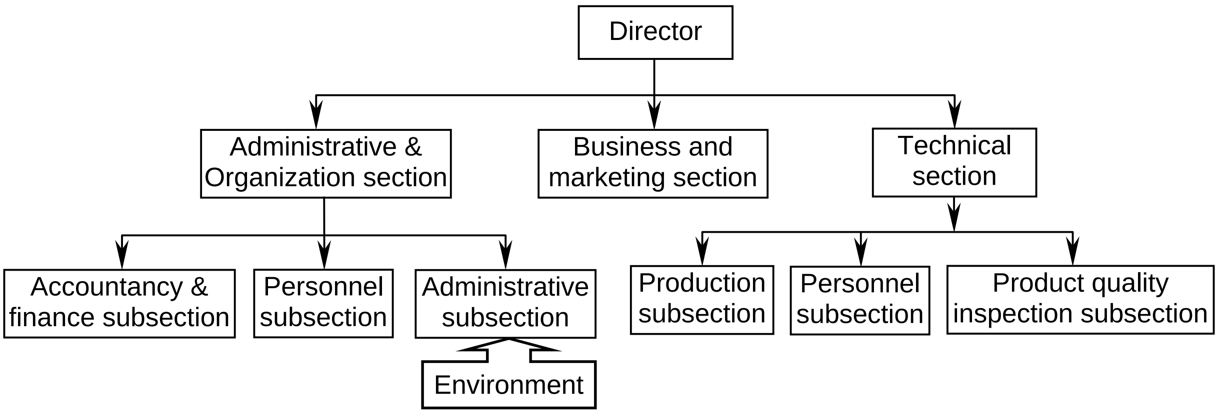
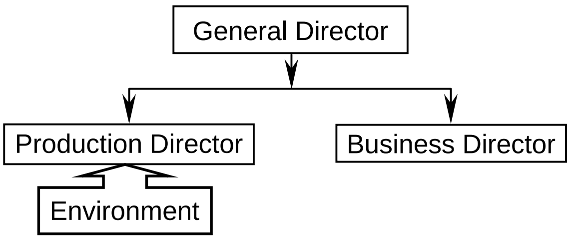
[20] Interview with Mrs. Nguyen Ngoc Quynh and Mr. Dao Duc Tho, Specialists, Marketing Department of Tan Thuan Industrial Promotion Company, Hiep Phuoc Industrial Park.
[21] Interview with Mr. Tran Thanh Hong, First Vice-President of SEPZONE Linh Trung.
[22] Interview with Ms. Thu Hien, Environmental Expert of Le Minh Xuan IZ Management Board.
[23] Interview with Mr. Phan Tat Dat, Vice Director of Dong Nai Chemical Factory, Bien Hoa 1 IZ.



(b) Organization structure of Vietnam Taya Company (Bien Hoa 2 IZ), where environmental management is task of administrative section[24].



(c) Organization structure of Sai Gon Steel Pipe Company (Bien Hoa 2 IZ), where environmental management is task of the company management board[25].

Fig. 4.4 Typical positions of the environmental management section of enterprises.

Table 4.1 Environmental management at enterprise level in Bien Hoa 1 IZ and Bien Hoa 2 IZ

No.	Name of enterprise	Name of IZ	Place of environmental management section	Main environmental protection activities
1	LENEX Company	Bien Hoa 1	- Belong to administrative section	- Labor safety
2	Bien Hoa Chemical Factory	Bien Hoa 1	- Belong to quality assessment section	- Operation of WWTS; - Environmental monitoring every quarter of a year
3	Dong Nai Mechanical Factory	Bien Hoa 1	- Belong to technical section - By mechanical engineer	- Labor safety
4	CFT Vietnam Copper Wire Company	Bien Hoa 1	- Belong to technical section	- Operation of WWTS; - Periodical inspection of WWTS performance every 6 months
5	Thanh Thanh Enameled Tile Company	Bien Hoa 1	- Belong to technical section - By chemical engineer	- Operation of air pollutants treatment system; - Environmental inspection by general Company every 6 months
6	Dong Nai Chemical Factory	Bien Hoa 1	- Belong to technical section	- Inspection working environment
7	Dong Nai Battery Enterprise	Bien Hoa 1	- Belong to technical section	
8	Viet Thai Enterprise	Bien Hoa 1	- Belong to technical section	
9	Dien Quang Neon Light Enterprise	Bien Hoa 1	- Belong to technical section	

[24] Interview with administrative officer of Vietnam Taya Company, Bien Hoa 2 IZ.
[25] Interview with Chief of Production Section of Sai Gon Steel Pipe Company, Bien Hoa 2 IZ.

Table 4.1 Environmental management at enterprise level in Bien Hoa 1 IZ and Bien Hoa 2 IZ (cont.)

No.	Name of enterprise	Name of IZ	Place of environmental management section	Main environmental protection activities
10	VINAPRO	Bien Hoa 1	- Belong to technical section & administrative section; - 2 staff members	- Labor safety
11	Bien Hoa Electronuc Company	Bien Hoa 1	- By one staff member	- Environmental reporting
12	VICASA Steel Factory	Bien Hoa 1	- By mechanical engineer	- Labor safety; - Operation of dust treatment system
13	Dong Nai Paint Factory	Bien Hoa 1	- By mechanical engineer	
14	DONANEWTOWER Company	Bien Hoa 1	- By microbiological engineer	- Labor safety; - Operation of WWTS
15	DONABOCHANG RATTAN WOOD MEG Co. Ltd.	Bien Hoa 1	- By two staff members	- Labor safety; - Collection of dust and waste-paper for burning
16	BIBICA Bien Hoa Candy Company	Bien Hoa 1	- Independent EMS - By environmental engineer	- Operation of WWTS
17	Dong Nai Paper Company (COGIDO)	Bien Hoa 1	- Independent EMS - Staffs were trained in WWST in Thailand and Sweden	- Labor safety; - Applying cleaner production; - Operation of WWTS.
18	Roofing & Construction Material Company	Bien Hoa 1	- Independent EMS - 3 staff members	
19	HAPPY VINA Company	Bien Hoa 2	- Belong to administrative section	- Labor safety
20	VIJAGA Company	Bien Hoa 2	- Belong to management board	- Labor safety; - Noise inspection every 3 months
21	HISAMITSU	Bien Hoa 2	- Belong to management board	- Solid waste incineration
22	TAYA Wire and Cable Company	Bien Hoa 2	- Belong to mechanic-electric section, 2 staff members	- Solid waste handling
23	Dong Nam Company	Bien Hoa 2	- Belong to personnel section	- Factory hygiene
24	NOVARTIS Company	Bien Hoa 2	- Belong to quality assessment section; - 3 staff members	- Auditing; - Operation of incinerator; - Recording wastes generation every month.
25	SPC Steel Pipe Company	Bien Hoa 2	- Belong to technical section	- Factory hygiene - Operation of WWTS, air pollutants treatment system.
26	NESTLE Vietnam Company	Bien Hoa 2	- Belong to technical section - By 2 staff members	- Labor safety; - Operation of WWTS; - Operation of incinerator.
27	SUN NETUREN Company	Bien Hoa 2	- By 1 staff member	- Environmental monitoring reporting.
28	Vietnam Machibi Motor Company	Bien Hoa 2	- By 2 staff members	- Factory hygiene - Achieving ISO 14001.
29	SANYO Company	Bien Hoa 2	- By 25 staff members from chiefs and deputies of different sections	- Labor safety; - Operation of WWTS; - Achieving ISO 14001.
30	INTERTRADE Company	Bien Hoa 2	- By business administration	- Labor safety.
31	Viet Tuong Electronic Company	Bien Hoa 2	- Environmental Management Section, 2 staff members	- Labor safety; - Factory hygiene.
32	ELF ATOCHEM Company	Bien Hoa 2	- Labor safety section - 2 staff members	- Reporting to Director every month.
33	TECHNOPIA Company	Bien Hoa 2	- Labor safety section - 1 staff member	- Labor safety; - Factory hygiene.
34	SY Weaving Factory	Bien Hoa 2	- Labor safety section - 1 staff member	- Factory hygiene.
35	Vietnam Chain Company	Bien Hoa 2	- Labor safety section - 1 staff member	- Factory hygiene.
36	NIPPON PAINT Company	Bien Hoa 2	- By 1 staff member	- Operation of WWTS.
37	KOLLMORGEN ARTUS VIETNAM Company	Bien Hoa 2	- Labor safety section - 1 staff member	- Labor safety.

Table 4.1 Environmental management at enterprise level in Bien Hoa 1 IZ and Bien Hoa 2 IZ (cont.)

No.	Name of enterprise	Name of IZ	Place of environmental management section	Main environmental protection activities
38	TUNG KWANG Company	Bien Hoa 2	- Belong to technical section	- Labor safety; - Operation of WWTS.
39	Vietnam-Japan Fertilizer Company	Bien Hoa 2	- Belong to technical section	- Labor safety; - Operation of WWTS; - Operation of dust treatment system.
40	BESTFOOD Company	Bien Hoa 2	- By 1 staff member	- Operation of WWTS.
41	VIKO MOONSAL	Bien Hoa 1	- No environmental section	
42	VITAGA Agro-Animal Food Processing Enterprise	Bien Hoa 1	- No environmental section	
43	The South Agro-Machine Company (VIKYNO)	Bien Hoa 1	- No environmental section	
44	PROCONCO Animal Food Processing Company	Bien Hoa 1	- No environmental section	
45	Dong Nai Rubber Company	Bien Hoa 1	- No environmental section	
46	BORAMTEX Company	Bien Hoa 2	- No environmental section	
47	CHIEn YOU VIETNAM Company	Bien Hoa 2	- No environmental section	
48	YNHUA Aluminum Company	Bien Hoa 2	- No environmental section	

4.2 ENVIRONMENTAL LEGISLATION

4.2.1 General Introduction to Environmental Legislation

Legislation related to environmental management of industry in Vietnam is marked by (1) the origination of the Law on Environmental Protection (LEP) in 1993, (2) appearance of several environmental regulatory documents issued by the government and (3) a number of documents promulgated by MOSTE and inter-ministries.

Though facing many difficulties due to lack of experiences, LEP was finally brought for discussion in the ninth National Assembly of the Socialist Republic of Vietnam, the fourth Section (from 6th to 30th December 1993). The LEP was approved officially by the National Assembly on 27th December 1993 and the President promulgated to publish it by the Order No. 29-l/CTN on 10th January 1994 (LEP, 1999). The law sets obligations and duties of state agencies, organizations and individuals on prevention and mitigation of environmental degradation, pollution and incidents. It also provides the legal framework for MOSTE, provincial/city PCs and DOSTEs. The LEP is the foundation of a legal system in environmental protection of Vietnam.

After the LEP, several environmental regulatory documents such as decrees, decisions, etc. were promulgated by the government to provide instructions and details on the implementation of the LEP. Decree No. 175-CP, named "Guideline for Implementation of Environmental Protection Law", issued on 18th October 1994, is the first and most important environmental regulatory document of this category. This Decree presents detailed stipulations for the implementation of the LEP. Responsibilities of different levels (state management, organizations and individuals) on environmental protection, environmental impact assessment (EIA), prevention of environmental deterioration and pollution and inspection of environmental protection are regulated in this Decree. The contents of EIA reports in different situations and the decentralization of EIA report appraisal are also described in detail in the appendixes enclosed to the Decree. The LEP and other relative legislative environmental documents have been enhanced efficaciously by establishment of Decree No. 26/CP (26th April 1996), which provides "Regulations on the Punishment of

Administrative Violation of Environmental Protection". This Decree indicates different types of administrative violations on environmental protection. These are, for instance, illegal import/export of wastes, violations on transportation and treatment of wastewater and solid wastes, making noise and vibrations exceeding the state permissible limits, harming the health of proximally located people and adversely affecting their life, failure in overcoming environmental incidents, etc. The degree of penalty for each case and jurisdiction for handling and procedures for implementing penalties are also described. Decree No. 19/2001/ND-CP (dated 11st May 2000) regulating punishment of administrative violation on radioactive safety and control is a supplement of the Decree No. 26-CP. In addition, Decree No. 12/CP (dated 18th February 1997) and Decree No. 24/2000/ND-CP (dated 31st December 2000) stipulate requirements on environmental protection for all imported equipment and materials into Vietnam and Instruction 199/TTg (dated April 1997) dealing with immediate measures for the management of solid waste in industrial and urban areas are other important documents among this category of environmental regulatory documents. Together with this, the Government has also promulgated many laws and regulations concerning environmental protection as presented in Box 4.1.

Box 4.1 Laws and regulations concerning environmental protection promulgated by Vietnamese Government

Forest Protection and Development Law (1991); the People Health Protection Law (1989); Land Use Law (1993); Law of Oil and Petrol (1996); Mineral Resource Law (1996); Water Resource Law (1998)l Criminal Affair Law (reform, 1999); Dykes Protection Ordinance (1989); Ordinance of Resources Taxes (1989); Ordinance of Aquatic Resources Protection (1989)l Ordinance of Radiation Safety and Control (1996); Ordinance of Vegetation Protection and Quarantine (1993).

Source: NEA, 2003.

A number of environmental regulations, circulars, decisions, standards, etc. were issued by MOSTE for further implementation of governmental environmental regulatory documents. These include decrees, circulars, decisions, regulations, standards, etc. Several regulatory documents promulgated by MOSTE stipulate the procedure for preparing, appraising and approving EIA reports such as Instruction No. 1420/QD-MTg dated 26th December 1994; Decision No. 1806-QD/Mtg dated 31st December 1994; Office Dispatch No. 812-Mtg dated 17th April 1996, Instruction No. 1100/TT-Mtg dated 20 April, 1997; Circular No. 490/1998/TT-BKHCNMT dated 29th April 1998, etc. In 1995, MOSTE issued the national environmental standards (TCVN-1995) including standards on water quality and discharged industrial wastewater characteristics, ambient air quality and industrial emission, noise and vibration in public and residential areas, and soil quality. Methods of measuring, collecting, analyzing and treatment of samples are also described in these standards. Until 1999, about 200 environmental standards had been developed in Vietnam (Phuong, 2002). In order to overcome shortcomings of TCVN-1995, which is based only on concentrations of contaminants, new standards (TCVN-2001) on industrial effluents discharged into the receiving water body and industrial emissions into the atmosphere were promulgated in 2001. These standards take into account both loading of contaminants to be discharged and self-purifying capacities of the receiving environment. These national standards form the basis for legal foundations to carry out EIA, environmental monitoring, enforcement and inspections. Promulgating Circular No. 1817/1999/TT-BKHCNMT (dated 21st October 1999), Circular No. 2/2001/TT-BKHCNMT (dated 15th February 2001), Decision No. 05/2001/QD-BKHCNMT (dated 11st April 2001), MOSTE encourages the implementation of waste treatment and environmental protection activities.

Various inter-ministerial regulatory documents refer to environmental protection. Inter-ministerial Circular No. 1590/1997/TTLT/BKHCNMT-BOXD by MOSTE and the Ministry of Construction give guidelines for implementation of Instruction No. 199/TTg. The Ministry of Industry and Ministry of the Interior issued Circular No. 01/1998/TTLT-CN-NV (13rd January 1998) providing guidelines for implementation of management, business and supply of industrial explosive materials.

Within the scope of this research, discussions on current environmental legislative documents will emphasize mainly on four aspects related to (1) end-of-pipe treatment and pollution control, (2) waste reuse and recycling, (3) cleaner production and (4) industrial ecology and ecological modernization.

4.2.2 Environmental Legislation Concerning End-of-Pipe Treatment and Pollution Control

Most environmental legislation of Vietnam emphasizes on handling of generated wastes to meet the national environmental standards. The Law on Environmental Protection (1993) stipulates that during the production stage, organizations or personnel have to implement environmental hygienic measures, install waste treatment facilities in order to meet environmental standards and prevent environmental deterioration and accidents. Decree No. 175 (1994) providing a guideline for implementation of the LEP also regulates that enterprises have to treat wastewater, air pollutants and solid wastes to meet environmental standards before discharging them. Promulgation of Decision No. 2920-QD/MTg (dated 21st December 1996) on “Implementation of Vietnamese Environmental Standards” force industrial enterprises to pay attention to generated wastes from their production processes. Recognition of the arising environmental problems due to solid wastes, Prime Minister of MOSTE issued Instruction No. 199-TTg on Urgent Measure in Management of Solid Wastes in Urban Areas and Industrial Zones. This instruction requires provinces and cities to carry out management of waste at source, collection and transportation. In concrete, regulations indicated in this instruction include prohibition of disposing wastes to rivers, lakes and roads; the intermediate and complete collection of waste; carrying out separation of solid wastes at source; applying suitable technologies to treat and dispose wastes to comply with environmental standards. In addition, promulgation of different environmental standards for different kinds of industrial wastes and pollution, for instance solid waste, wastewater, soil pollution, air pollution, noise and vibration, toxic materials and hazardous wastes, etc. compels waste generators to seek for end-of-pipe treatment to meet the standard. Besides, Vietnamese standards on design, construction and development of enterprises or industrial groups also focus on end-of-pipe solution. For instance, Vietnamese standard TCVN 4449-1987 on “Urban Construction Planning - Design Standards” regulates that heavy polluting enterprises should be equipped with a hazard waste treatment system. In TCVN 4616-1988 on “Layout Master Plan of Industrial Group-Design”, enterprises are required to apply modern dust and air pollutant extractors to collect dust and air pollutants, natural or artificial measures to collect generated wastes. Even legislative documents relating to encouragement and rewarding on environmental protection activities also focus strongly on end-of-pipe solutions. Environmental pollution treatment and waste processing projects are classified as projects of specific investment encouragement. Conditions, procedure to apply, authority for appraisal and approval of such projects are indicated in Circular No. 1817/1999/TT-BKHCNMT (21st October 1999) and Circular No. 2/2001/TT-BKHCNMT (15th February 2001).

4.2.3 Legislation Concerning Waste Reuse and Recycling, and Cleaner Production

Few paragraphs in some legislative environmental documents mention shortly about the application of waste reuse and recycling or/and cleaner production. For instance, article 11 of the LEP touch upon that the state encourages and creates convenient conditions for personnel, who use and exploit environmental components properly, apply modern technologies, cleaner production, reuse wastes, save raw materials, use recycling energy, apply biological products in scientific research, production and consumption. Inter-ministerial Circular No. 1590/1997/TTLT/BKHCNMT-BXD of MOSTE and Ministry of Industry providing guidelines for implementation of the Instruction No. 199/TTg also mentioned that organizations and personnel including industrial production organizations are responsible for management and minimization of waste generation. Decision No. 152/1999/QD-TTg (dated 10th July 1999) by the Prime Minister on Solid Waste Management Strategy for Urban Areas and Industrial Zones in Vietnam provides a target up till 2020 for separation of solid wastes at source, optimal collection, transportation and treatment, further recovery and recycling of solid wastes. Except for article 15 of Decree No. 29/CP (dated 12nd May, 1995 by the Government) mentioning about tax favor for cleaner production projects or projects on the reuse of wastes to reduce environmental pollution, no other legislative documents give concrete incentives, guidelines or instruments for practical implementation for such cleaner production and waste reuse and recycling projects and measures.

4.2.4 Legislation Concerning Industrial Ecology and Ecological Modernization

Only few sentences in article 1 and 14 of the LEP mention the requirement to ensure ecological balance during exploiting agricultural, forest, and aquaculture and carrying out environmental protection activities as well. Ideas of industrial ecology and ecological modernization have not appeared in any legislative environmental documents promulgated by Vietnamese National Assembly, Government, MOSTE or other ministries yet.

4.3 CONCLUSIONS

Based on data and information presented in this chapter, three main conclusions can be made on the existing industrial environmental management in Vietnam. First, there is an unclear definition of tasks of different actors in charge of environmental management of industry and there lacks on uniform administrative organizational structure of environmental management, especially for enterprises inside IZs. Second, existing environmental legislation emphasizes strongly on end-of-pipe solutions, while cleaner production and waste reuse and recycling are only mentioned briefly, without any concrete incentives and guidelines for implementation. Finally, ideas of industrial ecology and ecological modernization are completely absent in the current environmental legislation of Vietnam.

CHAPTER 5

INDUSTRIAL ECOSYSTEM AT VILLAGE LEVEL

A Case Study At Tra Co Tapioca Processing Village, Dong Nai Province, Vietnam

5.1 INTRODUCTION

Cassava (*Manihot esculenta* Crantz), also known as tapioca or manioc, is one of the major tuber crops grown in more than 80 countries of the humid tropics. It is a high-energy food obtained with low inputs and little effort. To the people in the tropics it is either a main or a secondary staple food. Most of the world production of cassava is used for human consumption in tropical countries, the other main uses are animal feeding and used as starch for several significant industrial production processes. Among tropical crops, cassava is one of the most important suppliers of calories (Cock, 1985). Cassava can help to enlarge total food supplies because production is possible on soil that is not suitable for cereals and other food crops. Moreover, growing cassava to provide animal feed means that better land, now devoted to the production of feed grains, can be transformed to food production areas. Cassava is a common raw material in starch production. There is great potential for the use of cassava in food products, wood, paper, textile, animal feed, pharmaceutical, high fructose syrup, alcohol and sweeter industry (Abass and Bokanga, 2001; O'Hair, 1995). Tapioca starch can be used in thousands of end products (Ostertag, 1996; Roper, 1996). According to Cock (1985) about 6% of the world's cassava production is used to process starch for industrial processes and food processing. Normal utilization of tapioca starch in different industrial sectors is listed in Table 5.1.

In Vietnam, among the subsidiary food crops, cassava accounts for about 25% of the agriculture area. In 2000, the total land area used for cassava cultivation was about 234,900 ha, of which the South Key Economic Regions (SKERs) accounted for 17,600 ha with an average yield of 9.63 ton/ha (General Statistical Office, 2001). The cassava production has helped Vietnam through at least two major famines since World War II and was an important staple of the Vietnamese army during the war with France and the USA. But now the crop acquires a new image as raw material for industry. Cassava is grown mainly for on-farm feeding of pigs, for direct human consumption, and for production of starch, maltose, noodles, cakes. The amount of cassava used for direct consumption is only about 12%, on-farm processing is 17%, on-farm animal feeding is 22% and 49% of cassava fresh roots is sold for further processing of tapioca starch (Khoa, 1998). Most of tapioca starch goes to domestic food processing, mainly into the production of monosodium glutamate, an important flavoring agent, while some is used in the production of textile, paper and other products.

Production of tapioca starch using traditional technology at rural households in Vietnam has been going on for decades. Though household-scale (also called family- or small- scale) tapioca production units contribute significantly to satisfy the demand on tapioca starch of domestic industrial purposes, it is now recognized as an industrial sector causing more and more serious environmental deterioration. Pollution of wells and springs in Binh Minh Commune, Dong Nai Province, a result of household tapioca processing activities, should be considered as a warning for all tapioca production villages or areas. Environmental improvement of tapioca producing households arises as an important issue that should be considered, especially now when the appearances of several large-scale tapioca factories in the South of Vietnam have not only pushed the tapioca industry to a rapid growth, but also influences the existence of these households.

Table 5.1 Utilization of tapioca starch in different industrial sectors

Industrial sectors	Utilization of tapioca starch
Food processing industries	- Bakery and pasty products - Noodles, vermicelli, etc. - Soup, sauces, etc. - Ice creams, yoghurts, lactic drinks, and other deserts - Processed meats - Sweets, chocolates, candy, chewing gums - Marmalades, jams - Canned fruits, juices - Soft drinks, beers - Snack foods - Taste enhancers, color enhancers - Fat substitutes for dietary products - Alternative protein sources - Sweeteners
Paper, cardboard and plywood industry	- Carton, high quality papers, plywood
Textile industry	- Fillers, stiffeners - Leather goods
Chemical and pharmaceutical industry	- Glues, paints, cements - Soaps, Detergents, bleaches, insecticides - Explosive - Oil drilling materials - Biodegradable plastics, polyesters, etc. - Industrial alcohol - Combustibles, ethanol, oils - Pharmaceuticals, vitamin C and B_{12}, antibiotics - Cosmetics - Water treatment agents
Feed industry	- Protein substitutes - Carbohydrate sources

Source: Henry and Westby, 1996.

Ascertaining suitable solution for the question on how to move these tapioca producing households into more sustainable industrial ecosystem is the core objective of this chapter. Starting with the description of the existing tapioca production technologies of households at four different provinces in Vietnam, section 5.2 provides useful information to understand the strengths and weaknesses of the available technologies. Learning these practical experiences is very helpful for later suggestions on technological options to prevent or reduce the generation of non-products (including wastes and emissions) and improve the production efficiency of the tapioca producing households mentioned in the case study at Tra Co Village. Introduction to Tra Co Village and its environmental implications due to tapioca processing are briefly described in section 5.3, to affirm the necessity of reforming the existing tapioca industrial development situation in this area. Depth study on tapioca production process at one household and material flow balances and cost benefit analysis is presented in section 5.4. This section also provides important information for the material flow network development in the next section. A physical model of a zero waste industrial ecosystem is developed step-by-step as described in section 5.5 and followed by analysis of involved actors and institutions in section 5.6. Possibilities to promote the proposed model and some main conclusions and recommendations are drawn in section 5.7 and section 5.8, respectively.

5.2 HOUSEHOLD-SCALE TAPIOCA PRODUCTION PROCESSES

In this section, the existing tapioca production technologies at household-scale of four different provinces including Dong Nai, Tay Ninh, Ho Chi Minh and Binh Dinh are described together with their strengths and weaknesses in terms of environmental improvement and resource conservation (see Table 5.2).

5.2.1 Household-Scale Tapioca Production Process in Tra Co Village, Thong Nhat District, Dong Nai Province

The tapioca production processes, which were observed at five households in Tra Co Hamlet, are similar. The only difference among them is the technique for root rinsing. In some households, cassava roots are submersed in overflow water tanks. In other households, they are rinsed by spraying water on the heap of roots. Depending on the available area, some households produce dry starch and others wet starch. The diagram of the common production process is shown in Fig. 5.1 and a simulated view of the production technology is drawn in Fig. 5.2. The average capacity is about 7 tons of roots/household.day. Fresh cassava roots have to be processed within the day received to ensure that the highest starch content is extracted. The fresh roots are rinsed to remove earth, dirt, sand, etc. from their outer skins. Some pieces of hard roots, which are unsuitable for the production of tapioca starch, are also removed manually during rinsing. This step is necessary to reduce the amount of dirt or sand settled in the starch layer at the bottom of the settling tanks, which are used to separate starch from starch milk. After that, the rinsed roots are ground into suitable sizes before transferring them into an extractor (mixing tank). The suspension containing starch and water, called starch milk, is seeped through a polyester cloth located near the bottom of the extractor and is transferred into the first settling tanks. Fibrous residues are removed through an outlet just above the cloth and stored in another tank for further processing.

Starch milk, which is left in the first settling tanks for about 8 hours, separates naturally into three layers. The upper layer is called milk sap, which contains impurities. This supernatant is skimmed from the tank after releasing water from the middle layer. The bottom layer is wet starch, which is collected from several tanks and gathered in a tank, mixed thoroughly with water, and left to settle a second time for about 12 hours (second settling stage). After 12 hours of settling, three layers are formed again. However, in this stage, the upper layer is water. The layer below is a starch layer consisting of dirt starch on top and good quality starch in lower layers. After releasing water out of the upper layer, dirt starch is moved to another tank and thoroughly mixed with fresh water (in mixing tank) to settle dirt and unqualified starch (called pulp). The remaining suspension is then transferred from the mixing tank into the third settling tank for further recovering of starch. It also takes about 12 hours to complete the third settling. The third settling stage is not always executed. This depends on the availability of settling tanks. Dimensions of settling tanks vary depending on available space. Typical sizes of length x width x depth are 3.85 (m) x 1.02 (m) x 0.61 (m) or 4.4 (m) x 1.48 (m) x 0.56 (m).

Good quality starch from the second and the third settling stages are sold as wet starch or, after drying under the sunshine, dry starch. Fibrous residues, tapioca milk sap from the first settling and pulp from the second settling (both tapioca milk sap and pulp are simplified as "pulp", and this word will be used throughout this study) are dried by the sun and sold as raw material for animal feed production. Pieces of cassava roots or hard roots from the root-rinsing step are also dried by the sun and used as firewood. All wastewater from the production process is discharged into existing open ditches without any treatment. A part of wastewater is collected for fish cultures. The remaining is discharged to surface water bodies such as Dia Spring, Mi Spring and Song May Lake.

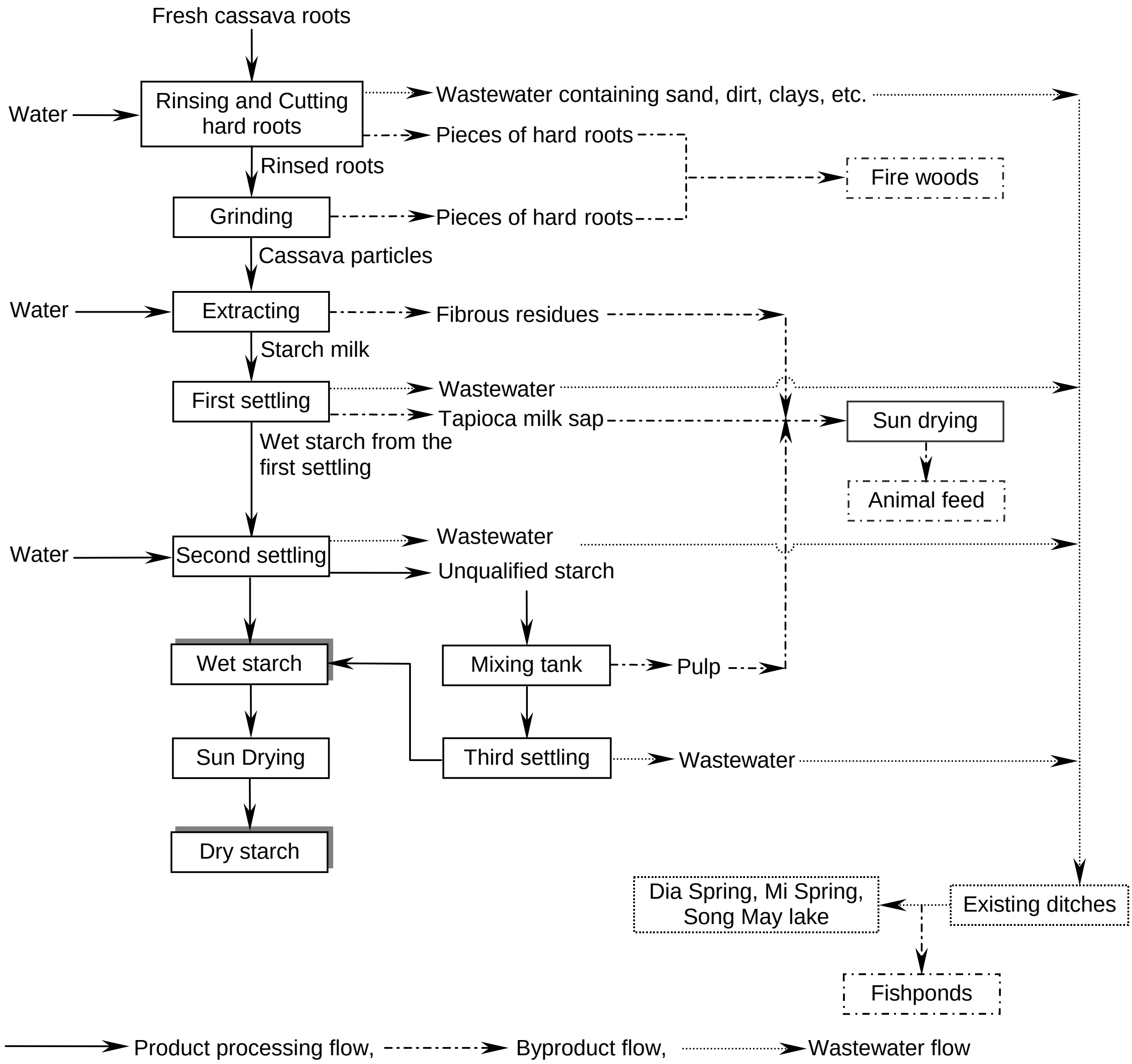


Fig. 5.1 Diagram of household-scale tapioca production process at Tra Co Village, Thong Nhat District, Dong Nai Province.

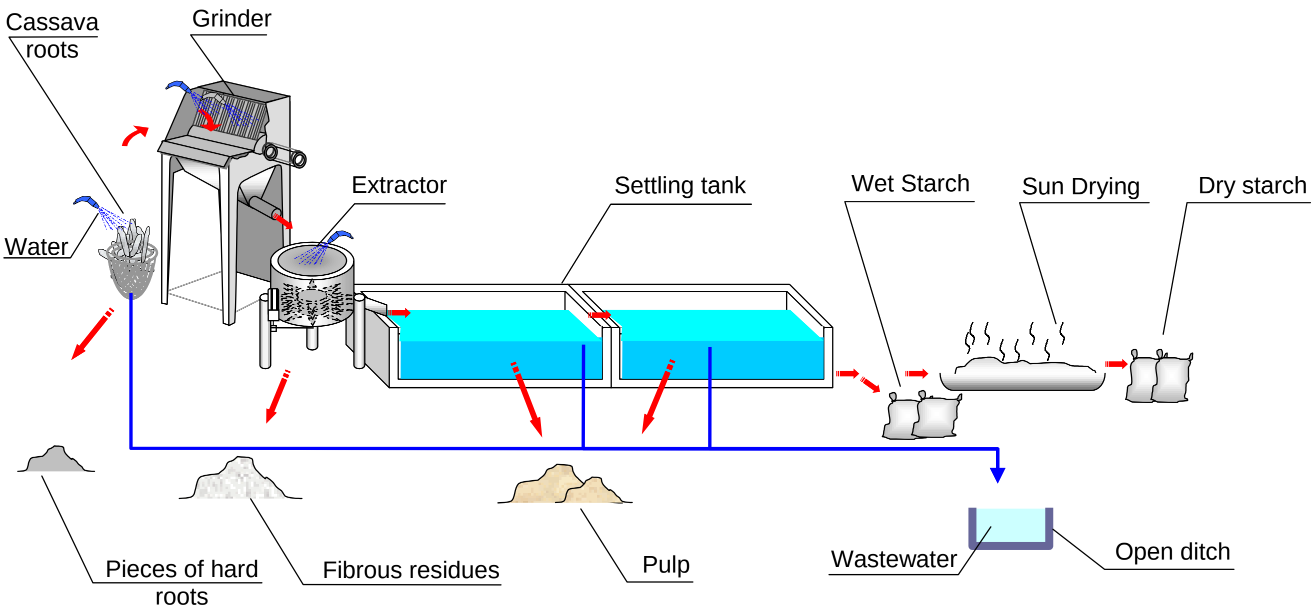


Fig. 5.2 Simulated view of the household-scale tapioca production technology at Tra Co Village, Thong Nhat District, Dong Nai Province.

5.2.2 Household- Scale Tapioca Production Process in Binh Minh and Tan Binh Hamlets, Tay Ninh Province

The household-scale tapioca production process in Binh Minh and Tan Binh Hamlet, Tay Ninh Province is mechanically more advanced than that of Tra Co Village, Dong Nai Province. The common production process is described in Fig. 5.3 and a simulated view of the production technology is drawn in Fig. 5.4. Pieces of hard roots are removed manually before the roots enter a conveyor to transfer to screw gutter for rising. Outer skins (both thin outer layer (peel) and cortex) of the cassava roots are removed as they are rubbed during turning of the screw. Fresh water is sprayed on the top and along the screw gutter to remove dirt. Rinsed roots are cleaner in this case than that of Tra Co Village as a result of better starch quality, shorter settling time and less amount of generated pulp. Then, the roots are ground into suitable sizes before transferring them into the mixer. A mixture of starch, fiber and water is filtered through a vibration screen to separate fibrous residues from suspension of water and starch (starch milk). Vibration of the screen causes a more efficient separation of starch and fibrous residues. A mixture of water and suspension passing the end of the screen is collected and recycled by transporting it back to the mixer for recovering of starch and reducing the amount of used fresh water. The starch milk passing through the screen is transferred into a tank to settle dirt, sands, etc. while the supernatant is released into several settling ditches of about 18 – 22 m length. The horizontal velocity of starch milk in the settling ditches is about 9.6 m/min. Starch settles on the bottom of the settling ditches, while water is flowing out from the surface into a reservoir. Wet starch can be collected within some hours. This technique takes about 12 hours for the whole process compared to 56 hours in Tra Co Village, Dong Nai Province. Households in this area have sufficient space for producing and drying starch. The production capacity is about 40 – 50 tons/household.day, about 6 times higher than that of households in Tra Co Village. Wet starch is either packaged to sell directly or dried under the sun to have dry starch products.

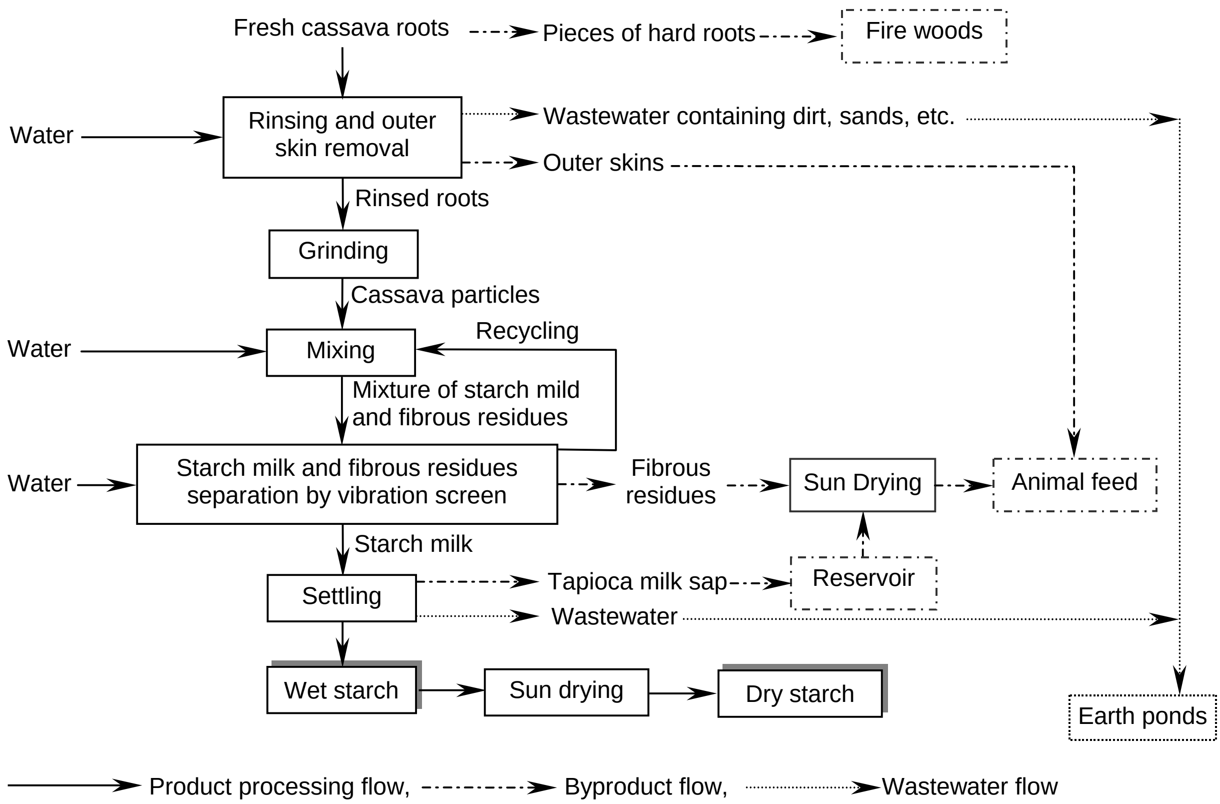


Fig. 5.3 Diagram of the household-scale tapioca production process at Binh Minh and Tan Binh Hamlets, Tay Ninh Province.

Outer skins and residual fiber are dried by sunshine and sold as raw materials for animal feed production. Pieces of hard roots are also sun dried to reuse as firewood. Tapioca milk sap, which is removed from the upper layer of settled starch layer, is stored in an earth pond to get a sufficient quantity before drying. Wastewater from the production process is discharged without any treatment into another earth ponds for storage and to evaporate water.

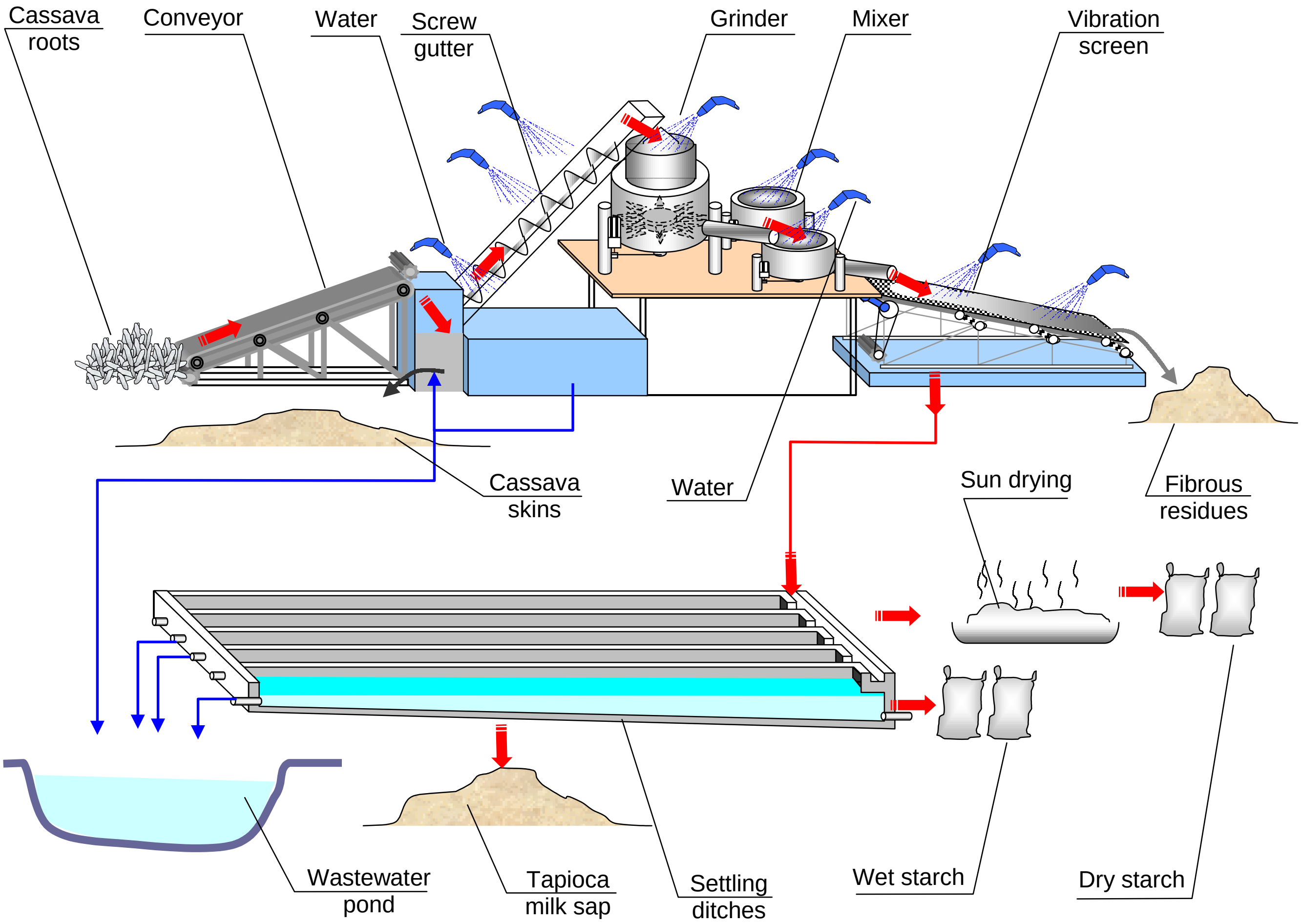


Fig. 5.4 Simulated view of the household-scale tapioca production technology at Binh Minh and Tan Binh Hamlets, Tay Ninh Province.

Compared to Tra Co Village, the tapioca production process of households at Binh Minh and Tan Binh Hamlets is mechanically more advanced from rinsing to settling stage, resulting in less time consumed for each production batch as mentioned above. Production efficiency and starch quality is higher because of better root rinsing and starch extraction. The production area of each household here varies from 5,000 m^2 to 20,000 m^2, which is about 25 to 100 times larger compared to Tra Co Village. Therefore, the area of tapioca production households at Binh Minh and Tan Binh Hamlets is sufficient to construct wastewater storage ponds and tapioca milk sap reservoir. Some households have two or three spare earth ponds for wastewater storage. Producers in these villages stated that at least 12 m^3 of fresh water is needed for processing 1 ton of fresh cassava roots (this value is higher compared to Tra Co Village) and they do not think that wastewater can be reused for fish culture. It is also observed that, although there is large space available close to the cassava fields, all generated wastewater is just stored in earth ponds without any treatment or reuse.

5.2.3 Household-Scale Tapioca Production Process in Binh Chieu Ward, Thu Duc District, Ho Chi Minh City

A field observation was carried out at household No. 76A/1 Binh Chieu Ward, Thu Duc District, Ho Chi Minh City. The average production capacity is about 5 – 7 tons of fresh roots/day and the product is wet starch due to limited space for sun drying. Tapioca production technology here is exactly the same as in Tra Co Village, Dong Nai Province. The only difference in this production process is the application of manual peeling in stead of rinsing only. Generated wastewater is currently directly discharged into the sewer network of the city. All solid byproducts are being sold.

5.2.4 Household-Scale Tapioca Production Process in Binh Dinh Province

Household-scale production process of tapioca starch in Binh Dinh Province is referred from Khoa and Boots (1998) and described in Fig. 5.5. In this process, fresh roots are peeled by hand to remove the outer layer of skin (peel) and a part of the cortex. Peels are reused as raw material for composting or as cattle food. The roots are then ground into very fine particles and stored until they can be further processed. The next step is a batch-wise extraction of the starch from the mixture. Water is added and thoroughly mixed with the starch and fiber mixture. Starch milk seeps through a polyester cloth near the bottom of the tank and is pumped to the settling tanks. The fibrous residues are removed from the tank through an outlet just above the cloth and are stored in another tank for further processing.

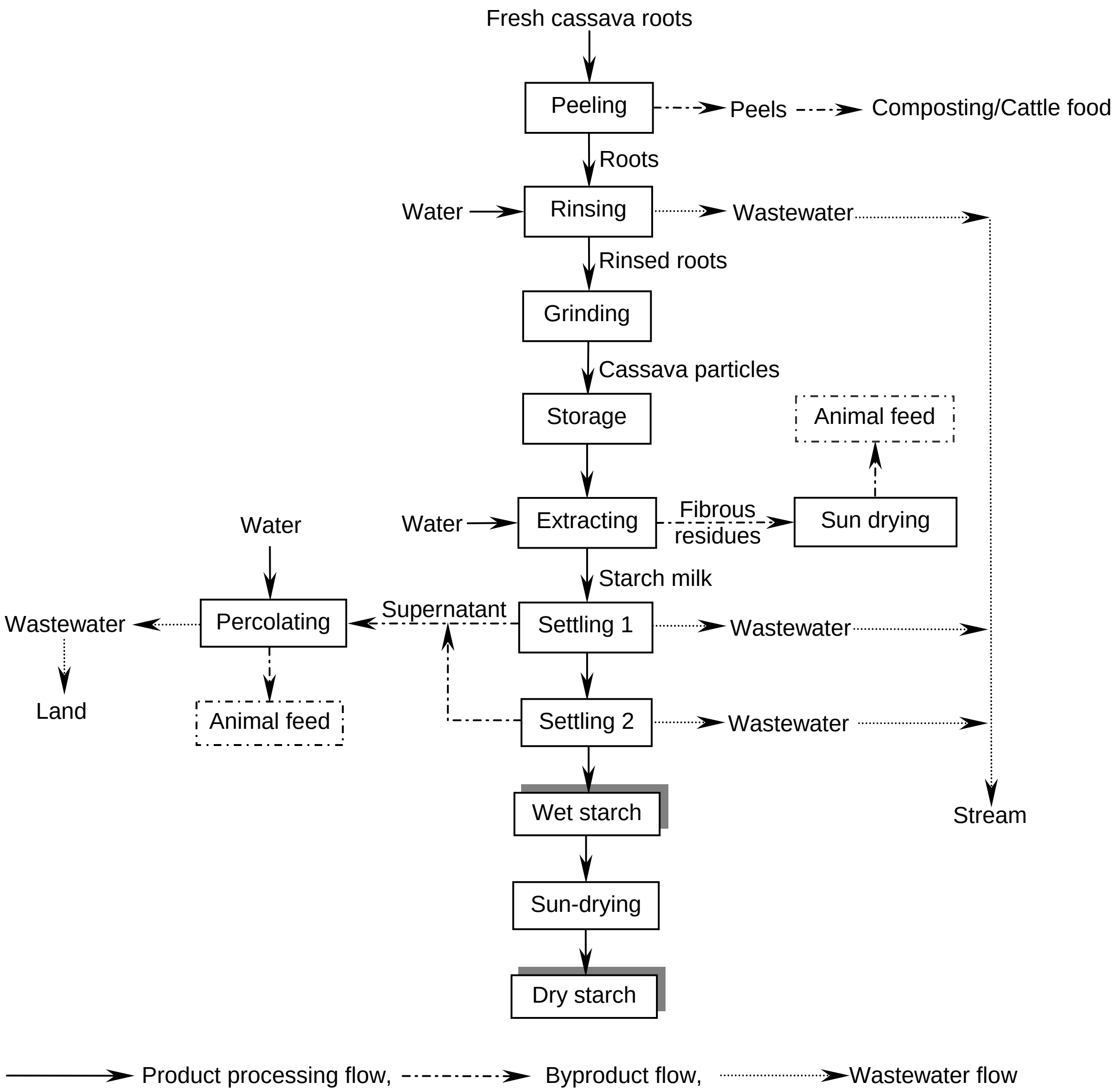


Fig. 5.5 Diagram of household-scale tapioca production process in Binh Dinh Province.

Starch milk is left in the settling tanks with a depth of 40 – 60 cm for one to two days. After this settling period, the starch milk is separated into three layers. The upper 10 – 15 cm layer consists of impurities (supernatant) containing the milk sap. This is skimmed from the tank using a shovel and is reused as animal feed. The middle layer mainly consists of water and is discharged into the canal. The bottom 15 – 20 cm layer of the first sedimentation tanks consists of wet starch. This is mixed with water again and pumped towards the second sedimentation tanks.

Starch from the second sedimentation tanks is usually broken into smaller pieces and dried under the sun on basket plates or bamboo trays. Sometimes, wet starch is sold directly without further drying. The milk sap is put into bags of a permeable cloth and held upright by ropes hanging from a roof. The liquid seeps through and concentrated pulp stays in the bags. The pulp is sold for cattle feed or can be dried under the sun immediately after collecting from the tanks.

In general, the production process in Binh Dinh is similar to that of Tra Co. The differences can be summarized as follows: (1) only two settling stages in stead of three stages (as sometimes in Tra Co Village), (2) milk sap is percolated through permeable cloth instead of direct sun drying.

5.2.5 Comparison of Tapioca Processing Technologies at Household Scale

At all four types of household-scale tapioca production processes in Dong Nai Province, Tay Ninh Province, Ho Chi Minh City and Binh Dinh Province, it is obvious that wastewater generation is the most serious environmental problem from tapioca production. The generated wastewater is discharged into streams such as springs, lakes, etc. (Tra Co Village, Dong Nai Province and Binh Dinh Province), sewer network (Binh Chieu Ward, Ho Chi Minh City) or stored in earth ponds (Binh Minh and Tan Binh Hamlets, Tay Ninh Province). Only in the case of Tra Co Village, about 20% of the total amount of generated wastewater are reused in fish cultures. The production processes of households in Tra Co Village, Binh Chieu Ward, and Binh Dinh Province are quite similar with some small differences as discussed above, which hardly affect waste generation and current environmental implications. The major difference appears between these production processes and the one of Binh Minh and Tan Binh Hamlets, Tay Ninh Province. Of course, the production process of households in Tay Ninh Province is currently not optimized in terms of material flow, but some principles applied here are useful for process modification in the case of Tra Co Village. The principles of countercurrent flow for root rinsing and water recycling during extracting stage are examples. Typical characteristics of the household-scale tapioca production processes in these areas are summarized in Table 5.2.

Table 5.2 Characteristics of household-scale tapioca production processes in the South of Vietnam

Characteristics	Tra Co Village (Dong Nai)	Binh Minh & Tan Binh Hamlets (Tay Ninh)	Binh Chieu Ward, Thu Duc Disttrict (HCMC)	Binh Dinh
Production capacity	6-12 tons roots/day	40-50 tons roots/day	5-7 tons roots/day	6-12 tons roots/day
Household area	About 200 m^2	5,000 - 20,000 m^2	About 200 m^2	About 200 m^2
Roots preparation	Manual removal of hard roots	Manual removal of hard roots and mechanical removal of outer skins	Manual removal of hard roots and outer skins	Manual removal of hard roots and outer skins
Root rinsing	Manually	Through screw gutter	Manually	Manually
Grinding	Grinder	Grinder	Grinder	Grinder
Extracting	Mixer	Mixer & vibration screener	Mixer	Mixer
Settling equipment	Tanks	Ditches	Tanks	Tanks
Solid byproducts treatment	Sun drying	Sun drying	Sun drying	Percolating by cloth
Solid byproduct reuse	Animal feed	Animal feed	Animal feed	Animal feed
Wastewater treatment	No	No	No	No
Wastewater reuse	Fish feed	No	No	No
Wastewater receiving	Springs, lake	Earth ponds	City sewer network	Streams

5.3 TRA CO VILLAGE AND ITS ENVIRONMENTAL IMPLICATIONS DUE TO TAPIOCA PRODUCTION

As presented in Fig. 5.6, Tra Co Village belongs to Tra Co Hamlet and is located close to Tan Binh and Tan Bac Hamlets. At the time of conducting this case study (2001), there were 65 households in this village earning money from tapioca starch production. During the period of cassava harvesting (around the end of December to the end of March), the production capacity reaches about 6-15 tons of fresh roots/household.day. Inhabitants in this area also earn money from swine breeding (about 17 swine breeding households, with 30-100 pigs/household) and slaughtering (about 6 households). Similar to other tapioca processing villages, Tra Co Village is facing serious environmental deterioration mainly caused by wastes from tapioca production, wastewater in particular. Characteristics of wastewater from different settling stages measured at some tapioca producing households in Tra Co Village on March, 2001 (Table 5.3) are the best illustration of the surface water pollution status in this area. Though no systematic monitoring data on quality of surface water resources surrounding Tra Co Village is available, the limited data measured on March 2001 can still provide us with an impression on the seriousness of the environmental situation. At present, Dia Spring is polluted heavily due to the discharge of tapioca wastewater from Tra Co Village. The BOD_5 and COD concentrations of samples at different cross sections of Dia Spring vary in the range of 1,380 – 10,000 mg/L and 2,200 – 11,600 mg/L, respectively. Ammonia, organic nitrogen and total phosphate concentrations of these samples are very high too, even compared to Vietnamese standards of industrial wastewater discharge (TCVN 5945-1995, see appendix 4) (Table 5.4).

Table 5.3 Characteristics of wastewater from the surveyed tapioca producing households in Tra Co Village

Sample	Wastewater	pH	TDS mg/L	SS mg/L	VSS mg/L	COD mg/L	BOD_5 mg/L	$N\text{-}NH_3$ mg/L	N-Org mg/L	$P\text{-}PO_4^{3-}$ mg/L	SO_4^{2-} mg/L
1	First settling	3.44	1,010	2,538	1,750	3,974	2,125	22	63	13.5	4
2	First settling	5.53	220	2,044	1,578	20,861	15,661	119	402	35.0	0
3	First settling	3.60	1,300	1,413	1,388	20,340	15,188	197	470	17.0	0
4	Second settling	3.48	730	2,050	1,900	11,353	9,824	102	276	36.0	3
5	Third settling	3.79	400	570	560	6,244	5,000	24	137	19.4	8

Samples 1, 2, 3, 4, 5 were taken at different tapioca producing households in Tra Co Village.

Table 5.4 Water quality of Dia Spring

Parameter	Unit	Value						TCVN 5945-4995	
		Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	A[26]	B[27]
pH	-	3,7	4,0	3,7	3,8	3,9	4,1	6.0-9.0	5.5-9.0
TDS	mg/L	345	340	1430	500	500	870	-	-
SS	mg/L	453	467	1,350	888	1,329	566	50	100
VSS	mg/L	397	400	1,100	675	1,117	766	-	-
COD	mg/L	2,375	2,208	11,637	3,510	5,563	2,457	50	100
BOD_5	mg/L	1,453	1,383	10,179	2,430	4,310	1,890	20	50
$N\text{-}NH_3$	mg/L	17	14	101	26	46	36	0.1	1
N-Organic	mg/L	38	42	262	80	112	60	30*	60*
SO_4^{2-}	mg/L	18	15	8	21	36	24	-	-
PO_4^{3-}	mg/L	13	11	46	14,2	24,6	16	4	4

* Total nitrogen, - not indicated in the standards.

[26] Industrial wastewater which the concentrations of substances are equal to or lower than the values specified in the column A are allowed to discharge into the water bodies using as domestic water supply sources.

[27] Industrial wastewater which concentrations of substances are equal to or lower than the values specified in column B are allowed to discharge only into the water bodies using for navigation, irritation purposes or for bathing, aquatic breeding and cultivation, etc.

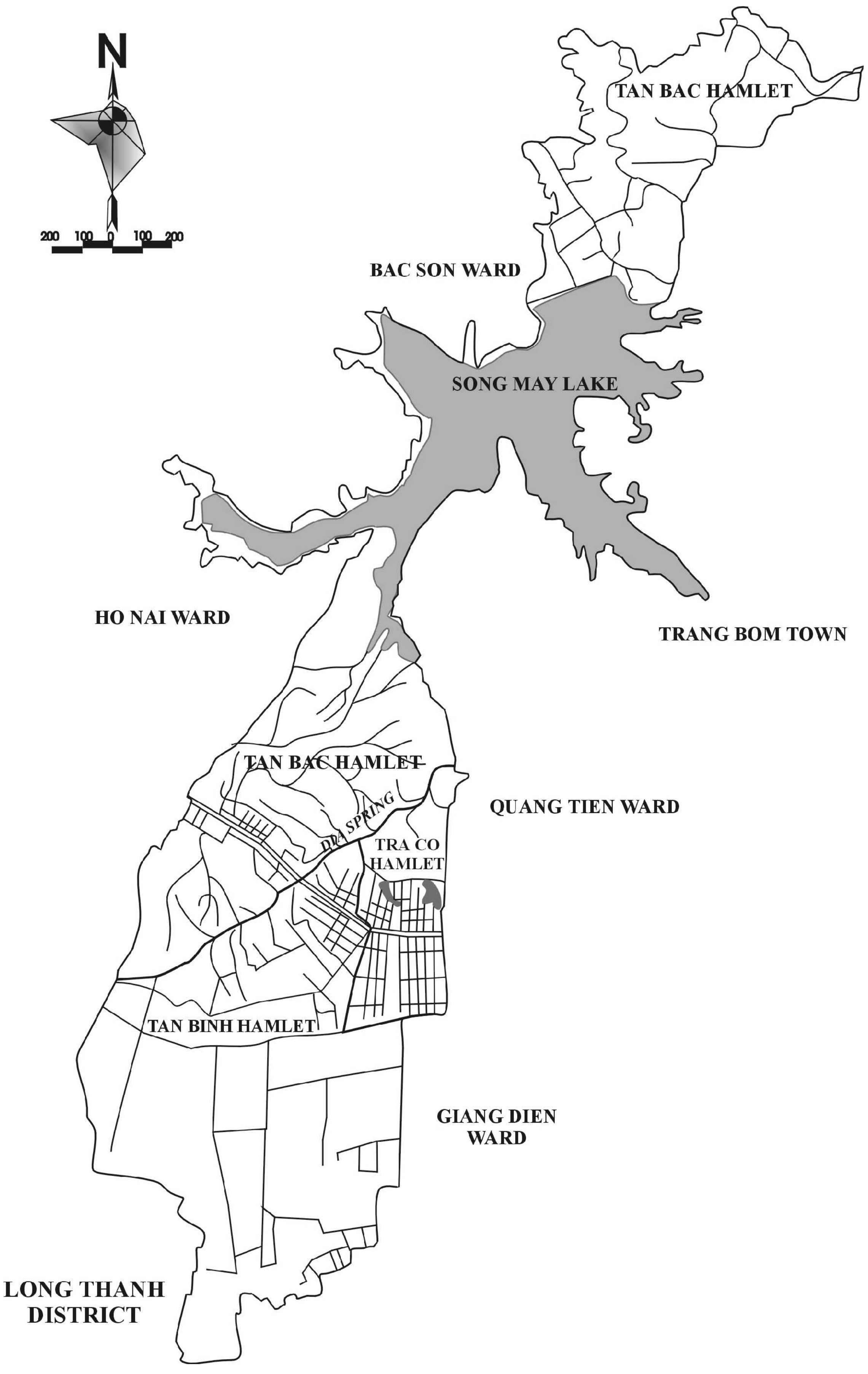


Fig. 5.6 Geographical location of Tra Co Hamlet, Binh Minh Commune.

During the cassava harvesting season, the flow rate of wastewater from 65 tapioca producing households in this area is up to 2,500 m^3/d, which is higher than that of a large-scale tapioca factory. Though the inhabitants have tried to reuse tapioca wastewater as fish feed as much as they can, still a lot of wastewater is discharged freely. In addition, wastewater from swine breeding and slaughtering together with domestic wastewater are also discharged directly into existing open ditches connecting to Mi Spring, Dia Spring, and Song May Lake without any pretreatment.

Main sources of solid non-products generated from tapioca production process are outer skin of cassava roots, fibrous residues and pulp. The total amount of outer skin and fibrous residues including pulp varies in the ranges of 2-3% and 15-20% of the raw roots by weight, respectively (Nandy et al., 1998). During the production process, fibrous residues generated from the extracting stage are stored in a tank or heaped. These residues' piles cause bad smell during storing and sun drying due to the occurring natural fermentation. Thus production activities in Tra Co Village extract needful raw materials (cassava, water, etc.) but return huge amount of needless materials, especially wastewater. Bad quality of surface water in this area (for instance Dia Spring) is evidence that the tapioca production development in Tra Co Village is going hand-in-hand with environmental deterioration.

5.4 MATERIAL AND ENERGY BALANCES AND COST BENEFIT ANALYSIS OF TAPIOCA PRODUCTION PROCESS AT ONE HOUSEHOLD IN TRA CO VILLAGE

5.4.1 Production Process of One Household

A detailed study on the material flow of the tapioca production process in Tra Co Village was conducted at the tapioca producing household of Mr. Nguyen Van Thinh (at 12/1, Tra Co Hamlet, Binh Minh Commune, Thong Nhat District, Dong Nai Province). The total production area is 144.6 m^2 (with a width of 11.00 m and a length of 13.15 m). Layout of the production area is described in Fig. 5.7. List of equipment and machines used are presented in Table 5.5.

Table 5.5 Equipment and machines used in the studied unit

Equipment/machines	Number of equipment/machines
Root rinsing tank	1
Root grinder	1
Extractor/Mixer	1
Intermediate tank	2
First sedimentation tank	6
Secondary sedimentation tank	4
Third sedimentation tank	1
Fibrous residues tank	1
Fresh water tank	2
Pump 1.5 Hp	3
Pump 2 Hp	1

For the material balance study, the production process was operated with 2.5 tons of fresh cassava roots per day with the same procedure as presented in section 5.2.1. Technical operation parameters of the production process are summarised in Table 5.6. Parameters representing characteristics and demand of inputs including raw materials, fresh water, energy, employees and outputs including product and non-products (wastewater, solid wastes or byproducts) are also described briefly in this section.

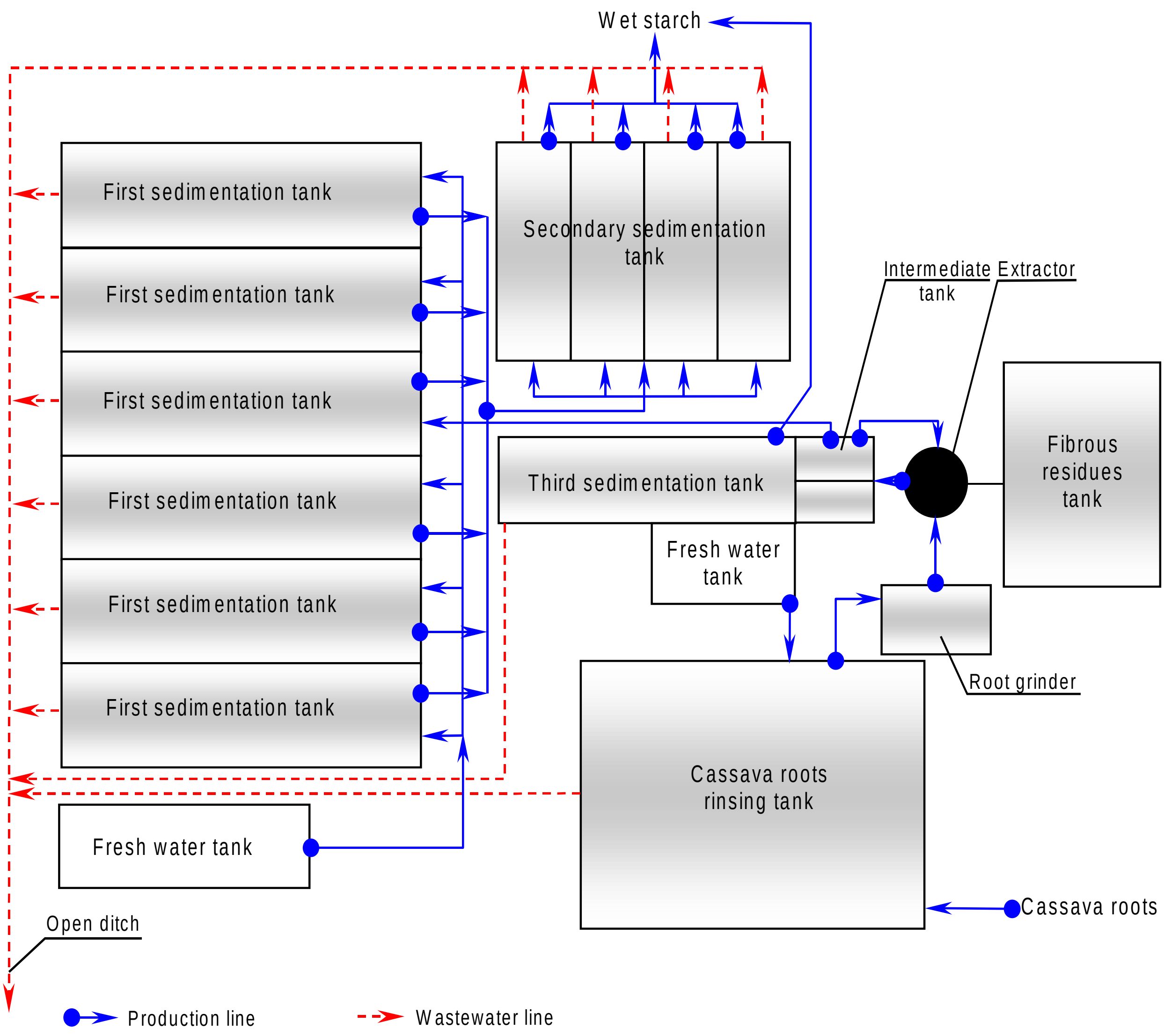


Fig. 5.7 Layout of the tapioca production process at household of Mr. Nguyen Van Thinh.

Table 5.6 Technical operation parameters of the studied tapioca production process

Production stage	Equipment/machines	Operation parameters
Root rinsing	Root rinsing tank	- Dimension: L x W x WD = 5.2 m x 3.2 m x 0.2 m
Grinding and extracting	Grinder and extractor	- Recirculating starch milk from intermediate tanks to increase extraction efficiency and reduce amount of used fresh water
The first settling stage	Three settling tanks	- Tank 1: L x W x WD = 3.85 m x 1.02 m x 0.61 m - Tank 2: L x W x WD = 4.40 m x 1.48 m x 0.56 m - Tank 3: L x W x WD = 3.70 m x 0.96 m x 0.23 m - Settling time was 9 hours
The second settling stage	One settling tank	- Dimension: L x W x WD = 4.40 m x 1.48 m x 0.35 m - Settling time was 12 hours
The third settling stage	One settling tank	- Mixing with fresh water twice to separate pulp - First time: L x W x WD = 3.85 m x 1.02 m x 0.49 m - Second time: L x W x WD = 3.85 m x 1.02 m x 0.33 m - Pulp layer was 15 cm - Settling time was 12 hours
Finishing		- Wet starch from the second and third settling stages

L = Length, W = Width, WD = Water Depth

Inputs

Raw Material. The used raw material was 2.5 tons fresh cassava roots. Starch content of small cassava roots and big cassava roots was 39.9% and 40.2% (by dry weight), respectively.

Energy. Electricity is required for root grinding and starch extracting (about 8 kW/ton of fresh roots), mixing and pumping (about 2 kW/ton of fresh roots). Thus, total electricity used for processing 1 ton of fresh cassava roots is 10 kW.

Labor. All activities required at least 3 persons for the whole production process.

Fresh Water. Fresh water is needed for root rinsing, starch extracting, secondary settling and third settling. The demand of fresh water to process 2.5 tons of fresh cassava roots in this case was measured as follows:

- Volume of water needed for roots rinsing:

  5.20 m x 3.20 m x 0.20 m = 3.33 m^3, equals to 1.33 m^3/ton of fresh cassava roots

- Volume of water needed for starch extracting is approximately equal to the total volume of starch milk in three first settling tanks and water in fibrous residues, calculated as follows:

  - Volume of starch milk in the first sedimentation tanks

    Tank 1: 3.85 m x 1.02 m x 0.61 m = 2.40 m^3
    Tank 2: 4.40 m x 1.48 m x 0.46 m = 3.65 m^3
    Tank 3: 3.70 m x 0.96 m x 0.23 m = 0.82 m^3

    Thus, total volume of starch milk was 2.40 + 3.65 + 0.82 = 6.87 m^3, equals to 2.75 m^3/ton fresh cassava roots

  - Volume of water retaining in fibrous residues

    Average moisture content of fresh cassava root and fiber residue in this case were 64% and 92% (by wet weight), respectively. Thus, amount of water retained in fibrous residues was 2,500 kg x (0.92 – 0.64) = 700 kg, equals to 0.28 m^3/ton fresh cassava roots.

    Thus, total volume of water needed for starch extracting was 2.75 + 0.28 = 3.03 m^3/ton fresh cassava roots.

- Volume of water supplied for the secondary sedimentation:

  4.40 m x 1.48 m x 0.35 m = 2.28 m^3, equals to 0.91 m^3/ton fresh cassava roots

- Volume of water supplied for the third sedimentation is approximately equal to the total volume of fresh water added to subtract to the volume of polluted starch layer in secondary settling tank.

  Volume of water added 1: 3.85 m x 1.02 m x 0.49 m = 1.92 m^3
  Volume of water added 2: 3.85 m x 1.02 m x 0.33 m = 1.30 m^3

Thus, volume of water supplied for the third settling stage was 1.92 + 1.30 – 4.40 x 1.48 x 0.15 = 2.24 m^3, equals to 0.90 m^3/ton fresh cassava roots

- Total volume of water used for the whole process was 6.17 m^3/ton of fresh cassava roots and is specified in Table 5.7.

Table 5.7 Volume of water used per ton of fresh cassava roots

Production stage	Demand (m^3/ton of fresh roots)
Root rinsing	1.33
Starch extracting	3.03
Secondary settling	0.91
Third settling	0.90
Total	**6.17**

Outputs

Product. Processing 2.5 tons of fresh cassava roots results in 950 kg of wet starch with a moisture content of 45%.

Wastewater. Wastewater is generated from root rinsing, fibrous residues storing, first sedimentation, secondary sedimentation and third sedimentation. It is measured as follows:

- Volume of rinsing wastewater is approximately equal to the amount of water supplied, which was 1.33 m^3/ton fresh cassava roots.

- Volume of wastewater from fibrous residues is the water excess in the fibrous residues compared to moisture content of the fresh cassava roots, which was 0.28 m^3/ton fresh cassava roots.

- Total volume of first settling wastewater is approximately equal to volume of wastewater released from three first settling tanks:

  Tank 1: 3.85 m x 1.02 m x 0.540 m = 2.12 m^3
  Tank 2: 4.40 m x 1.48 m x 0.495 m = 3.22 m^3
  Tank 3: 3.70 m x 0.96 m x 0.205 m = 0.73 m^3

  Thus, total volume of the first settling wastewater was 6.07 m^3, equals to 2.43 m^3/ton fresh cassava roots.

- Volume of secondary the settling wastewater is approximately equal to volume of wastewater released from the secondary settling tank:

  4.40 m x 1.48 m x (0.35 – 0.15) m = 1.30 m^3, equals to 0.52 m^3/ton fresh cassava roots

- Volume of wastewater from the third sedimentation is approximately equal to the volume of wastewater released after mixing twice with fresh water:

  2.24 – (3.85 x 1.02 x 0.1) x 2 = 1.45 m^3, equals to 0.58 m^3/ton fresh cassava roots

- Total volume of wastewater generated was 5.14 m^3/ton of fresh cassava roots and is specified in Table 5.8.

Table 5.8 Volume of wastewater generated per ton of fresh cassava roots

Stage	Value (m^3/ton fresh roots)
Root rinsing	1.33
Fibrous residues	0.28
First settling	2.43
Secondary settling	0.52
Third settling	0.58
Total	**5.14**

Fibrous residues. After extracting, fibrous residues were released into the storing tank intermittently. Every 100 kg of processed fresh cassava root generates about 96 – 105 kg wet fibrous residues. Therefore, an average value of 100 kg of fibrous residues is selected for all calculations below. The total amount of wet fibrous residues formed was 1 ton/ton fresh root with a moisture content of about 92% (by wet weight), and a starch content of about 50% (by dry weight). Thus, the amount of dried fibrous residues was 0.08 ton/ton fresh roots.

Pulp. Total amount of generated wet pulp was 0.04 ton/ton fresh roots, equal to 0.02 ton of dried pulp/ton fresh roots.

Pieces of hard root. In this case, the amount of generated pieces of hard root was negligible.

5.4.2 Material and Energy Balances for One Tapioca Processing Household

These balances are carried out around the boundary of the studied tapioca producing household with three main routes: solid material, liquid material and energy balance. All calculations are based on the results of the in depth survey as presented in section 5.4.1.

Solid Material Balance

This balance considers flow of all solid materials through the production process including raw materials, products, byproducts and wastes. These are fresh cassava roots, wet starch product, pieces of hard roots, fibrous residues, pulp and solid wastes that may release together with wastewater. Mass balance calculations by dry weight can be described by the following equation:

Mass of fresh root = mass of starch product + mass of fibrous residues + mass of pulp + mass of solid materials loss with the wastewater (mass of wastes)

$$2{,}500 \times (1 - 0.64) = 950 \times (1 - 0.45) + 2{,}500 \times (1 - 0.92) + 50 + \text{mass of wastes}$$

Thus, the amount of dry solid material that could not be measured in solid form was 127.5 kg, equivalent to 14.1% of raw material by dry weight. This means that a high amount of solid materials is discharged together with the wastewater. Mass balances for solid material flow, in term of dry weight and wet weight, are described in Fig. 5.8.

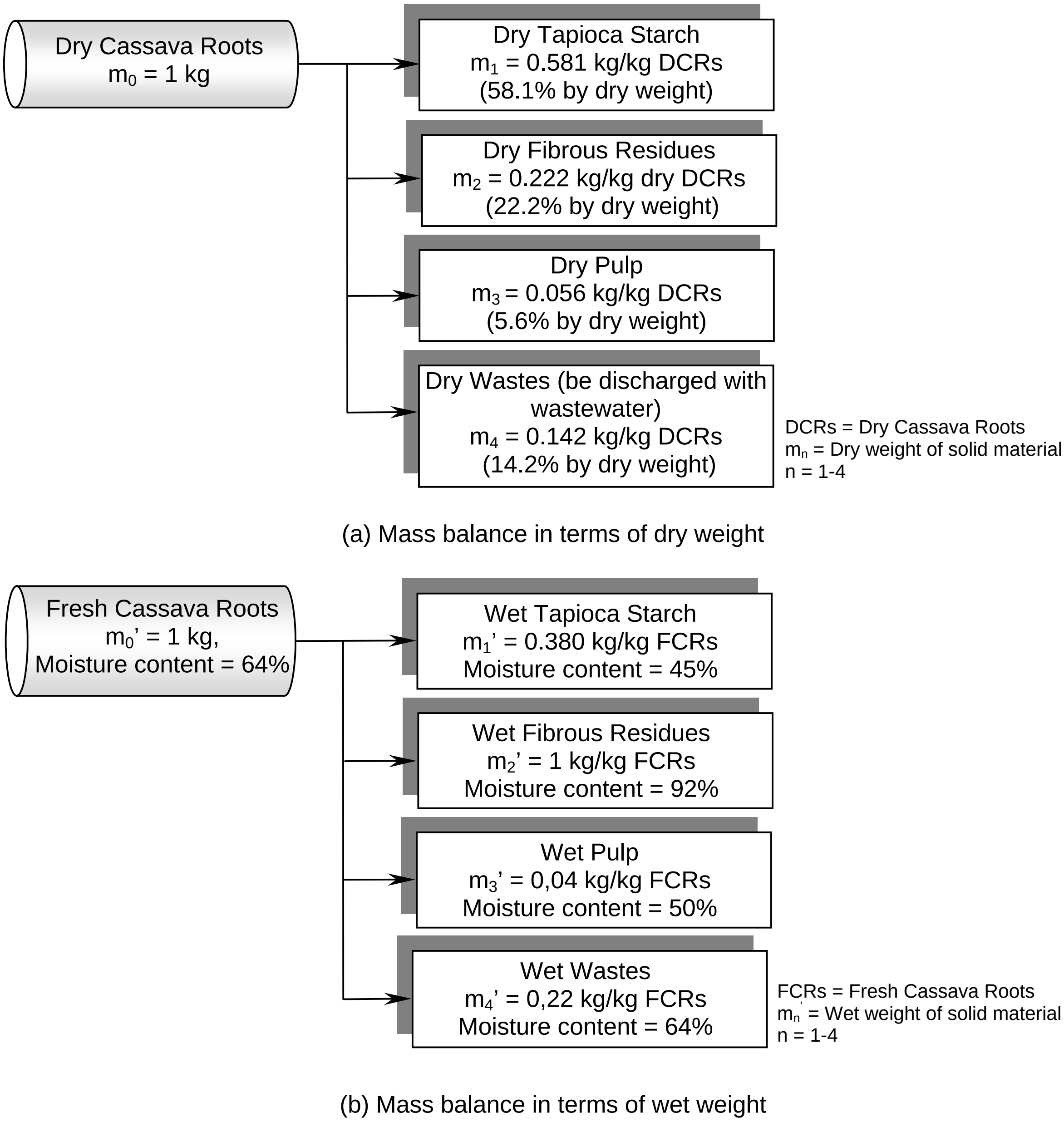


Fig. 5.8 Mass balance in terms of dry weight (a) and wet weight (b) for solid material flows of the surveyed household-scale tapioca producing unit at Tra Co Village.

Liquid Material Balance

In this case, all liquid materials including supplied water and generated wastewater are considered. The volume balance of liquid material flows is described in Fig. 5.9.

Energy Balance

As described above, electricity is only supplied for grinding, starch extracting, mixing and pumping. Fibrous residues and pulp were dried under the sun. Therefore no extra supply of energy was required for this stage. The energy balance is presented in Fig. 5.10. No other energy was generated from the current production process.

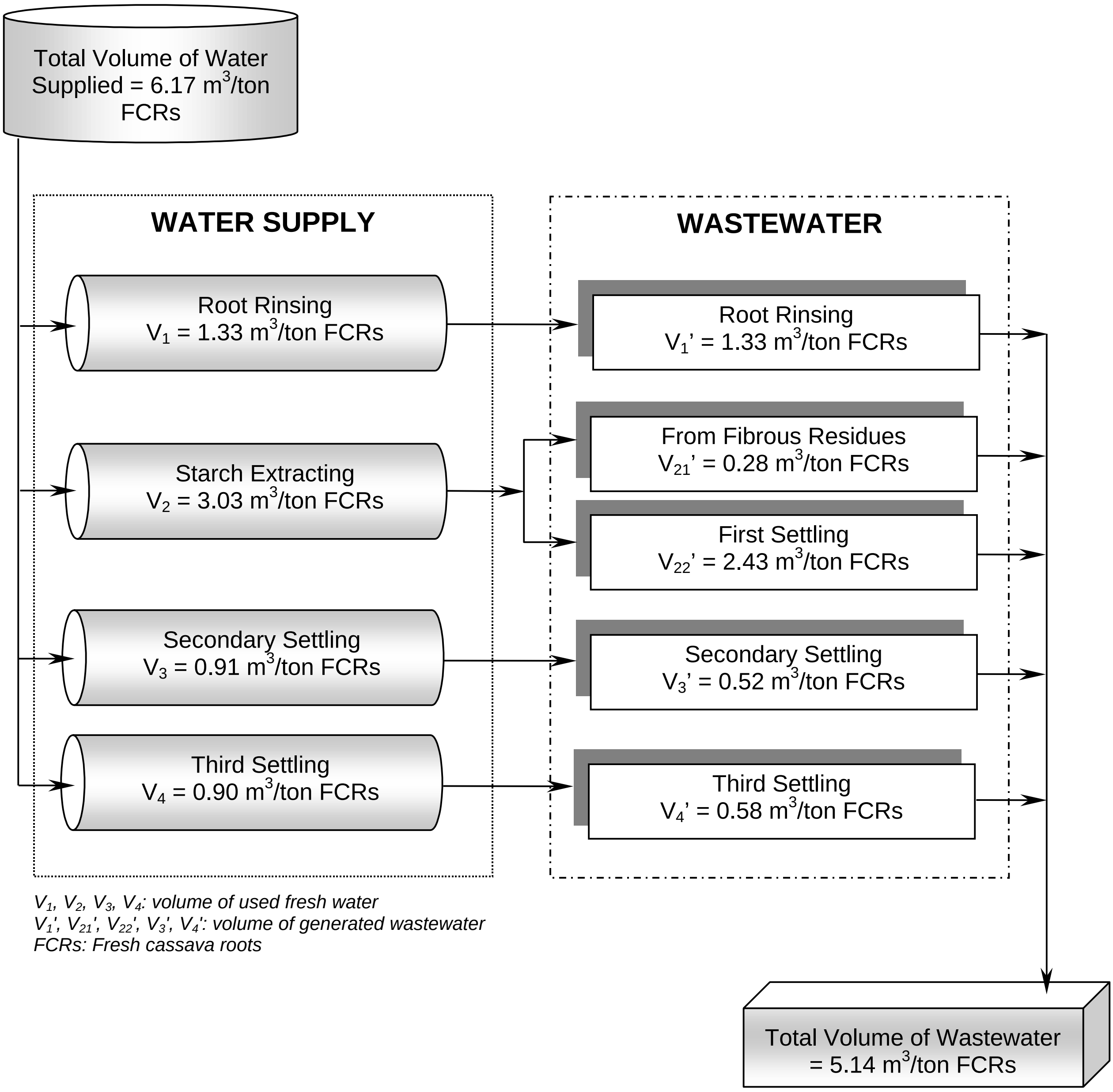


Fig. 5.9 Volume balance for liquid material flow of the surveyed household-scale tapioca producing unit at Tra Co Village.

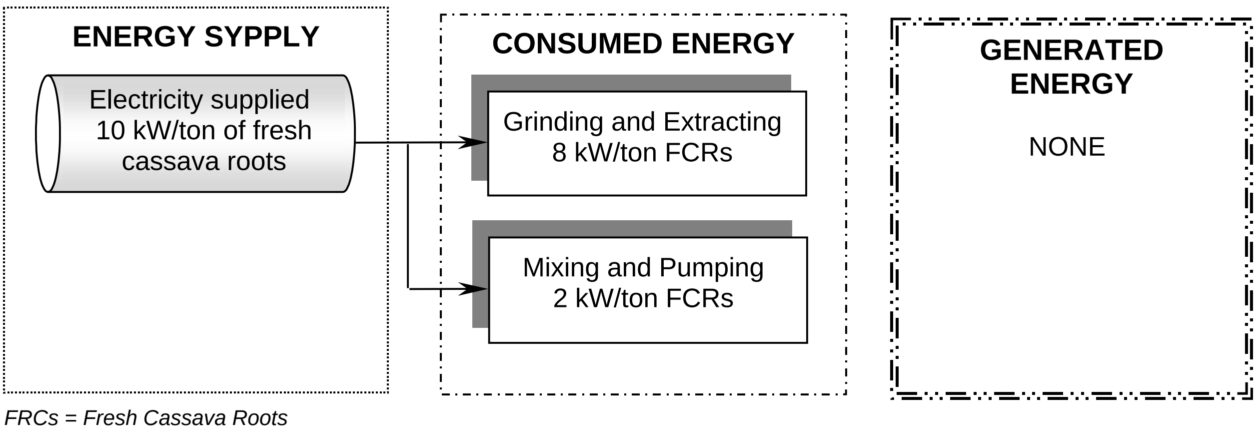


Fig. 5.10 Energy balance of the surveyed household-scale tapioca producing unit at Tra Co Village.

5.4.3 Cost Benefit Analysis

Costs of each production batch are based on purchasing fresh cassava roots, electricity and labor. In this calculation machine depreciation is excluded, because most tapioca production processes in this village were installed long time ago and invested capital has been completely recovered. Some additional investments such as replacement of polyester cloths in extractor or grind-sheet in the grinder are negligible. Fresh water is supplied from the well, free of costs. The producer can earn money from selling wet tapioca starch, sun dried fibrous residues and pulp. Total production costs and incomes are described in Table 5.9 and 5.10. Net profit is the difference between income and production costs.

Table 5.9 Production cost per kg processed fresh cassava roots

Items	Unit	Amount	Unit Cost	Total Cost (VND)	Cost (VND/kg fresh root)
Fresh cassava roots	kg	2,500	380 VND/kg	950,000	380.0
Electricity	KWh	25	1,000 VND/KWh	25,000	10.0
Labor payment	kg root*	2,500	17 VND/kg root	42,500	17.0
Total (in VND/kg fresh roots)					407.0
Total (in USD/kg fresh roots)[28]					0.0271

* Labor cost is not calculated based on number of working hours of each worker, but based on the amount of fresh cassava roots processed. Thus, salary of each worker depends on the number of workers and amount of fresh roots processed.

Table 5.10 Income per kg processed fresh cassava roots

Items	Unit	Amount	Unit Cost (VND/kg)	Total Cost (VND)	Cost (VND/kg fresh root)
Wet tapioca starch	kg	950	1,200	1,140,000	456.0
Fibrous residues	kg	200	680	136,000	54.4
Pulp	kg	50	680	34,000	13.6
Total (in VND/kg fresh roots)					524.0
Total (in USD/kg fresh roots)					0.0349

It is worth to notice that the data gathered for this study came from nearly the end of cassava harvesting season. The starch content in fresh roots was lower compared to the previous periods. Therefore, the net profit was only about 117 VND/kg fresh roots, equivalent to 0.078 USD/kg fresh roots. This value can be higher as the starch content in fresh roots increases. However, it should be kept in mind that the calculated production costs exclude costs for environmental protection. All the wastewater was discharged directly into the environment without any pretreatment. When 65 tapioca processing units in this village all operate with an average capacity of 7 tons of fresh roots/household.day, approximately 2,340 m^3 of heavy polluted wastewater are daily discharged freely into surface water. With characteristics of wastewater from three settling stages (Table 5.3) and knowledge about the amounts of generated wastewater, it is not difficult to imagine how serious the impact is to the environment from this pollution source. But if each tapioca producing household in this village was requested to construct a wastewater treatment system (WWTS) to treat wastewater properly before discharging, the treatment costs may exceed the profit gained from the production, even if they can achieve a higher starch recovery ratio. The impossibility to solve environmental problems from tapioca processing in this village by considering each individual production household separately forms an additional argument to study the tapioca processing at village scale.

[28] Exchange rate in 2001 was 1 USD = 15,000 VND. This value is used for all related calculation of this chapter.

5.5 PHYSICAL-TECHNOLOGICAL MODEL OF A ZERO WASTE INDUSTRIAL ECOSYSTEM AT TRA CO VILLAGE

5.5.1 Preventing and Minimizing the Generation of Non-products

All the data presented in section 5.4 are used as guideline and inspiration to select appropriate possibilities for prevention and minimization of the generation of non-products (including wastes and byproducts) within individual tapioca producing households. In this line, different cleaner production measures are assessed and designed to deal with solid non-products and tapioca wastewater.

Solid Non-Products

Pieces of hard cassava roots, fibrous residues and pulp are the main solid non-products generated from the tapioca production process. They can be called solid byproducts because they are all reusable. Except for uncollected solid byproducts, which are discharged together with the wastewater, these byproducts do not cause damage to the environment if they are adequately used. Therefore, in this case, the purpose of prevention and minimization is to increase the tapioca production efficiency and decrease the loss of the byproducts via the wastewater.

The amount of generated pieces of hard roots is not affected by the kind of production technologies or equipment because they are removed manually. It depends very much on the quality of fresh cassava roots. Therefore, preventing and minimizing the generation of hard roots has to be dealt with during cassava cultivation rather than in the tapioca production stage. In fact, this solid byproduct source amounts to a very small percentage (less than 1% by wet weight) of fresh cassava roots processed and is sometimes negligible.

Fibrous residues and pulp are major solid byproducts from the tapioca production process. As presented in the previous section, about 14.2% by dry weight of solid materials (a part of fibrous residues, pulp, milk sap, and starch) are discharged together with the wastewater. This results in a relatively high concentration of suspended solids in settled wastewater (around 600 - 2,900 mg/L). It is observed in the field that some households, not belonging to the ones producing tapioca, can also earn money by recovering pulp from tapioca wastewater when it is flowing along the open ditches into the existing springs. Villagers apply the principle of screen and filtration using "simple available technologies" to recover pulp. For instance, wastewater is released into a small earth tank with a cloth liner to evaporate water under the sun and thereafter the pulp retaining on cloths is collected and sold as raw material for livestock feed production. Placing cloth bags containing sand across the wastewater flow direction is another example of a simple pulp recovery method. This activity of villagers is not only useful for them to gain some extra income, but also meaningful in pollution reduction. On one hand, this shows that it is possible to recover and reuse suspended solid (mainly pulp) from tapioca wastewater. On the other hand, this affirms that current tapioca production processes are not operated efficiently and need to be improved. The amount of fibrous residues and pulp, which is generated from the production process and released together wastewater, depends on the efficiency of grinding and extracting stages. All tapioca producing households in this area use the same kind of grinder for grinding. The only difference among the used grinders is the grind-sheet, which effects the size of the formed cassava particles and the efficiency of the extracting stage. Too coarse or too fine cassava particles are both attributed to low efficiency of the extracting stage. This is one of the reasons why the starch extraction efficiency among these households differs from 2 to 5 kg wet starch per 100 kg fresh cassava roots. A suitable grind-sheet can currently only be adjusted by experiences of producers themselves. If they are willing to share their experiences among each other, they could improve the production efficiency significantly. Otherwise, assistance of a research institute is required to disseminate proper technical characteristics of grind-sheet for all these households.

Though it is known that applying three stages of settling can reduce the amount of generated pulp, it is not always implemented in practice due to lack of space. More precisely, this depends very much on the availability of settling tanks for the third settling stage. This is the same reason why suspended solids (mainly pulp, milk sap and starch) is not recovered from settling wastewater. If there is enough space to install settling tanks for further settling of suspended solid in the first and the second settling wastewater, the amount of solid byproducts released to the environment together with the wastewater will be reduced. Proper scheduling settling tanks in limited space may be helpful in this situation too.

Liquid Non-Product (Wastewater)

Wastewater is generated during root rinsing and settling. Currently, cassava roots are rinsed by submerging them in a water tank or spraying water on the cassava roots pile. In both cases, wastewater is released continuously into open ditches without any consideration to the amount of water used. Reducing wastewater in the rinsing stage will be possible if the countercurrent principle is applied. To do so, roots are submerged in root rinsing tank for a certain time, after which they are collected into a steel basket, and then re-rinsed with fresh water before transferring into the grinder. In this case, instead of releasing wastewater from the root-rinsing tank continuously, it is stored for use. Roots rinsed in two steps by submerging in root rinsing tank and re-rinsing with fresh water not only result in cleaner roots before grinding, but also reduce the amount of water needed in this stage. Similarly, another possibility to apply the countercurrent principle is dividing the current tanks into three smaller counterparts (see Fig. 5.11). Roots are rinsed in three steps during passing through these counterparts. When the water quality of the last counterpart become worse and needs to be renewed, this water will be reused in the second compartment, while water in the second compartment will be reused in first compartment. In other words, water flow and cassava roots pass the rinsing tank in opposite direction. By doing so, it is not necessary to release water from the rinsing tank continuously as happens in the current system, while roots are cleaner after rinsing.

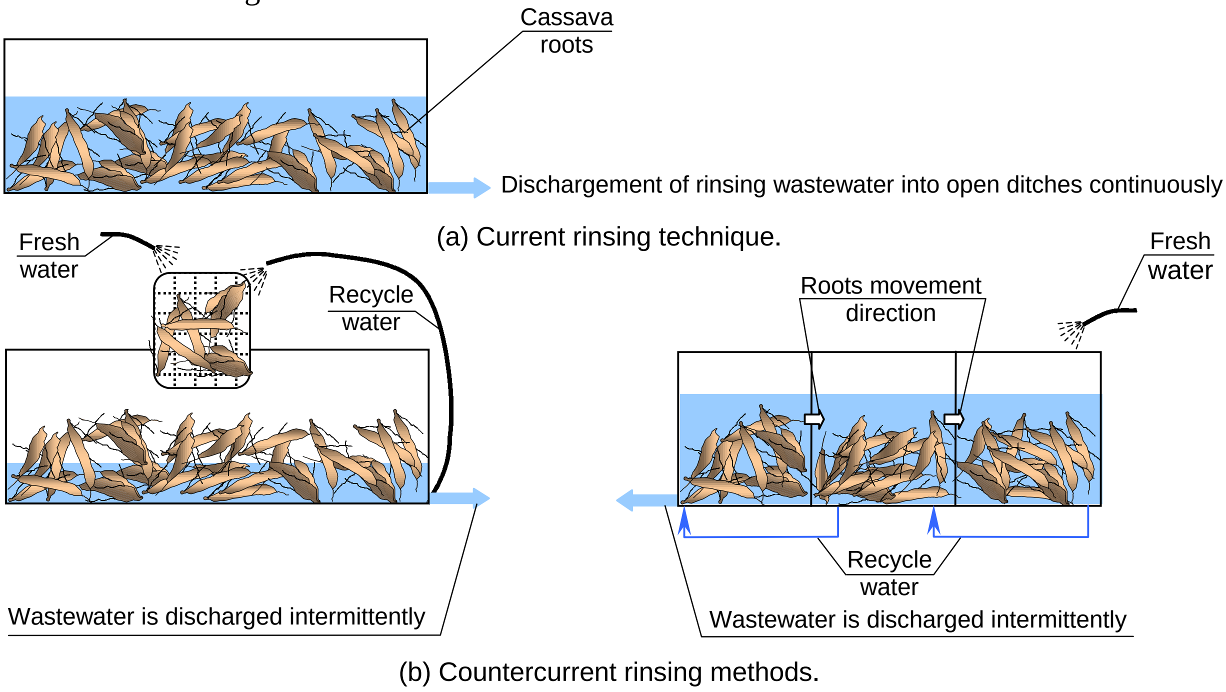


Fig. 5.11 Modification of the rinsing technique.

Suspended solids in root rinsing wastewater mainly consist of inorganic matters such as cork cell, clay and sand particles, dirt, etc., which can only be reduced by better removal of clay and dirt on outer skins cassava roots during harvesting. In a study on waste minimization in tapioca starch industry in Thailand, Vigneswaran et al. (1999) stated that washing water can be reused again in the washing process after sedimentation during the dry season and using chemical coagulation followed by sedimentation during the wet season. In the case of Tra Co Village, treatment of rinsing wastewater by sedimentation for reuse could be a technological possibility from a technological point of view, but in practice it often can not be implemented due to the limited availability of space for the installation of an additional settling tank.

A major amount of wastewater is generated during settling stages. After a certain settling period, wastewater is released from the settling tanks by over flowing. Therefore, it is hard to reduce the generated amount of settling wastewater within the production process itself. Reusing the third settling wastewater for the first settling stage might be a possibility. However, this option has not been applied yet, because producers are afraid that the quality of the remaining water of the third settling stage may be not clean enough, while there is good quality ground water available for free. In addition, it should be kept in mind that a reduction of the amount of pulp discharged together with the wastewater is important to reduce the organic loading of the wastewater and the solid byproduct lost as well. Without changing the current production technology, the only possibility to achieve this purpose is good housekeeping. Workers have to pay attention during skimming of tapioca milk sap and pulp out off the settling tanks to ensure minor losses of these materials to the wastewater.

Research of Marder and Trim (1996) showed that application of hydrocyclone technology can be used as part of an integrated pollution control strategy by conversing water and reducing wastewater generation, whilst maintaining product quality and production levels in the cassava starch extraction industries. Their study indicated that water consumption and wastewater generation was reduced by around 49-52% in case of starch factories and 51-53% in case of sago factories (Table 5.11) and with little difference in the characteristics of the wastewater with or without hydrocyclone use (Table 5.12). These results imply that the use of hydrocyclone unit not only reduces the quantity of the required water, and thus the volume of generated wastewater, but also considerably reduces the overall pollution load. At present, application of a hydrocyclone unit in family-scale tapioca production process in Tra Co Village is difficult because of the required high investment capital and labor skills. However, this alternative might be a future possibility and would, if implemented, have a major effect on the required capital and costs of a wastewater treatment system (WWTS).

Table 5.11 Comparative crushing capacity and water usage for hydrocyclone trials

Trial	Regular process		Hydrocyclone process		
	Root crushing capacity (ton/h)	Water usage (m^3/h)	Root crushing capacity (ton/h)	Water usage (m^3/h)	Water saving (%)
	Starch factory trials				
1	2.55	17.30	2.55	8.26	52.2
2	2.88	19.05	2.85	9.33	51.0
3	3.32	19.44	3.92	9.91	49.0
	Sago factory trials				
1	3.92	21.72	3.93	10.19	53.1
2	4.12	22.48	4.19	10.76	52.1
3	4.28	23.07	4.32	11.15	51.7

Source: Marder and Trim, 1996.

Table 5.12 Comparative quality of wastewater from sago factory for hydrocyclone trials

Sample	pH	TDS (mg/L)	TSS (mg/L)	BOD (mg/L)	COD (mg/L)	CN^- (mg/L)
	Untreated wastewater from regular process					
1	5.50	6,500	1,280	4,518	8,141	0.83
2	4.61	4,478	1,474	5,775	6,264	0.03
3	4.60	4,407	1,628	4,625	6,832	0.03
	Untreated wastewater from hydrocyclone process					
1	4.53	6,805	1,730	5,250	9,482	0.02
2	4.16	4,344	1,498	5,875	7,200	0.07
3	4.22	4,644	1,347	4,350	6,520	0.07

Source: Marder and Trim, 1996.

5.5.2 Material Flow Network Creation

For non-products that are unavoidable, including fibrous residues, pulp and wastewater, possible solutions to reduce and eliminate their impacts on the environment are reuse and recycling in other suitable processes. In this line, this section emphasizes on analyzing the possibilities for offsite reuse and recycling of non-products and the creation of a material flow network.

Solid Non-Products

Solid non-products from tapioca processing in Tra Co Village consist mainly of fibrous residues and pulp (amount of hard roots is negligible). Currently, these are dried under the sun and sold to companies for animal feed manufacturing. This proofs that in practice it is possible to reuse tapioca processing solid non-products or byproducts as raw material for animal feed production. Fibrous residues and pulp can also be reused in alcohol and fertilizer/compost production (Bi and Guozhen, 1996; Agu et al., 1997 and Sriroth et al., 2000). However, several reasons make these two options to be less feasible than the current used method in Tra Co Village. There is no reason to reuse fibrous residues and pulp as raw materials for composting, because these materials can be efficiently used in animal feed production and there is swine manure available for composting. Though utilization of fibrous residues and pulp in alcohol production has been proved to be successful in practice by a number of enterprises in Gaungxi Province, China (Bi and Guzhen, 1996), there are still many disadvantages to apply this option in Tra Co Village. The following reasons are attributed to the limited implementation:

- Tapioca processing in this village is operated seasonally, mainly for 3 months a year. That means, the proposed ethanol production enterprise can only be operated for 3 months/year, unless real raw material can also be processed in the same system or the waste is stored in order to have a continue process. However, by doing so, the advantage of directly reusing wet fibrous residue and pulp and wastewater for alcohol production will be lost.

- This option is only feasible for on-site waste reuse and recycling, because costs for transportation of wet fibrous residues, pulp, and wastewater may be higher than that of substituted raw materials. In addition, installation of an enterprise in residential area is not encouraged by the Ministry of Science, Technology and Environment (MOSTE) and local Department of Science, Technology and Environment (DOSTE), because it is more difficult to control separated enterprises than concentrated ones in industrial zones. Besides, these enterprises often cause direct impacts on public health due to improper operation, which may be dangerous for residents if industrial accidents occur. Or improper wastes treatment and management may lead to nuisance, pollutant emission, ground water contamination, etc.

- The production process requires specific machines and equipment. It also requires skilled labor for operation and maintenance, which is not available at the moment.

- Ethanol production by this process generates about 40 m^3 of sludge/ton ethanol (Bi and Gouzhen, 1996) equivalent to 1.136 ton dry sludge/ton ethanol. Residues in the sludge can be fermented and reused as feed-stuff (Bi and Gouzhen, 1996). However, remaining liquid waste needs proper treatment before discharging.

In addition, the possibilities of this application depend very much on the market demand of industrial grade alcohol in Vietnam in the future. With many disadvantages mentioned above, this option might be only suitable for medium or large-scale tapioca processing factories. On village scale, it is unattractive to apply.

Though it is hard to find reports about reusing fibrous residues and pulp for animal feed production in literature (Piyachomkwan and Oates, 2000), some reliable information prove it to be possible. First, this method is not only applied in Tra Co Village, but in many other tapioca production villages too as mentioned in section 5.2. Secondly, the chemical composition of dry fibrous residues and pulp is suitable for substituting cassava in animal diets. Third, the cellulose content in fibrous residues and pulp is one of the necessary components of the animal diets.

Cassava roots are generally high in carbohydrate, thus ought to be an excellent substitute of maize in supporting energy source (Thanh, 1974; Castillo, 1974; Hrishi, 1974; Montilla, 1977; Omole, 1977; Gomez, 1977; Gregory, 1977; Montaldo, 1977; Devendra, 1977; Khajarern et al., 1977; Oke, 1984; Cock, 1985; Sanhez, 1990). The FAO developed the following substitution values of cassava for maize based on their relative feeding values in poultry, swine and ruminants (Aanchez, 1990):

1 kg maize = 0.988 kg dried cassava + 0.148 kg soybean meal (poultry)

1 kg maize = 0.884 kg dried cassava + 0.156 kg soybean meal (swine)

1 kg maize = 1.044 kg dried cassava + 0.116 kg soybean meal (ruminants)

According to Douglass and William (1984), fresh cassava roots typically contain 70% moisture, 24% starch, 2% fiber, 1% protein, 3% fats, minerals and sugar. Analytical results of cassava roots used in material balance case study in Tra Co showed that the starch content was about 25.6% by wet weight. This is in line with starch content values of five major cassava varieties in Vietnam as indicated by Hung Loc Research Center for Agriculture Development (1995) (Table 5.13). The moisture content of cassava chips is 11.7% (by dry weight) (Montaldo, 1977; Nandy et al., 1995), equivalent to a starch content in dry cassava chips of about 71%.

Table 5.13 Yield, starch content and harvest period of five major cassava varieties in Vietnam

Items	Unit	Cassava varieties				
		KM94	KM60	HL20	HL23	HL24
Crop yield	tons/ha	38.6	27.2	20.2	19.8	20.0
Starch content	% (by wet weight)	28.6	27.2	24.5	26.5	25.8
Harvest time	month	7-12	6-9	7-12	6-9	6-9

Source: Khoa, 1998.

The chemical composition of the sun-dried fibrous residues and pulp, identified by Nandy et al. (1995), is summarized in Table 5.14. Fibrous residues generated from the surveyed processes also contain 50% (by dry weight) of starch. These figures show the possibility to replace maize by dry fibrous residues and pulp, which arises the question what percentage of such substitution is suitable.

Table 5.14 Chemical composition of sun-dried mixture of fibrous residues and pulp

Constituent	Sun-dried mixture of fibrous residues and pulp (% of dry weight)
Moisture content	12.50 - 13.00
Starch content	51.80 - 63.00
Crude fiber	12.80 - 14.50
Crude protein	1.50 - 2.00
Total ash	0.58 - 0.65
Free reducing sugar	0.37 - 0.43
Hydrocyanic acid	0.008 - 0.009
Pentosan	1.95 - 2.40
Other polysaccharides	4.00 - 8.49

Source: Nandy et al., 1995.

Studies of Visser (1993), Quin (1996) and Houdijk (1998) indicate that five main components including the energy supply source, carbohydrate, protein, minerals, and vitamins should be maintained in the formula of swine food (Table 5.15). Different raw materials can be used for these purposes. For instance, Visser (1993) uses 48.00% maize starch and 4.00% maize gluten (totally 52% by weight of the diet), while Quin (1996) uses 38.33% maize starch in combination with 3.34% wheat middlings and 8.76% casein (totally 50.43%). Instead of supplying soybean hulls (0.58%), coconut expeller (1.12%) and linseed expeller (0.88%) as in the formula of Visser (1993), Houdijk (1998) uses cellulose (4.20%). Referring to the existing poultry and swine food production in Vietnam, for instance from PROCONCO, a Vietnam-France Joint Venture Company, located in Bien Hoa 1 IZ, Dong Nai Province, a part of maize is substituted by bran (Table 5.16). Though percentages of raw materials used in these diets are different, the total percentages of the four main components are quite similar. That means substitution raw materials in feeds by other materials is possible, provided that the standard nutrient demands are maintained in modified diets.

The same studies of Visser (1993), Quin (1996), and Houdijk (1998) also show that cellulose in swine diets is kept in the range of 1.4 - 4.20 % (by weight). Thus, with an average cellulose content of 13.5% in sun-dried fibrous residues and pulp (Table 5.14), it is impossible to substitute 100% of maize or dried cassava by this material source (in case of only maize or cassava are used as energy supply source). However, it is not difficult to estimate that, with the diet presented in Table 5.16, substitution of 40% of maize starch by sun-dried fibrous residues and pulp resulting in 1.41% of cellulose content would be a possibility. In this case, sun-dried fibrous residues and pulp occupy about 13% (by weight) of the diet. This utilization does not only help to reduce pollution, but also ameliorates the present situation by creating new feed from non-products of tapioca processing. Both tapioca producers and livestock feed manufacturers benefit from such utilization. Of course, establishment of a new livestock feed production enterprise for such purpose may face many difficulties in practice and takes a while to be implemented. However, with the existence of a number of swine breeding households as well as several livestock feed production companies in the surrounding areas, implementation of this option is feasible. In fact, this activity requires only labor, which can be fulfilled easily by the available labor in this village. In addition, all sun-dried fibrous residues and pulp are always collected by some companies, so villagers do not have to worry about having a market for this kind of byproduct.

Table 5.15 Swine diet ingredients

Component	Visser (1993)		Quin (1996)		Houdijk (1998)	
	Weight (g)	%	Weight (g)	%	Weight (g)	%
Maize starch	480	48.00	573	38.33	470.75	47.08
Maize gluten	40	4.00	0	0	0	0
Wheat middlings	0	0	50	3.34	0	0
Casein	0	0	131	8.76	185.0	18.50
Herring meal	0	0	50	3.34	0	0
Oat husk meal	0	0	0	0	60.0	6.00
Soybean meal	159	1.59	0	0	0	0
Potato protein	40	0.40	0	0	0	0
Soybean hulls	58	0.58	0	0	0	0
Coconut expeller	112	1.12	0	0	0	0
Linseed expeller	88	0.88	0	0	0	0
Cellulose	0	0	21	1.40	42.0	4.20
Sunflower oil	0	0	10	0.67	0	0
Soy oil	0	0	0	0	25.0	2.50
Dextrose	0	0	60	4.01	0	0
Glucose	0	0	0	0	150.0	15.00
Cane molasses	0	0	40	2.68	0	0
Vitamin premix	7	0.07	10	0.67	10.0	1.00
$CaCO_3$	7	0.07	19	1.27	10.0	1.00
$CaHPO_4.2H_2O$	0	0	286	19.13	0	0
$CaHPO_4$	0	0	0	0	20.0	2.00
$Ca_3(PO_4)_2$	4	0.04	0	0	0	0
NaCl	0	0	30	2.00	5.0	0.50
Dl-methionine	0	0	11	0.74	0	0
L-threonine	0	0	06	0.40	0.8	0.08
L-trytophan	0	0	02	0.13	0.5	0.05
L-cysteine	0	0	0	0	1.7	0.17
$NaHCO_3$	0	0	122	8.16	2.0	0.20
$KHCO_3$	0	0	64	4.28	16.5	1.65
MgO	5	0.05	0	0	0.5	0.05
Marker Cr_2O_3	0	0	10	0.67	0	0
Chromium oxide	0	0	0	0	0.25	0.03
Total	1,000	100	1,495	100	1,000	100

Source: Visser, 1993; Quin, 1996 and Houdijk, 1998.

Table 5.16 Components of livestock feed produced by PROCONCO Company

Raw materials	Demand (tons/day)	Ratio (% by weight)
Maize	250	26.18
Bran	250	26.18
Soy-bean cake	250	26.18
Vitamins and minerals	5	0.52
Fish powder, meat powder, powder milk, DCP (De-Calcium-Phosphorous)	200	20.94
Total	955	100.00

Source: PROCONCO Company, 1999.

In this case study, the group of tapioca producing households in Tra Co Village is the heart of the material network, the anchor. Therefore, in order to design the scale of the livestock feed production enterprises, it is necessary to analyze the material balance for the group of tapioca producing households. As introduced in section 5.3, 65 households located in Tra Co Village have own tapioca processing systems with average capacities of 7 tons/household/day and operate mainly 3 months/year. With the data obtained from the in depth study on material balance for a household-scale tapioca processing unit (section 5.4), the material balance for the whole group of tapioca producing households in Tra Co Village is derived and described in Fig. 5.12.

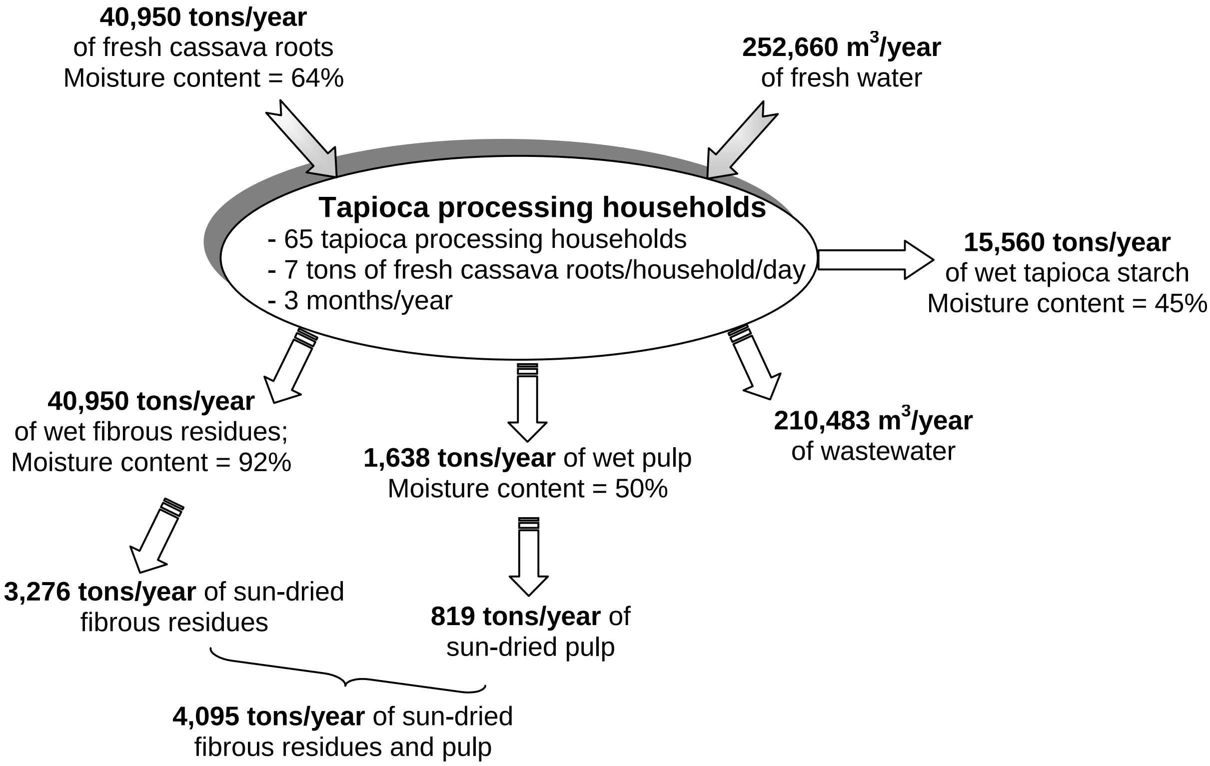


Fig. 5.12 Material balance for the group of tapioca producing households in Tra Co Village.

The raw material input for tapioca production consists of fresh cassava roots and fresh water. Cassava roots are purchased either in Binh Minh Commune or at other places as Binh Duong Province and Song Be Province. Fresh water comes from household wells, for which only the electricity for pumping has to be paid. The product is either wet tapioca starch or dry tapioca starch depending on the customers' requirement. Dry tapioca starch is formed by sun drying of wet tapioca starch, the simplest and cheapest method. Solid non-products or byproducts consisting of wet fibrous residues and pulp are sun-dried as well and sold to other enterprises for livestock feed production. Wastewater is directly discharged into existing ditches. Thus, this system currently looks like an industrial ecosystem of type II (Richards et al., 1994), which is characterized by some internal cycling of materials occurs, but there is still a need for virgin material input and wastes continue to be generated and disposed of outside the industrial system. By applying cleaner production and waste minimization as presented in section 5.5.1, tapioca-processing households, to some extent, can reduce the amount of generated non-products. With the selected feasible alternatives such as modification of the grind-sheet for better grinding of cassava roots, installation of extra settling tanks or proper arrangement of settling tanks to add the third sedimentation stage, applying the countercurrent principle in the roots rinsing stage, only a small proportion of the amount of non-products are prevented from being generated.

All generated wet fibrous residues and pulp are collected right after each production batch and are dried under the sun without any specific equipment, machine or energy requirement. Either roofs or village roads are utilized for such purpose. There is need for some manual labor, which is always available in every household in the village. Sun-dried fibrous residues and pulp are mainly sold to other enterprises for livestock feed preparation and partly reused on-site for swine breeding. Thus, in environmental respect, in fact, these byproducts do not cause any serious problem, except for smell due to natural fermentation. Interviewed tapioca starch producers responded that they gained about 680 VND/kg (equivalent to 0.0453 USD/kg) sun-dried fibrous residues and pulp. Additionally, by supplying 40% maize in livestock diet, for instance swine diet (Table 5.16), livestock feed producers increased their profits about 86 VND/kg (0.0057 USD/kg) as calculated below:

- If substituting 100% dried cassava of swine diet by sun-dried fibrous residues and pulp, the substitution equation becomes:

  1 kg maize = 1.255 kg sun-dried fibrous residues and pulp + 0.156 kg soybean meal

- Increase in profit of swine food producer will than be:

  0.2618 kg maize/kg feed x 0.4 x 1,950 VND/kg maize – 0.2618 kg maize/kg feed x 0.4 x 1.255 kg sun-dried fibrous residues/kg maize x 680 VND/kg = 114.8 VND/kg feed = 0.0076 USD/kg feed

Thus, reusing and recycling sun-dried fibrous residues and pulp as livestock feed promises to be a very attractive approach, not only regarding waste reduction and environmental protection, but also in economic terms because no additional investments are needed. The material balance for this option is presented in Fig. 5.13. The amount of swine feed, which can be produced using sun-dried fibrous residues and pulp to replace 40% maize, is estimated as follows:

$$\frac{4{,}095 \text{ tons/year}}{1.255 \times 0.2618 \times 0.4} = 31{,}159 \text{ tons swine feed/year}$$

In this case, the profit will increase 31,195 tons/year x 114.8 VND/kg swine feed = 3,577,053,000 VND/year = 238,808 USD/year.

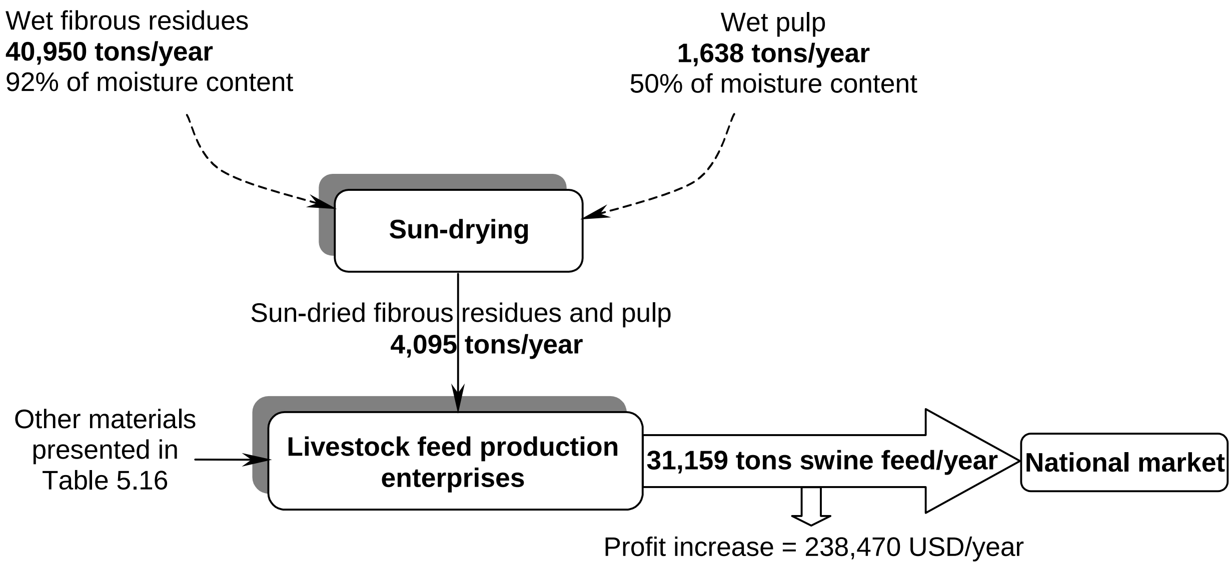


Fig. 5.13 Material balance of reuse fibrous residues and pulp as livestock feed.

Liquid Non-Products

The liquid non-product in this case is tapioca wastewater. The first priority is to reuse the untreated wastewater as much as possible for fish cultures. Direct reuse of untreated wastewater for irrigation might be a possibility if the organic loading is being controlled properly to avoid deterioration of soil and underground water quality. However, tapioca wastewater with a very high organic concentration is improper to apply directly on land. In other words, treatment before using to irrigate and discharge to the receiving surface water resource is strongly recommended.

Reuse of Tapioca Wastewater in Fish Culture. According to Polprasert (1996), there are basically three techniques for reusing organic wastes in aquaculture: (1) by fertilization of fish ponds with excreta, sludge, or manure; (2) by breeding fish in effluent-fertilized ponds, and (3) by rearing fish directly in wastewater stabilization ponds (such as maturation ponds). The second and the third techniques of waste reuse in aquaculture have been practiced in developing and developed countries. For instance, there are about 2,500 ha of sewage-fertilized fishponds in Calcutta, India; 270 ha in Hunan, China; 233 ha in Munich, Germany; 50 - 100 ha in Israel; and a smaller scale operation in Hungary (Polprasert, 1996). When properly operated the productivity of the fishponds using wastewater has been found to be higher than that of inorganically fertilizer ponds (Allen and Hepher, 1976). Some data on yields of fish raised in waste-fed ponds in various countries are presented in Table 5.17. These fishponds were not only fed by wastewater but also by solid wastes such as cattle manure, duck manure, livestock wastes, nightsoil, composted nightsoil, sugar-beet wastes, and septage. However, it is hard to find any report about reusing of tapioca wastewater for fish culture in literature. Inhabitants in Binh Minh Commune, who earn money from fish culture, have found that they can reduce the amount of fish feed and get a higher fish yield capacity if the fishpond is pre-fed by tapioca wastewater. Villagers reuse the wastewater based on their experiences. All fishponds, which are at suitable locations to receive wastewater, are fed with wastewater once a year (only during the tapioca processing season), while the other ponds are fed with fish feed. Normally, one-third of the volume of a fishpond is fed with the wastewater and is left for 1 to 2 months for stabilization and plankton development. After that, the pond is filled up with fresh water from wells or even with rainwater. Some small fishes are added into the pond for a week to check whether the environment in the pond is suitable for fish. If the fishes can grow up, the pond is ready for fish culture. Measurement dimensions of fishponds in Tra Co Village showed that tapioca wastewater-fed fishponds are usually larger than normal fishponds. For instance, in case of Mr. Nguyen Van Hien's household, the surface area of tapioca wastewater-fed fishpond is about 7,750 m^2, while a normal fishpond (without feeding by tapioca wastewater) has a surface area of only 1,900 m^2 (Table 5.18). This is logical because more benefit can be gained from tapioca wastewater-fed fishponds. According to the master plan for land use of Binh Minh Commune, the total area for aquaculture will be 16.14 ha by the year 2005. About 80% of fishponds in this area at this moment are tapioca wastewater-fed fishponds. With a water depth of 1 m, the total amount of tapioca wastewater needed to supply these fishponds can be estimated as follows:

$$\text{Volume of wastewater needed} = 16.14 \ (ha) \times 0.8 \times 1 \ (m) \times \frac{1}{3} \times 10{,}000 \ \left(\frac{m^2}{ha}\right) = 43{,}040 \ \text{m}^3$$

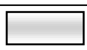
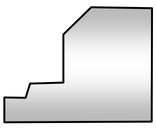
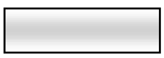
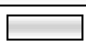
Reports of Edwards (1985), Polprasert et al. (1982) and Edwards et al. (1988) indicated that wastewater fed in wastewater fishponds is controlled so that organic loading in term of kg BOD_5 or COD/ha.day only vary in the range of 50-150 kg COD/ha.day. Thus, with an average of 11,700 mg/L of COD in tapioca wastewater discharged from Tra Co Village and assuming 100 kg COD/ha.day is required to feed the fishponds, the total amount of tapioca wastewater needed is about 40,000 m^3/year. This value matches with the estimated value (43,040 m^3) from the villagers' experience. In normal fishponds, about 0.48 ton fish feed/ha.year is required, while in tapioca wastewater-fed fishpond, only 30% of this amount of fish feed (equivalent to 0.144 ton/ha.year) is needed. Thus, with a fish feed price of 1,400,000 VND/ton (93 USD/ton), about 470,400 VND/ha.year (31.4 USD/ha.year) is saved by reducing the bought fish feed. In this case, fish culture households profit both from the reduction of bought fish feed and the selling of fish. There is no cultural barrier for reusing tapioca wastewater for fish culture in Tra Co Village, Binh Minh Commune. Fish from tapioca wastewater-fed fishponds are publicly accepted because of no public health risk as other waste-fed ponds, which are fed by animal manure or other kinds of wastewater. However, it is still safer to separate tapioca wastewater and domestic wastewater completely instead of discharging them together in open ditches as currently happens.

Table 5.17 Fish yields in waste-fed ponds

Country	Type of waste	Yield	Remarks	Reference
Israel	Cattle manure	10,950 kg/ha.year	Extrapolated from experiment	Schroeder, 1977
	Duck manure and waste duck food	14,600 kg/ha.year	Extrapolation	Wohlfarth and Schroeder, 1979
	Wastewater, loading = 25 – 45 kg BOD_5/ha.day	5,000 kg/ha.year	Extrapolation	Edwards, 1985
Philippines	Anaerobic digested sludge	8,000 kg/ha.year	-	Maramba, 1978
Indonesia	Livestock wastes	7,500 kg/ha.year	-	Djajadiredja and Jangkaru, 1978
Poland	Sugar-beet wastes	400 –500 kg/ha-growing season	-	Thorslund, 1971
Taiwan	Nightsoil	6,893 – 7,786 kg/ha.year	-	Tang, 1970
Calcutta, India	Wastewater	958 – 1,373 kg/ha.year	India carp	Edwards, 1985
China	Wastewater	6,000 – 10,000 kg/ha.year	-	Edwards, 1985
Munich, Germany	Wastewater, loading = 30 – 77 kg BOD_5/ha.day	500 kg/ha-growing season	Common carp	Edwards, 1985
Hungary	Wastewater	1,700 kg/ha-growing season	Polyculture, Chinese carp and common carp	Edwards, 1985
USA	Wastewater effluent, 37% of wastewater	126 – 218 kg/ha.year	Channel catfish	Colt et al., 1975
		5,000 kg/ha.year	Silver carp, bighead carp	Henderson, 1983
Asian Institute of Technology, Thailand	Septage, loading = 150 kg COD/ha.day	5,000 – 6,000 ha/ha.year	Tilapia (extrapolation)	Edwards et al., 1988
	Composted nightsoil, loading = 100 kg COD/ha.d	2,800 – 5,600 kg/ha.year	Tilapia (extrapolation)	Polprasert et al., 1982

Source: Polprasert, 1996.

Table 5.18 Surface areas of some fishponds in Binh Minh Commune

Household's name	Shape of pond	Surface area (m^2)	
		Tapioca wastewater -fed fishpond	Normal fishpond
Nguyen Van Hien		-	1,900
Nguyen Van Hien		7,750	-
Nguyen Thi Thao		2,200	-
Nguyen Van Hung		7,000	-
Unidentified name		-	1,500

Beside created fishponds, the natural Song May Lake, which has a water capacity of about 15 million m^3 and 30 million m^3 during respectively the dry and rainy season, is also used for fish culture. Every year, about 250 tons of fish is harvested from this lake. Song May Lake is the final receiving of all wastewater discharged from Binh Minh Commune (including Tra Co, Tan Binh, and Tan Bac Hamlets). Until now, the self-purification of Song May Lake is still very good therefore at the moment the effect from tapioca wastewater seems to be negligible at this moment. However, there is a high risk of losing the self-purification ability in the future if the lake still receives about 170,000 m^3 of tapioca wastewater with organic concentration of about 11,000 mg/L from Tra Co Village every year. Therefore, treatment of un-reusable wastewater from this village is necessary.

The toxicity of tapioca wastewater depends on the cyanide compounds. In this case, it is at an un-harmful level, because after a 1-2 month stabilization, all cyanide compounds are degraded and converted into nitrogen compounds. Results of cyanide analysis of tapioca wastewater collected on the first day and stored for 3-5 days showed that cyanide concentration decreased from 19 - 28 mg/L (on the first day) to 0 mg/L (on the third day) (Mai et al., 2001). Currently, the average yield from tapioca wastewater-fed fishponds in this area is about 3 tons/ha.year. To some extent, this yield is about 2-5 times lower compared to references in Table 5.17. This difference is attributed to the difference in fish culture technology. Field observations and direct interviews with fishponds' owners at Tra Co Village showed that tapioca wastewater fishponds are operated based on their experiences. Different households may culture different types of fish such as hypothalmichthys, carp, catfish, etc. Sometimes, different types of fish are grown in the same fishponds so that small fish become food for the bigger ones.

In food chains of the tapioca wastewater-fed fishpond, the residue in tapioca wastewater is the organic waste input (Fig. 5.14). Residues and waste material produced by fish and decaying biomass will settle at the bottom of the pond and be decomposed by bacteria (the decomposers), resulting in the release of CO_2 and NH_3 required for the primary producers (algae and aquatic plants). The primary producers synthesize organic materials (or biomass cell) through photosynthesis, utilizing the nutrients in the water and sunlight.

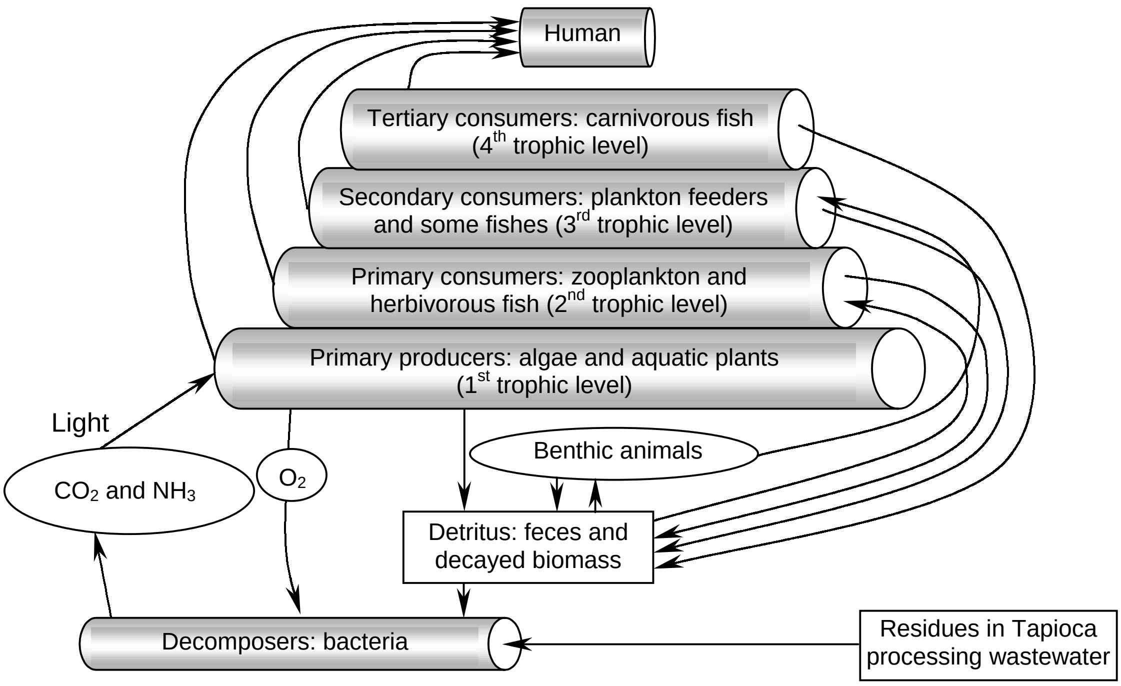


Fig. 5.14 Food chains in tapioca wastewater-fed fishpond (referring from Polprasert, 1996).

The second level of the food chain is the primary consumer group, mainly zooplankton and herbivores, which consume the primary producers. About 29 different types of zooplankton are found in fishponds (both tapioca wastewater-fed fishpond and normal fishpond) in the studied area. Their densities in tapioca wastewater-fed fishponds and normal fishponds are different (Table 5.19). These zooplankton and herbicores are in their turn prey for secondary consumers such as small fish and other plankton-feeders. In this step, some fish consume benthic animals, which grow at the pond bottom. Some herbivore fish, such as silver carp, consume phytoplankton directly, and can also take detritus. Tertiary consumers prey upon small fish. Depending on the type of stocked fishes, they feed on phytoplankton and zooplanton, and are primary consumers, secondary consumers, and tertiary consumers (Polprasert, 1996). Therefore, biomagnification and bioaccumulation are not important in this food chain.

Table 5.19 Zooplanktons in fishponds and Song May Lake, Binh Minh Commune, Thong Nhat District, Dong Nai Province, Vietnam[29]

Unit: number/m^3

No.	Zooplankton	Song May Lake			Artificial fish ponds		
		S1	S2	S3	S4	S5	S6
	Protozoa	450	600	500	1900	100	7214
1	Volvox aureus - Ehrenberg	+					
2	Euglena acus - Ehrenberg	+	++	++	+++	+	+++
3	Euglena gracilis - Klebs	+	+	+	+++		+++
4	Euglena granulata - Klebs	+	++	++	++		+++
5	Arcekke vulgaris - Ehrenberg			+			
	Rotatoria	8650	13800	7100	1000	2700	4500
6	Asplanchna sieboldi - Leydig	++	++	++		+	
7	Brachionus calyciflorus - Pallas	+++	+++	+++	++	+++	++
8	Brachionus caudatus - Apstein	++	++	++			
9	Brachionus falcatus - Zacharias	+++	+++	+++	++	+++	+++
10	Brachionus plicatilis - Muller	++	++	++		+++	++
11	Brachionus quadridentatus - Hermann	+++		++			
12	Brachionus urceus - Linnaeus			+			
13	Filinia terminalis - Plate	++	+	+			
14	Lecane luna - Muller				+		
15	Philodina rosela - Ehrenberg	+	+				
16	Polyarthra vulgaris - Carlin			+			
17	Testudinella patina - Hermann	+	++	+			
18	Trichocerca longiseta - Schrank	++			+		
19	Trichocerca - Muller		+	+			
20	Trichocerca - Muller			+			
	Cladoxera	50		50	2900	1400	15750
21	Diaphanosoma sarsi - Richard						+++
22	Diaphanosoma leuchtenbergianum-Fischer					+++	+++
23	Moinodapnia macleayii - King	+		+	+++	+++	+++
	Copepoda	600	100	150	400	1250	19000
24	Allodiaptomus gladiolus						+++
25	Eodiaptomus draconisignivomi – Brehm						++
26	Tripocyclops prasinus - Fischer				+	+	++
27	Tripocyclops chinei - Dang	++	+	+			
28	Messocyclops leukarti - Claus	+			+		+++
29	Thermocyclops hyalinus - Rehberg				+	+++	+++

+ level of appearance
S1= near a farm, at T- junction with a spring; S2 = at T – junction with Dia spring; S3 = fish port.
S4= Tapioca wastewater-fed fishpond of Mr. Hien; S5 = fishpond of Mrs. Thao Son, S6 = fishpond of Mr. Tho.

Thus there is no doubt about the possibility to reuse tapioca wastewater for fish cultures. The material balance for this option is presented in Fig. 5.15.

[29] Analyzed at laboratory of the Center for Environmental Technology and Management (CENTEMA) and sent samples to Department of Biology, University of Natural Science for checking.

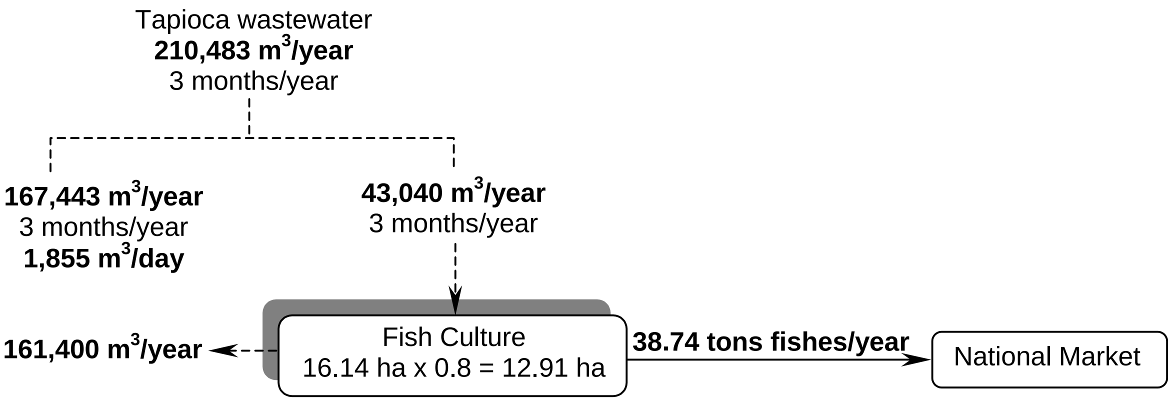


Fig. 5.15 Material balance of reuse tapioca wastewater in fish culture.

Treatment of Remaining Tapioca Wastewater for Cassava Irrigation. Though 43,040 m^3 tapioca wastewater are direct reused in fish culture, about 170,000 m^3 tapioca wastewater still need to be handled every year (as presented in Figure 5.15). In addition, other kinds of wastewater in this area including slaughter wastewater, swine breeding wastewater, domestic wastewater and rain discharging through the existing combined open ditch system heavily pollute surrounding springs and also need to be considered. It is known that the characteristics and flow rates of these kinds of wastewater are very different. Therefore combination of them will cause some difficulties for collection and treatment system such as:

- Diameter of the sewer will have to be increased in order to discharge all wastewater into the sewer system. Consequently, the construction costs will increase. This is an inefficient designed solution because the sewer system will only reach full design capacity during tapioca processing season and rainy season (if included).
- Pathogen from domestic wastewater influences the tapioca wastewater in such a way that it can not be used to feed fishponds, nor can residues be recovered from the wastewater.

Installation of a separate sewer network, in which slaughter wastewater, swine breeding wastewater and domestic wastewater are transported by one sewer network, while tapioca wastewater and rain are transported by the other sewer network, will bring the following advantages:

- It is feasible to partly reuse tapioca wastewater in fish culture and partly recover residues in tapioca wastewater for livestock feed production without any effect from pathogens from domestic wastewater.
- Each wastewater treatment plant can always operate at design capacity with the same wastewater characteristics.
- Domestic sewer network works efficiently throughout the whole year.
- Diameter of the sewer is reduced.

However, this option still faces some difficulties: (1) the needed increased sewer length, (2) it requires two wastewater treatment plants and (3) increasing operation and maintenance cost. Therefore, it is better to install a new sewer network for domestic wastewater and wastewater from pig breeding and slaughtering, called a domestic wastewater. The existing open ditch system is modified to a closed-ditch system and used to transport tapioca wastewater to the treatment plant during the tapioca processing season and to transport rain water to the water body during the rainy seasons. Both tapioca and domestic wastewater will be treated in the same WWTS. Tapioca wastewater is received in a separate settling-equalization pond. A part of the wastewater from this pond is released into tapioca wastewater-fed fishponds. Suspended solids, mainly pulp, are recovered and sun-dried to sell as reusable raw material for livestock feed production. Results from laboratory studies on the recovery of residues in tapioca wastewater showed that about 74-90% of residues settle after 2 hours (Table 5.20). That means, about 2 tons/day of residues can be recovered at the WWTS. The remaining tapioca wastewater after feeding the fishponds is then released into an intermediate tank to be mixed with domestic wastewater and an alkaline solution for dilution, pH adjustment before entering UASB (Upflow Anaerobic Sludge Bed) wastewater treatment system.

Table 5.20 Residues recovery from laboratory model

Wastewater from	Suspended solid concentration (mg/L)		Residues[30] recovered (mg/L)	Recovered efficiency (%)
	At the beginning	After 2 hours		
First settling	2,044	524	1,520	74
Second settling	2,050	158	1,892	92
Third settling	570	40	530	93

Domestic wastewater, which is collected in a separate sewer network, passes through a screen and grit chamber for coarse refuses and sands removal. Both screenings from screen and sands from the grit chamber are collected and disposed at a landfill. The wastewater then is transferred to the primary settling tank for removal of suspended solids before entering the intermediate tank. Raw sludge from the primary settling tank is dewatered to be disposed in a landfill or it may be transferred to the composting plant for composting together with swine faeces. After mixing in the intermediate tank, the mixture of tapioca wastewater and domestic wastewater is biologically treated in the UASB and followed by pond system. As discussed above, about 167,000 m^3 of tapioca wastewater per 3 months, equivalent to 1,855 m^3/day, need to be treated. Estimated average flow rate of domestic wastewater in this area is about 2,300 m^3/day (see appendix 8) consisting of wastewater from households, schools, swine breeding, and slaughtering in Binh Minh Commune. Laboratory analysis of tapioca and domestic wastewater samples in this area show that the organic concentration in terms of COD and BOD_5 of tapioca wastewater (about 11,000 mg/L and 8,800 mg/L, respectively) is much higher than that of domestic wastewater (about 800 mg/L and 640 mg/L, respectively). Thus, COD and BOD_5 of the mixture from these kinds of wastewater will be approximately 5,300 mg/L and 4,280 mg/L. Therefore, the biological treatment stage of the WWTS will be designed based on these values. In the anaerobic process, organic matters are converted into biogas, mainly methane gas, and new cell. If during tapioca processing period, 70% of the consumed organic matter is converted into methane gas, the WWTS can produce about 4,660 m^3 CH_4/d, which can be reused for fibrous residues and pulp drying. If methane gas is not reused, proper treatment of generated biogas is necessary to eliminate its greenhouse effect. Biological treated wastewater is disinfected to complete get rid of pathogen before discharging into surface water resource. The proposed WWTS for both the tapioca and domestic wastewater in this area is described in Fig. 5.16. The design parameters of each unit in the WWTS are summarized in Table 5.21.

Researches of Hien et al. (1999), Mai (2000), and Mai et al. (2001) indicate that UASB and activated sludge are suitable treatment technologies for organic removal from tapioca wastewater in Vietnam. The efficiency of a complete wastewater treatment system consisting of a primary sedimentation tank, UASB-reactors, attached growth activated sludge reactor and oxidation pond system was investigated by Hien et al. (1999). Under laboratory conditions, organic loading rates applied in the UASB reactor were up to 40 kg COD/m^3.day with a

[30] Residues in wastewater consist of pulp and starch particles.

treatment efficiency of 90-95%, reducing the COD concentration from 13,499 mg/L to 624-780 mg/L and the final effluent COD (soluble) was lower than 10 mg/L. However, in the case of Tra Co Village, the tapioca-processing season is only 3 months a year, therefore it is not efficient to apply an activated sludge process.

Table 5.21 Design parameters of the proposed WWTS for Binh Minh Commune

Parameters	Unit	Grit chamber	Settling tank	Equalization pond	Intermediate tank	UASB system	Pond system
Flow rate	m^3/day	2,300	2,300	1,855	4,155	4,155	4,155
Hydraulic retention time	min	3	-	-	15	-	-
Hydraulic retention time	h	-	1	6	-	12	-
Hydraulic retention time	day	-	-	-	-	-	50
Influent COD	mg/L	-	-	-	-	5,300	425
Organic loading rate	kgCOD/m^3.day	-	-	-	-	12	
Surface loading rate	kgCOD/ha.day	-	-	-	-	-	200
Volume	m^3	5	96	464	43	1,040	-
Surface area	m^2	7	48	155	43	210	88,090
Treatment efficiency	% (by COD)	-	-	-	-	92	90

HRT: hydraulic retention time

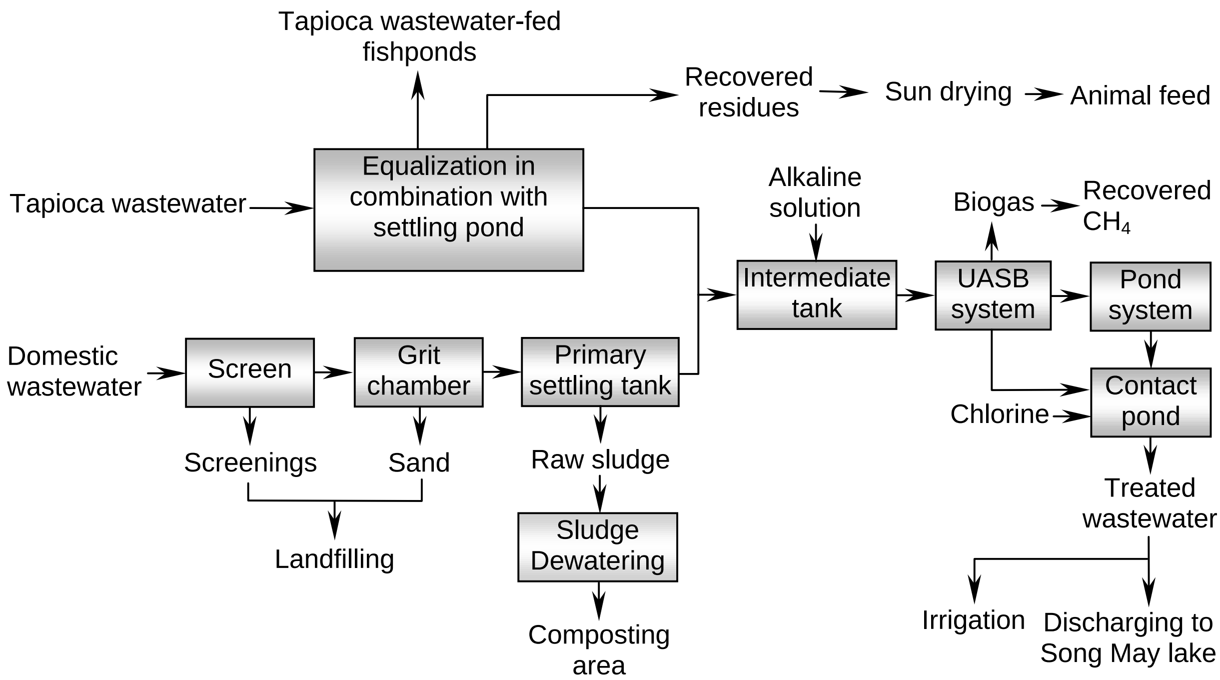


Fig. 5.16 Proposed WWTS for Binh Minh Commune.

During the non tapioca-processing period, domestic wastewater can still be treated biological using the UASB and pond system proposed in the WWTS. Research of Behling et al. (1997) indicates that after operating for 90 days in order to reach a steady-state condition, domestic sewage could be treated successfully in tropical regions using an UASB reactor. According to Seghezzo et al. (1998), the USAB process for direct treatment of the sewage is being applied successfully in Europe, Asia and the Americas (Table 5.22). Several full-scale UASB reactors have been implemented for domestic sewage treatment in several countries such as Kanpur (Draaijer et al., 1992) and Mirzapur, India (Haskoning, 1996); Bucaramange, Colombia (Schellinkhout and Collazos, 1992); Brazil (Vieira and Souza, 1986; Vieira, 1988). Moreover, an UASB reactor was modified and applied to single households in isolated locations, like farms and recreational facilities not connected to the centralized sewerage system (Seghezze et al., 1998). The design is almost as simple as that of conventional septic tanks but the treatment efficiency is much higher (Zeeman, 1997). This system was called UASB-septic tank because it shares features of both methods. Bogte et al. (1988, 1993) tested three 12 m^3 UASB reactors in different rural locations in the Netherlands with varying results but a similar configuration was tested in Bandung (Indonesia) by Lettinga et al. (1993). The UASB process was also applied to treat sewage from small-size communities (235 households) in Brazil (Vieira et al., 1994). Currently, the UASB-septic-tank technology is not yet applied in Vietnam. However, it might be a possibility in the future as the UASB process has successfully been applied in Vietnam for different kinds of industrial wastewater treatment from tapioca processing, seafood, soft drink industry, etc. and also for treatment of leachate from landfill[31]. If an UASB-septic-tank technology is applied, the capacity of the proposed WWTS can reduce significantly (from about 4,155 m^3/d to 1,855 m^3/d) and the treatment process will become more simple as presented in Fig. 5.17. It is proposed to reuse treated wastewater in cassava irrigation to utilize the nutrients from the wastewater. With regard to health, reuse criteria refer mainly to fecal coliform content which, according to WHO (1989), should be less than 10^3 per 100 mL. This can be usually reached by any disinfection method (Oron et al., 1999). In the proposed WWTS, disinfection is done in the contact pond using chlorine as disinfectant. Optimum chlorine dosage, retention time and pH value have to be determined to ensure effective disinfection and avoid problems of amine-chloride compounds creation as a result from a chemical reaction between chlorine and ammonium compounds present in the wastewater. If treated wastewater is reused in aquaculture, such as fish culture or aquatic macrophyte culture, the fecal coliform content should be less than 10^4 per 100 mL (Mara and Cairncross, 1989).

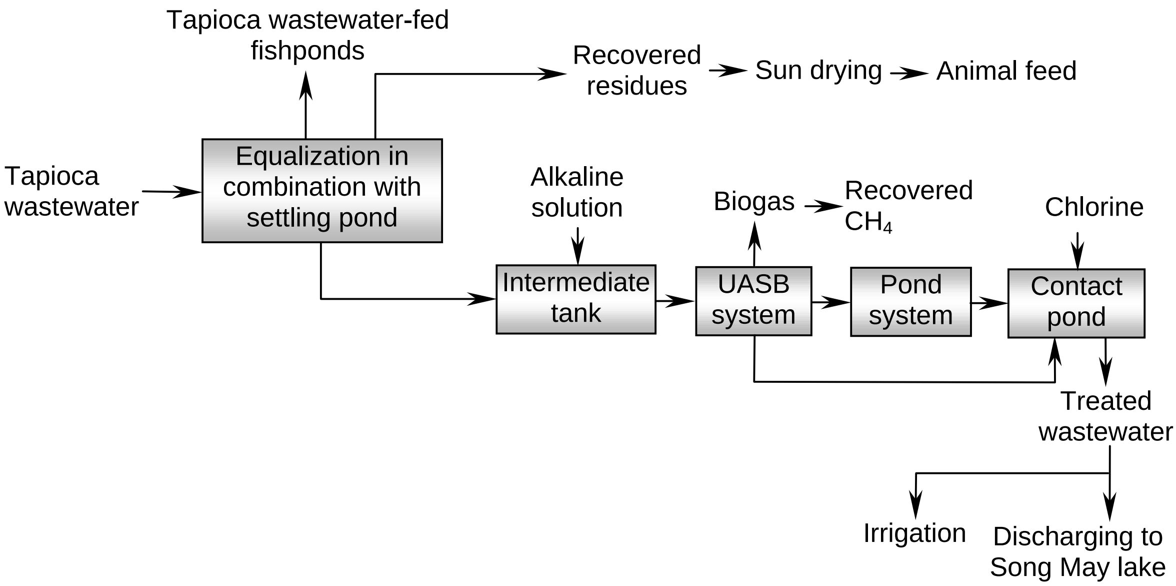


Fig. 5.17 Proposed WWTS for Binh Minh Commune in case domestic wastewater is treated separately by UASB septic tank.

Both effluents from the UASB system or from the pond system can be applied on cassava cultivation area. Montaldo (1972) indicated that the average rain level of 1,000 mm to 2,000 mm a year is suitable for cassava cultivation. Thus, in an area of 296 ha, total water demand is in the range of 2,960,000 to 5,920,000 m^3/year. In Binh Minh Commune, the two kinds of cassava plant cultivated are KM60 and KM94, starting at the end of March to May and the end of September to November. Thus, all treated wastewater from the WWTS, 4,155 m^3/d during tapioca processing season and 2,300 m^3/day in the other period, can be reused for cassava irrigation. Material balance for this element is described in Fig. 5.18.

[31] Personal experiences gained from working in different wastewater treatment plants, which were constructed and operated by the Center for Environmental Technology and Management (CENTEMA), Ho Chi Minh City.

Table 5.22 Applications of UASB reactor for sewage treatment

Place	Volume (m^3)	Temperature (^0C)	Influent concentration (mg/L)			Inocolum	HRT (h)	Removal efficiency in the reactor (%)			Start-up (months)	Period (months)	Reference
			COD	BOD (COD_{sol})	TSS			COD	BOD (COD_{sol})	TSS			
South Africa	0.008	20	500	(148)	NP	Active sludge	24	90	(49)	60-65	1	1	Pretorius, 1971
Netherlands	0.003	21	520-590	(73-75)	NP	Digested sewage sludge	9	57-79	(50-60)	30-70	NP	1	Lettinga et al., 1983
Netherlands	0.120	12-18	420-920	(55-95)	NP	Digested sewage sludge	32-40	48-70	(30-45)	90	NP	3	Lettinga et al., 1983
Netherlands	0.120	18-20	248-581	(163-376)	NP	Granular sludge	12	72	(62)	NP	NP	17	Lettinga et al., 1983
Netherlands	0.120	7-18	100-900	53-474	10-700^8	Granular sludge	4-14	45-75	(38-59)	50-89	NP	12	de Man et al., 1986
Netherlands	6	10-18	100-900	53-474	10-700*	Granular sludge	9-16	46-60	(42-48)	55-75	NP	12	de Man et al., 1986
Netherlands	20	11-19	100-90	53-474	10-700*	Granular sludge	6.2-18	31-49	(23-46)	NP	NP	12	de Man et al., 1986
			150-5550	43-157	50-400*								
Colombia	64	25	267	95	NP	Digested cow manure	6-8	75-82	75-93	70-80	6	9	Kooijmans & van Velsen, 1986; Lettinga et al., 1987
Netherlands	0.120	12+20	190-1180	(80-300)	NP	Granular sludge	7-8	30-75	(20-60)	NP	NP	NP	de Man et al., 1988
Mexico	0.110	12-18	465	NP	154	Adapted aerobic sludge	12-18	65	NP	73	NP	>12	Monroy et al., 1988
Brazil	0.120	19-28	627	357	376	None	4	74	78	72	4	9	Barbosa & Anna, 1989
Italy	336	7-27	205-326	55-153	100-250	None	12-42	31-56	40-70$^+$	55-80$^+$	NP	12	Collivignarelli et al., 1991; Maaskant et al., 1991
India	1200	20-30	563	214	418	None	6	74	75	75	2.5	12	Draaijer et al., 1992
Netherlands	120	>13	391	(291)	-	Granular sludge	2-7	16-34	(20-51)	None	NP	35	van der Last & Lettinga, 1992
Colombia	35	NP	NP	NP	NP	NP	5-19	66-72	79-80	69-70	NP	48	Schellinkhout & Collazos, 1992
Netherlands	1.2	13.8	976	454	641*	Digested sewage sludge	44.3	33	50	47.0*	NP	28	Bogte et al., 1993 (UASB-septic tank)
Netherlands	1.2	12.9	821	467	468	Digested sewage sludge	57.2	3.8	14.5	5.8*	NP	24	Bogte et al., 1993 (UASB-septic tank)
Netherlands	1.2	11.7	1716	640	1201	Granular sludge	202.5	60	50	77.1*	NP	13	Bogte et al., 1993 (UASB-septic tank)
Indonesia	0.86	NP	NP	NP	NP	NP	360	90-93	92-95	93-97	NP	60	Lettinga et al., 1993 (UASB-septic tank, black water)
Indonesia	0.86	NP	NP	NP	NP	NP	34	67-77	Up to 82	74-81	NP	60	Lettinga et al., 1993 (UASB-septic tank, grey + black water)
Thailand	0.030	30	450-750	NP	NP	Different sludge	3-12	90	NP	NP	> 2	4	Gnanadipatly & Polprasert, 1993
Brazil	120	18-28	188-459	104-255	67-236	Granular sludge	5-15	60	70	70	> 2	24	Vieira & Garcia, 1992
Colombia	3360	24	380	160	240	None	5.0	45-60	64-78	~60	> 6	> 36	Schellinkhout & Osorio, 1994
Brazil	67.5	16-23*	402	515	379	Digested sludge	7.0	74	80	87	NP	14	Vieira et al., 1994
Puerto Rico	0.059	~20	782	352	393	Digested sludge	6-24	57.8	NP	76.9	~4	16	Tang et al., 1995
India	12000	18-32	1183	484	1000	NP	8	51-63	53-69	46-64	5	13	Haskoning 1996, Tare et al., 1997
India	6000	18-32	404	205	362	NP	8	62-72	65-71	70-78	5	11	Haskoning 1996, Tare et al., 1997
Brazil	477	NP	600	NP	303	Non adapted sludge	13	68	NP	76	2	>7	Chernicharo & Borges, 1997

Source: Seghezzo et al., 1998.
NP: not provided; $_{sol}$: soluble; *: expressed as COD; $^+$: obtained at temperature of 15-20^{0}C, HRT of 12 h and upflow velocity of 0.58 m/h.

The presence of a WWTS in this case plays an important role in the reduction and elimination of generated contaminants, conservation of water resources, improvement of the cassava production capacity by sufficient and proper water supply. There is no doubt about the proposed treatment technology as has been illustrated by many existing WWTSs treating different wastewater containing high concentration of organic pollutants from different factories in the South of Vietnam.

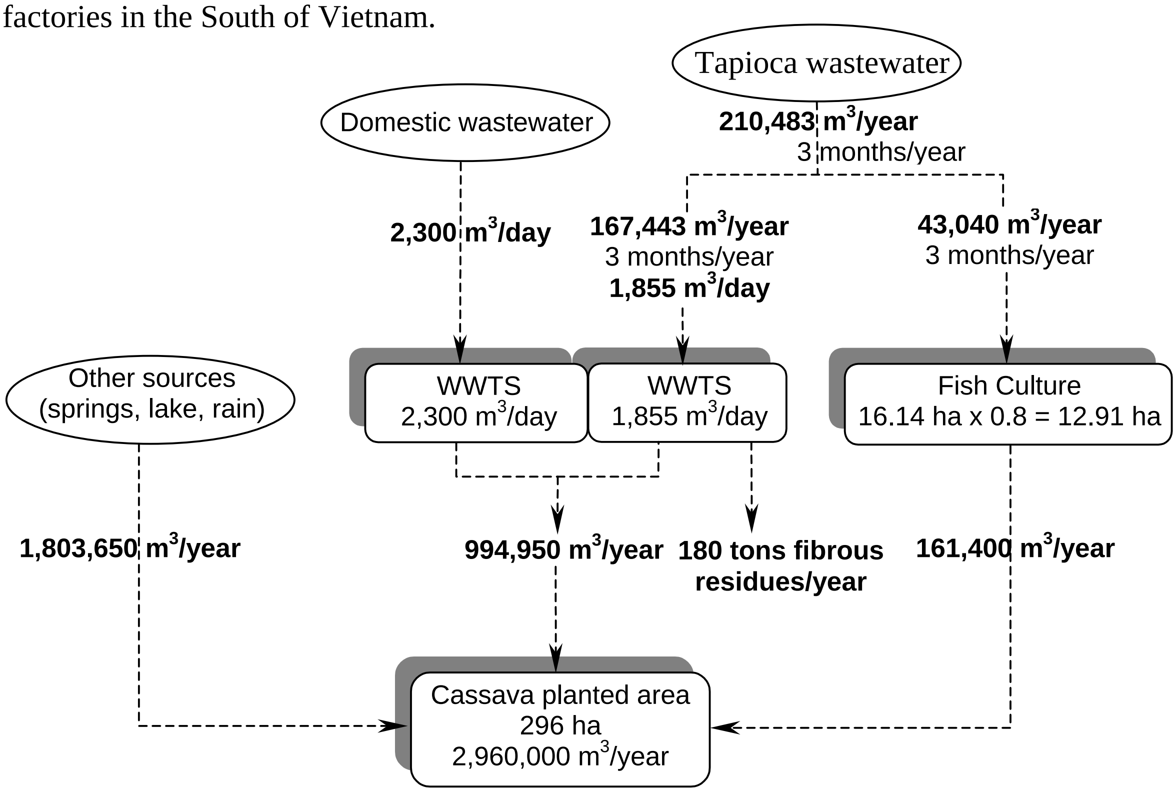


Fig. 5.18 Material balance of WWTS and cassava cultivation area.

Thus, by combining all niches, which reuse non-products from tapioca producing households presented in this section, a waste material network can be simulated in Fig. 5.19.

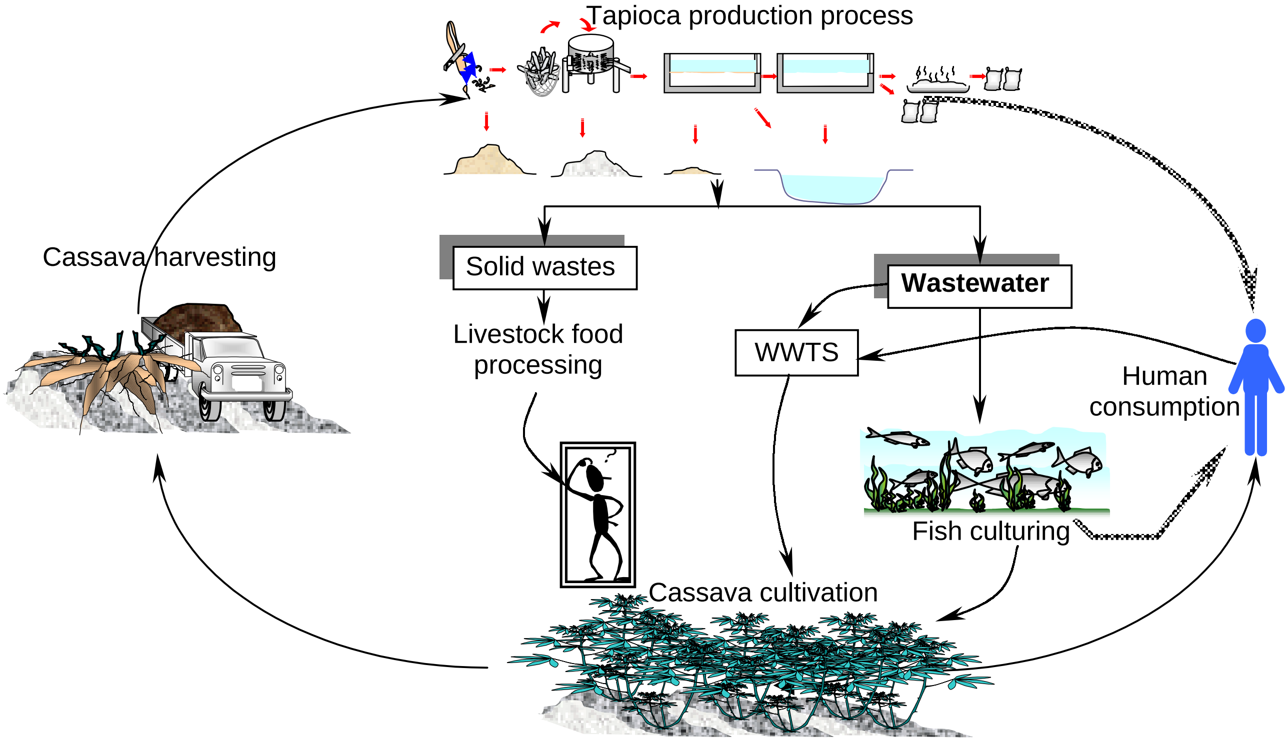


Fig. 5.19 Simulated view of material network approaching a zero waste industrial ecosystem at Tra Co Village.

Though the created network more or less approach a zero waste industrial ecosystem compared to the existing situation of Tra Co Village, Fig. 5.19 shows that there is still a possibility to strengthen the environmental performance of the system by adding a new niche. The characteristics and suitability of niche is discussed in the next subsection.

5.5.3 Adding New Recycler

Figure 5.19 shows that there is an indirect link between the output of animal feed production enterprises and the cassava cultivation field. In fact, livestock breeding, especially of swine, is one of the main businesses in Tra Co Village. Statistical data (1996) indicate that in Binh Minh Commune (consisting of Tra Co, Tan Binh and Tan Bac Hamlets), about 2,028 swine, 128 cattle, and 6,015 poultry are being bred annually. Recent observations (2001) indicate that about 17 households earn money from swine breeding (about 30-100 swine/household). Thus, there is not much difference between the current situation and the number of livestock breeding in the Commune during the period of 1996 to 2001. Until now, all livestock manure in this area is disposed through the open ditches or together with domestic solid waste. Only a small amount of livestock manure is reused in some households to fertilize their gardens. Thus, villagers in this area have been wasting a good raw material source for soil enrichment, especially for cassava fields.

Based on the amount of faeces produced by livestock (Table 5.23) and the number of livestock bred in Binh Minh Commune, it is estimated that about 8.53 tons/d of livestock manure are generated, consisting of 840 kg/day, 3,850 kg/day and 3,840 kg/day respectively from poultry, swine and cattle. These kinds of manure can be mixed, for instance, with rice straw, sawdust, sludge, etc. to control the C/N ratio and moisture content. It took about 60-90 days to complete each composting batch depending on the type of composting facilities. The simplest facility is the pile type (Fig. 5.20). With a typical dimension of a pile (height x width x length = 1.0 m x 4.0 m x 20 m), about 1 ha is required to compost all the livestock manure in this area.

Table 5.23 Characteristics of livestock manure from one animal

	Production (kg/day)	Moisture (%)	Total N (%)*	P_2O_5 (%)*	K_2O (%)*	CaO (%)*	MgO (%)*	Total C (%)*	C/N
Poultry									
Layer	0.14	78.0	6.18	5.19	3.10	10.98	1.44	34.7	5.6
Broiler	0.13	78.0	4.00	4.45	2.97	1.60	0.77	-	-
Swine									
Faeces	1.90	75.0	3.61	5.54	1.49	4.11	1.56	41.3	11.4
Urine	3.50	98.0	32.50	-	-	-	-	-	-
Cattle									
Faeces	30.00	80.0	2.19	1.780	1.76	1.70	0.83	34.6	15.8
Urine	20.00	99.3	27.10	trace	88.60	1.43	1.43	-	-

Source: Haga, 1990.
*: % of dry matter; -: unidentified.

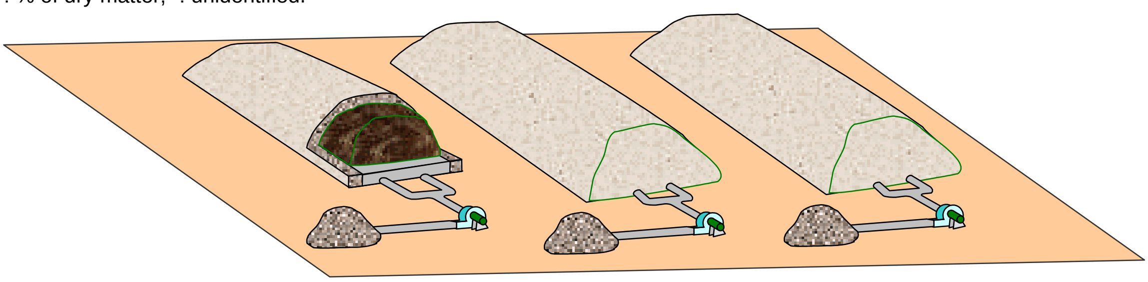


Fig. 5.20 Pile type for composting.

Phien et al (1997) found that application of N-P-K fertilizer in combination with farm-yard manure (swine manure) produces a higher cassava yield than that of N-P-K fertilizer and lime (Table 5.24). However, the combination of N-P-K fertilizer with lime and pig manure gave the highest yield. As presented in Table 5.21, about 3 tons swine manure was applied on 1 ha of cassava field for 3 years. In other words, on average, it requires about 1 ton of swine manure/ha/year. Thus, with about 300 ha of cassava field area in Binh Minh Commune, approximately 300 tons of swine manure/year is required in combination with P-K-N fertilizer. It is important to keep in mind that when raw materials are composted, more than twice the amount of organic matter accumulates than when the same amounts of raw materials are applied (Shiha, 1997). Therefore, only about 150 tons of compost is required annually for fertilization of cassava field area in Binh Minh Commune. This can be supplied by livestock manure compost produced in the area itself.

Odor emission containing sulfurous compounds such as hydrogen sulfide, methylmercaptan and methyl sulfide (Haga et al., 1978, Haga, 1990) during composting cause secondary pollution problems. However, in proper controlled conditions, composting brings various advantages as stabilizing the putrescible organic matter in raw wastes, reducing offensive odors, killing weed seeds and pathogenic organisms and finally producing a uniform organic fertilizer suitable for land application (Haga, 1990; Harada, 1990; Polprasert, 1996; Yang, 1997).

Table 5.24 Affects of annual application of fertilizer on crop yield in cassava-grain legume inter-cropping system at Hoa Son, Vietnam for three years

Treatment	Cassava yield (ton/ha)	Inter-crop yields (kg/ha)	
	Mean (1992-1994)	Black bean (1992)	Peanut (1993-1994)
Farm yard manure (FYM)	11.5	78	546
Low N-P-K + Lime	14.4	96	730
Low N-P-K + FYM	16.8	129	836
High N-P-K + Lime	14.8	104	731
High N-P-K + FYM	16.5	143	788
High N-P-K + Lime + FYM	18.8	162	870

Source: Phien et al., 1997.
FYM = 3 ton pig manure/ha
Low N-P-K = 25 kg N, 50 kg P_2O_5, 50 kg K_2O/ha
High N-P-K = 50 kg N, 100 kg P_2O_5, 100 kg K_2O/ha

With approximately 2,000 swine/year, the amount of generated swine manure is sufficient to improve a cassava cultivation area of 296 ha in Binh Minh Commune. The material balance for this option is presented in Fig. 5.21. All the data applied are based on the assumption that swine are fed until they have reached 100 kg living weight, which means after 7 months. Collected swine manure is mixed with either rice straw or sawdust to create C/N ratio of 25:1 and moisture content of 65% before piling. With 651 ha of rice field and annually capacity of 3.56 tons/ha/year, total rice yield in Binh Minh Commune reach 2,318 tons/year, of which rice straw occupies 7% (Ponlranz, 1981) or about 162 tons/year. That is sufficient to mix with 555 tons/year of wet swine manure. Another 245 tons/year of wet swine manure is mixed with 109 tons/year of sawdust to create the same quality of compost product.

This is the likeliest technique in a cottage village, because no specific machine, equipment, skilled labor nor payment of raw materials is required to operate the system. However, operation of this element will face some difficulties because swine breeding is not done on farm scale. They are bred at individual households. Thus, a system to collect swine manure and transport it to the composting plant is required. Either households or operators are proposed to be responsible for that. Because swine manure may contain pathogens, construction of the plant has to pay attention to the sanitary condition. Proper liners must be installed at the manure storage and windrow area to avoid leachate and underground water contamination. If all precaution is implemented properly, this system can operate without any technical problems. The presence of this element is helpful to reduce generated waste, produce a valuable product and contribute to land improvement.

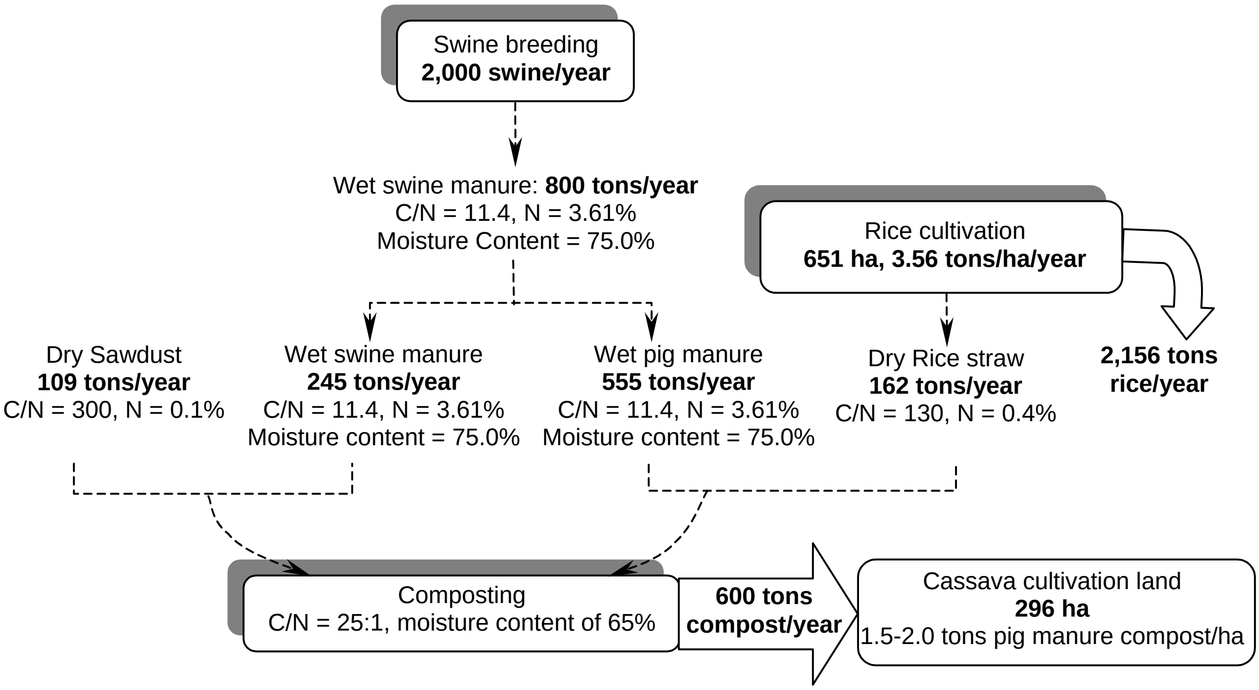


Fig. 5.21 Material balance of composting plant.

5.5.4 Physical-Technological Model of A Zero Waste Industrial Ecosystem

A physical-technological model of a zero waste industrial ecosystem at Tra Co Village is created by integrating all options discussed in the previous section. The material flow network of the physical-technological model is simulated in Fig. 5.22. Three boundaries of Tra Co Hamlet, Binh Minh Commune and Dong Nai Province indicate the operational area of each element. Because Tra Co Village is located in a group of three hamlets all belonging to Binh Minh Commune, some elements that are related to the natural ecosystem such as fish culture, cassava cultivation, rice cultivation, etc. can not be developed for Tra Co Village separately. Some elements such as a livestock feed production enterprise, which is not located within Tra Co Village boundaries nor even in Binh Minh Commune, but exists somewhere in Dong Nai Province and receives non-products from Tra Co Village, is included in the model. The market serves as an exchange center to receive and distribute products within the model and the outside.

In this model, except for the sun drying process and the growing of cassava, which uses the sun as energy source, most elements need electricity to operate. The only possibility for energy recovery is at the WWTS, in terms of methane gas. The energy balance of the developed model is described in Table 5.25. If methane gas, generated from anaerobic treatment process of the WWTS, is not recovered for reuse, it must be treated properly to limit its hazard, especially on the greenhouse effect.

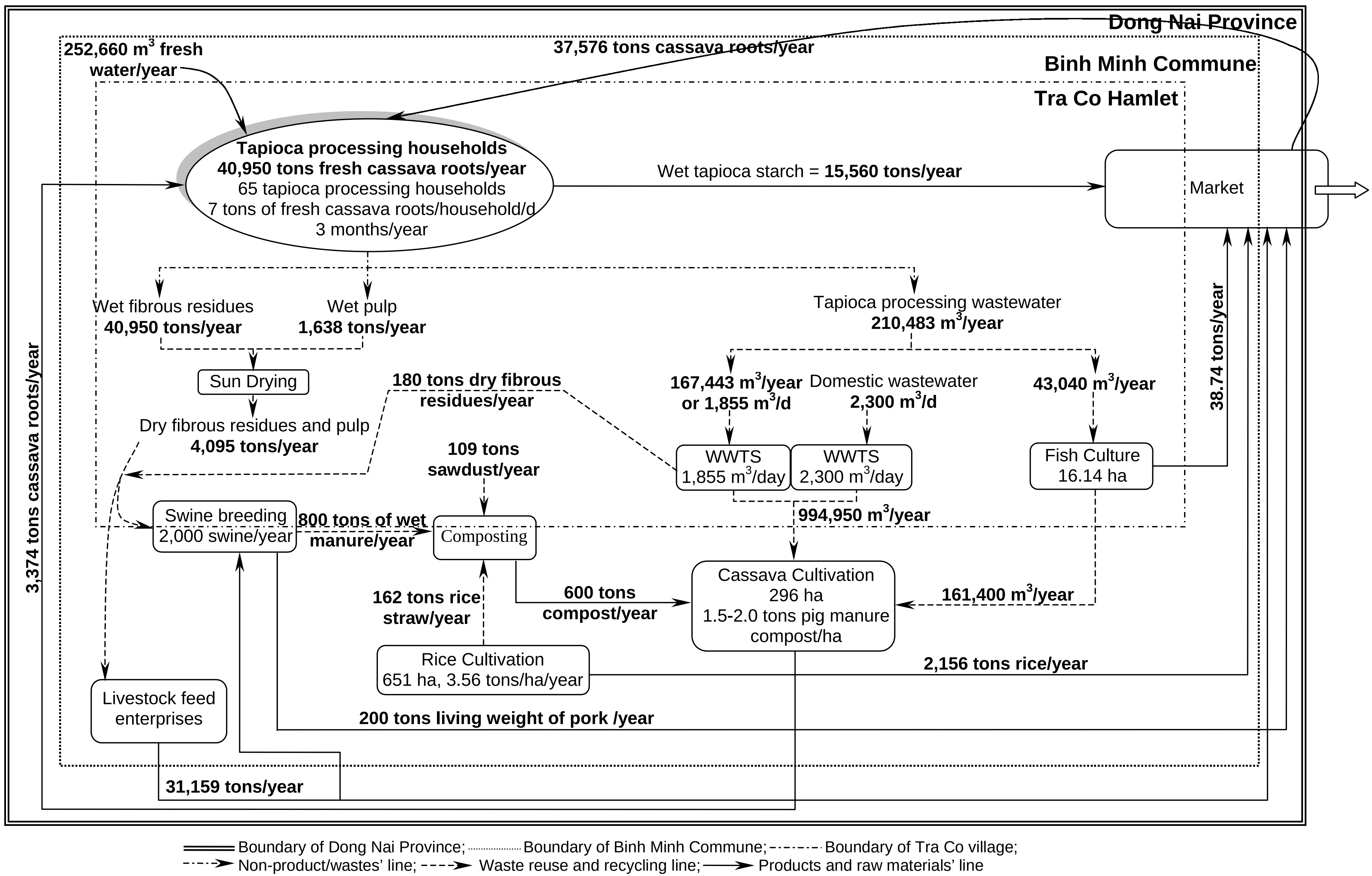


Fig. 5.22 Material flow network of the physical-technological model of a zero waste industrial ecosystem at Tra Co Village.

Table 5.25 Energy balance of the developed physical model in Tra Co Village

Element	Energy consumed	Energy recovered
Tapioca processing	Electricity to operate pumps, grinders, mixers (about 409,500 kW/year)	None
Drying fibrous residues and pulp	Sunshine	None
WWTS	Electricity to operate pumps, aerators, lighting	CH_4 (317 m^3/d in 9 months and 4,660 m^3/d in 3 months)
Composting	Electricity for lighting	None
Fish culture	Electricity to operate pumps	None
Cassava cultivation	Electricity to operate pumps	None

5.6 ACTORS AND INSTITUTIONS IN INDUSTRIAL ECOSYSTEM OF TRA CO VILLAGE

The previous sections have dealt with the physical transformation in order to improve the environmental quality in Tra Co Village. But technical transformations do not take place automatically and the tapioca producing households in this area are not isolated entities. How can the developed physical model – or parts and options of this model – be implemented in Tra Co Village? To shed light on that question we have to analyze the institutions and interactions governing the tapioca producing households and identify how these (might) enable and constrain the further implementation towards industrial ecology. The economic, policy and societal networks, in which tapioca producing households are engaged, will be analyzed.

5.6.1 Economic Network

Within the economic network, the following analyzed interactions and arguments will be conducted: (i) the relationships between tapioca producing households in a product chain by looking at the vertical interactions from input suppliers to producers, recyclers and consumers; (ii) the relationships between the households in Tra Co Village with other tapioca processing villages, enterprises, or via branch association; (iii) the interactions between tapioca producing households and other economic agents and research institutes, and (iv) regional relations and interactions in restricted geographical areas. In general, the economic network of the proposed physical-technological model of a zero waste industrial ecosystem at Tra Co Village is presented in Fig. 5.23.

Vertical Interactions from Input Suppliers to Producers, Recyclers and Consumers

Suppliers. Suppliers for tapioca processing at households in Tra Co Village include cassava suppliers (cassava cultivation households in this area or from other places), water supplier and electricity supplier.

Cassava suppliers. Fresh cassava roots are provided either from cassava cultivating households within and surrounding Tra Co Village, Binh Minh Commune or from other nearby provinces such as Binh Phuoc and Song Be[32]. Tapioca producing households usually have to negotiate with cassava cultivating farmers on the price and amount of cassava roosts to be purchased either before or during the harvesting period. The cassava price varies depending on the starch content of the cassava roots, which is tested based on the buyers' experience[33].

[32] Interview with tapioca processing households in Tra Co Village.

[33] Interview with Mr. Hung, staff of Thong Nhat District People Committee, a tapioca producing household of Tra Co Village. Principally, the testing method of starch content is the same as presented in the case of Tan Chau-Singapore Company (see chapter 6).

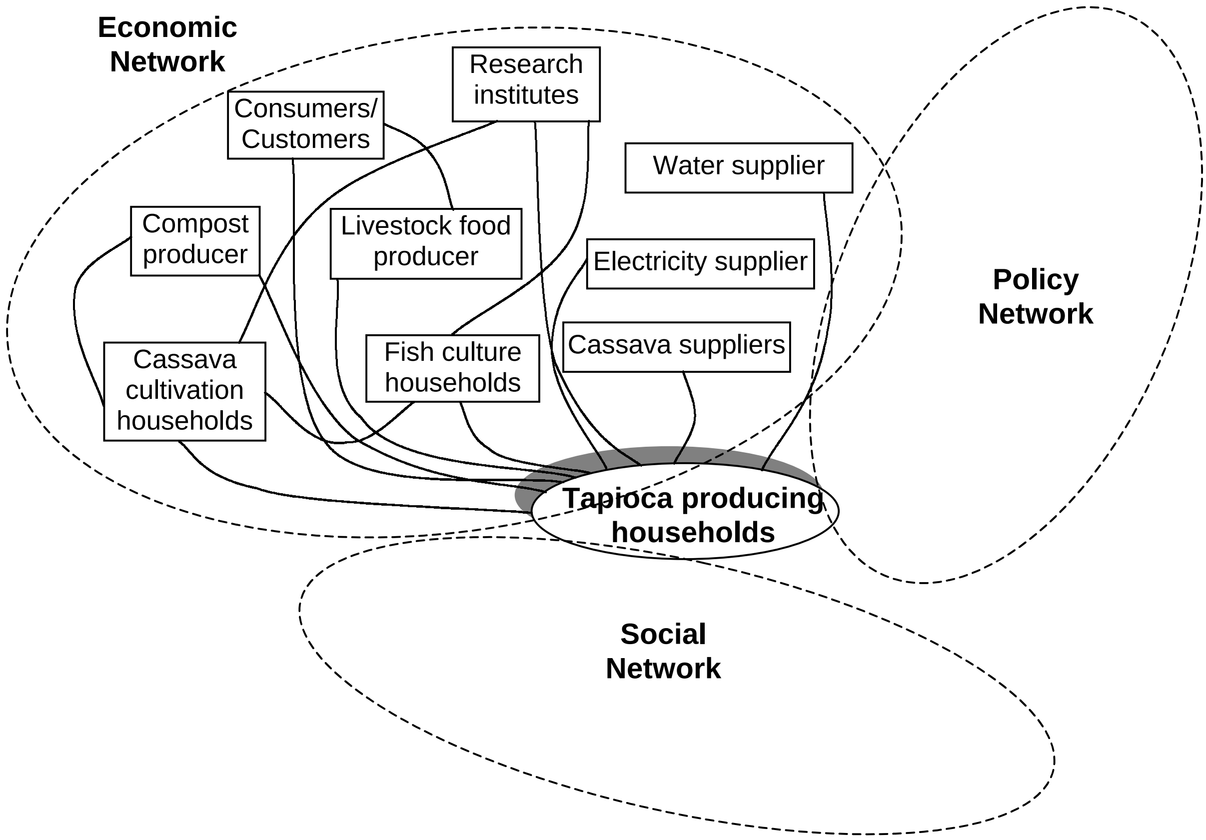


Fig. 5.23 Economic network embedding Tra Co tapioca processors.

At present, the cassava productivity as well as the starch content in roots from Binh Minh Commune is rather low, because the cassava fields have been cultivated for a long time without auxiliary fertilization, resulting in devastated and poor soil[34]. Therefore Binh Minh Commune is not able to provide the tapioca producing households in this area with a sufficient quantity of fresh cassava roots. The consequence is that the tapioca producing households increasingly to buy cassava roots from elsewhere. This is a hidden constraint for farmers cultivating cassava. There is a high potential for poverty due to the low selling price of cassava roots and low productivity. Consequently, it is more difficult for the cassava cultivation households to invest in soil enhancement, therefore they are not able to improve quality nor productivity of their fields. While in Tay Ninh Province, cassava cultivating farmers can increase their income from their cassava fields by inter-cropping, unfortunately soil of the existing cassava fields in Tra Co Village is too poor to do so[35]. Continuing existence of cassava cultivation households depends very much on the cassava productiveness or more precisely on how much money they can earn from their cassava fields. Some tapioca producing households indicated that they used to cultivate cassava some years ago, but the cassava harvest decreased year after year and income from this business was also low compared to tapioca production. Consequently they sold their cassava fields to others. Thus, cassava cultivation might decrease followed by the destruction of the closed material flow of the proposed no waste industrial ecosystem. Existence of cassava cultivation households plays a crucial role in the model as cassava suppliers are reusers of compost from the composting plants and treated wastewater from WWTS. Of course, other crops can take over the role of

[34] Interview with leader of Tra Co ward and tapioca cultivation households.

[35] Observation from cassava fields in Binh Minh and Tan Binh Hamlets as well as at Tan Chau-Singapore Company, Tay Ninh Province showed that sugarcane, peanut, peanut are the most applied inter-crops. Though inter-cropping cassava with many other crops is feasible, the most suitable crop combination depends on sol and climatic conditions, varieties used, availability of labor and market conditions.

reuser but cassava is the most suitable crop as the nutrient demand in soil of cassava fields is the least. In other words, it is easier to convince cassava farmers to use compost than other agricultural producers. In addition, in Tra Co Village and Binh Minh Commune, rice and cassava are the main cultivated crops.

Electricity supplier. Electricity is the only required energy source for tapioca processing. It is produced and distributed nationally by one governmental electricity company: Electricity of Vietnam. The production households are charged according to their consumption. Power selling price for production (0.08 USD/KWh), which is about 2.5 times higher than the price for public lighting (0.03 USD/KWh)[36], is an economic incentive for tapioca producing households to save electric consumption as much as they can.

Water supplier. Water for the starch extraction is supplied free of charge from households' wells. Therefore, to reduce water use, the price of water and a wastewater disposal fee seem to be crucial. It is recognized from field studies that employees do not need to care about minimizing water losses, because it costs almost nothing. Current water prices do not take into account the cost of scarcity and water losses due to wastewater generation. In addition, subsidization by the Government to keep the price of fresh water low does not encourage the minimization of water use. No efforts have been made to alter the price to internalize the externalities of natural resource use. This obstacle will not be solved if underground water is still considered a free natural resource and water conservation is not initialized. Beside lack of an incentive to use fresh water economically, there is a major lack of environmental awareness among the employees, also because, the generated wastes finally do not end up in their own yards. The producers in this area have fallen into a habit of discharging the produced wastes freely into the environment, because this has been done for a long time and has not caused any major problems yet. They seem neither to care about waste minimization nor to recognize the need of environmental protection, because there is no real benefit and they do not have to pay for the discharge of tapioca wastewater.

Recyclers. Recyclers play an important role in the reduction of generated wastes and creation of a waste material flow network. In this case, recyclers are specified as a person, a group of people or industrial entities, which are involved in recycling activities, including fish culture households, livestock feed production enterprises, cassava cultivation households, compost producer and the owner of wastewater treatment plant.

Fish culture households. The reuse of tapioca wastewater in aquaculture is a remarkably efficient reuse option that only needs some stimulation and optimalisation. The only existing danger is groundwater contamination if no precautionary measures are taken. By feeding fishponds with the wastewater, fish cultivation households benefit from reduction of the required amount of synthetic fish feed and simultaneously reduce an equal amount of waste, which is discharged freely into the environment at present or must be treated otherwise in the future. Though fish cultivating households use tapioca wastewater from tapioca producing households as “raw material” for growing fish and increase their income, no agreement, contract or any other similar requirements are established between them. They can get tapioca wastewater freely from the ditches and drainage where it is released into the springs and lakes. So far, there is no money exchange between fish cultivation households, who use tapioca wastewater and tapioca producing households, who get rid of tapioca wastewater[37]. Currently, tapioca producing households do not have to pay for wastewater treatment, so they do not see that they are making profit and saving money from this activity and that the

[36] Annex of Decision No. 20/VGCP-TLSX dated July 26, 1994 by Head of Government Committee for Price of Goods.
[37] Interview with owners of tapioca wastewater-fed fishponds.

existence of this relationship is necessary and useful for them. However, it seems logical that tapioca producing households themselves will keep on maintaining this relation in future, when they are requested to pay for the wastewater treatment.

Livestock feed production enterprises. The tapioca producing households themselves participate in pre-treatment of fibrous residues and pulp, by drying in the sun, before selling to reuse and recycle. Livestock feed production enterprises, which purchase dry fibrous residues and pulp to substitute proportional amount of maize in processing livestock feed, are important recyclers. These enterprises are an excellent actor to create a waste material flow network of the proposed physical-technological model, because the required quality of the dry fibrous residues and pulp can be achieved by the villagers with the available technology. Price of dry fibrous residues and pulp is set by negotiation between tapioca producing households and buyers. The quality of dry fibrous residues and pulp is assessed by their experiences. At present, not only in the case of Tra Co Village, but also in other tapioca production villages such as Tan Binh and Binh Minh (Tay Ninh Province), Binh Chieu (Thuc Duc District, Ho Chi Minh City) or companies, all fibrous residues and pulp are purchased[38]. It is not easy to predict the future demand on this byproduct, but the existing situation give us the impression that the demand is still higher than the supply.

Owner of wastewater treatment plant. The economic push towards a wastewater treatment system can come from reuse possibilities for irrigation and soil structure improvement. However, at this moment, it is proven to be hard to force the tapioca producers themselves to install the WWTS, unless it will be subsidized by governmental authorities to construct, operate and maintain the system. In fact, the provincial environmental authority, Dong Nai DOSTE, has planned the installation of a WWTS for tapioca and domestic wastewater in Binh Minh Commune recently[39], but it needs financial support and a stringent enforcement regime to realize. The WWTS may be constructed using financial supporting from the Government and operated using payment of polluters (tapioca households). Dong Nai PC and DOSTE can sign a contract with an environmental center to carry out this job. Of course, without assistance of Dong Nai DOSTE in forcing polluters to pay for their wastewater, it is difficult for the environmental center to maintain proper operation of the WWTS. Payment from tapioca producing households for treatment of tapioca wastewater is necessary not only to compensate the operation and maintenance costs of the WWTS, but also to push them to minimize the generation of wastewater from their production processes. Participation of cassava cultivation households in the proposed physical-technological model as reuser of treated wastewater from the WWTS is useful with respect to resource conservation and saving treatment cost. Because instead of using surface or ground water for irrigation, treated wastewater is a good substitute and complete treatment of wastewater before discharging into surface water is of course more difficult and costly than treatment for irrigation.

Compost producer. A composting plant is an element, which indirectly gets involved in recycling activities. Establishment of a composting plant is based on the reuse possibilities for soil improvement of cassava cultivation fields. This creates relationships between swine breeding households, who need a place to dispose swine faeces, compost producers, who can reuse swine faeces as raw material for their production processes and cassava cultivation households, who use compost to enhance soil of cassava fields. So far, this relationship has not been established yet, for several reasons. First, swine breeding households do not have to pay to get rid of swine faeces. Though in recent years, Dong Nai DOSTE has promulgated the regulation that all swine breeding households have to store swine faece in a septic tank to

[38] Interview with several tapioca production households and companies.

[39] The feasibility study of this project was carried out by Center for Environmental Technology and Management (CENTEMA) and I was a member of the study team.

produce biogas, practical application in Tra Co Village do not seem reflect this[40]. Precisely, swine faces are disposed together with domestic solid wastes or discharged into open ditches. Therefore they do not have to look for someone, who can reuse swine faeces. Second, villagers in this area have less experience and interest in compost production because there seems to be a small market for that. Third, cassava cultivation households neither have experience in producing and using of compost to enhance the soil quality of cassava fields. Thus, applying the polluter-pay-principle and setting a fee for disposing swine faeces higher than the fee paid to the compost producer to get rid of swine faeces might be an incentive to encourage the reuse of swine faeces for composting. In addition, support from governmental authorities to produce qualified compost with a reasonable price is necessary to ensure existence of the composting plants in the future. Market development for compost should be stimulated from now onwards if reuse of organic solid wastes is an expected option.

Cassava cultivation households. As discussed above, it is obvious that cassava cultivation households also play a role as recycler because their cassava fields are the perfect receivers for compost from the composting plant and treated wastewater from the wastewater treatment plant.

Consumers/Customers. The main consumers of wet and dry starch from Tra Co Village are the local markets, VEDAN Tapioca Company (Binh Phuoc Province) and other markets in the Middle and North regions. With the current production technology, quality of tapioca starch from Tra Co Village does not answer the raw material requirements to manufacture sodium glutamate, one of the major products of tapioca starch in the South of Vietnam. Therefore, tapioca producing households can not sell the starch directly to sodium glutamate producer or other manufacturers. They have to sell it to medium or large-scale tapioca companies for further processing. At present, large-scale and medium-scale tapioca companies in the South of Vietnam can not satisfy the need of tapioca starch as raw material for industrial uses with their current production capacity. Use of starch produced by household-scale units as intermediate material is a reasonable solution for both household-scale units as well as large-scale companies. However, there is consequently a high risk for household-scale units to loose market, if large- and medium-scale companies increase their production capacities or new large-scale companies are established in the future. Competition between household-scale units and large-scale companies might lead to up-scaling and/or gradual replacement household-scale units by medium- or large-scale companies. Thus, one of the essential prerequisites to continue their production in the longer term, household-scale tapioca processing units in Tra Co Village and more generally in Vietnam need to improve their quality of starch product as well as their productivity.

Horizontal Interactions between the Producers and Other Tapioca Processing Villages, Enterprises, or via Branch Association

At present, there is hardly any cooperation between tapioca producing households in this village. In fact, each tapioca producing household in this village is an enterprise, to be precise a private micro-enterprise. Therefore, they compete with each other to get a higher production efficiency and better starch quality in terms of color (the whiter the starch, the better the quality). The households have limited information exchange and do not cooperate on common interests such as marketing, technology development, or waste treatment. The field survey indicated that with the same production technology, the difference in production efficiency among these households range from 2 to 5 kg of starch per 100 kg of fresh cassava roots. Increase in starch extraction efficiency means decrease in the generated waste load. Thus if

[40] Observed open ditches around Tra Co Village and interview with swine breeding households and slaughterhouses in this area.

these households could share each others experience, they could not only improve the production efficiency but also reduce environmental impacts and represent common interest towards customers and government. As presented in section 5.2, tapioca production technology at Binh Minh and Tan Binh Hamlets, Tay Ninh Province, has a higher production efficiency than that of the other tapioca production villages. Therefore, the starch product price from Tay Ninh Province can always be lower compared to other places. That is a reason why sometimes tapioca producing households in HCMC and Dong Nai Province purchase tapioca starch from Tay Ninh Province and mix it with their product before selling to consumers[41]. By doing so, they can always supply their customers with sufficient quantity, reasonable quality and in time, while they still profit from the difference between purchase and selling prices. Thus, in the future, if the production technology of Tay Ninh Province and other villages is improved and extended, and especially if other large-scale tapioca processing companies are established, tapioca producing households in Tra Co Village may lose their markets.

It seems to be difficult to convince the households to exchange their experiences voluntary to help each other. Support from the government on production technology consultancy and waste minimization may be an incentive to start further cooperation among the households, potentially towards a cooperative.

The Interactions between Tapioca Producing Households and Other Economic Agents and Research Institutes

Economic Agents. Production activities of the tapioca producing households in Tra Co Village are under management of the Economic Section of Thong Nhat District, which belongs to Thong Nhat PC and also the tax-collection agency. The tapioca production villagers said that no preferential tax has been applied yet and they can only have a loan from banks if the value of their property is equivalent to the loan[42]. At present, influence from these economic agents does not seem to encourage the tapioca producing households in Tra Co Village to improve their production efficiency. Though in other Asian countries such as India, Indonesia, Taiwan, etc., soft loans and special schemes giving benefits on taxes help to make cleaner production to be attractive (Chandak et al., 1995; Roestamsjah and Cahyaningsih, 1995; Rock, 1996), the tax system in Vietnam does not provide any incentive for industrial producers to apply cleaner production (Phuong, 2002). In general, no tax exemption or tax reduction is applied for enterprises, which invest in cleaner production. However, Dong Nai governmental authorities may learn from Ho Chi Minh City experiences on application of environmental funds with preferential interest rate to facilitate the implementation of cleaner production in recent years[43]. In Ha Noi, with assistance of the Vietnam Cleaner Production Center, 24 companies have successfully carried out a cleaner production application (Box 5.1). These programs have been applied successfully in some selected medium- or large-scale companies. It is attributed not only to awareness of industrial producers on environmental

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[41] Interview with tapioca production households in Binh Chieu Ward, Thu Duc District, Ho Chi Minh City and Tan Binh and Minh Minh Hamlets, Tay Ninh Province.

[42] Interview with tapioca production households in Tra Co Village.

[43] A demonstration project on “Reduction of Industrial Pollution in Ho Chi Minh City - Project TF/VIE/97/001” were carried out in collaboration between Swedish International Development Co-operation Agency (SIDA), Department of Science, Technology and Environment of Ho Chi Minh City (DOSTE), and United Nations Industrial Development Organization (UNIDO). Cleaner production case studies were conducted successfully in food processing (Thien Huong Noodle factory and VISSAN Slaughterhouse), pulp and papers (Xuan Duc Paper Company and Ling Xuan Paper company), textile processing sectors (Phuoc Long Textile Company and Thuan Thien Bleaching and Dyeing company). In 1999, DOSTE of Ho Chi Minh City started other project on preferential fund for medium and small-scale companies carrying out cleaner production measures. This project is under support of ADB.

protection, but also to sufficient initial investment to implement the cleaner production project. Thus it is important to both enhance environmental awareness of tapioca producing households and encourage the implementation by providing soft loans.

Box 5.1 Cleaner production assessment by sector carried out with assistance of the Vietnam Cleaner Production Center

Sector	Number of company	Product	Maximum annual benefit (USD)
Textile	4	Dyed fabric, zippers, thread	73,000
Food and beverage	6	Agar-agar, beer, seafood, noodle, sugar	300,000
Pulp and paper	9	Printing paper, tissue, cardboard	160,000
Metal	2	Wire and nets, steel pipes	260,000
Other	3	Foots wears, pesticides, cement	249,000

Source: VCPC, 2003.

Research Institutes. So far, it is hard to find a relation between research institutes and farmers and villagers in this area, though several studies related to agriculture development at Tra Co Village were carried out. For instance, the Department of Soil and Fertilizer Research, which belongs to the Institute of the South Agricultural Science carried out a study on “Management measures of cassava cultivation soil in the Southeast of Vietnam” in the period of 1995-1997. This study was conducted with Acrisols soil at Tra Co Village, Thong Nhat District, Dong Nai Province (Tam, 1998). Hung Loc Agricultural Research Center also carried out a research on N-P-K fertilization of cassava fields in Dong Nai Province in period of 1994-1996 (Vuc and Kim, 1997). Besides, some suitable generic types of cassava for Dong Nai Province are ascertained by the Center for Dong Nai Agricultural Encouragement during 1995-1996 (Do, 1997). Though results of these studies could really be helpful to cassava cultivating farmers, most farmers did and do not know about this information or how to apply the techniques/technologies in practice, especially the ones for soil enrichment. This is especially counts for farmers in Tra Co Villages because they are too poor to ask for consultancy, while no system of agricultural extension, where these information trickles down to farmers, is available in this area. Though Vietnam Cassava Research and Extension Network conducted successfully a Farmer Participatory Research at mountainous and hilly areas of the North Vietnam in order to transfer technologies to cassava households (Bien et al., 2003), this seems to be unknown in Tra Co Village. Similarly, in the case of tapioca producing households, some do not know how to improve their production efficiency, and most of the other households do believe in the current technology and do not want to modify their operational habits[44]. They all have the prejudice that any change in the process takes too long to be implemented and may affect the production efficiency. However, in the future, with a competitive market mechanism as well as more stringent regulation for environmental protection, they will have to improve the production technology to maximize productivity and minimize waste generation. Technical assistance from research institutes could play an important role for this purpose. Besides, optimalisation of the reuse activities of other elements in the proposed physical-technological model such as fish culture using tapioca wastewater, cassava irrigation by treated wastewater, cassava cultivation soil improvement from swine compost, etc. needs assistance from research institutes too. Therefore it would be a possibility for future improvement of the village and development of research institutes if the laboratory researches are further demonstrated and implemented in full-scale. This, of course, needs financial support from the Government or any other organizations, but the research institutes themselves have to take into account the importance of demonstration and full-scale application of the laboratory studies.

[44] Interview with tapioca production households in Tra Co Village.

Regional Relations and Interactions in Restricted Geographical Areas

The tapioca producing households in Tra Co Village have the advantage for being locating quite near other elements of the proposed physical-technological model such as tapioca wastewater-fed fishponds, cassava cultivation fields and other local retailers. Besides, compared to other tapioca processing areas such as Binh Minh and Tan Binh Hamlets in Tay Ninh Province or Binh Chieu Ward, Thu Duc District, Ho Chi Minh City, the households in Tra Co Village are closed to VEDAN Tapioca Company (Binh Phuoc). This advantage helps to reduce the costs to transport products from Tra Co Village to VEDAN Company, one of the major customers of the tapioca producing households. Because these households produce the same products and non-products and are located nearby each others, they are able to share common facilities for recycling non-products such as wastewater treatment plant, cassava cultivation fields, fishponds, etc. and infrastructure such as tapioca drainage network as well.

By contrast, other elements of the model such as fish culture households, cassava cultivation households, etc. also benefit from the existence of tapioca producing households in this area. Composting plant will not be proposed to establish if no swine breeding and no cassava cultivation households are available.

5.6.2 Policy Network

This section aims at analyzing the existing policy network to see how this can be used to move the existing industrial tapioca production system at Tra Co Village to a zero waste industrial ecosystem. Policy institutions and the roles of actors at different levels (including provincial, district, and village level) related to environmental improvement of Tra Co Village are addressed in this section. The policy network of the proposed zero waste industrial ecosystem at Tra Co Village is presented in Fig. 5.24.

Actors in Environmental Management of Tra Co Village

Administratively, the state management organizations of Tra Co Village or Tra Co Hamlet include Binh Minh Commune People Committee (PC) (commune level), Thong Nhat District PC (district level) and Dong Nai Province PC (province level). However, the environmental management of production activities in Tra Co Village is under direct management of Dong Nai DOSTE at provincial level and MOSTE at national level. MOSTE does not influence directly the environmental improvement at Tra Co Village yet. However, the program on greening of traditional production villages in Vietnam started last year (2001) with a first case study on tapioca processing villages at Binh Minh and Tan Binh Hamlets, Tay Ninh Province[45], MOSTE made the provincial DOSTEs and PCs pay more attention to environmental protection of such villages. This has revealed in support of Dong Nai PC to Dong Nai DOSTE to carry out a feasibility study on construction of a sewer system in Binh Minh Commune[46]. The core objective of this project is to minimize environmental pollution from tapioca producing households and improvement of the environmental quality in this area. From this suggestion and decision of MOSTE, Dong Nai DOSTE hopes to be able to get support from MOSTE and Dong Nai PC for further improving the environmental condition at Tra Co Village, especially by first (re)constructing adequate infrastructure of this area. Dong Nai PC could provide infrastructure support for development of the proposed zero waste industrial ecosystem as it is in charge of spatial planning and building of physical infrastructure of the province. Besides, Dong Nai PC is also responsible for economic

[45] Interview with Mr. Hoang, Vice Director of Tay Ninh DOSTE in 2001.

[46] Dong Nai DOSTE collaborated with Center for Environmental Technology and Management (CENTEMA) to carry out this study in 2001. I was a member of the study team.

development and social condition of the province, therefore the project presenting high possibilities to improve both environmental condition and income of villagers will be attractive for them to support.

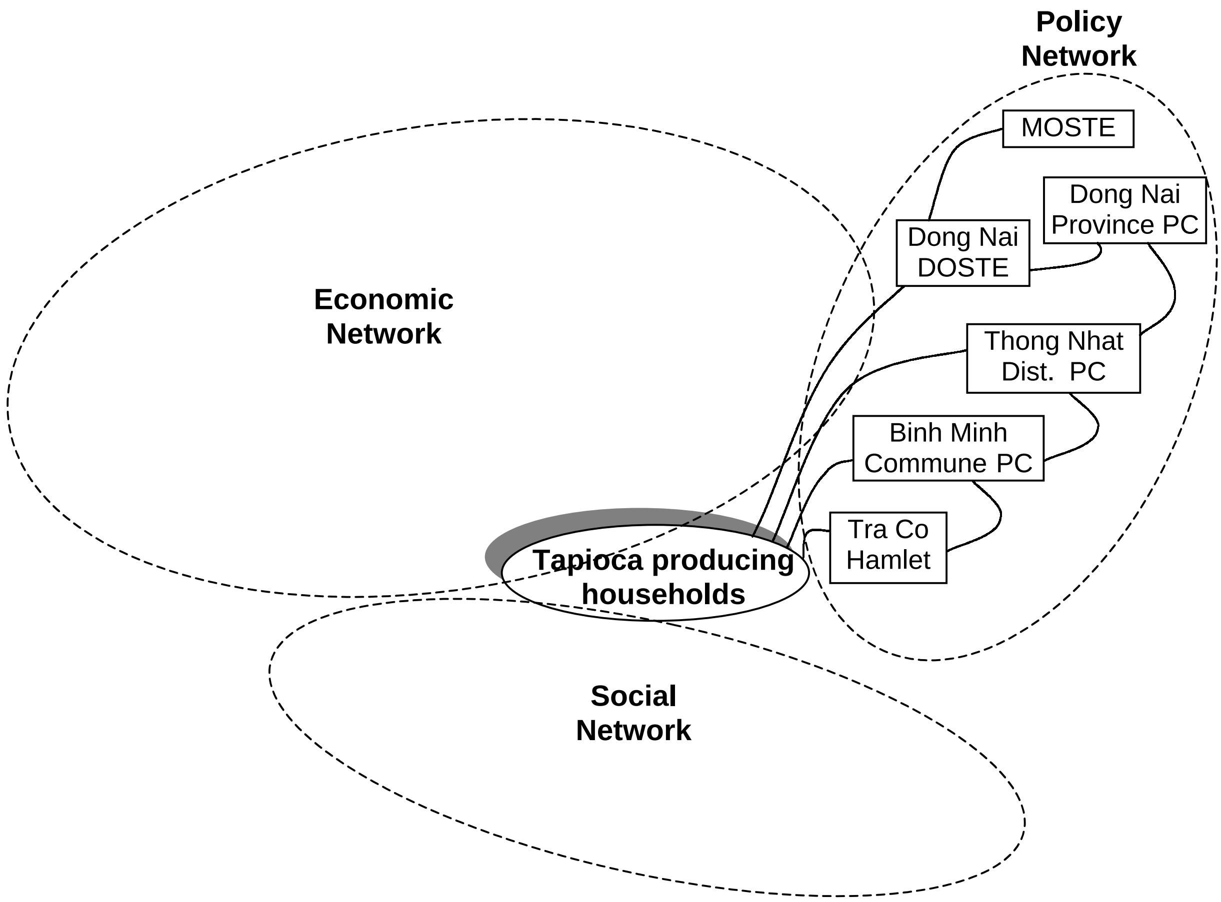


Fig. 5.24 Policy network embedding Tra Co tapioca processors.

At provincial level, environmental control and enforcement of Tra Co Village is the formal responsibility of the environmental authorities of Dong Nai Province (Dong Nai DOSTE). With only 7 professional staff members, 6 assistants, and a working area consisting of 10 major IZs and some 2,000 small and medium sized enterprises outside these zones, it should not surprise us that environmental pollution at Tra Co Village has only been put on the agenda in 2001. Rapid industrial development during the past few years has resulted in many environmental problems, especially from medium- and large-scale enterprises and IZs. This made environmental agencies concentrate all efforts on solving problems in these sectors only. In addition, disputes or complaints on pollution related to production activities are supposed to be initially dealt with by District Urban Environmental Management Company, but, in case of Dong Nai Province, they are usually transferred directly to Dong Nai DOSTE. This also keeps Dong Nai DOSTE overloads with work.

Local agencies including People Committees of Tra Co Hamlet, of Binh Minh Commune and of Thong Nhat District are representatives of state management agencies at local level. Up till now, these PCs play a limited role in encouraging environmental protection activities of Tra Co Village because they are too busy with solving civilian disputes about land and wealth, etc. to consider environmental issues. In addition, they also lack awareness, knowledge, equipment and funding to do this task. Leaders of Tra Co Hamlet and Binh Minh Commune, who know their villagers and other production activities in this area very well such as locations and characteristics of different tapioca producing households, tapioca wastewater-fed fishponds, cassava cultivation, surrounding polluted springs, are not aware of the necessity of environmental protection. Strengthening awareness, knowledge of staff and environmental capacity of local agencies seems important to ensure future implementation of the proposed model.

Policy Instruments and Legislation Related to Environment

Current environmental policy following the command-and-control model does not work well in this case, not only because of the conventional difficulties with implementing these environmental policy instruments, but also due to the far reaching social consequences potentially limited to it. It is very difficult for Dong Nai DOSTE to use enforcement instruments such as fines, administrative punishment or closure to all 65 tapioca producing households that violate environmental regulation, because this will create other social problems due to increase of unemployment and heavy influence on the life of villagers. In addition, most villagers are Christian, so it is considered a “sensitive political area”. Therefore, the governmental authorities rarely apply enforcement instruments in this area. Besides, it is impossible for individual households to install and operate a wastewater treatment system to meet environmental standards due to lack of funding, knowledge on treatment technology, and space to install the system. Thus, with a heavy reliance on command-and-control regulation but scarce resources for monitoring and effective enforcement, the future pushing Tra Co Village towards a more environmentally sound production in this manner is unsure.

Moreover, specific regulations and incentives for industrial production units to both make their production process more ecologically sound and reuse and recycle wastes are at the moment completely lacking. Current methods to dispose swine faeces in this area are attributed to that failure. By discharging swine faeces through open ditches or disposing it together with domestic solid wastes, villagers not only cause environmental pollution, but also waste a good resource for soil enhancement. This is attributed to unclear regulations and lack of control on what kinds of solid waste should be collected and disposed in sanitary landfills. In addition, a strong preoccupation with conventional end-of-pipe treatment systems, in stead of cleaner production, waste minimization and waste exchange options, endangers the implementation of several options.

5.6.3 Societal network

The societal network of the physical model of an industrial ecosystem at Tra Co Village consist of resident communities, Youth Union, Women Association, and mass media (Fig. 5.25). It appears that there is a close relation between the tapioca producing households and local residents. To be precise, the tapioca producing households, swine breeding households, fish culture households are living close together with other residents in Tra Co Village and Binh Minh Commune. In most cases, the local communities play an important role as ‘alarm bell’ for environmental impact from industrial activities, because they are affected by pollution and it is expected from them to change the situation. Several authors, who have analyzed what they call community driven regulation in Vietnam (O’ Rourke, 1999; Woltjer, 2001; Phuong, 2002), found that environmental reforms are in several cases strongly triggered by local communities complaining about environmental deterioration. In Tra Co Village, however, where the local community is equal to the producers and profiteers of environmental problems, this model of community driven regulation plays no role. The village is too small, too socially integrated and hardly differentiated to allow complaints about neighbors and colleagues. It might require a further modernization and social differentiation of these social systems before community driven regulation starts playing a role. Some households earn money from tapioca wastewater simply by screening the remaining residues on the releasing way of the wastewater. Other households need tapioca wastewater for fish culture. Therefore, these households benefit from a lax environmental enforcement since they earn money by recycling wastes. In addition, most people living in this area are poor with a low education level and social organizations such as the Youth Union, the Women Association, and the Veterans have not shown any interest in environmental issues yet. Even general clean-up activities such as “Green Weeks” or “Green Sunday”, usually organized by these social organizations, for instance in Ho Chi Minh City, to get villagers to pay more attention on the living environment have not taken place here.

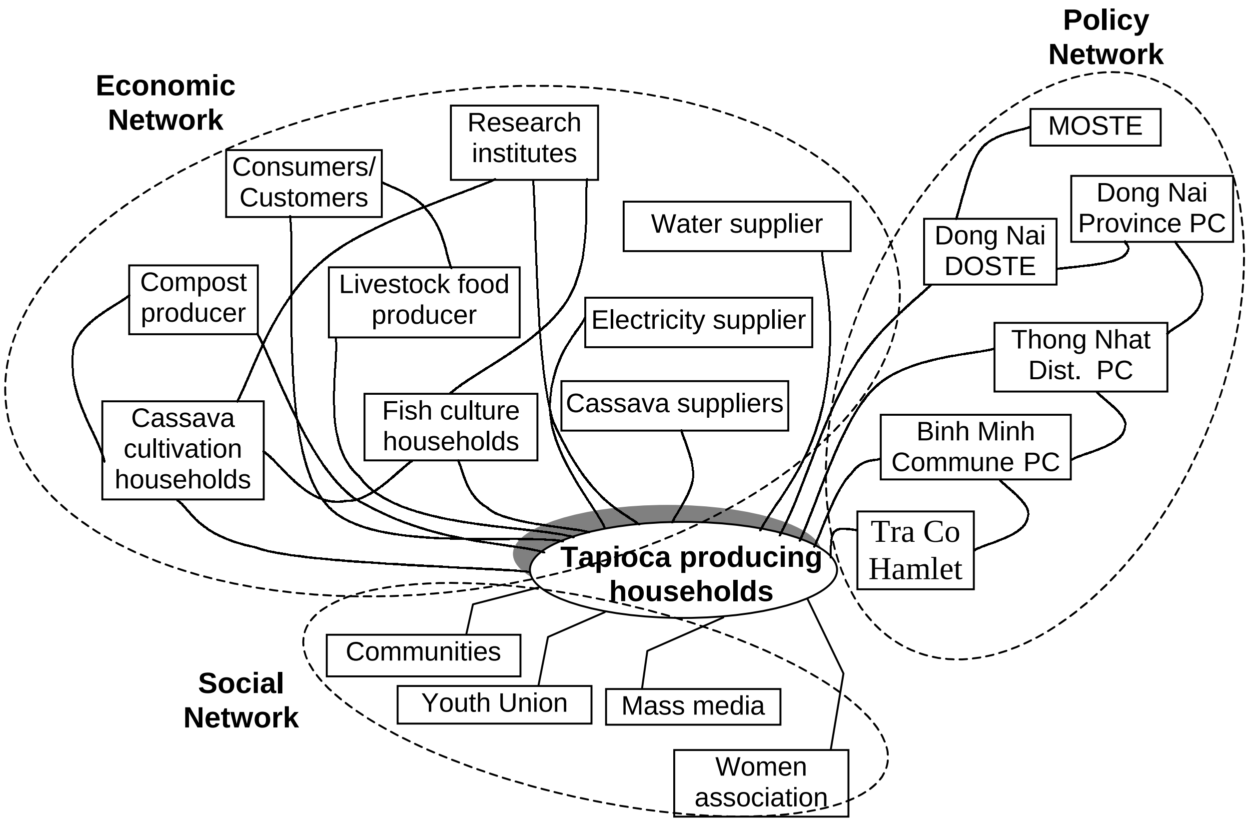


Fig. 5.25 Networks embedding Tra Co tapioca processors.

The mass media such as television, radio, newspaper, etc. are also considered an important actor of the social network. At present, television, radio and local newspaper are available and in use at Tra Co Village. Except for fish culture and cassava cultivation households, about 50 percents of tapioca producing households have televisions. Some of the remaining have a radio. Reading newspapers is not a habit and of no interest to villagers because they have to pay about 1,000 VND/newspaper. O’Rourke (1999: 163) confirms that “two main sources generate public pressure on industrial polluters and the officials who regulate them: citizen complaints and media coverage”. However, in case of Tra Co Village, the mass media has not played any direct role yet in environmental improvement. Both environmental impacts and successful applications of tapioca wastewater for fish cultivation and livestock feed production have not been published. This is a reason why tapioca producers from other places were very surprised and seemed not to believe that tapioca wastewater can be reused for fish culture. Environmental authorities should take advantages of available special programs on science and education focused on environment of television and radio as well as newspaper to praise good environmental performance cases and to criticize bad practice ones. This is believed to influence changes in industrial activities because industrial polluters are embarrassed by public disclosure of their poor environmental practices. Moreover, introduction of successful implementations on cleaner production and waste reuse and recycling via these programs is a good way to demonstrate and encourage producers emphasizing on both production and environmental improvement. Interviewing swine breeding households illustrated that cassava cultivation households asking for swine faeces are very rare. A clear reason is that they do not know how to produce good compost from swine faeces while the use of chemical fertilizers is easier and more efficient.

5.7 CONCLUSIONS

Though some large-scale tapioca processing factories are operating in the South of Vietnam, tapioca producing households are still finding a market for their products. Only these units seem to be able to satisfy the demand of local markets and other family-scale processing units such as cake, candy, noodle, rice paper, etc. with the small quantity of dry or even wet tapioca starch. Existence of the household-scale tapioca producing units is not only necessary for themselves but also for other household-scale processing units, which consume dry or wet tapioca starch as raw material. This is the main reason why the 13 traditional tapioca processing villages in Vietnam continue to exist even while using (old) traditional technology.

In the past, when self-purification of the local natural environment was still high, it could be used as a receiving body of tapioca-processing wastes. However, at present, it is visible that household-scale tapioca producing units cause environmental deterioration. Solving environmental problems caused by these units do not seem easy, even when installing end-of-pipe treatment systems. In fact, the households have tried to recover reusable materials from wastes as much as they can. This has been done not because of environmental awareness but because of economic benefits.

Building upon these practices, a model of a zero waste industrial ecosystem at Tra Co Village has been developed that tries to reuse all wastes generated from tapioca producing households and from other sources linked to that in the village to increase income of villagers taking the environmental protection into account. Cleaner production measures (schedule for conducting three settling stages in stead of two stages and application of counter current root rinsing method) can reduce the amount of pulp discharging together with wastewater and reduce amount of fresh water used or rinsing wastewater generation. The implementation of these measures may not increase much income of individual tapioca producing households, but for the whole village, this is meaningful in terms of environmental protection and natural resource conservation. Proposed reuse and recycling (or waste exchange) solutions show that the developed physical-technological model is a combination between industrial (tapioca, livestock feed, compost) and agricultural (fish, cassava) production system. Reuse and recycling fibrous residues for livestock feed production is currently applied. However, tapioca producing households can only dry fibrous residues and pulp to sell. In other words, further reuse of such byproducts depends on the livestock production enterprises. Available surface water resource in this area allows reusing only 20% of generated wastewater for fish culture and the remaining has to be treated. Without assistance both regarding in financial and expertise for construction, operation and maintenance, treatment of the remaining 80% of generated wastewater for reusing in cassava irrigation will not be implemented. Production of swine compost is an other environmental friendly solution as it not only helps to get rid of waste, but also to produce useful product for agricultural use. If all precautions are well implemented and each element in the model is operated properly, no waste will be generated from this system. However, this is far from easy to achieve.

Future implementation of a zero waste industrial ecosystem model should not rely too much on the role of environmental authorities in the near future, given their priorities and limitations in resources. Establishing cooperation structures between tapioca producing households seems to be a more promising trigger towards further reuse and recycling. Fierce external competition with large scale producers might drive these household into cooperative structures, which sets the institutional conditions for further exchange of information on increased production efficiency and reduced loss via waste streams. Although without support from environmental authorities a treatment system is not very likely to be established, a joined proactive request might make the best chance, either at the Vietnamese authorities or via foreign assistance.

CHAPTER 6

INDUSTRIAL ECOSYSTEM AT COMPANY LEVEL
A Case Study at Tan Chau-Singapore Company, Tay Ninh Province, Vietnam

This chapter presents a case study at a large scale tapioca processing plant called Tan Chau-Singapore Company, Tay Ninh Province. Again, an integrated model of pollution prevention is applied aiming at pushing the current industrial system of Tan Chau-Singapore Company towards a zero waste industrial ecosystem. The chapter starts with an introduction to this company and its environmental implications (section 6.1) and is followed by a detailed material flow study of its production process to clearly understand the current production technology, material inputs, products, by-products, wastes output and profits (section 6.2). A physical-technological model of a zero waste industrial ecosystem is developed step-by-step in section 6.3. Technological solutions for minimizing and eliminating wastes from the production process are proposed, based on the characteristics of the current production technology, available technologies and experiences of the producers in this area in combination with references from international literature. Roles of actors and institutions in implementation of the physical-technological model are analyzed in section 6.4. Finally, conclusions and recommendations are drawn in section 6.5.

6.1 TAN CHAU-SINGAPORE COMPANY AND ITS ENVIRONMENTAL IMPLICATIONS

Tan Chau-Singapore Company is a joint-venture company of 30/4 Tan Chau Tapioca Company, Tay Ninh Province, Vietnam and Inter Agi Commodities Ltd., Singapore. The company is located in zone No. 4, Tan Chau Town, Tay Ninh Province on an area of 80,000 m^2. The borders of the company area are defined as follows:

- The Northern border is 200 m from Road No. 247 to Dau Tieng Lake, 50 – 100 m from the nearest residential area and 300 m from Tan Chau Hospital.
- The East borders on Tha La River, which is an up branch of Dau Tieng Lake.
- The South and West border on sugar cane and cassava cultivation areas.

The designed capacity of the company is 30.000 tons tapioca starch/year or 100 tons/day (equivalent to about 120,000 tons cassava/year or 400 tons cassava/day). The production process of the company is operated continuously for 24 hours a day, 300 days every year[47]. At present (February 2002), the production capacity of the company reaches 85-92 tons/day, equal to 85-92% of the designed capacity. Eighty percent of the product is exported to Indonesia, Malaysia, China and particularly to Singapore. The remaining twenty percent is consumed domestically. The quality of tapioca starch of the company is indicated by the following parameters:

- Starch content : 85.0% (by weight of dry starch)
- Moisture content : 12.5% (by weight of dry starch)
- Protein content : 0.2 ml/50g (4 ml/kg dry starch)
- Ash content : 0.2%

[47] The company is not operated within September and October as this is the end of cassava harvesting season.

- pH : 5.5 – 7.0
- Color : White
- Smell, taste : no strange smell nor taste.

Production activities of the company have not yet caused serious pollution to the environment as in the case of Tra Co Village, because most wastes, particularly wastewater, are stored within the company. About 2,000 m^3 of wastewater is generated per day (with characteristics as presented in Table 6.1) and stored in an earth pond system consisting of 5 anaerobic ponds, 2 facultative ponds and 1 ditch chamber (Fig. 6.5). All wastewater generated from the start (1994) until now has been stored in these ponds, which have not overflowed yet because the wastewater either penetrates through the soil layer or evaporates to the atmosphere during the dry season. Though monitoring data on characteristics of wastewater of the earth pond system and ground water in surrounding areas are not available, analytical results of wastewater samples at present can still provide us with an impression of high potential of heavy pollution from this waste source. The data representing characteristics of tapioca wastewater from Tan Chau-Singapore Company, especially wastewater from the centrifuging process (Table 6.1) is comparable to that of Song Be-Singapore Company, VEDAN Company and Vietnam-Singapore Company as presented in Table 6.2[48]. Wastewater from root rinsing stage, in the case of Tan Chau-Singapore Company, contains very high organic concentrations (total COD of 9,649 mg O_2/L and BOD_5 of 7,405 mg O_2/L). This is because of the recycling of wastewater from the starch extracting stage for rinsing cassava roots. Though so far, no serious environmental problems have been caused by wastes from Tan Chau-Singapore Company, high organic and cyanide concentration of its wastewater is a potential of heavy pollution of Tha La River. This is especially the case for illegal discharge or an incident similar to the incident, which happened at Song Be-Singapore Company[49]. From Table 6.2, it is remarkable that concentrations of ammonia (N-NH_3), organic nitrogen (N-Org), phosphate (P-PO_4^{3-}), sulfate (SO_4^{2-}) and cyanide (CN^-) of tapioca wastewater from VEDAN Company (Mai et al, 2001) and Vietnam-Singapore Company (Oanh et al., 2001) vary in the same range.

Table 6.1 Characteristics of tapioca wastewater from Tan Chau-Singapore Company (April, 2002)[50]

Parameter	Unit	Sample 1	Sample 2	Sample 3
Color	-	White	Yellow white	White
pH	-	4.40	4.24	4.50
TDS	mg/L	703	1,625	595
Acidity	mg $CaCO_3$/L	520	2,600	526
SS	mg/L	2,900	8,600	4,920
VSS	mg/L	2,360	8,200	4,740
BOD_5	mg/L	7,405	19,018	7,500
COD_{total}	mg/L	9,649	27,348	11,629
COD_{filter}	mg/L	6,070	20,192	4,537
N-NH_3	mg/L	28.0	120.4	33.6
N-NO_3^-	mg/L	1.11	2.29	0.80
N-Org	mg/L	176	683	67
SO_4^{2-}	mg/L	Trace	6.27	7.19
PO_4^{3-}	mg/L	32.60	11.61	35.12
CN^-	mg/L	24	96	24

Sample 1: wastewater from root-rinsing stage; Sample 2: Wastewater from decanter;
Sample 3: Wastewater from open ditch, before releasing to pond system.

[48] These are all large-scale tapioca processing companies in Southern Vietnam.

[49] In 1997, one of the walls of the biological wastewater treatment ponds of Song Be-Singapore Company in Binh Phuoc Province was broken leading to releasing of wastewater into Tham Rot Spring (Lao Dong Newspaper, 1997). Consequently, about 300 kg of fishes was killed and flora was destroyed. Toxicity of cyanide is reported to be generally fatal to fish at concentration of 1 mg/L (Bridgwater & Mumford, 1997). Therefore, with cyanide concentration of 11 mg/L in the wastewater, water of Tham Rot Spring was too polluted for fish to stay alive.

[50] These samples were analyzed by the Center for Environmental Technology and Management – CENTEMA.

Other non-products generated from the production process of the company include hard roots and wood shells, fibrous residues and gaseous emission from heater. Currently, hard roots, wood shells, and fibrous residues are sold to farmers. Emissions from the heater are released freely through the chimney to the atmosphere. This does not only mean loss of heat but also contributes to deterioration of air quality in this area.

Table 6.2 Characteristic of wastewater* from large-scale tapioca processing companies in Vietnam

Parameters	Unit	Song Be-Singapore Company	VEDAN Company	Vietnam-Singapore Company
pH	-	4.1	4.9 - 5.7	4.5 - 5.1
SS	mg/L	1,142	500 - 3,080	3,750 - 4,100
COD_{total}	mg/L	15,613	7,000 - 14,243	14,262 - 41,406
BOD_5	mg/L	14,363	6,200 - 13,200	7,125 - 23,077
$N\text{-}NH_3$	mg/L	-	45 - 73	45 - 73
N-Org	mg/L	-	90 - 367	90 - 367
$P\text{-}PO_4^{3-}$	mg/L	-	10 - 45	10 - 45
SO_4^{2-}	mg/L	-	26 - 73	26 - 73
CN^-	mg/L	11	19 - 28	19 - 28

Source: Khoa and Boot, 1998; Mai et al., 2001; Oanh et al., 2001.
* Wastewater was only taken from the centrifuging process.

6.2 MATERIAL AND ENERGY BALANCES AND COST BENEFIT ANALYSIS FOR TAPIOCA PRODUCTION PROCESS AT TAN CHAU-SINGAPORE COMPANY

6.2.1 Production Process

The production process is divided into two main steps: (1) determination of weight and starch content of cassava roots and (2) starch processing.

Determination of Weight and Starch Content of Cassava Roots

Fresh cassava roots are transported to the company by trucks or ox-carts. The trucks and ox-carts entering the company are weighed at a balance. Cassava roots are then unloaded at the platform in front of the production workshop. About 18 kg of cassava roots is brought to a Starch Determination Room for starch content determination. The starch content of the roots is determined by comparing the weight of 5 kilograms of roots in air and in water. The percentage of starch in the roots is estimated from the determination of their specific gravity. At the Starch Determination Room, cassava roots are cut into small pieces of 4 – 6 cm without root-heads. Five kilograms of cassava pieces are then released into a balance basket submersed in water (Fig. 6.1). Counterpoise is adjusted to get the balance-beam equilibrium and the starch content can be read from the balance. This process is repeated 2-3 times and the final starch content is the average value of these tests.

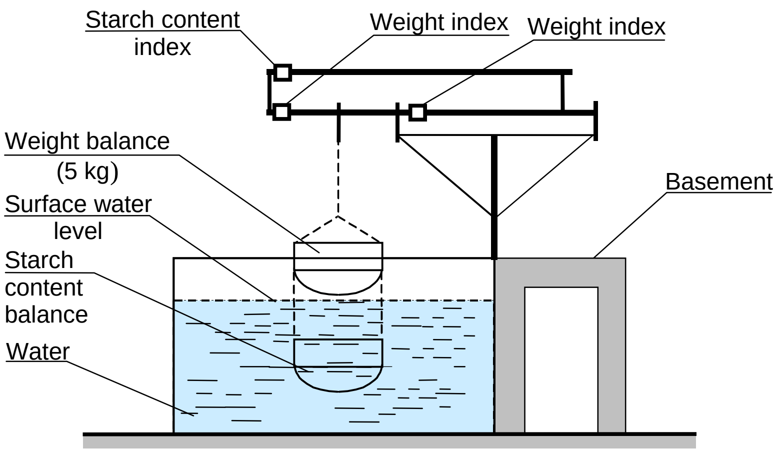


Fig. 6.1 Starch content determination.

After determining the starch content, the unloaded-trucks or ox-carts have to be re-weighed at the weight station to indicate the amount of cassava roots to be purchased by the company. Purchase cost is calculated as follows:

$$T = M \times (1 - m) \times h$$

Where M is the amount of cassava roots (kg), T is the purchase cost (VND), h the purchase unit cost, which is based on the starch content (VND/kg of starch) and m is the impurity content (m = 0.02-0.03).

Starch Processing

The tapioca starch production process at Tan Chau-Singapore Company can be described according to the following ten main stages (Fig. 6.2):

- Rinsing stage;
- Chopping and grinding stage;
- Raw fibrous residues separation stage;
- Milk sap separation stage;
- Fine fibrous residues separation stage;
- Dewatering by separators;
- Dehydration by dehydration horizontal centrifuges;
- Drying stage;
- Sifting stage;
- Machine cleaning.

Rinsing stage. From the storing area, cassava roots are transferred to a feed funnel by shovel machine. The cassava roots are dropped on a rubber conveyer, which leads to a grit screen. Along the conveyer, two workers are responsible for removal of the heads of the cassava roots.

The grit screen consists of parallel steel bars. Dirt, sand and a small proportion of wood shells are removed from cassava roots by applying colliding and frictional force between the screen and roots separating it from the roots through the bar-spaces of the screen. This solid waste source is stored at the solid waste storage area within the company.

After removing dirt and sand, the roots are transferred into a rinsing gutter. The gutter consists of three compartments containing a horizontal rotation axis with rotation bars on it (Fig. 6.3). The first compartment acts as a distribution section and removes remaining wood shells before transferring the roots into the second compartment, where the roots are submerged into water and mixed thoroughly by rotation bars. In addition, water from the distribution system falling down at high speed results in better removal of dirt, sand and a part of outer skins. Water used in this step is recycled water from the extracting stage (wastewater from separators).

Roots gradually move from the second compartment to the third one following the movement of the rotation axis and bars. The main differences between the third part and the two previous parts are: (1) the bottom of this part has parallel bar spaces of 50 mm x 10 mm for draining out washed water and (2) the water used in this step is fresh water. It takes about 5 minutes for cassava roots to pass through the rinsing gutter. The amount of generated wastewater from this stage is in the range of 25-30 m^3/h.

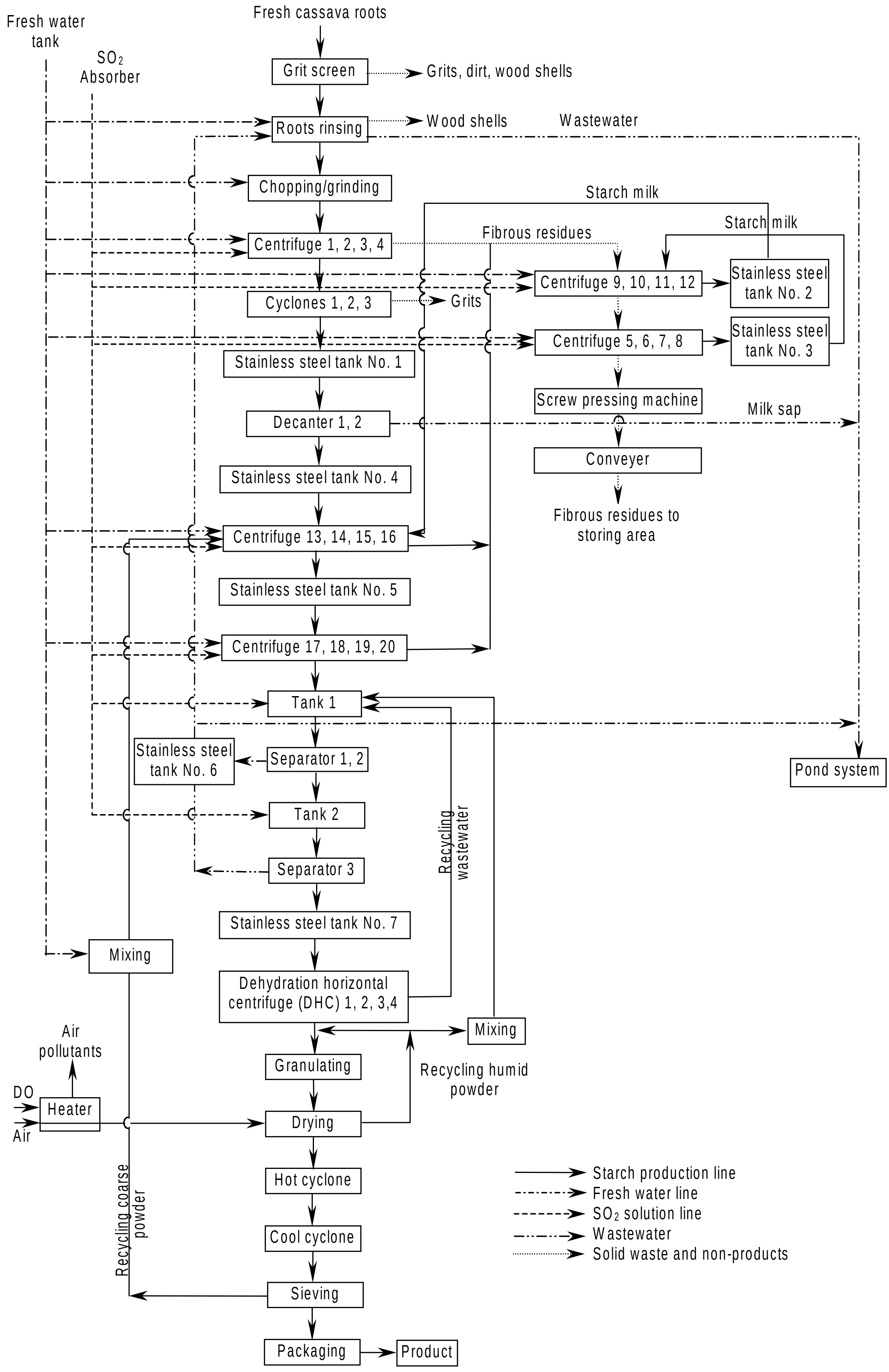


Fig. 6.2 Tapioca production process at Tan Chau-Singapore Company, Tay Ninh Province.

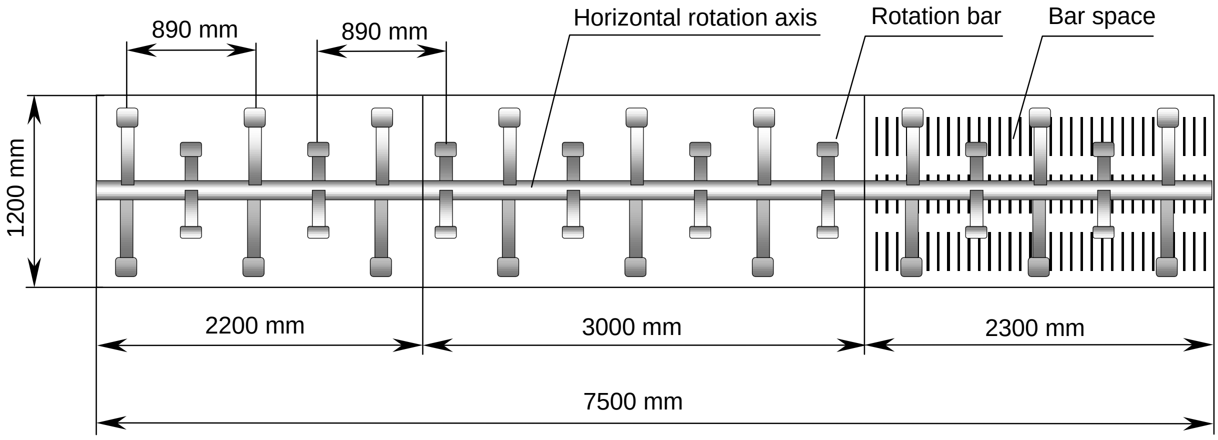


Fig. 6.3 Rinsing gutter.

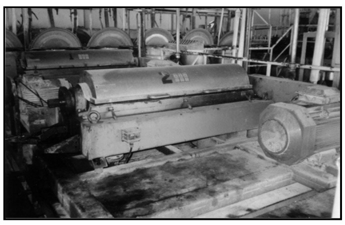
Chopping and grinding. The clean cassava roots are cut into smaller pieces of 20 x 20 mm by the cutting blade of the chopper before entering two 75 kW-grinders, where the cassava pieces are then grounded to fine particles. Before pumping into the centrifuges for separation of the fibrous residues, fresh water is added into the ground cassava mixture in order to avoid pump clogging.

Raw fibrous residues separation. The resulted mixture of starch and fibrous residues is pumped into the extracting system consisting of 4 centrifuges named 1, 2, 3 and 4 (as presented in Fig. 6.2). Fresh water and SO_2 containing water is added into the centrifuges to make a suitable dilution. With a speed of 480 rpm, the mixtures in the centrifuges are separated into starch milk and fibrous residues, which are treated further as follows:

- Starch milk is leaded through 3 cyclones for grit removal and then stored in stainless steel tank No. 1. Grits from these cyclones are removed every 1 hour.

- A large part of the fibrous residues is split up and pumped into centrifuges named 9, 10, 11 and 12, respectively for the second centrifugal stage. Starch milk from these centrifuges is stored in stainless steel tank No. 2 and pumped into the first fine fibrous residues separation system, while fibrous residues are transferred into centrifuges 5, 6, 7 and 8 for recovering remaining starch. Starch milk from centrifuges 5, 6, 7, 8 are stored in stainless steel tank No. 3 and returned to centrifuges 9, 10, 11 and 12. Separated fibrous residues from centrifuges 5, 6, 7 and 8 are passed through the screw pressing machine for fibrous residues dewatering. Water from this process is recycled to the stainless steel tank No. 3 and dewatered fibrous residues move along the conveyer to the storing area. The total amount of dewatered fibrous residues is about 20 tons/day (by wet weight). Wet fibrous residues are sold directly at a price of 70 VND/kg of wet fibrous residues or 350 VND/kg of dry fibrous residues.

Milk sap separation. Starch milk, which is produced from the previous step and stored in the stainless steel tank No. 1, is pumped into the decanters 1 and 2. These are horizontal cylindrical centrifuges, separating most of the impurities such as protein, fat, soluble saccharides (oligo-saccharides and mono-saccharides) and other soluble substances, which are called milk sap, out of the stream. This starch milk is stored in stainless steel tank No. 4 and then pumped into centrifuges 13, 14, 15 and 16 for the first fine fibrous residues separation. Removed milk sap is discharged into open ditches



Decanter

and released into the wastewater pond system. The amount of generated wastewater from this stage is in the range of 30-32 m^3/h.

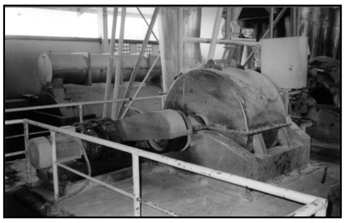
Centrifuges

Fine fibrous residues separation. The separated starch milk from the previous step, which is contained in the stainless steel tank No. 4, is pumped into centrifuges 13, 14, 15 and 16. From these centrifuges, separated fibrous residues are returned back to the centrifuges 9, 10, 11 and 12, while starch milk is stored in stainless steel tank No. 5 and then transferred into the second fine fibrous residues separation system consisting of 4 centrifuges numbered 17, 18, 19 and 20. The starch milk from this process is stored in tank 1 before transferring it into the separator, while separated fibrous residues are returned back to the centrifuges 9, 10, 11 and 12.

During centrifuging, fresh water and sulfur dioxide (SO_2) containing water are pumped into each centrifuge for separation of starch milk and fibrous residues and for starch bleaching. In order to produce SO_2 containing water for starch bleaching, solid sulfur is oxidized at 180^oC to form SO_2. Formed SO_2 is absorbed in fresh water to form H_2SO_3 solution with a pH of 1.5-2.5. This solution is added to the centrifuges and tank 1 and 2 for starch bleaching. The SO_2 concentration in the processing water is controlled in an appropriate way in order to produce good quality starch (white color and low microbial contamination). After drying, there should be no sulfur dioxide left (or less than 0.002%S) in the final product.

Dewatering by separators. After centrifuging, the left over starch milk in tank No. 1 containing a low starch content (of about 5^o bome'[51]) is pumped into separators 1, 2 for dewatering. Starch milk released from separator 1 and 2 has a starch content of about 15^o bome' and is stored in tank No. 2. Removed water is stored in stainless steel tank No. 6 and reused in the root-rinsing stage (about 5-6 m^3/h). The starch milk from tank No. 2 is then dewatered again in separator 3 to increase the starch content up to 18-20^o bome' before storing it in stainless steel tank No. 7. Removed water from separator 3 is also returned back to the stainless steel tank No. 6. Excess wastewater from the stainless steel tank No. 6 (about 15 - 18 m^3/h) is released into the open ditches.

Separator for dewatering process



Dehydration horizontal centrifuge (DHC)

Dehydration. The dewatered starch milk, which is generated from the previous dewatering step and stored in the stainless steel tank No. 7, is pumped into 4 dehydration horizontal centrifuges (DHC) 1, 2, 3 and 4 for centrifuging at a speed of 1,450 rpm. In this step, starch is concentrated at a moisture content of about 35% and then granulated (forming powder) by a starch raker. Water separated from DHCs is recycled back to tank No. 1.

Drying. Wet powder starch is transferred into drying machines by a screw conveyer and raker system. The drying temperature of 180^0C is supplied by a heater using fossil fuel oil (FO and DO) as fuel. On contact with hot air in a 30 m-drying column, starch particles are dried. Dry particles, which due to the light density have a tendency to flow up, are collected through a hot (consisting of 10 parallel-cyclones) and cool (consisting of 3

Drying column and hot cyclone

[51] Unit indicates starch content.

successive cyclones) cyclone system. Starch, which contains higher moisture will fall down to the bottom of the drying column and is recycled back to the raker.

Sifting. Dry starch from hot and cool cyclone system is transferred into a sieving system. Starch passing through the sieving system is packed, while the remaining starch is collected, mixed with fresh water and returned back to centrifuges 13, 14, 15 and 16.

Machine cleaning. Centrifuges are cleaned after operating for an interval of 2 hours. Filter clothes are replaced every 8 hours (every shift). Water from the rinsing gutter (about 1.5 m^3) is also renewed before operating a new shift.

On average, it takes about 45 minutes to produce dry starch from fresh cassava roots. The company is operated continuously 24 hours a day, for 3 shifts/day with 27 workers/shift.

6.2.2 Inputs and Outputs of Tapioca Production Process

Inputs

Raw material demands. Raw materials required for production activities of the company (Table 6.3) consist of (1) materials for water treatment and (2) materials for starch production process. Starch content of fresh cassava roots varies in the range of 20-30% by wet weight.

Table 6.3 Demand of raw materials for production of the company

Raw material	Unit	Maximum amount	Note
Fresh cassava roots	tons/year	120,000	For starch processing
Sulfur	tons/year	38	For starch processing
Wrapping	bags/year	600,000	For starch processing
Alum	tons/year	50	For supply water treatment
Chlorine	kg/year	650	For supply water treatment
$Ca(OH)_2$	tons/year	40	For supply water treatment
NaOH	kg/year	500	For supply water treatment

Source: Tan Chau-Singapore Company, 2002.

The price of fresh cassava roots varies depending on the starch content (Table 6.4), which is determined as presented in section 6.2.1.

Table 6.4 Purchasing prices of fresh cassava roots in accordance with starch content

Starch content (% by wet weight)	Purchase price (VND/kg of fresh cassava roots)
30	530
29	510
28	490
27	470
26	455
25	435
24	415
23	400
22	396
21	380
20	370

Source: Tan Chau-Singapore Company, 2002.
Exchange rate = 15,400 VND/USD (February, 2002)

Electricity demand. Total energy consumption of all electric machines used in the production process is about 37.4 KWh/ton cassava roots, equivalent to 14,960 KWh/day.

Fuel demand. Fuel used in the production process consists of 30 liters fossil fuel oil (FO) and 3,900 liters diesel oil (DO) a day.

Labor demand. All activities of the company required 93 staff and workers in total.

Water supply demand. Tha La River's water is a supply source for the production activities of the company and is treated before use. With the production process as described, water is needed for root rinsing, chopping and grinding, starch extracting by centrifuges, mixing unqualified starch before recycling, absorption of SO_2 and machine and floor washing at the end of each shift. The demand of fresh water used to process 400 tons of fresh cassava roots per day was measured and calculated as the sum of the following water usage during the process.

- Amount of water needed for roots rinsing including:

  + Fresh water, which is supplied continuously to the third compartment of the rinsing gutter with a flow rate of 40 m^3/h. Thus, total amount of water supplied for this process is 960 m^3/day.

  + Freshwater needed for filling the second compartment of the gutter: at the end of each shift, dirty water in the second compartment of the rinsing gutter is drained off completely before filling it with fresh water. The amount of wastewater drained from this compartment is estimated based on the dimensions of the second compartment of the rinsing gutter as illustrated in Fig. 6.4. With a length of 3 m, the total amount of fresh water supplied intermittently in this process is

$$(0.40 \times 1.20 \times 3.00) + \left(\frac{\pi \times \frac{1.20^2}{4}}{2} \times 3.00 \right) = 3.14 (m^3/shift) = 9.42\ (m^3/day)$$

→ Thus, total flow rate of water needed for root rinsing is 969.42 m^3/day.

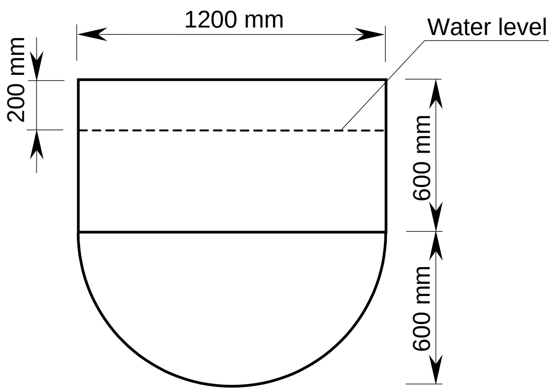


Fig. 6.4 Cross-section of the second compartment of the rinsing gutter.

- Amount of water needed for chopping and grinding stage

  Water supply in this stage is used to dilute the ground mixture to create a better condition for pumping. The flow rate of the water used in this process is 0.4 m^3/h, equivalent to 9.6 m^3/day.

- Amount of water needed for starch extracting stage consisting of:

  + Fresh water, that is supplied continuously to 20 centrifuges with a flow rate of 2 m^3/h/centrifuge;

  + Fresh water which is supplied for washing the centrifuges with flow rate of 1 m^3/h for 3 minutes. Each centrifuge is cleaned every two hours. On average, each centrifuge is cleaned for

$$\frac{24\frac{h}{d}}{2\frac{h}{time}} \times 3\frac{\min}{time} \times \frac{1}{60}\frac{h}{\min} = 0.6 \text{ (h/day)}$$

  Therefore, the actual water supply time for each centrifuge is (24 – 0.6) = 23.4 (h/day). In other words, total amount of fresh water supplied to the centrifuges is:

  2 m^3/h/centrifuge x 23.4 h/day x 20 centrifuge = 936 m^3/day.

  → Total amount of fresh water supplied for washing of the centrifuges is

  1 m^3/h/centrifuge x 0.6 h/day x 20 centrifuge = 12 m^3/day.

- Amount of water needed for mixing unqualified starch before recycling

  About 2 tons/day of unqualified starch from the drying and sifting stage are mixed with water and recycled to centrifuges 13, 14, 15 and 16 for re-extracting. Such starch is mixed with fresh water in 1 m^3 stainless steel according to a ratio of 50 kg of starch to 0.6 m^3 of water. Thus, the total amount of fresh water used for this purpose is 24 m^3/day.

- Total amount of water needed for the absorption of SO_2 is 33.6 m^3/day.

- Amount of water needed for machine and floor washing is the sum of:

  + Amount of water needed for washing 4 dehydration horizontal centrifuges of 2 m^3/shift;
  + Amount of water needed for washing 20 centrifuges of 12 m^3/day.
  + Average of amount of water needed for floor washing of about 10 m^3/day.

→ Thus the total amount of water needed for this purpose is 28 m^3/day.

From all the data as presented, the total amount of water supplied for the tapioca production process of Tan Chau-Singapore Company is 2,000 m^3/day or 5.0 m^3/ton fresh cassava roots (Table 6.5).

Table 6.5 Water demand for tapioca production process of Tan Chau-Singapore Company

Stage	Demand	
	(m^3/day)	(m^3/ton of fresh cassava roots)
Root rinsing	969.4	2.424
Chopping and grinding	9.6	0.024
Starch extracting	936.0	2.340
Mixing unqualified starch	24.0	0.060
SO_2 absorption	33.6	0.084
Machine and floor washing	28.0	0.070
Total	**2000.6**	**5.002**

Outputs

Product. Processing 400 tons of fresh cassava roots (FCR)/day produces 92 tons dry starch/day.

Wastewater discharging. Wastewater is generated from root rinsing, milk sap removal, dewatering by separators and machine and floor washing. Determination of the generated wastewater of each production step was limited due to current arrangement of equipment and machines in the production process and its operation procedure. Actual measurements only determined the total amount of wastewater of the whole production process and the amount of wastewater from milk sap removal. Other values are estimated by making a wastewater balance.

The total amount of wastewater generated from the whole production process was determined by measuring the wet cross section of the combined wastewater ditch and the velocity of the stream. By measuring the time needed for a leaf to move over a distance of 5 m, the surface velocity (V_s) of the stream can be estimated and interpreted in terms of meter per second. The velocity of the stream (V) is estimated by 0.8 V_s (Nhan and Nga, 1999). The total amount of wastewater generated is the product of the wet cross section area and the velocity of the stream (Table 6.6).

Table 6.6 Total amount of wastewater from the production process of Tan Chau-Singapore Company

	Surface velocity (V_s)			Velocity of the stream	Area of wet cross section	Amount of wastewater	
	Length (m)	Average time (s)	V_s (m/s)	V= 0.8 V_s (m/s)	(mm x mm)	(m^3/s)	m^3/day
Operating	5	9.41	0.53	0.424	600 x 85	0.0216	1,866
End of shift	5	7.57	0.66	0.528	600 x 90	0.0285	51
Total							**1,917**

Thus, the total amount of wastewater generated was about 79.88 m^3/h or equivalent to 4.8 m^3/ton fresh cassava roots. The amount of wastewater generation in this case is less than the amount generated in Tra Co Village (5.14 m^3/ton of fresh cassava roots) (chapter 5). This is attributed to recycling of wastewater from the dewatering stage for rinsing fresh cassava roots. Separate streams of wastewater were measured and calculated as follows:

- Amount of wastewater from the milk sap removal stage ($Q_{decanter}$) was determined by measuring the wastewater flow rate of decanter's discharge pipe. A known volume container was filled with this wastewater and filling time was counted exactly. The flow rate is the ratio of the filled volume and the determined time. The survey result shows that the average flow rate of generated wastewater from this stage is 6.08 m^3/h (or 145 m^3/day) which approximately equals to 0.363 m^3/ton fresh cassava roots.

- Amount of wastewater from the dewatering stage can be determined by the following balance:

  $Q_{dewatering} = Q_{operating} - Q_{decanter} - Q_{thirdcompartment}$

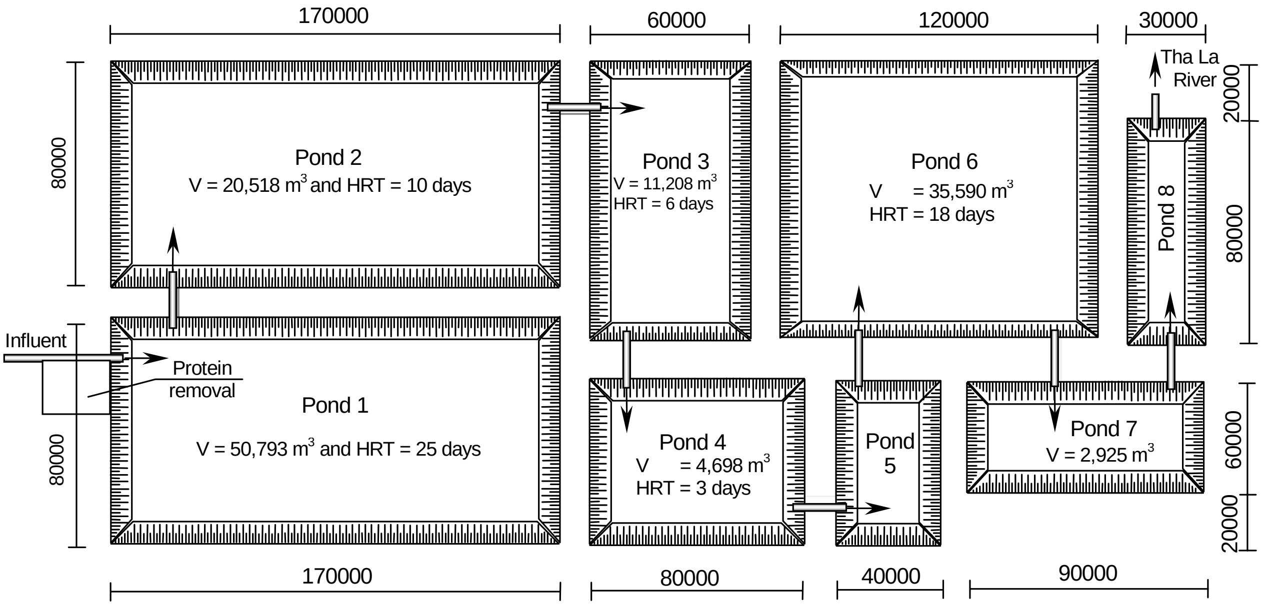
  $Q_{dewatering} = 1866 - 145 - 960 = 761$ (m^3/day) or 1.903 (m^3/ton of fresh cassava roots)

- Amount of rinsing wastewater generated consists of wastewater from the third compartment of the rinsing gutter, the second compartment at the end of each shift and recycling wastewater from the dewatering stage. Thus, the total amount of wastewater from rinsing stage is

  $Q_{rinsing} = Q_{thirdcompartment} + Q_{secondcompartment} + Q_{dewatering}$

  $Q_{rinsing} = 960 + 9.42 + 761 = 1{,}730$ (m^3/day) or 4.325 (m^3/ton of fresh cassava roots)

All generated wastewater from the tapioca production process of the company from 1994 up till now is stored in a pond system as presented in Fig. 6.5.



** Dimension unit of the ponds presented in this figure is in millimeter.*

Fig. 6.5 Layout of wastewater pond system at Tan Chau-Singapore Company, scale 1/2500.

Table 6.7 presents the characteristics of wastewater from the discharged point into the first pond, effluent of the second pond and at the end of the last pond before releasing into Tha La River. Organic matters are degraded gradually while passing through these ponds. However, effluent from the pond system still does not even meet Class B of the TCVN 5945-1995[52] (the bold numbers in Table 6.7 indicated values above the standards). The current solution can only reduce adverse impact to the river water, but it faces obstacles of low efficiency of pollutant removal, limitation of land and waste of water resources. It would be more useful in terms of economic and environmental benefits to use 69,700 m^2, occupying by the current wastewater treatment system, for tapioca production, cassava cultivation or fish culture.

Table 6.7 Characteristics of wastewater [53]in the pond system at Tan Chau – Singapore Company

Parameter	Unit	Sample 1	Sample 2	Sample 3	Sample 4	TCVN 5945-1995	
						Class A	Class B
Color	-	White	Black	Black	Green	-	-
pH	-	**4.50**	6.86	7.31	8.44	6-9	5.5-9
TDS	mg/L	595	1,315	1565	775	-	-
Acidity	mg $CaCO_3$/L	526	304	104	0	-	-
SS	mg/L	**4,920**	**1,529**	**400**	**288**	50	100
VSS	mg/L	4,740	1,143	346	252	-	-
BOD_5	mg/L	**7,500**	**1,307**	**371**	**233**	20	50
COD_{total}	mg/L	**11,629**	**2,055**	**721**	**511**	50	100
COD_{filter}	mg/L	4,537	432	230	153	-	-
N-NH_3	mg/L	**33.6**	**196**	**255**	**42**	0.1	1
N-NO_3^-	mg/L	0.80	Trace	Trace	Trace	-	-
N-Org	mg/L	67	106	67	42	-	-
SO_4^{2-}	mg/L	7.19	Trace	Trace	Trace	-	-
PO_4^{3-}	mg/L	**35.12**	**62.54**	**69.30**	**56.55**	4	6
CN^-	mg/L	**24**	**8**	**16**	**0.6**	0.05	0.1

Sample 1: Wastewater from open ditch, before releasing to the first pond;
Sample 2: Effluent from the first pond;
Sample 3: Effluent from the second pond;
Sample 4: Effluent from the last pond before discharging into Tha La River.

[52] Vietnamese Industrial Wastewater Discharge Standards (see appendix 4).
[53] These samples were taken at the same time.

Fibrous residues generation. Total amount of dewatered fibrous residues is 59.26 tons/day (by wet weight) corresponding to 0.148 ton/ton fresh cassava roots with a moisture content of about 65% (by wet weight). Wet fibrous residues are sold to farmers for further drying before re-selling it for animal feed production. However, during period of heavy rain, farmers will not purchase wet fibrous residues, so the company has to leave it in the heaps. Natural fermentation in the fibrous residues' heaps converts it into a kind of soil enhancement material, which is normally given free of charge to farmers for fertilizing cassava fields or disposed as municipal solid wastes

Pieces of hard roots and wood shell generation. Total amount of generated hard roots and wood shells is in the range of 0.023 tons/ton fresh cassava roots with a moisture content of about 30% (by wet weight). At present, hard roots and wood shells are incubated to produce compost and given free of charge to farmers.

Air Emission. Air pollutants emit mainly from the heater where diesel oil (DO) and fossil fuel oil (FO) are used. Consumption of 3,900 L/day of DO and 30 L/day FO causes an emission of about 92 kg/day of SO_2, 13 kg/day of SO_3, 45 kg/day of NO_x and 1.07 kg/day of dust into the atmosphere. So far, gas emission from the heater is released directly into the atmosphere through a chimney with a height of 18 m and a diameter of 0.6 m.

6.2.3 Material and Energy Balances

These balances are carried out around the boundary of Tan Chau-Singapore Company with three main routes: solid material (cassava roots, tapioca starch, solid non-products and wastes), liquid material (supplied water and generated wastewater) and energy (electrical and thermal energy) balance. All calculations are based on the results of the in depth survey as presented in section 6.2.2.

Solid material balance. This balance only considers the flow of all solid materials through the production process including raw materials, products, byproducts and wastes. These are fresh cassava roots, dry starch product, pieces of hard roots and wood shells and dewatered fibrous residues. Mass balance in terms of dry weight for solid material flows can be expressed as follows:

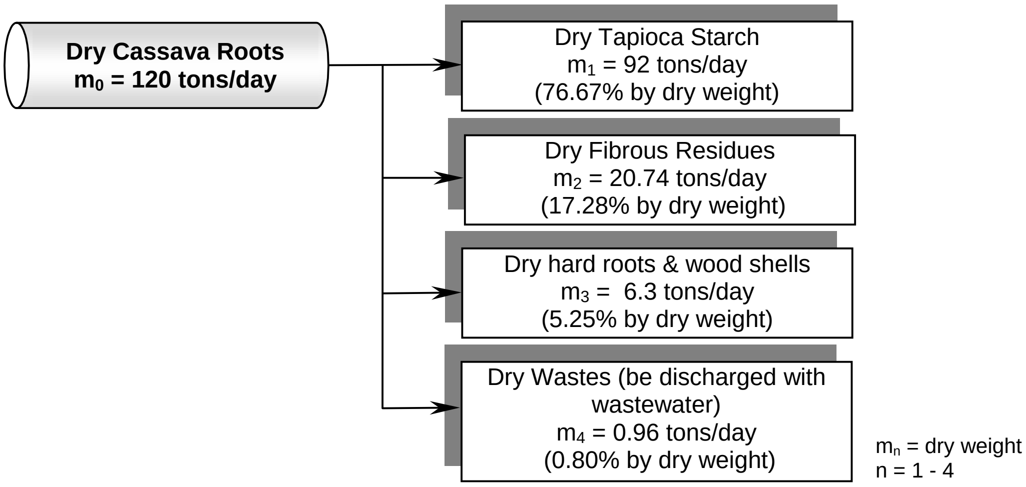
Mass of cassava roots = mass of dry starch product + mass of fibrous residues + mass of hard roots and wood shells + mass of loss (mass of waste):

$$400 \times (1 - 0.70) = 92 + 59.26 \times (1 - 0.65) + 9 \times (1 - 0.3) + \text{mass of wastes}$$

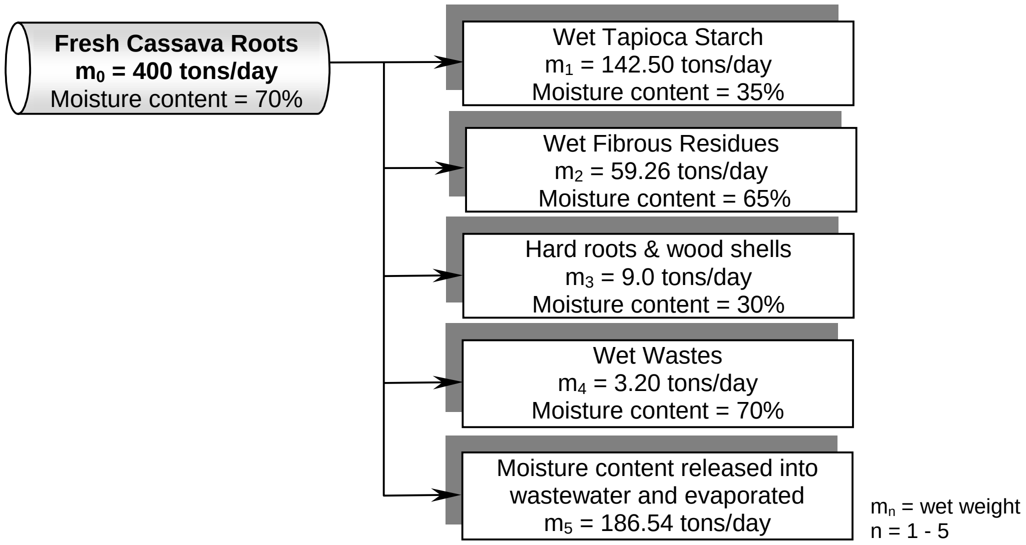
$$120 = 92 + 20.74 + 6.3 + \text{mass of waste}$$

Mass of waste = 0.96 tons/day

Thus, the amount of dry solid material that could not be measured in solid form was 9.87 tons/day, equivalent to 0.8% of the raw material by dry weight. This amount of solid material is discharged together with the wastewater. The mass balance for solid material flows in terms of dry and wet weight are described in Fig. 6.6.



(a) Mass balance in terms of dry weight for solid material flows.



(b) Mass balance in terms of wet weight for solid material flows.

Fig. 6.6 Mass balance in terms of dry weight (a) and wet weight (b) for solid material flows of the tapioca processing at Tan Chau- Singapore Company.

Liquid material balance. In this balance, all liquid materials including supplied water and generated wastewater are considered. The volume balance of liquid material flows is described in Fig. 6.7.

A difference of about 0.2 m^3 supplied water/ton cassava roots compared to the generated wastewater is attributed to water loss both through evaporation and containing in solid byproducts.

Energy balance. The most important cost factor in the tapioca processing is the energy consumption, which is divided into two groups, namely electrical energy and thermal energy (from burning fuel). Most machines such as the rinsing gutter, chopper and grinder, centrifuges, separators, dehydration horizontal centrifuges, mixing, pumping and screw conveyors are installed with motors and work continuously. Tan Chau-Singapore Company consumes about 28.8 KWh/ton of fresh cassava roots. To supply the thermal energy for the drying process, 39 L of fuel (DO) per ton of starch product are consumed. The energy balance is presented in Fig. 6.8. All supplied electricity and fuel was consumed, no other energy sources were generated from the current production process.

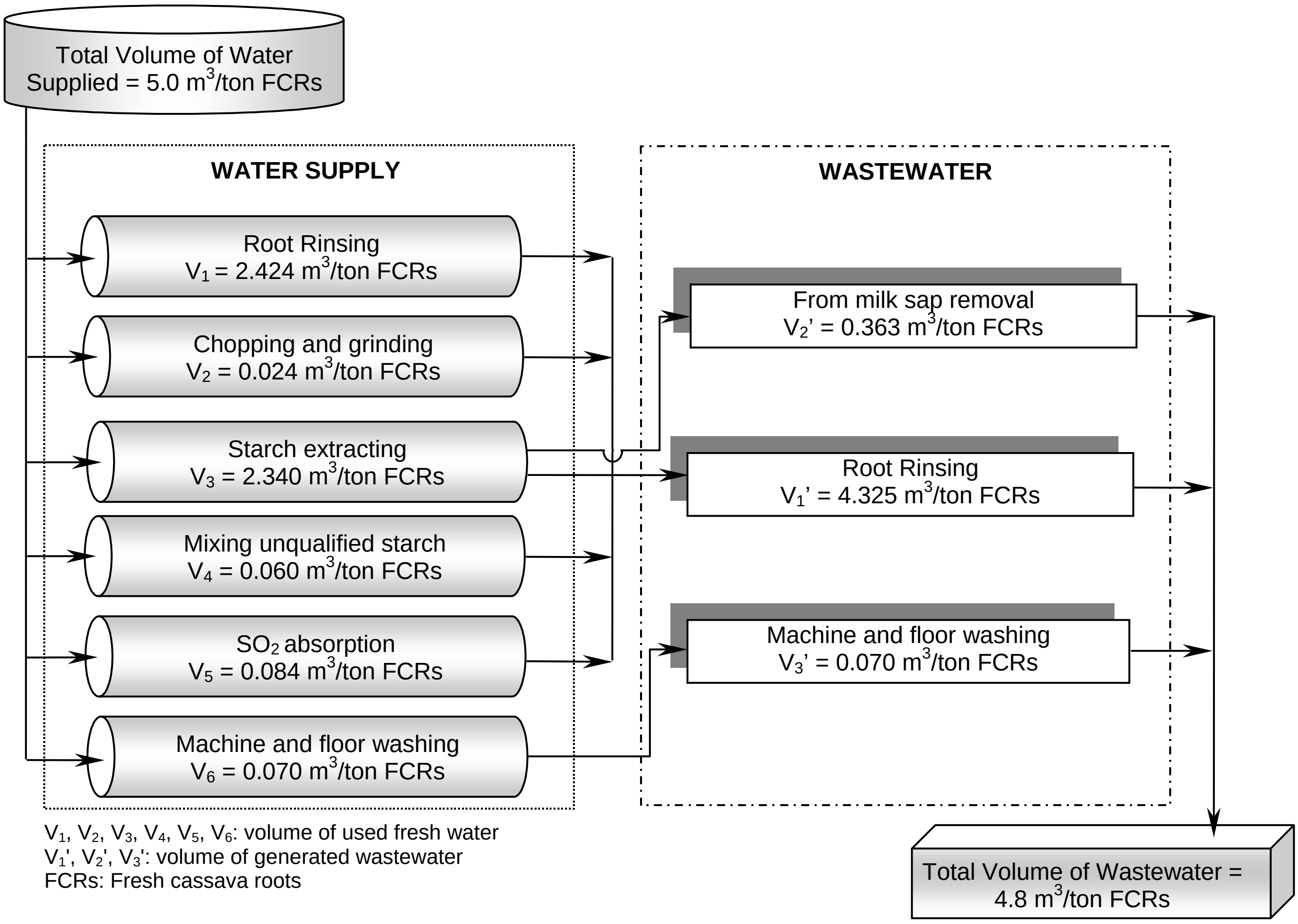


Fig. 6.7 Volume balance for liquid material flow of the tapioca production process at Tan Chau-Singapore Company.

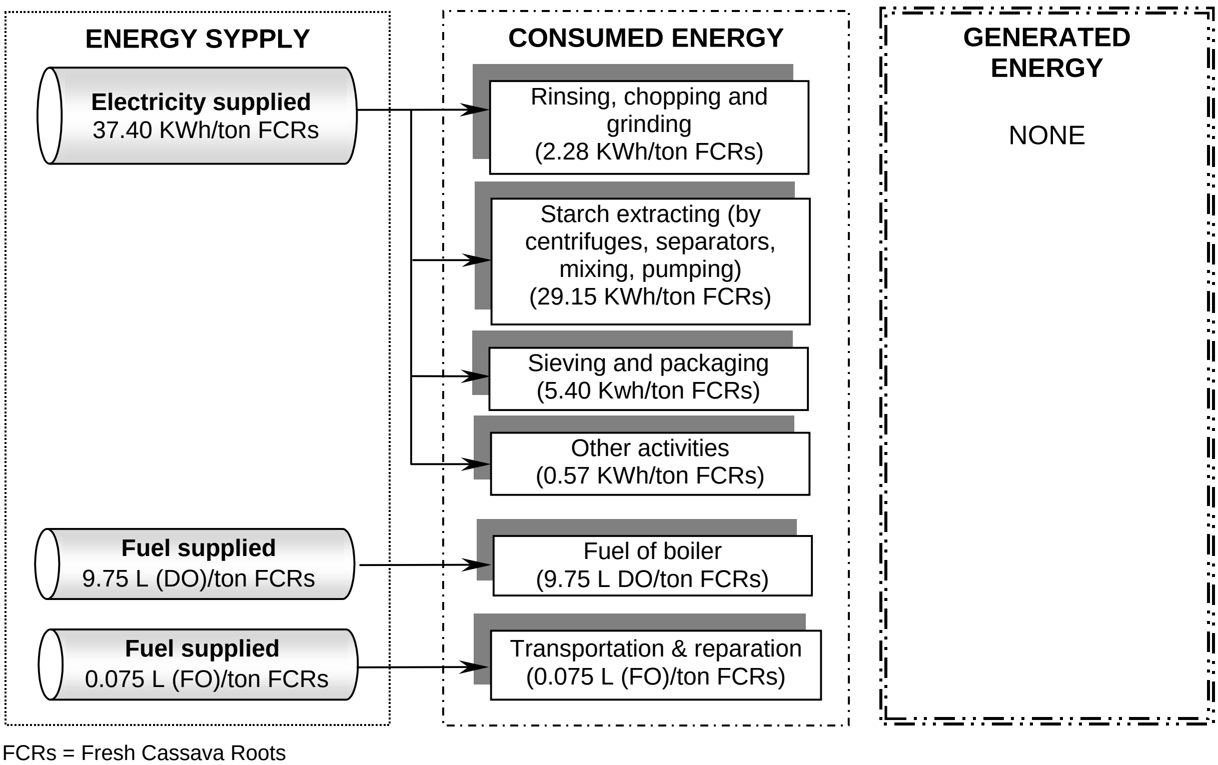


Fig. 6.8 Energy balance of the tapioca production process at Tan Chau-Singapore Company.

6.2.4 Cost Benefit Analysis

Production costs consist of the expenditure for purchasing fresh cassava roots, electricity, fuel, water supply, machine depreciation and labor. The producer earns money from selling dry tapioca starch and wet fibrous residues. The total production costs and incomes are described in Table 6.8 and 6.9, respectively. Net profit is the difference between income and production costs.

Table 6.8 Production cost per kg processed fresh cassava roots

Items	Unit	Amount	Unit Cost	Total Cost (VND/d)	Cost (VND/kg fresh root)
Fresh cassava roots	kg/day	400,000	450 VND/kg	180,000,000	450.00
Sulfur	kg/day	50	50,000 VND/kg	2,500,000	6.25
Electricity	KWh/day	14,960	1,200 VND/KWh	17,952,000	44.88
FO	L/day	30	1,800 VND/L	54,000	0.14
DO	L/day	3,900	3,800 VND/L	14,820,000	37.05
Supply water*	m^3/day	2,000	190 VND/m^3	380,000	0.95
Depreciation**	%/year	5	2,706,550,000 VND/year	9,021,833	22.55
Labor	Person/day	93	50,000 VND/person/d	4,650,000	11.63
Total (in VND/kg fresh roots)					573.45
Total (in USD/kg fresh roots)					0.0372

* Cost of water supply is estimated in Table 6.10. Exchange rate = 15,400 VND/USD (February, 2002).

** Total investment capital (including machine and building) is 3.515.000 USD and the system is proposed to operate for 40 years (Tan Chau-Singapore Company, 1996). However, for depreciation, the calculation is based on 20 years or equivalent to 5%/year.

Table 6.9 Income per kg processed fresh cassava roots

Items	Unit	Amount	Unit Cost	Total Cost (VND/day)	Cost (VND/kg fresh root)
Dry tapioca starch	kg/day	92,000	2,700 VND/kg	248,400,000	621.0
Fibrous residues	kg/day	59,260	70 VND/kg	4,148,200	10.37
Total (in VND/kg fresh roots)					631.37
Total (in USD/kg fresh roots)					0.0410

Exchange rate = 15,400 VND/USD (February, 2002)

Thus, net profit from the production process of the company is about 57.92 VND/kg fresh roots or 23,168,000 VND/day, equivalent to 1,504 USD/day.

Table 6.10 Cost of supply water

Items	Unit	Amount	Unit Cost	Total Cost (VND/year)	Cost (VND/m^3 treated water)
Alum	tons/year	50	2,000,000 VND/ton	100,000,000	167
Chlorine	kg/year	650	5,000 VND/kg	3,250,000	5
$Ca(OH)_2$	tons/year	40	200,000 VND/ton	8,000,000	13
NaOH	kg/year	500	5,000 VND/kg	2,500,000	4
Total in VND/m^3					190

6.3 PHYSICAL-TECHNOLOGICAL MODEL OF A ZERO WASTE INDUSTRIAL ECOSYSTEM AT TAN CHAU-SINGAPORE COMPANY

Based on the analysis of the existing material and energy flows at Tan Chau-Singapore Company, this section continues to develop a physical-technological model of a zero waste industrial ecosystem at Tan Chau-Singapore Company as presented in four sub-sections. Possibilities for prevention and minimization of waste generation within the company are described in sub-section 6.3.1. Waste material flow network creation is a successive sub-section (subsection 6.3.2), in which possibilities for offsite reuse and recycling or waste exchange are discussed. Sub-section 6.3.3 is devoted to treatment methods for the remaining wastes to avoid their harm to the environment. Finally, all selected options are integrated to develop the physical-technological model.

6.3.1 Preventing and Minimizing the Generation of Non-products

Solid Non-Products

As described in section 6.2.1, the collected solid non-products mainly are pieces of hard roots and wood shells, and fibrous residues. Besides, uncollected solid materials (consisting of fibrous residues and starch particles), that account for about 0.8% by dry weight of solid material (Fig. 6.6) is discharged together with the wastewater. This causes the high concentration of volatile suspended solid, which is found in wastewater from the open ditch (around 4,900 mg/L). Similar to the case of Tra Co Village, the collected non-products, called solid byproducts are all reusable and not harmful to the environment. Therefore, prevention and reduction of the generation of these solid byproducts aims mainly at increasing the production efficiency.

Hard roots and wood shells must be removed because they do not contain starch. The major compounds of wood shells are cellulose and hemicellulose without starch. The wood shell layer acts as a protector for the cassava root of external forces. The wood shell layer is rather thin, occupies about 0.5-2% by weight of fresh cassava roots and needs to be removed as much as possible during tapioca processing. Additionally, during the rinsing stage, the shell layer (which is sequential to the wood shell layer) is also removed. This shell layer occupies 5-20% by weight of fresh cassava roots and comprises of cells. The cell walls consist of cellulose. Interior of the cell are starch particles, nitrogen compounds and cytoplasm, which contains tannin, pigment, toxin, enzymes, etc. Even though this shell layer contains 5-8% of starch, components of cytoplasm can affect the color of starch product and it is thus necessary to remove a proportion of this layer. Thus, the generation of 16 tons/day, equivalent to 2.25% (by weight of fresh cassava roots), of hard roots and wood shells (including shell layer) is a reasonable estimation. In other words, the generated amount of this byproduct is in an acceptable range and it is not necessary to apply other technologies to minimize its generation.

Fibrous residues are generated during the extraction stage. It is indicated from a mass balance of wet weight for solid material flow (Fig. 6.6) that about 59.26 tons/day of wet fibrous residues with a moisture content of 65%, equivalent to 14.82% by weight of total fresh cassava roots, are removed from three stages of starch extraction. Experiences from 41 modern tapioca factories in Thailand show that the amount of generated fibrous residues is around 6-10% by weight of fresh cassava roots with a moisture content of about 50% (Sriroth, 1996). Consequently, our value does not indicate a high efficiency of the starch extraction stage but does show a good performance of fibrous residues dewatering stage. The use of a screw press for fibrous residues dewatering causes a higher moisture content (65%). However, this only affects the drying stage of fibrous residues that are reused for animal feed production. Energy to dry fibrous residues is a major factor to decide whether it is necessary to modify the dewatering machine or to invest in new machines for drying fibrous residues.

Milk sap, containing most of the impurities such as protein, fat, soluble saccharides and other soluble substances (which affect quality of starch), is separated by decanters and discharged together with the wastewater. In this case, the generation of milk sap is unavoidable. In addition, milk sap separation is carried out mechanically using modern decanters, so that the generation of milk sap is at minimum level. Therefore, recovery of fibrous residues released together with other components in the milk sap stream is a better solution than reduction of its generation.

Wastewater

With a water circulation in the production process as presented in Fig. 6.2, wastewater is generated mainly from root-rinsing, milk sap removal and machine and floor washing. The balance of the liquid material flow (Fig. 6.7) shows that the total net amount of generated wastewater is 4.8 m^3/ton fresh cassava roots, equivalent to 20.9 m^3/ton starch. Experiences of Thailand in tapioca production indicated that the consumption of water varies from 15 to 30 m^3/ton starch, depending on the availability of water and the efficiency of water circulation within the production process (Sriroth, 1996). A decrease in the amount of consumed water or generated wastewater can be achieved by designing and installing a system for optimum water circulation in the process and/or by introducing a new type of separator (3 phase separator), which produces high quality starch (as concentrate), a medium phase and a light phase (water for recirculation). Application of hydrocyclone technology can reduce around 49-52% of the amount of water consumption and wastewater generation and there is little difference in the characteristics of wastewater with or without hydrocyclone use (Marder and Trim; 1996 and see also section 5.5.1). Though installation of a new three-phase separator or using a hydrocyclone would be possible, new installation will create extra costs, which is always undesirable from a company point of view and it will be difficult to convince the company to apply these. Therefore, it is suggested to modify water circulation of the production process to decrease water consumption as well as wastewater generation. We share the experiences from Thailand that it is possible to recycle the liquid stream from separators 1, 2 and 3 (from stainless steel tank) to the centrifuges 5 to 12 and recycle a proportion of the liquid stream from the centrifuges 9, 10, 11, 12 to the choppers and grinders. By doing so, the amount of fresh water consumed in these stages is reduced and as a result the amount of generated wastewater is also reduced. All the company needs to do is to change the positions of some of their liquid pipes. This option is simple and feasible, because there are nearly no extra costs. Of course, it is necessary to adjust the current operation procedure following the new water circulation. However, this can be done easily because the water balance in the process is well understood by the workers. The modification of water circulation in the production process of Tan Chau-Singapore Company is described in Fig. 6.9.

Energy

Electrical energy consumption in the production process can not be reduced because the quantity and types of used machines are fixed. Thermal energy for the drying process consumes 39 L of DO per ton of produced starch. This value is much lower than that in Thailand (60 L of FO/ton starch) (Sriroth, 1996). It is attributed to better controlling of the combustion and because a suitable insulator is applied. The price of DO is cheaper than gas, however it causes more air pollution. Therefore, a suitable solution would be either proper treatment of the emitted polluted air from heater before releasing into the atmosphere or replacement of DO by gas.

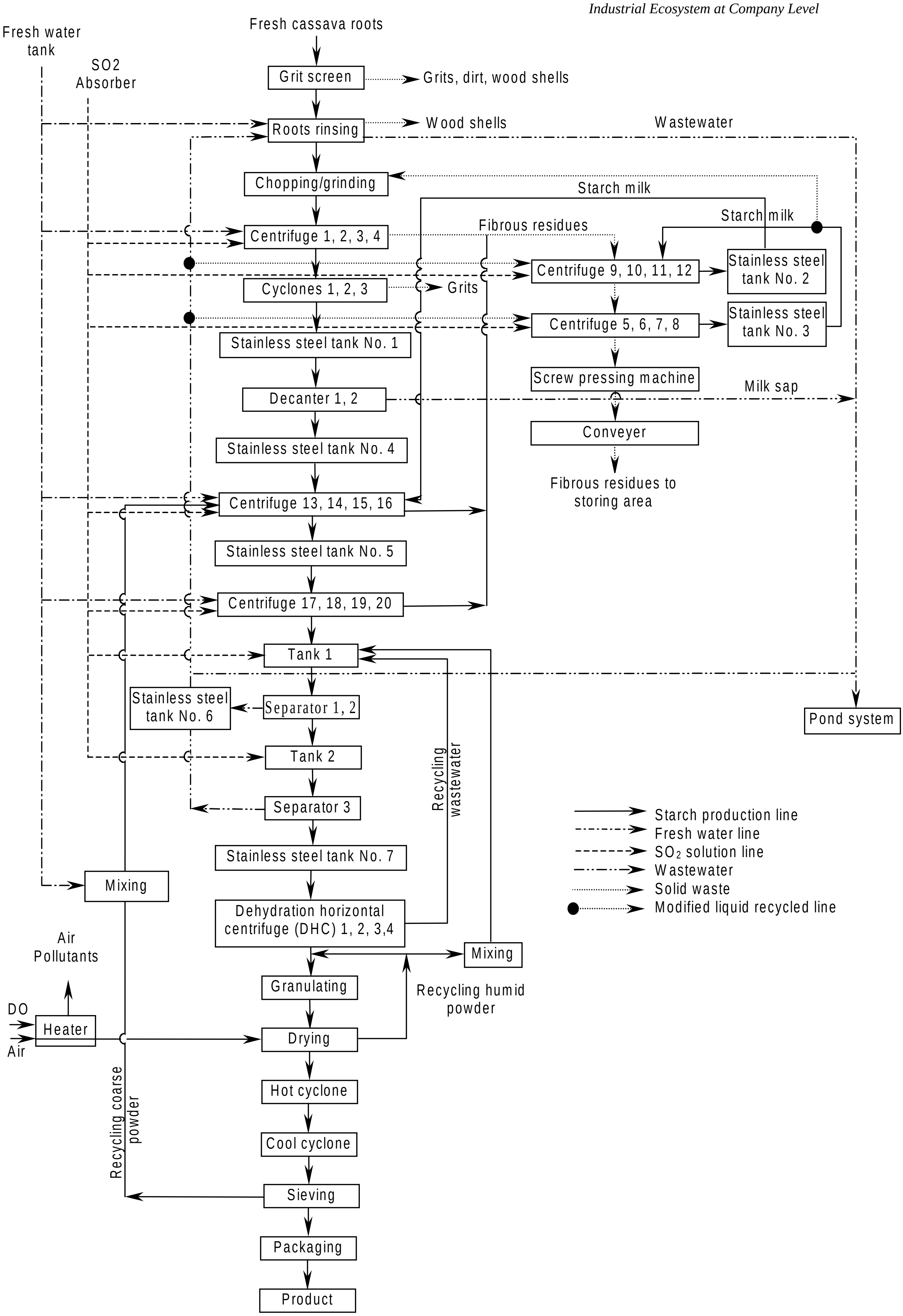


Fig. 6.9 Tapioca production process at Tan Chau-Singapore Company with a modified water circulation.

the emitted polluted air from heater before releasing into the atmosphere or replacement of DO by gas. Co-generation of heat by replacing a proportion of DO by gas is also a possibility to minimize the generation of air pollutants. However, this option requires further study to determine suitable ratio of DO and gas at specific ambient air quality surrounding Tan Chau-Singapore Company to ensure the emission is not over Vietnamese emission standards[54]. Besides, reuse of high temperature off gases for drying wet fibrous residues is also suggested, to recover heat and at the same time to reduce its temperature of waste gas before entering the treatment system.

6.3.2 Material Flow Network Creation

For non-products (both wastes and byproducts), which are unavoidable such as hard roots and wood shells, fibrous residues, wastewater and air pollutants, possible solutions for reducing and eliminating their impacts on the environment are reuse and recycling in other suitable processes. This section emphasizes on analyzing possibilities for offsite reuse and recycling of non-products and the creation of material flow network.

Solid Non-Products

Solid non-products from tapioca processing of Tan Chau-Singapore Company consist of fibrous residues and hard roots and wood shells. Possibilities for offsite reuse and recycling and relative material balance of each kind of solid non-product will be described respectively.

Fibrous Residues. As discussed in section 5.5.2 (see chapter 5), fibrous residues from the tapioca production process can be reused as raw material for producing (1) animal feed, (2) industrial grade alcohol and (3) fertilizer/compost. Similar to the case of Tra Co Village, wet fibrous residues from Tan Chau-Singapore Company are currently sold for reuse in animal feed processing. Thus, there is no reason to reuse it to manufacture compost. In addition, the option of reusing fibrous residues for alcohol production[55] is also less attractive at present because (1) the production process of alcohol is more complicated than animal feed, (2) there is less demand than animal feed[56], and (3) it creates other non-products such as sludge (which can be reused as feed-stuff) and wastewater (which needs to be treated). However, this option might be a possibility in the future when the demand on alcohol as an industrial raw material and fuel source increases and/or the demand for animal feed decreases[57]. Thus, reuse of fibrous residues as raw materials for animal feed production seems to be the most feasible option. Three alternatives to be discussed are (1) selling wet fibrous residues directly to farmers (current applied solution), (2) drying generated fibrous residues before selling and (3) reusing fibrous residues for onsite animal feed manufacturing.

Alternative 1 – selling wet fibrous residues to farmers. At present, Tan Chau-Singapore Company is applying this option. The company sells wet fibrous residues to farmers, who dry it further under the sun (Fig. 6.10) before re-selling it to animal feed production companies. By doing so, the company gains about 4,148,200 VND/day, equivalent to 269 USD/day. This is extra benefit without any additional work or installations. Additionally, this option creates

[54] TCVN 5937-1995, TCVN 5938-1995, TCVN 5939-1995 and TCVN 6993-2001 (see appendix 5).
[55] See appendix 6.
[56] All generated fibrous residues, not only from Tan Chau-Singapore Company but also other tapioca production companies and villages are purchased for animal food production. Currently, it seems to be easier to sell fibrous residues for animal food production than reuse for alcohol production. In addition, so far, no enterprise producing alcohol production from fibrous residues exists in Vietnam yet.
[57] Of course, profit from reuse fibrous residues for alcohol production compared to that of raw material is also an important factor for selecting this option. Primarily estimation of benefit from reusing fibrous residues for alcohol production is presented in appendix 6.

new jobs and helps to increase the income of farmers in this area. However, two main disadvantages should be considered: (1) farmers will not purchase wet fibrous residues during the rainy season and (2) the company also loses benefit because the price of wet fibrous residues (70 VND/kg) is much lower than that of the dry one (600 VND/kg).

Fig. 6.10 Manual sun drying of fibrous residues by farmers in front of Tan Chau-Singapore Company.

Alternative 2 - Drying fibrous residues before selling. When drying fibrous residues before selling, the company needs (1) extra labor and land if selecting a sun drying method or (2) extra labor, additional thermal-energy and a drying system if selecting a mechanical drying method. For sun drying of generated fibrous residues, an area of about 1,200 m^2 and 12 workers is required. The selling price of sun dried fibrous residues for animal feed production is 600 VND/kg. Subtracting cost of labor and land renting, in this case, the company will gain about 10,608,000 VND/day, equivalent to 689 USD/day from this non-product material. Compared to the case of direct selling wet fibrous residues, the company gains an extra profit of about 420 USD/day, shown by the following calculation:

Income from selling dry fibrous residues – labor cost – land renting – income from selling wet fibrous residues = Extra profit of alternative 2 using the sun drying method

or

20,740 kg dry fibrous residues/day x 600 VND/kg – 12 labors x 50,000 VND/labor/day x 3 days – 1,200 m^2 x 30 VND/m^2.day – 4,148,200 VND/day of wet fibrous residue selling = 6,459,800 VND/day = 420 USD/day.

When applying a thermal drying system using FO as fuel, about 54 L of FO is required to dry 1 ton wet fibrous residues with a moisture content of 65%. In this case, the total thermal energy costs for drying 59.26 tons/day of wet fibrous residues is 5,760,072 VND/day, equivalent to 374 USD/day. Labor costs equal half of that in case of sun drying (about 300,000 VND/day or 19.48 USD/day). Investment capital for thermal drying system is about 600,000,000 VND (38,961 USD) and with the assumption of depreciation over 10 years, the gained net profit is about 5,883,928 VND/day, equivalent to 382 USD/day calculated as follows:

Income from selling dry fibrous residues – labor cost – thermal energy cost – investment depreciation = Net profit of alternative 2 using the thermal drying system

or

20,740 kg dry fibrous residues/day x 600 VND/kg – 6 labors x 50,000 VND/labor/day x 2 days – 5,760,072 VND/day – 200,000 VND/day = 5,883,928 VND/day = 382 USD/day.

In this case, the net profit (382 USD/day) is lower than in the case of sun drying (689 USD/day). Extra profit compared to direct selling wet fibrous residues is only 112 USD/day.

If treatment cost of air pollutants are included (SO_2, SO_3 and NO_x removal[58]), the extra profit value will be much lower. This is a reason why direct selling of wet fibrous residues and sun-drying methods are preferred. However, there is still a possibility to increase this extra profit if the company reuses the heat of the exhaust gas (which normally has temperatures in the range of 150-200^oC) from the heater or applies onsite production biogas (referred to discussion of below paragraphs relates to hard roots and wood shells) for fibrous residues drying.

Alternative 3 - reusing fibrous residues for onsite animal feed manufacturing. As discussed in section 5.5.2, dry fibrous residues occupy about 13% (by weight) of swine diet, which substitutes 40% of maize starch. If all dry fibrous residues generated from the tapioca production process of Tan Chau-Singapore Company (20.74 tons/day) are reused for swine feed production, it can contribute to 162 tons swine feed per day. Based on the equation derived from FAO's equation (1 kg maize = 1.255 kg dry fibrous residues + 0.156 kg soybean meal), it is estimated that about 16.53 tons of maize starch per day is saved by substitution of 20.74 tons of dry fibrous residues per day. In other words, swine feed producers can increase their income of about 32,233,500 VND/day, equivalent to 198,972 VND/ton swine feed. For onsite swine feed production, the company has to install a drying machine, grinder and mixer following the common production process as presented in Fig. 6.11. Based on experiences of PROCONCO and VITAGA Animal feed Production Companies, which are located in Bien Hoa 1 IZ, Dong Nai Province, Vietnam, it is estimated that the fixed capital needed to install swine feed production system with a capacity of 162 tons/day is about 2,780,000 USD. The required production area is about 1,500 m^2. Net profit from reusing fibrous residues for swine feed production is estimated as presented in Table 6.11.

Table 6.11 Profit from reusing fibrous residues for swine feed production

Items	Unit	Amount[59]	Unit cost[60]	Total (VND/day)
Production cost				
Maize	tons/day	24.79	1,950,000 VND/ton	48,340,500
Fibrous residue	tons/day	20.74	0	0
Bran	tons/day	41.31	1,450,000 VND/ton	59,899,500
Soybean cake	tons/day	41.31	3,500,000 VND/ton	144,585,000
Fish powder, meat powder, powder milk	tons/day	33.04	4,000,000 VND/ton	132,160,000
Vitamins and minerals	tons/day	0.81	5,000,000 VND/ton	4,050,000
Electrical energy	Kwh/day	1,480	1,200 VND/Kwh	1,776,000
Thermal energy	L DO/day	1,072	3,800 VND/L	4,073,600
Labor	person	170	50,000 VND/person/d	8,500,000
Machine depreciation	%/year	5	2,140,600,000 VND/year	7,135,333
Land renting	m^2	1,500	30 VND/d	45,000
Total production cost				***410,564,933***
Total product	tons/day	162.00	3,600,000 VND/ton	583,200,000
Total income	VND/day			***583,200,000***
Net profit = Total income - Total production cost (in VND/day)				**172,635,067**
Net profit in VND/ton swine feed				**1,065,649**
Net profit = Total income - Total production cost (in USD/day)				**11,210**
Net profit in USD/ton swine feed				**69.2**

Compared to option 1 and option 2, onsite reuse and recycling fibrous residues to produce livestock feed creates advantages of complete reuse of fibrous residues, especially during the rainy season and highly increases the benefits for the company. However, this option will probably face two main difficulties. First, the company has to invest in a new livestock feed production process and skilled labors (need expertise) to operate the system. Second, as

[58] Following Vietnamese standards: TCVN 5937-1995, TCVN 5939-1995, and TCVN 6993-2001 (appendix 5).
[59] Data of the diet is obtained from an existing livestock food production company (PROCONCO company) in Bien Hoa 1 IZ, Dong Nai province, Vietnam.
[60] These are current selling prices in the local market (by end of 2002).

indicated in Table 6.11, because fibrous residues occupy only about 12.5% (by dry weight of product- livestock feed), in order to recycle about 20 tons/day of fibrous residues, an extra 140 tons/day of other material is required. Thus, this option will only be attractive if there is large demand on livestock feed. Besides, establishment of such new livestock feed production enterprises will influence farmers, who currently earn money from selling sun-dried fibrous residues.

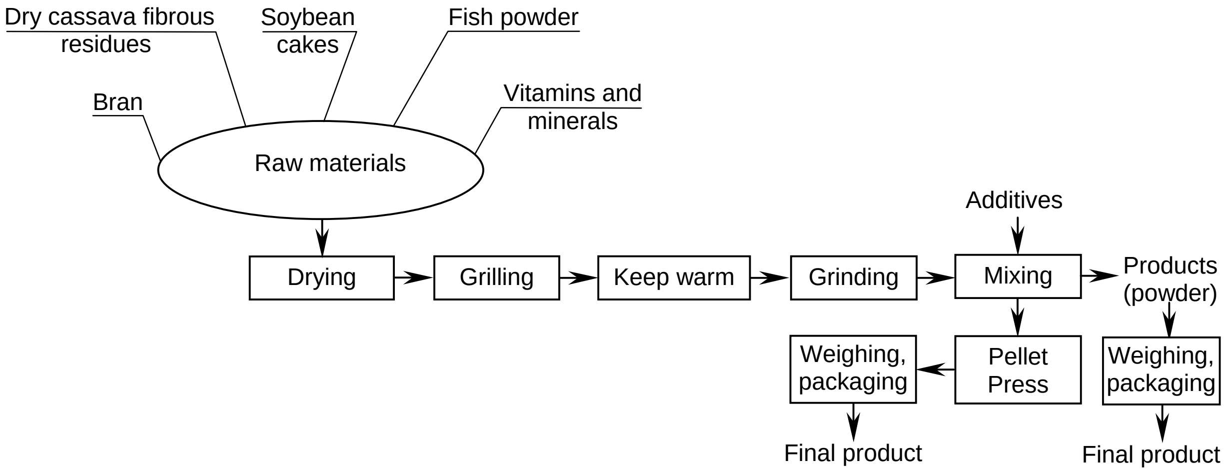


Fig. 6.11 Swine feed production process (summarized from the production processes of PROCONCO and VITAGA Animal Feed Production Companies in Bien Hoa 1 IZ, Dong Nai Province, Vietnam).

In this case study, Tan Chau-Singapore Company is at the heart of the physical-technological model. The scale of the related elements will be developed based on the scale of the company. Therefore, it is logical to start the analysis from Tan Chau-Singapore Company. At present, the production capacity of the company (92 tons starch/day) almost reaches the design capacity of 100 tons starch/day. General Director of the company, Mr. Huynh Duy Hau said that the company tries to operate at maximum capacity (100 tons starch/day) and maintains to do this until 2035. In other words, the physical-technological model will be developed based on the current capacity of the company with the assumption that the production capacity of the company will not be changed within the coming 30 years. With data obtained from the field study at Tan Chau-Singapore Company as presented in section 6.2.2, the material balance from tapioca production process of the company is described in Fig. 6.12.

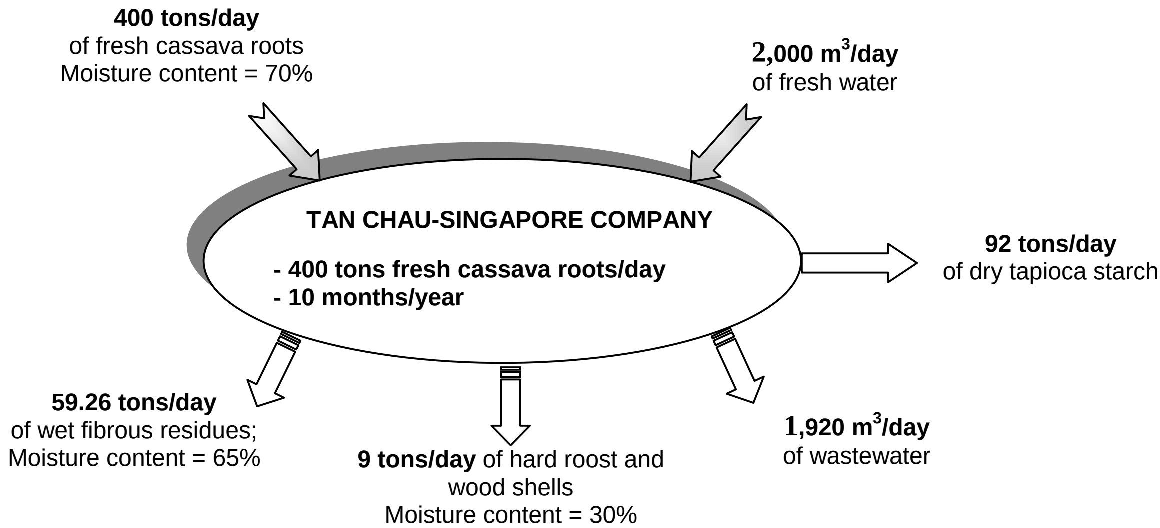


Fig. 6.12 Material balance for tapioca processing in Tan Chau-Singapore Company.

As discussed before, reuse of fibrous residues as raw materials for swine feed production is an attractive option. Though implementation methods may be different such as direct selling wet fibrous residues to farmers, drying fibrous residues before selling, onsite manufacturing swine feed, the total amounts of swine feed that can be produced are the same. The material balance for this option is presented in Fig. 6.13. If swine feed producer purchase dry fibrous residues (600 VND/kg dry fibrous residues), profit increase (for the swine feed producer, due to substitution of maize by fibrous residues) is minimal and equal to 1,285 USD/day. If swine feed production is conducted by Tan Chau-Singapore Company, the profit increase is maximal and equals to 2,093 USD/day.

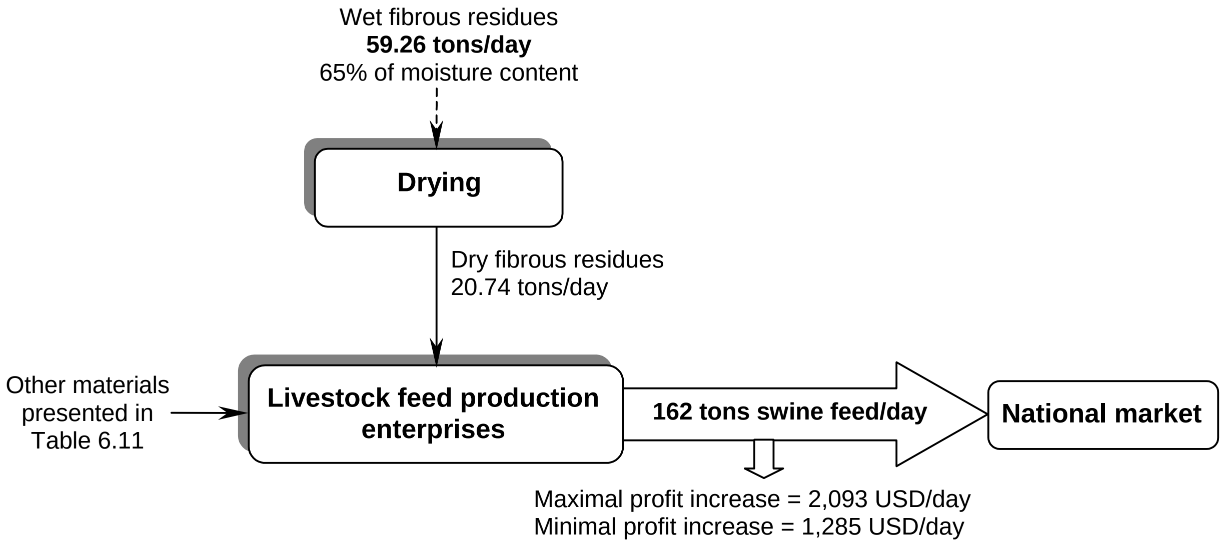


Fig. 6.13 Material balance of reuse fibrous residues as raw material for swine feed production.

Hard Roots and Wood Shells. About 9 tons/day of hard roots and wood shells with a moisture content of 30% is generated from the production process. This solid non-product mainly contains cellulose with C/N ratios in the range of 200 – 500 and 0.1 % (by dry weight) of nitrogen (similar to sawdust, which is referred from Golueke (1972), Polprasert (1989), Polprasert (1996)). The moisture content of hard roots and wood shells are high, while the nitrogen content is low. Therefore, it is necessary to mix it with some nitrogen-enrichment material to control C/N ratio between 20:1 to 30:1 and moisture content around 60% (Polprasert, 1898; Haga, 1990; Polprasert, 1996). It is proposed to reuse cassava leaves and stems after harvesting for compost. The C/N ratio of cassava leaves and stems is considered similar to the C/N ratio of non-legume vegetable waste (C/N = 11-12 and N = 2.5-4% by dry weight). Thus, if all 9 tons/day of hard roots and wood shells (moisture content of 30%, C/N = 200, N = 0.1% by dry weight) are composted, it is estimated that about 8.75 tons/day cassava leaves and stems (moisture content of 70%, C/N ratio of 11 and 3% nitrogen by dry weight) are required to control the C/N ratio of the composting mixture equaling to 25. It took about 60-90 days to complete each composting batch depending on the type of composting facilities. The simplest one is the pile type. With a typical dimension of a pile height x width x length = 1.0 m x 4.0 m x 20 m, about 1.5 ha is required to compost all the hard roots and wood shells from the company. However, seasonal cultivation of cassava makes this solution only possible during cassava harvesting.

If cassava leaves and stems are not available, it is recommended to use swine manure as nitrogen-enrichment material. In this case, about 9 tons swine manure per day with a C/N = 11.4, N = 3.61% and moisture content of 75% needs to be mixed with 9 tons of hard roots and wood shells per day. Mixing swine manure and cassava leaves and stems is also a possibility, provided that C/N of the composting mixture is maintained in the range of 20:1 to 30:1 with a moisture content of 60%. Odor emission during composting containing sulfurous compounds such as hydrogen sulfide, methylmercaptan and methyl sulfide (Haga and Harada, 1990; Harada, 1990) causes secondary pollution problems, especially during the initial stage of poorly aerated compost. Therefore it is important to maintain aerobic condition during composting. In proper control conditions, composting brings various advantages as stabilizing the putrescible organic matter in raw wastes, reducing offensive odours, killing weed seeds and pathogenic organisms and finally producing an uniform organic fertilizer suitable for land application (Haga and Harada, 1990; Polprasert, 1996; Yang, 1997). As mentioned in section 5.5.3, application of N-P-K fertilizer with lime in combination with swine manure produces the highest cassava yield (Phien et al., 1997). In addition, sludge from wastewater treatment system, which is proposed to be installed, will also be reused for composting. The material balance for this option is presented in Fig. 6.14. It is estimated that about 1,350 tons compost is produced per year. That is not only sufficient to supply the about 22 ha cassava fields surrounding the company, but also to cultivate about 700 ha cassava area in Tay Ninh Province.

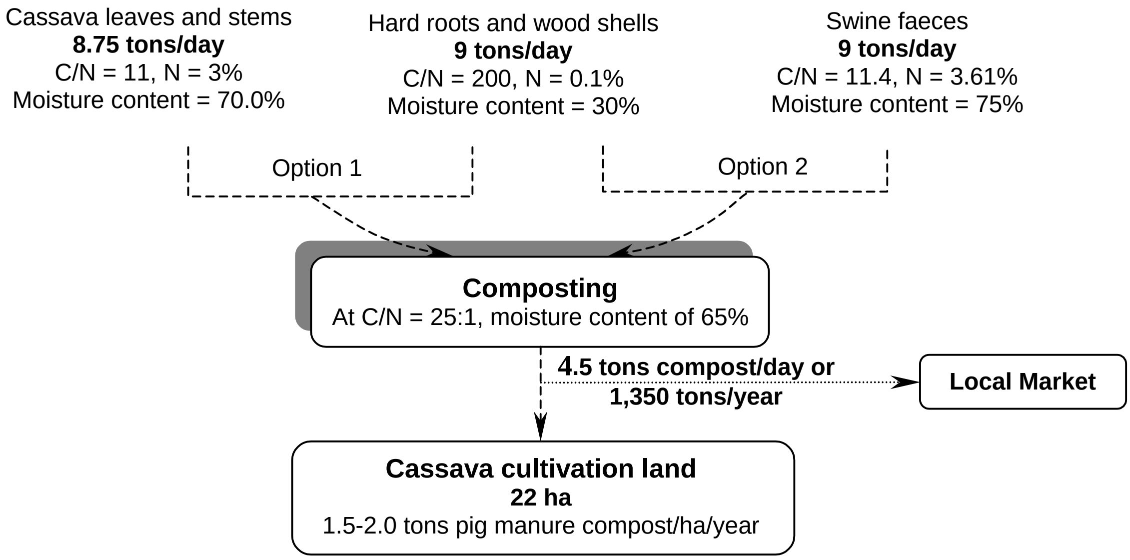


Fig. 6.14 Material balance of reuse hard roots and wood shells for composting.

Besides the option to reuse a mixture of hard roots and wood shells and swine faeces for the production of compost, it is also possible to reuse this mixture for biogas production. Biogas production by admixing different industrial organic wastes with manure has been reported by several authors (Saha, 1994; Augenstein et al., 1994; Lanari and Franci, 1998; Mæng et al., 1999; Al,-Masri, 2001; Axaopoulos and Panagakis, 2002; Lastell et al., 2002; Bouallagui et al., 2003). Conversion of these wastes to methane can not only provide energy, but has a beneficial effect on the environment too. Simple estimations based on experiences of biogas plants in Denmark[61] give the impression that a mixture of 18 tons/day hard roots, wood shells and swine manure can produce about 360-540 m^3 biogas/day, equivalent to 2.1-3.2 ton fuel oil/day or 2,300-3,450 KWh/day[62]. According to Mæng et al. (1999), the production price of biogas, which energy equivalent is accounted by 1 m^3 biogas equal 23 MJ, is about 0.28

[61] At the end of 1997, a total of 20 biogas plants had been built in Denmark, of which 19 are still operating. The gas production is based on numerous kinds of organic industrial waste and manure. The biogas plants have an installed reactor capacity varying from 500 m^3 to 7,500 m^3. The supply to the plants ranges from approximately 50 to 500 tons of manure per day supplied with 10-30% organic wastes mainly from industries. The resulting gas production from the plants is in the range of 1,000-15,000 m^3 gas per day (Hæng et al., 1999).

[62] 1 m^3 biogas = 23 MJ (Hæng et al., 1999).

USD/m^3. Thus it is cheaper to use energy from biogas, wherever possible, than electricity[63]. Of course, the requirements for machines, equipment and technological process of biogas production are more complicated compared to anaerobic composting. However, benefits from economic saving and environmental protection of this option suggest further consideration and research on how to implement it by the company.

Liquid Non-Products

The liquid non-product in this case is tapioca wastewater. As discussed in section 5.5.2, there are two possible options to reuse and recycle tapioca wastewater: (1) reuse untreated tapioca wastewater for fish cultures and (2) reuse of treated tapioca wastewater for cassava irrigation.

Reuse of Tapioca Wastewater in Fish Culture. At present, many tapioca producers in Tay Ninh Province do not believe that it is possible to reuse-tapioca processing wastewater for fish culture. In both large-scale as well as family-scale tapioca producing units, the generated wastewater is stored in earth ponds. Practical experiences from Tra Co Village, Dong Nai Province, Vietnam (chapter 5) and from international literature (Schroeder, 1977; Maramba, 1978; Djajadiredja and Jangkaru, 1978; Wihkfarth and Schroeder, 1979; Polprasert, et al., 1982; Henderson et el., 1983; Edwards, 1985; Edwards et al., 1988; Polprasert, 1996) show that it is feasible to breed fish in tapioca wastewater-fed fishponds by controlling the organic loading in the range of 50-150 kg COD/ha.day. With an average COD of the wastewater generated from the production process of Tan Chau-Singapore Company of 11,700 mg/L, about 3,000 m^3 wastewater/year are required for feeding one ha of tapioca wastewater-fed fishpond. Experiences from Tra Co Village indicate that in normal fishponds, about 0.48 ton fish feed/ha.year is required, while in tapioca wastewater-fed fishponds, only 30% of this amount of fish feed (equivalent to 0.144 ton/ha.year) is needed. With a current fish feed price of 1,600 VND/ton, about 537,600 VND/ha.year is saved by reducing the supply of fish feed per ha fishpond.

It is proposed to reconstruct about 4 ha of the existing wastewater ponds to fishponds. Liners of fishponds can be constructed by 0.6 m compacted-clay layer. With a permeability coefficient of 0.00009 m/day, it takes about 18 years for organic contaminants to pass through the liners. A period of 18 years is excessive to complete biodegradation of organic matters. In other words, a compacted clay layer is suitable to prevent ground water pollution from wastewater-fed fishponds. Because of the limited area for fish culture (4 ha), only a small proportion of generated wastewater, about 9,000 m^3/year, equivalent to wastewater generated within 4-5 days, is sufficient to feed fishponds. Thus, this recycling option will only reduce a very small amount of the tapioca wastewater, only 9,000 m^3/year, compared to the quite high wastewater flow rate of about 1,920 m^3/day generated continuously for 10 months/year. That is the reason why installation of wastewater treatment plant is the unavoidable solution.

Treatment of Tapioca Wastewater for Cassava Irrigation. At present, wastewater from the production process is collected and stored in earth ponds as described in section 6.3.1 before it is treated based on a natural biodegradation process. Therefore, a large area is required for this wastewater treatment system but the effluent still does not reach Vietnamese standards[64] to discharge it into Tha La River. The new wastewater treatment plant (WWTP) will treat tapioca wastewater making it suitable for cassava irrigation and able to discharge it into Tha

[63] 1 m^3 biogas equals to 6.4 KWh. Production cost of 1 m^3 biogas is only 0.28 USD (Hæng et al., 1999), which is about 45% cheaper than total payment (about 0.512 USD) for 6.4 KWh electricity with current price in Vietnam of 0.08 USD/Kwh.

[64] Vietnamese standards for discharged industrial wastewater include TCVN 5945-1995 and TCVN 6980-2001 (see appendix 4).

La River. In this case, production activities are in-operation for 10 months/year, therefore it is possible to apply a combined anaerobic (UASB) and aerobic (activated sludge and stabilization pond) treatment technology. Domestic wastewater is primary treated by existing septic tanks and then released into an aeration tank for further treatment, while rain water is collected by separate open ditches and released directly into Tha La River. With standard domestic wastewater generation of 120 L/person.day, the total amount of domestic wastewater from 93 staff and workers of the company is approximately 11 m^3/day. Therefore, if wastewater is not reused for cassava irrigation, the flow rate of wastewater entering aeration tank is a sum of tapioca processing wastewater (1,920 m^3/day) and the domestic wastewater (11 m^3/day), equivalent to 1,931 m^3/day. Depending on the volume of wastewater reused for irrigation, capacity of the aeration tank, secondary sedimentation tank, stabilization pond, disinfection tank and sludge treatment system will be reduced respectively. The flow chart of wastewater treatment technology is presented in Fig. 6.15 and design parameters of each unit in the system are summarized in Table 6.12.

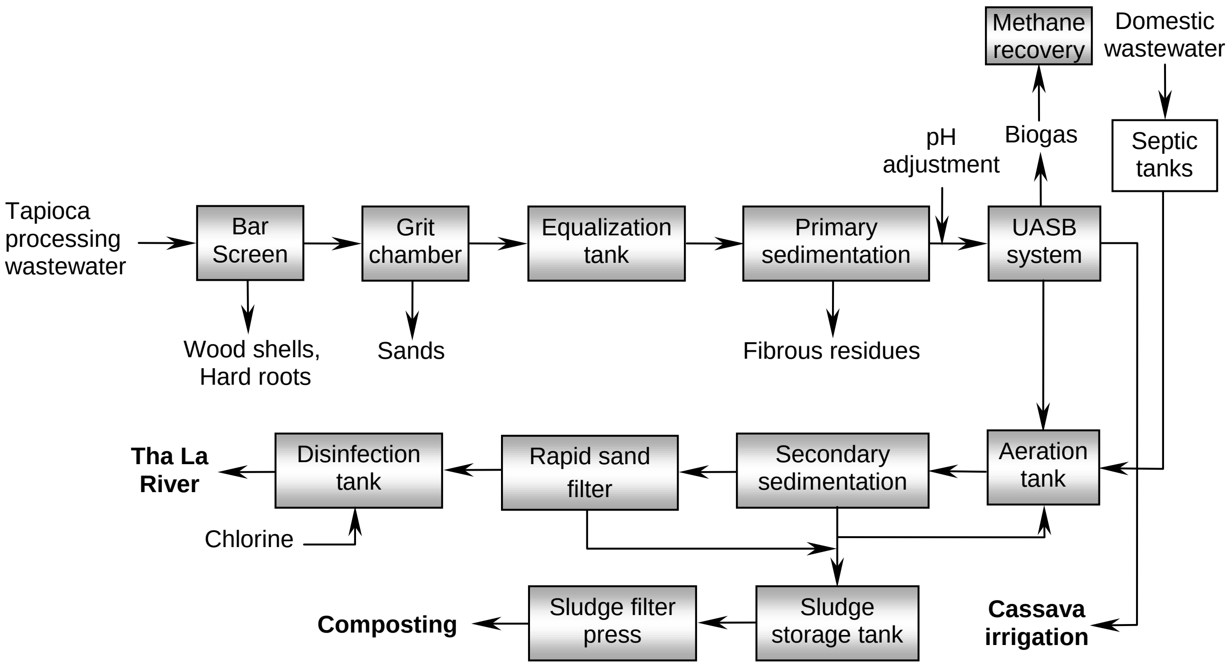


Fig. 6.15 Proposed WWTP for tapioca processing wastewater in combination with domestic wastewater at Tan Chau-Singapore Company.

Table 6.12 Design parameters of the proposed WWTP for Tan Chau-Singapore Company

Parameters	Unit	Bar screen	Grit chamber	Equalization tank	Primary sedimentation	UASB	Aeration tank
Flow rate	m^3/day	1,920	1,920	1,920	1,920	1,920	1,931
Velocity through screen	m/s	0.6					
Hydraulic retention time	min		3				
Hydraulic retention time	h			1.5	1	12	6
Influent COD	mg/L					11,629	1,200
Organic loading rate	kgCOD/m^3.d					12	4
Volume	m^3		4	120	80	1,860	579
Surface area	m^2		6	40	32	310	166
Treatment Efficiency	% (by COD)					90	90

Table 6.12 Design parameters of the proposed WWTP for Tan Chau-Singapore Company (continued)

Parameters	Unit	Secondary sedimentation	Rapid sand filter	Disinfection tank	Sludge storage	Filter press
Flow rate	m^3/day	1,931	1,931	1,931	22	45
Flow velocity	m/min			2		
Hydraulic retention time	min			30		
Hydraulic retention time	h	2			48	
Influent COD	mg/L					
Volume	m^3	161	57	40	45	
Surface area	m^2	54	15	40		
Back washing frequency	time/day		1			

It is proposed to reuse effluent from UASB system for cassava irrigation. With a COD of 579 mg/L or BOD_5 of 460 mg/L, at a depth of 450 mm, organic matters exist at BOD_5 concentration of about 248 mg/L. However, at a depth of 2,000 mm, most organic matters are degraded. Observation of significant changes resulting from application of effluent from UASB system for cassava irrigation is necessary to ensure no adverse impact on the environment. The components of the environment that need to be observed include wastewater, ground water and soils upon which wastewater is applied. Otherwise, effluent from secondary sedimentation tank could be used for irrigation instead of effluent from UASB reactor. The cassava cultivation fields around Tan Chau-Singapore Company occupy an area of 22 ha, thus, total water demand for cassava irrigation is about 220,000 m^3/year. The material balance of reuse wastewater for fish culture and cassava irrigation is described in Fig. 6.16.

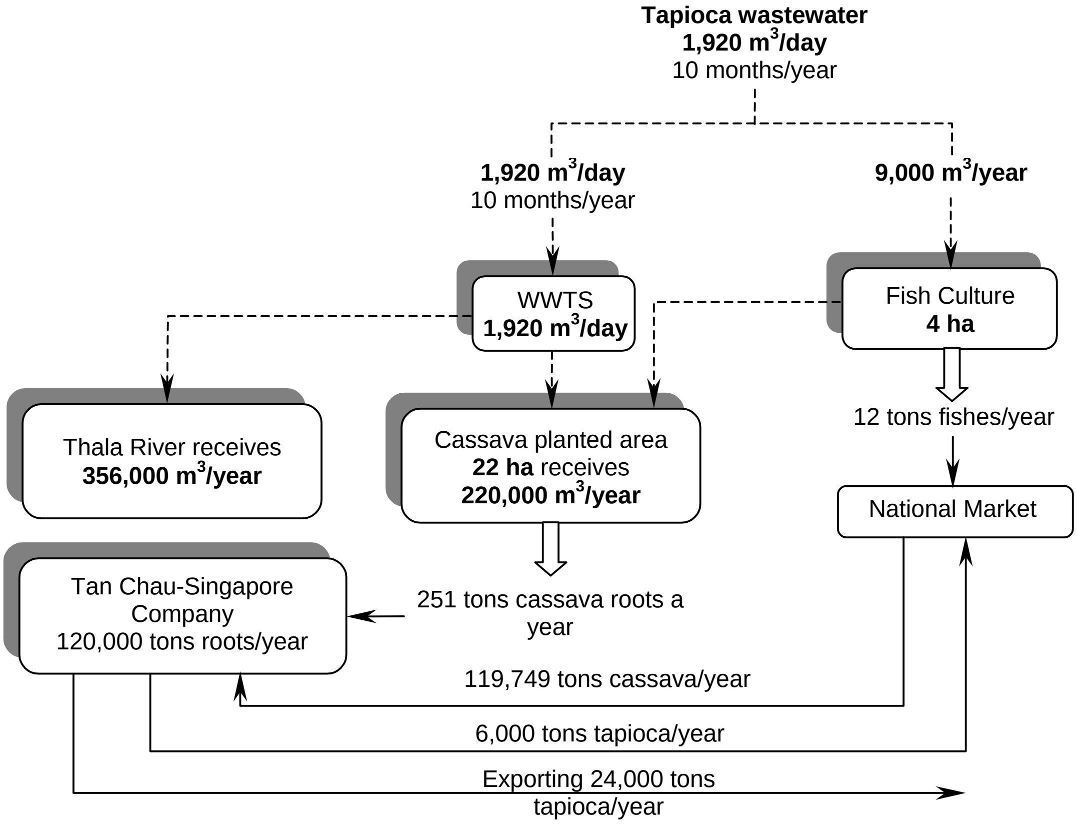


Fig. 6.16 Material balance of reuse wastewater for fish culture and cassava irrigation.

Furthermore, if an UASB system is operated well, the anaerobic biodegradation process will convert organic matter into simpler end products, principally methane and carbon dioxide. The methane production per cubic meter of treated wastewater can be expressed as follows (van Buuren and Hamerlers, 2003):

$M = (1 - Y).\ r.\ C_i.\ 0.35\ m^3/m^3$ wastewater

Where:

- M is the volume of methane gas (m^3) produced (m^3 methane/m^3 of treated wastewater);
- Y is the sludge production factor, Y = 0.02-0.04 (mg VSS/mg BOD_5.day) = 0.0125-0.025 (mgVSS/mg COD.day)[65];
- r is COD removal efficiency, r is assumed to be 70%[66];
- C_i is COD in influent (kg/m^3), C_i = 11.629 kg/m^3 (corresponding to BOD_5 = 7.500 kg/m^3)[67];

M = (1 – 0.025) x 0.7 x 11.629 x 0.35 = 2.78 m^3 CH_4/m^3 of treated wastewater

Thus, total amount of methane gas produced from the UASB system (if treatment efficiency reaches 70% in terms of COD removal) will be 5,338 m^3 CH_4/day. If the efficiency of electricity generation is 50%, total amount of energy produced from CH_4 is about 90.7 GJ/day[68], equivalent to 25,205 KWh/d, which is sufficient to provide not only 100% of the electrical energy demand of the company but also to be reused for drying fibrous residues. Therefore, additional installation of biogas collection, treatment and electricity generation from biogas is strongly recommended.

6.3.3 Exhausted Gas Treatment

Exhausted gas from the heater mainly consists of acid gases such as SO_x, NO_x, CO_x and dust. These acid gases can result in reduced visibility, corrosion of metals and the production of acid rain or fog. Several methods are available to control acid gases, including (1) wet scrubbing, in which liquid solutions are used to scrub and neutralize acid gases and (2) dry scrubbing, in which neutralizing slurries are injected directly into the polluted gas stream. A typical wet scrubber system consists of a venturi scrubber and demister, a lime-slaking system and a filter press for dewatering the resultant scrubber sludge prior to disposal (Fig. 6.17).

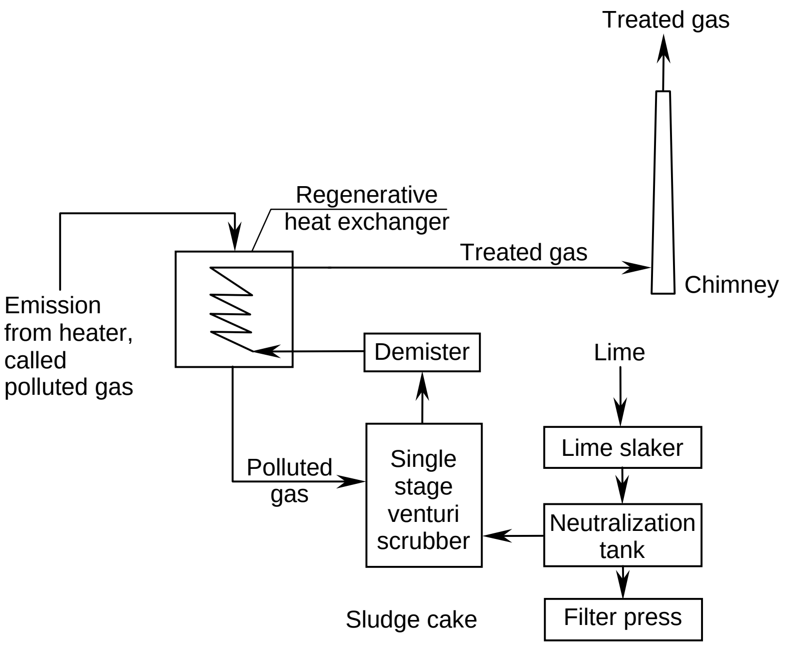


Fig. 6.17 Schematic flow diagram of the wet scrubber system.

[65] Typical value of Y of anaerobic biodegradation (Metcalf and Eddy, 1991).
[66] Normally efficiency of UASB system can be as high as 70-95% in term of BOD removal.
[67] See Table 6.7.
[68] Calorific value of CH_4 is 34 MJ/m^3 CH_4.

A regenerative heat exchanger is also a part of the system, first cooling the gases by about 50°C prior to the scrubber, then re-heating the gases prior to release in the stack. The cooling step is required to enhance the efficiency of the scrubbing operation and the reheat step is required to enhance the buoyancy of the plume (Tchobanoglous et al., 1993).

Dry scrubbing systems are another approach to acid gas removal. Two techniques are used: (1) spray drying (mainly to remove SO_2) and (2) dry injection. A typical spray dryer system is shown in Fig. 6.18. Sodium carbonate and lime solutions are pumped into the spray dryer, where they react with the polluted gases. The acid gases (CO_2, SO_2/SO_3) are adsorbed on the surface of the droplets, reacting to form neutral salts such as calcium sulfate ($CaSO_4$) and sodium sulfate (Na_2SO_4). The solid salt particles are removed in a downstream bag-house along with the fly ash.

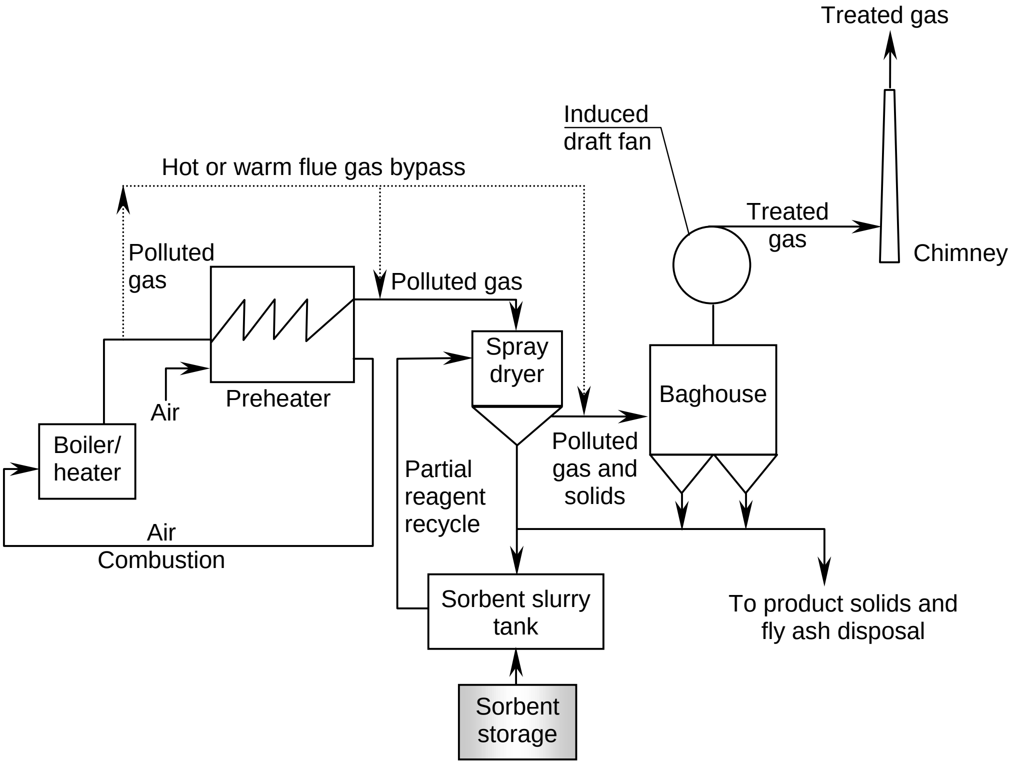


Fig. 6.18 Schematic flow diagram of the spray dryer for acid gas removal.

Another approach to dry scrubbing is dry injection. A lime solution is sprayed into a quench chamber, neutralizing the acid gases. The water in the solution completely evaporates, so there is no liquid sludge to deal with. A proprietary agglomerating agent, Tesisorb, is added to the gas stream after the quenching chamber to help coagulate very fine particles prior to collection the downstream bag-house.

6.3.4 Physical-Technological Model of a Zero Waste Industrial Ecosystem

A physical-technological model of a zero waste industrial ecosystem at Tan Chau-Singapore Company is created by integrating all options as discussed in this chapter. The material flow network of the model is simulated in Fig. 6.19.

In this model, tapioca production process of Tan Chau-Singapore Company is used as a starting point for the model development. Existing cassava cultivation fields surrounding the company, new designation of livestock feed enterprise, modification of the existing wastewater ponds to become fishponds, construction of composting plant and a wastewater treatment system are all designed to reach a model of a zero waste industrial ecosystem.

About 80% of total tapioca products (30,000 tons tapioca starch/year) is exported to Malaysia, China, Indonesia and mainly to Singapore and the remaining is domestically consumed. It is designed that 59.26 tons wet fibrous residues/day recovered from the tapioca production process are reused to produce about 162 tons swine feed/day, equivalent to 48,600 tons/year. This amount of swine feed is sufficient to breed all currently present swine in Tay Ninh Province and is able to provide the local market with about 12,040 tons living weight of pork/year. 9 tons hard roots and wood shells can be mixed with 8.75 tons/day of cassava leaves and stems or 9 tons/day of swine faeces to produce about 4.5 tons compost/day. This is an excellent option for reusing these non-product materials onsite and returning compost back to the 22 ha of the existing cassava cultivation fields near the company. The remaining compost is sold at local markets. Sludge from the WWTS will be tested in practice to decide whether it is possible to compost. Though it is more complicated compared to the option of composting in terms of technological process, machines, equipment as well as skilled labor, biogas production is also a possibility for the company to increase their benefit from energy saving, while it reduces the environmental pollution.

The existing wastewater ponds covering 6.4 ha will be reconstructed to become a 4 ha tapioca wastewater-fed fishponds, 0.15 ha livestock feed production enterprise, 1.5 ha composting plant, and 0.10 ha WWTS. Per year 9,000 m^3 of tapioca wastewater is reused for fish culture. The remaining part is treated to reuse in cassava irrigation and discharged into Tha La River. Yield of fish (about 9 tons/year) and cassava (251 tons/year) are used on-site or supply the local market.

In this model, except for the sun drying process, which uses the sun as energy source, most elements need electricity to operate. The only possibility for energy recovery is at the WWTS, in terms of methane gas. It is estimated that about 5,338 m^3 CH_4 is generated everyday from UASB system if it is operated well (achieving 70% COD removal). Even if the efficiency of the electrical generation from methane gas is 50%, total electricity produced from the generated methane gas (about 25,205 KWh) is sufficient to provide 100% electricity requirement of the company for both tapioca production and fibrous resides drying. If generated methane gas from the WWTS is not recovered for reuse, it must be treated properly to limit its hazard, especially its contribution to the greenhouse effect. Heat of exhausted gas from the heater can be reused to dry fibrous residues and requires further treatment to meet Vietnamese standards before releasing into the atmosphere.

The main boundary of the developed model is Tan Chau-Singapore Company. However, some elements such as cassava cultivation and swine breeding, which are not located within the company, are also included. Therefore the boundary of the Tan Chau Town and even Tay Ninh Province is used to indicate the operational area of these elements. The market and the river serves as an exchange centre to receive and distribute products within the model and the outside. Layout of industrial ecosystem at Tan Chau-Singapore Company is simulated in Fig. 6.20.

The proposed physical-technological model approaches a zero waste industrial ecosystem only if Tan Chau-Singapore Company keeps producing at current capacity (92 tons starch/day). Therefore, two questions arise from that assumption: (1) what would happen if the company decreases or increases its production capacity? and (2) which interrelations exist between the company and other elements in the model to ensure feasibility of the implementation.

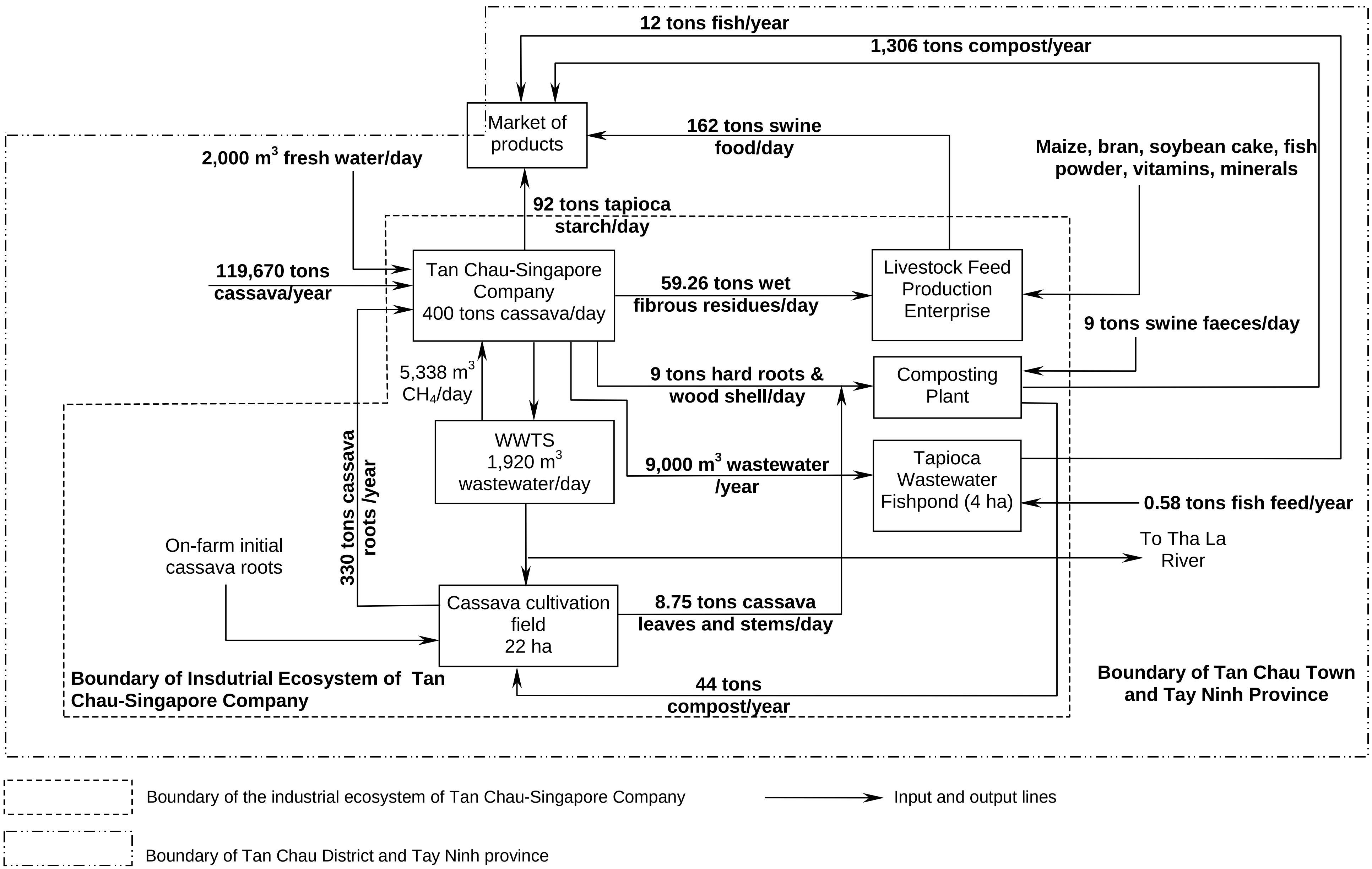
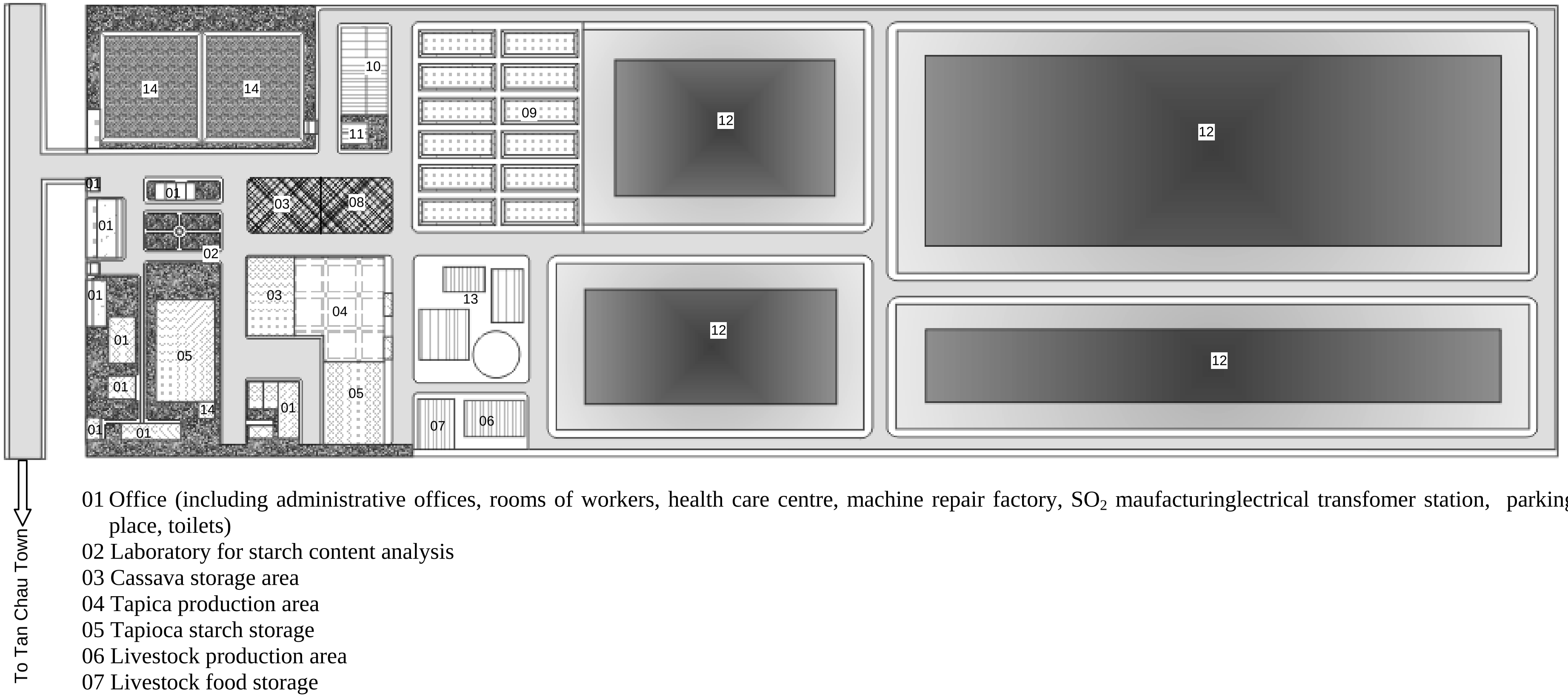


Fig. 6.19 Material balance of the proposed physical-technological model of a zero waste industrial ecosystem at Tan Chau-Singapore Company.



01 Office (including administrative offices, rooms of workers, health care centre, machine repair factory, SO_2 maufacturinglectrical transfomer station, parking place, toilets)
02 Laboratory for starch content analysis
03 Cassava storage area
04 Tapica production area
05 Tapioca starch storage
06 Livestock production area
07 Livestock food storage
08 Storage of raw materials for composting
09 Composting area
10 Compost storage
11 Composting operation room
12 Tapioca wastewater fed fishponds
13 Wastewater treatment plant
14 Fresh water tanks

Fig. 6.20 Layout of the proposed physical-technological model of a zero waste industrial ecosystem at Tan Chau-Singapore Company.

First, we will discuss the case that Tan Chau-Singapore Company will decrease its production capacity and the consequence to other elements of the model. From the material flow balance of the proposed model presented in Fig. 6.19, it is obvious that without the market and the natural environment (for instance the river), the proposed industrial ecosystem is not completely closed. This means that the designed capacities of recyclers are not only sufficient to handle the non-products from the tapioca processing, but excess to supply each others within the boundary of the industrial ecosystem based on Tan Chau-Singapore Company. Consequently, the elements, especially the recyclers of the proposed model will be less influenced from reduced production capacity of Tan Chau-Singapore Company. For instance, the composting plant is designed to reuse 9 tons hard roots and wood shell per day as raw material for composting and produce about 4.5 tons compost/day. The amount of compost from the proposed composting plant is sufficient to fertilize the whole 600 ha cassava cultivation fields in Tay Ninh Province. In other words, the compost demand for the 22 ha cassava cultivation fields near the company is very small compared to the total productivity of the composting plant. Thus, unless Tan Chau-Singapore Company reduces more than 96.7% of its production capacity, the composting plant can still provide sufficient compost for the surrounding 22 ha cassava fields. Moreover, if there is the availability of a market making it able to operate at the designed capacity, the composting plant can always find other substitutes for hard roots and wood shells such as bagasses from cane sugar companies, rice straw, or even cassava hard roots and wood shells from Tay Ninh Tapioca Company or tapioca processing households in Binh Minh and Tan Binh Hamlets. To continue supplying tapioca wastewater for fish culture on 4 ha of the existing wastewater ponds, only about 9,000 m^3 of tapioca wastewater per year is needed. Following the fish culture procedure as indicated in section 5.5.2, this amount of tapioca wastewater should fed the fishponds during 1 month and only once a year. In other words, unless the company reduces more than 84% its production capacity, there is still sufficient tapioca wastewater for fish culture in an area of 4 ha. The proposed wastewater treatment plant is designed to operate continuously based on the current operation procedure of tapioca production process. If the production capacity of the tapioca process decreases, the amount of generated wastewater will decrease correspondingly. At that time, it is not necessary to operate the WWTS continuously. The designed WWTS is able to operate in batches to save the need on energy and manpower. If Tan Chau-Singapore Company decides to construct a livestock feed production enterprise for onsite reuse and recycling of fibrous residues, the profit of the enterprise will probably be influenced if the tapioca production capacity reduces. Because in such case, the onsite livestock feed enterprise either has to purchase cassava fibrous residues from other tapioca processing units within or outside Tay Ninh Province or use original raw material for keeping its production activities. However, this does only mean that the livestock feed enterprise will lose profit from free fibrous residues, spending less for original raw material (for instance maize) and transportation cost. But it does not mean that the enterprise will not gain profit from its production activities. In other words, without supplying cassava fibrous residues for recycling, livestock feed enterprise will not play the role of recycler any more, but it remains an industrial production unit. Secondly, if Tan Chau-Singapore Company increases its production capacity in the future, the designed elements will be over capacity. Depending on the size of the increase of tapioca production capacity, other elements of the model will expand correspondingly. However, it is not necessary to expand the proposed elements only within the boundary of Tan Chau-Singapore Company. It is possible to install similar units at other places, which are suitable for transportation and distribution of materials and products within the province. The most important driving force for establishment of these recyclers is the availability of consumers/customers for their products and profits of owners.

If Tan Chau-Singapore Company itself is interested in putting the proposed physical-technological model to work, there is a big advantage of a qualified leader who knows the existing situation of the company and has the authority to speed up re-construction and rearrangement activities. That would help rapid implementation and easy control of the model in future. In addition, only a little change in the current administrative organization of Tan Chau-Singapore Company is necessary to obtain an industrial ecosystem model (Fig. 6.21). In this case, the current general director of Tan Chau-Singapore Company is responsible for all rearrangements of infrastructure and organization, so that he can manage both production and environmental protection activities of the whole system. He is also responsible for the pollution control of all components in the model and report to Tay Ninh DOSTE about it. Relationship between the company and cassava cultivation households can be maintained by contracts with special articles on supply sides of both.

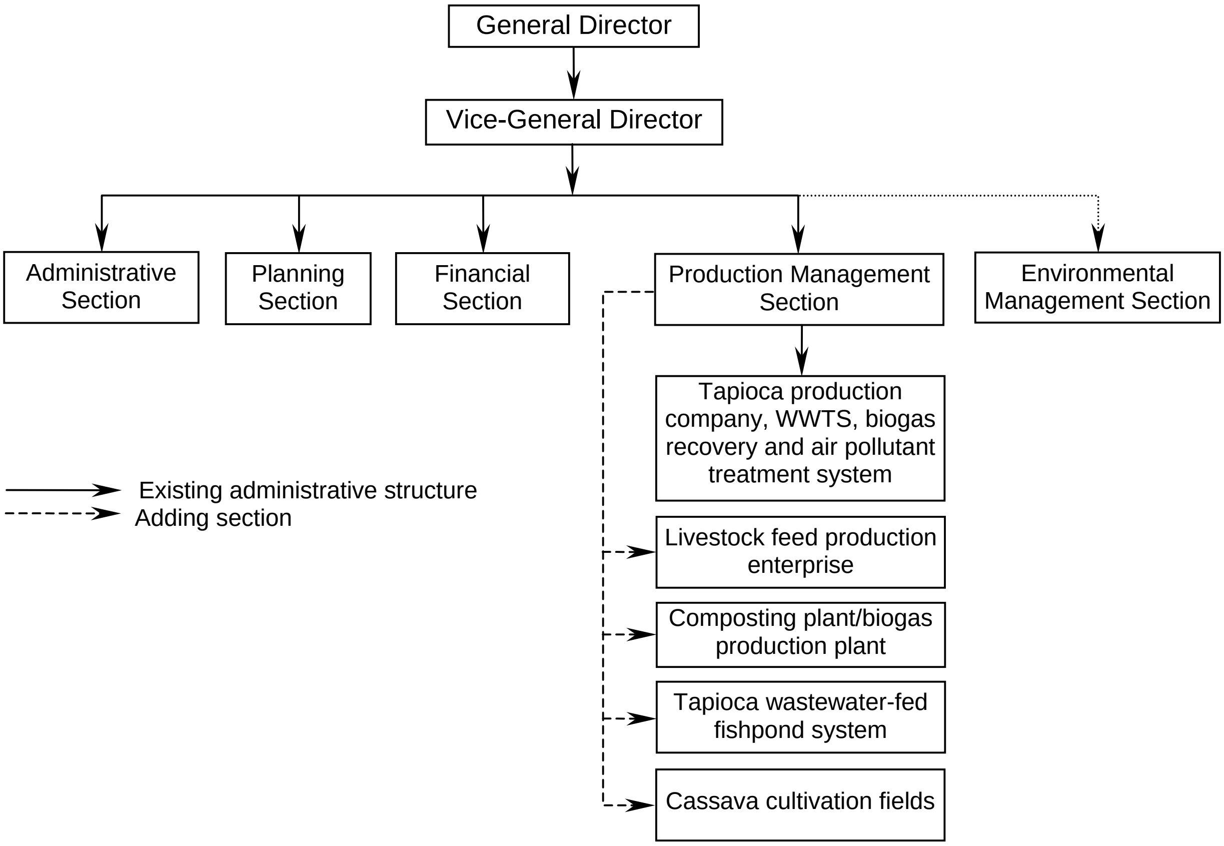


Fig. 6.21 Modification of the current administrative organization structure of Tan Chau-Singapore Company corresponding to the developed model.

If Tan Chau-Singapore Company has no ambition to operate other elements than tapioca processing, the company has to seek for other owners, who want to participate in this system as recyclers. In this case, the company has to create relationship with livestock feed enterprise, composting plant, fish culture households, and cassava cultivation households.

6.4 ACTORS AND INSTITUTIONS IN INDUSTRIAL ECOSYSTEM OF TAN CHAU-SINGAPORE COMPANY

The developed physical-technological model has been strongly based on the material balance and preliminary assessment of available technology and practical needs. However, the developed model has to be implemented and operated through interaction with other factors and actors. Therefore, it is again important to analyze the institutions and actors governing Tan Chau-Singapore Company and identify how these might enable and constrain the further implementation of the whole or parts and options of this model. To do so, this section focuses on an analysis of economic (section 6.4.1), policy (section 6.4.2) and societal networks (section 6.4.3), in which Tan Chau-Singapore Company is engaged.

6.4.1 Economic Network

Within the economic network, the following interactions will be analyzed: (i) the relationships between Tan Chau-Singapore Company and its suppliers, recyclers, and consumers/customers; (ii) the relationships between the company with other tapioca production companies within and outside Tay Ninh Province; (iii) the interactions between the company and other economic agents and research institutes, and (iv) regional relations and interactions in restricted geographical area. In general, the economic network of the proposed physical-technological model of a zero waste industrial ecosystem at Tan Chau-Singapore Company is presented in Fig. 6.22.

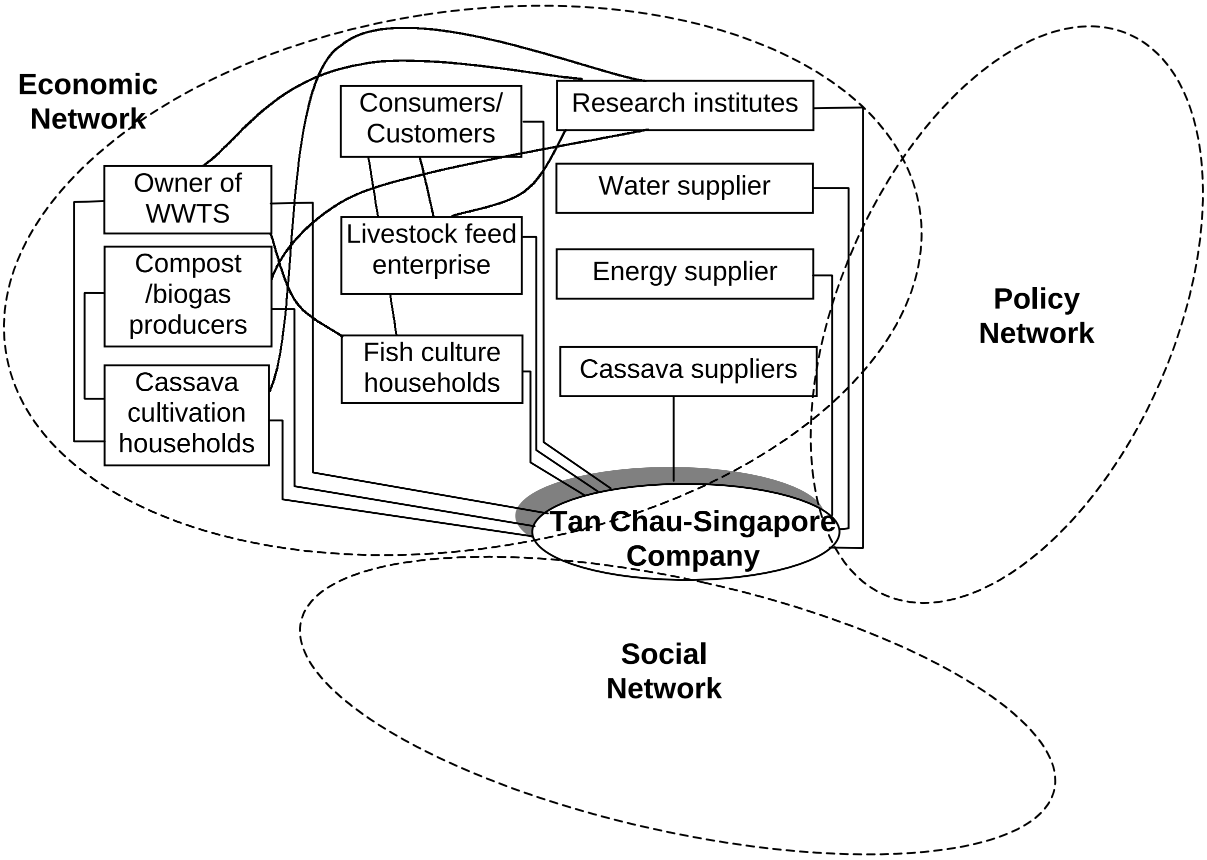


Fig. 6.22 Economic network embedding Tan Chau-Singapore Company.

The Vertical Interactions from Input Suppliers to Producers, Recyclers and Consumers

Input Suppliers. Input suppliers for tapioca production at Tan Chau-Singapore Company include cassava suppliers, the water supplier, and electrical and thermal energy suppliers.

Cassava suppliers. At present, the company operates at nearly its full design capacity, which requires about 120,000 tons cassava roots/year. Whole Tay Ninh Province can only provide about 9,000 tons cassava/year (General Statistical Office, 2001), approximate 6.6% of the company's demand. Though Tay Ninh Province has the highest yield of cassava among the Southeast provinces, limitation on cassava cultivation land causes its low gross output of cassava (Table 6.13). That is a reason why the company still has to purchase cassava from other provinces while being located in the best cassava cultivation area. Advantage of being located next to cassava cultivation fields give the company the opportunity to reduce transportation cost for the about 330 tons cassava/year, which are produced from the 22 ha surrounding cassava cultivation fields, but this is only 0.275% of the company's demand. Thus, a large competition on low cost cassava roots between Tan Chau-Singapore Company and other tapioca production companies in Tay Ninh[54] or other provinces is certain. The company has signed "agreements" (a kind of contract) with cassava cultivation households to maintain its cassava supply. The purchased prices of fresh cassava roots, which vary depending on the starch content, were also agreed on between cassava suppliers and the tapioca producer (Tan Chau-Singapore Company)[55]. The company also helps cassava cultivation households to enhance the soil quality of their cassava fields by giving them incubated hard roots and wood shells for free[56]. This creates and maintains a friendly relation between cassava suppliers (farmers) and the company. In addition, making the price of cassava depends on its starch content (section 6.2.2), it is a financial incentive for farmers and contractors to supply cassava roots with a high starch content. At the same time, the tapioca production efficiency is improved because less roots are needed for the same production output, leading to less solid waste, less wastewater, reduced water use and energy consumption. In addition, cultivation of high starch content varieties is stimulated leading to the need of enhancement of cassava cultivated soil.

Table 6.13 Cultivation area, yield and gross output of cassava by the Southeast provinces in Vietnam

Provinces	Cultivation area (ha)	Yield of cassava (tons/ha/year)	Gross output of cassava (tons/year)
Ho Chi Minh City	200	6.13	1,226
Ninh Thuan Province	800	9.50	7,600
Binh Phuoc Province	1,000	14.38	14,380
Tay Ninh Province	600	15.00	9,000
Binh Duong Province	1,200	7.77	9,324
Dong Nai Province	8,000	7.69	61,520
Binh Thuan Province	5,300	7.37	39,061
Ba Ria-Vung Tau City	3,600	14.44	51,984

Source: General Statistical Office, 2001.

Though limitation on cassava cultivation area in Tay Ninh Province is difficult to change, this is a weak point of the proposed model because cassava cultivation households play not only a role as cassava supplier but also as recycler of pre-treated wastewater from WWTS and compost from the composting plant. Imbalance between the available cassava cultivation area and the required area to receive pre-treated wastewater and compost cause an increase in spending for thorough wastes' treatment before discharging. Besides, the company faces a high risk of losing cassava suppliers because it has to compete with other enterprises/companies in Tay Ninh and other provinces. However, this might change when the Master Plan on Social-Economic Development of Tay Ninh Province that has planed to create about 15,000-20,000 ha areas[57] for cassava cultivation with a productivity in the range of 27.5-30.0 tons/ha/year up to 2010 will be realized (Tay Ninh PC, 2000).

[54] Four tapioca production companies in Tay Ninh are Tay Ninh-Tapioca Co. Ltd (a joint venture with Thailand, located in Tan Binh Village, Hoa Thanh District), Tan Chau-Singapore Company (a joint venture with Singapore, locates in Tan Chau Town), Cheng Vi Starch Enterprise (100% Taiwan owned capital, located in Thanh Duc Village, Go Dau District), Heng Chang Tapioca Co. Ltd. (100% Malaysia owned capital, located at Chau Thanh Town) (IDECO, 2003).

[55] Interview with Mr. Huynh Duy Hau, General Director of Tan Chau-Singapore Company, Tay Ninh Province.

[56] Interview with Mr. Tu, Head of Technical Section of Tan Chau-Singapore Company, Tay Ninh Province.

[57] It is planned to cultivate cassava in Tan Bien, Tan Chau, Duong Minh Chau, Hoa Thanh, Chau Thanh Districts and Tay Ninh Town on areas to get stable productivity of 450,000-550,000 tons cassava/year by 2010.


Reuse generated wastewater in root-rinsing stage

Water supplier. Tha La River is used as water supply source of Tan Chau-Singapore Company. The company has to treat water properly before using it in the production process to ensure product quality. Though the company does not have to pay a fee for surface water resource exploitation, costs for water treatment forces the company to optimize water utilization within the production process. By reusing generated wastewater from the dewatering process (using (centrifuges) for the root-rinsing stage (section 6.2.1), the company reduces both the amount of water demand as well as the wastewater generation. This does not only benefits the company by reducing cost for water supply and wastewater treatment, but is also meaningful for natural resource conservation.

Electrical and thermal energy suppliers. Electrical and thermal energy are the main required energy sources for tapioca processing in Tan Chau-Singapore Company. Electricity is supplied by Electricity of Vietnam with a selling price as indicated in the annex of Decision No. 20/VGCP-TLSX, which was approved by Head of Government Committee for Price of Goods dated July 26, 1994[58]. The price of electricity and spending on fuel is an economic incentive for the company to save its electrical and thermal energy consumption as much as it can. Recovery and reuse of biogas from the proposed wastewater treatment system or from the biogas production system using the mixture of hard roots, wood shells and swine manure is a possibility for self-supplying in its energy demand.

Recyclers. Recyclers, who are involved in recycling activities, include fish culture households, livestock feed production enterprises, composting producers, owner of wastewater treatment system (WWTS) and cassava cultivation households.

Fish culture households. Distinct from the case study at Tra Co Village (Dong Nai Province), tapioca producers in Tay Ninh Province do not reuse tapioca wastewater as feed for fish culture[59]. Fish culture by tapioca wastewater is not applied in Tay Ninh Province yet. So far, the only solution for wastewater generated from their production processes is storage in the earth ponds. Every tapioca enterprise has a series of ponds to store wastewater and ensure that no wastewater is released into the surrounding rivers, springs or ground. Organic matters and decomposed products from discharged wastewater have accumulated in the earth ponds for a long time form extremely polluted wastewater with nuisance odor, black color and too toxic to grow fish. Application of tapioca wastewater-fed fishponds in this case will face a too high risk of failure, because farmers in this area are not experienced to operate such fishponds. In addition, one big disadvantage is that fish culture in Tay Ninh Province is not developed yet (Tay Ninh PC, 2000). This means that even in case of conventional fish culture, farmers also have less experience. Thus, in order to implement this option, it is required to provide technical assistance by organizing training or even demonstrations to help farmers to be able to operate the system properly. Success or failure in the first application of this new fish culture method will strongly affect the farmers' encouragement to continue or to try it again. Though there is little uncertainty to application of tapioca wastewater-fed fishponds in Tan Chau-Singapore Company, practical evidence at Tra Co Village allows us to believe on its successful implementation in future.

Livestock feed production enterprises. At present, wet fibrous residues are sold at a cheap selling price of 70 VND/kg to farmers[60] for further drying under the sun before selling it to

[58] Decision on Selling Price of Electric Power.
[59] Interview with tapioca producing households in Tan Binh and Binh Minh Hamlets, Tay Ninh Province.
[60] Interview with farmers, who were drying fibrous residues in front of Tan Chau-Singapore Company in 2002.

livestock feed production enterprises. This solution is applied quite widely, especially for household-scale enterprises in Ho Chi Minh City, Dong Nai and Tay Ninh Province. However, with an operation time of about 300 days/year, the sun drying method is limited during the rainy season from May to October every year[61]. Therefore, it is suggested to establish a livestock feed production enterprise within the boundaries of Tan Chau-Singapore Company both to overcome the shortcoming of the rainy season as well as to reduce transportation costs and to control environmental protection activities easily. However, extra investment for establishment of the livestock feed production enterprise may force the company to select the current alternative of selling wet fibrous residues for off-site livestock feed production. In both cases, the important role of a livestock feed production enterprise in approaching the proposed model towards zero waste industrial system is equal. In addition, breeding is one of the major agricultural activities in Tay Ninh and other neighbor provinces, so it leads to the continuous demand for livestock feed at present and in future. This proves the suitability and feasibility of adding the livestock feed production enterprise in the proposed physical-technological model of a zero waste industrial ecosystem at Tan Chau-Singapore Company.

Compost producers/Biogas producers. So far, no compost nor fertilizer production company has been constructed in Tay Ninh Province. Farmers usually apply onsite, natural composting consisting of leaves, plant bodies, etc. after harvesting and add by chemical fertilizer. At present, hard roots and wood shells from Tan Chau-Singapore Company are partly returned, free of charge, back to the surrounding company cassava fields after being naturally incubated for some days. This evidences the demand and possibility of reusing such kinds of non-product solid materials for composting. If a proper composting process is applied, the produced compost would be an excellent soil amendment not only for cassava cultivation but also for other agricultural plants in Tay Ninh Province, especially sugarcane fields.

At present, no biogas production on industrial scale is available in Vietnam. However, in small-scale farms, biogas production and reuse, as cooking fuel, have been practiced in Vietnam for more than 20 years (An, 2002), following the traditional ideal farming system in rural areas, called VAC system: V stands for vegetation, A for aquaculture and C for cage of the animal and these are unique about material and byproduct recycling in the system. For instance, if a farmer has swines, cows and chickens, their manure can be reused to produce biogas for cooking, instead of fuel energies. Decomposed manure is then used as compost for vegetation as well as to feed fish. Products and byproducts from vegetation such as rice bran, residuals of vegetables and fruits can be feed for swine. This farming system as a minimal emission and is considered to have a material cycle and seems to be environmental friendly (Yasunobu et al., 1999). Though household biogas systems have been practiced in several households in rural areas of Vietnam such as Ha Tay, Tuyen Quang, Vinh Phuc (Chinh et al., 2002), An Son (Binh Duong) (Hedlun and An, 2000), and others[62], its application on industrial scale to produce cooking gas from biogas is still a question of technology and costs. However, this is still a possibility for Tay Ninh Province to apply in the future saving energy becomes a nationwide and worldwide target.

[61] According to Mr. Tu, Head of Technical Section of Tan Chau-Singapore Company, during rainy season, fibrous residues are heaped within the company and later on given free of charge to farmers for reuse as compost or are just disposed as domestic solid wastes.

[62] Vacvina, Vietnam's national horticultural training association, has successfully installed roughly 3,000 household biogas systems in rural, agricultural areas of Vietnam. These systems use the waste from one to two pigs in general owned by a farmer to produce sufficient methane to meet the daily cooking requirements. Total project financing was USD89,500, all of which was provide by E+CO (E+Co is a United States corporation that provides business development service and financing to establish enterprises that provide sustainable energy) (Vacvina, 2003).

Owner of the wastewater treatment system. High flow-rate of wastewater generation from the tapioca production process of Tan Chau-Singapore Company and limitation of onsite fish culture area lead to the need of a WWTS to pre-treat wastewater for irrigation and thorough treat it before discharging into Tha La River. A WWTS is an important element in the proposed model to ensure achievement of a zero waste industrial ecosystem. So far, the company deals with generated wastewater via storage in earth ponds. Except for land rental and pond digging costs at the construction, the company does not have to spend for operating and maintaining the pond system. This is a reason why this solution is preferable in Tay Ninh and tapioca producers do not try other solutions. The proposed WWTS will cost the company not only extra investment for installation of a new mechanical WWTS but also costs for operation, maintenance and implementation of the monitoring program. In addition, a skilled engineer is required to operate the WWTS. Though the new WWTS seems a good solution to reuse treated wastewater for cassava irrigation and to treat wastewater thoroughly before discharging into Tha La River, the implementation of this option faces difficulties of finance and skilled manpower. However, in the case of Tan Chau - Singapore Company, it seems to be possible to convince the company in installing the WWTS. Because when discussed the idea of developing a model of zero waste industrial system base on Tan Chau-Singapore Company, Mr. Huynh Duy Hau, General Director of the company, responded that:

> *"Initial investment is not a big problem for the company as compared to qualified manpower. The company would really like to approach an environmental sound system, but they do not know how to improve it better than the current situation. Besides, any proposed solutions, which promise to bring in profit for the company, will be considered first. In the last 3 years, the company allowed a company from Ho Chi Minh City to install a drying system for onsite mechanical drying of wet fibrous residues, but it stopped working because of low gains".*

He also reminded that it is hard to find any modern WWTS installed at industrial enterprises in Tay Ninh, so it is a little bit difficult to be informed about experiences on tapioca wastewater treatment technology from similar enterprises/companies.

Cassava cultivation households. Though Tan Chau-Singapore Company does not have its own cassava cultivation fields, 22 ha cassava field of other owners surrounding the company can serve as an excellent existing element of the proposed model. So far, these cassava cultivation households are cassava suppliers of Tan Chau-Singapore Company. Location of their cassava fields close to the company is an advantage for the proposed model, because they serve as receiver of compost from the composting plant and treated wastewater from the WWTS. Preferential buying cost of compost, using treated tapioca wastewater free of charge instead of water from Tha La River for irrigation and having a stable customer (Tan Chau-Singapore Company) is of interest to the cassava cultivation households in maintaining the existing relationship and a more voluntary participation in the proposed model.

Consumers/Customers. At present, the main market of tapioca starch from Tan Chau-Singapore Company are Singapore and other Asian countries such as Indonesia, Malaysia and China, which consume about 80% of its total product[63]. The remaining 20% is supplied to the domestic market. Competition on the international market forces the company to maintain and improve its product quality continuously. However, the roles of customers in pushing the company to take into account both qualities of product and environment and trigger on interest in ISO certification are not taking place at this moment. One can expect that the company conducts program of waste and emission reduction to improve the public image of the company among customers when it moves to the European and American markets. Besides, the connection with the mother company in Singapore might be instrumental in an

[63] Interview with Mr. Huynh Duy Hau, General Director of Tan Chau-Singapore Company, Tay Ninh Province.

ISO 14001 accreditation process in the future. This might be one of the reasons that make the Company Management Board willing to help researching the possibilities on a zero waste industrial ecosystem.

Horizontal Interaction between the Producers and Other Tapioca Production Companies

Tan Chau-Singapore Company is one of five large-scale tapioca production companies in Vietnam (Tay Ninh Tapioca Company, in Tay Ninh Province, and Song Be-Singapore Company, VEDAN Tapioca Company in Binh Phuoc Province, and VEDAN Tapioca Company in Dong Nai Province). Though four others follow the technology of Thailand, the production technology of these five companies is almost the same. Therefore, production efficiency in terms of tons of starch per ton cassava roots is similar among these companies. The only difference found between these companies is the amount of generated wastewater, due to difference in water circulation within the production processes. Similar to the case of Tra Co Village, these companies do not collaborate with each other on common interests such as technology development and environmental service. These large-scale tapioca production companies have their own WWTSs using different treatment technologies[64] and have different treatment efficiencies, but they have not learnt from each other's experiences to improve their treatment system[65]. However, different with the case of Tra Co Village, these companies do not compete with each other on production efficiency and product quality, but rather seek for the world market, though there is still room for them in the domestic market. This is attributed to the goal of the mother companies. The mother company has forced Tan Chau-Singapore Company to comply with the requirement of Tay Ninh DOSTE on environmental protection, for instance by storing wastewater in earth ponds. However, so far, the mother company emphasizes more strongly on the product quality and production target than improvement of environmental performance of the company. It is also worth to mention that so far there is no business association on the tapioca sector that represents the cooperation towards the governments and could fulfil tasks of common interests to tapioca production.

The Interactions between Tan Chau-Singapore Company and Other Economic Agencies and Research Institutes

Economic Agents. Relevant economic agents in the economic network include banks, the tax collection agency and insurance company. The company has to follow legislation of State Banks on interest rate on loans[66], purchase shares[67], obligations to sell and the right to purchase foreign currencies[68], etc. Besides, the company also has to comply with laws on turnover tax, profit tax[69], and import and export tax[70]. So far, economic agencies such as banks, insurance companies and tax agencies have not provide any incentives for the

[64] Tay Ninh Tapioca Company, Tan Chau-Singapore Company and Song Be-Singapore Company use a pond system technology. VEDAN Company (Binh Phuoc province) applies anaerobic treatment (UASB) in combination with pond system technologies.

[65] Interview with Mr. Thach (Tay Ninh Tapioca Company), Mr. Tu (Tan Chau-Singapore Company), Mr. Hoang (VEDAN Company).

[66] Decision 546/2002/QD-NHNN dated May 30, 2002 by the State Bank of Vietnam, establishing a new management regime on interest rates.

[67] Decision 260/2002/QD-BKH dated May 10, 2002 by the Ministry of Planning and Investment.

[68] Decision 61/2002/QD-TTg dated May 15, 2002 by the Prime Minister, amending Article 1, Clause 1 of Decree 61/2001/QD-TTg dated April 25, 2001 by the Prime Minister on obligation to sell and the right to purchase foreign currencies.

[69] Official Letter 1860 TCT/CS dated May 10, 2002 by the General Department of Taxation on VAT payments.

[70] Law on Export Tax and Import Tax dated July 5, 1993 by the IX National Assembly and Law Amending and Supplementing a number of Articles of the Law on Export Tax and Import Tax dated May 20, 1998 by the National Assembly.

company to apply cleaner production and pollution prevention measures. This is attributed to the common situation in Vietnam. For instance, insurance companies have only emerged recently in Vietnam and are mainly related to health insurance rather than risk insurance for industries. This is confirmed by Phuong (2002: 112) in her study on industrial zone:

> *"I found no environmental criteria or preconditions to be incorporated in the requirements for insurance among the scarce forms of risk insurance that exist. Hence no incentives exist for firms to invest in preventive environmental protection measures such as cleaner production and ISO 14000 (EMS)".*

Except for some demonstration projects on cleaner production in Ho Chi Minh City (ADB, 1999)[71] and Ha Noi (VCPC, 2003), banks only provide credit with short payback periods and without preferential interest rate for environmental investment. Therefore the company will face difficulties in getting a loan from a bank for new environmental investment. However, Tay Ninh governmental authorities can learn the experiences on the implementation of cleaner production projects in Ho Chi Minh City and Ha Noi to practice it in Tay Ninh Province. Besides, in order to achieve socio-economic development of Tay Ninh Province as set in the master plan by Tay Ninh PC, several targets have been set for the bank and the financial system in Tay Ninh[72]. These include: (1) carrying out researches to adjust the interest rate to attract industries to invest in clean technology and cleaner production measures, (2) simplifying the loan procedure and (3) organizing a bank for rural people, so that both companies and households are able to get loans for production and environmental improvement. By doing so, these economic agents will gradually involve in production and environmental improvement.

Research Institutes. There is hardly any relation between research institutes and the company in neither tapioca production nor environmental protection. So far, it does not seem to be necessary to ascertain a more modern tapioca production technology, because the production system is operated mechanically, except for hard root removal. However, other technical problems will appear as soon as the proposed model is implemented, especially for tapioca wastewater-fed fishponds, composting plant/biogas production, WWTS and the biogas recovery system. Technical assistance from research institutes for operating the fishponds and composting plant and from environmental centers for installing and operating the WWTS with biogas recovery system would contribute to putting the model into practice. In addition, Vietnam Cleaner Production Center (VNCPC), which has organized several activities to promote cleaner production[73], would play a role in training and helping the company to implement the proposed cleaner production measures.

Regional Relations and Interactions in Restricted Geographical Areas

Located in Tay Ninh Province, where cassava and sugar cane are the main agricultural products, Tan Chau-Singapore has the benefit of being near the raw material supply source,

[71] The project on cleaner production pilot component has been managed by Ho Chi Minh City DOSTE and conducted based on an ADB loan to Improve Environment in Ho Chi Minh City. For this project, a revolving fund of 2.5 USD million will be passed on to the Ho Chi Minh City Investment Fund for Urban Development, the grace period of 6 years and an interest rate of 2 percent per annum (ADB, 1999).

[72] Master plan for Socio-Economic Development of Tay Ninh province up to 2010.

[73] Vietnam Cleaner Production Center (VNCPC) organized train-the trainer program from May 1999 to August 2000, a sector specific training, a special skill training, a tailor-made training and seminar. So far, VNCPC organized 21 seminars in different provinces and cities nationwide (in Bac Ninh, Binh Duong, Can Tho, Da Nang, Dong Nai, Ha Noi, Hai Duong, Hai Phong, Ho Chi Minh, Khanh Hoa, Nghe An, Ninh Binh, Phu Tho and Thai Nguyen) on Introduction to Cleaner Production (19 seminars) and Introduction of Cleaner Production into Curriculum (2) (in Ha Noi and Ho Chi Minh City). Besides, VNCPC also supports the MOSTE/NEA in compiling Environmental Strategy 2000-2010 and drafting the National Cleaner Production Action Plan 2000-205.

but faces the disadvantage of limited cassava production in this area. The existence of Tay Ninh Tapioca Company, two medium-scale tapioca companies[74] and other tapioca processing households in Tay Ninh Province increases the influence on the cassava prices. Though fish culture by tapioca wastewater has not been applied in Tay Ninh Province yet (but it is proved to be possible), all elements of the proposed model seem to be suitable in an agricultural development region as Tay Ninh Province.

6.4.2 Policy Network

In this section, the relationship and interactions between Tan Chau-Singapore Company and the environmental management agencies and authorities will be clarified. The current legislation related to the environment, which may influence environmental innovation of the company and the proposed industrial ecosystem, is also analyzed. The policy network of the proposed physical-technological model of a zero waste industrial ecosystem at Tan Chau-Singapore Company is presented in Fig. 6.23.

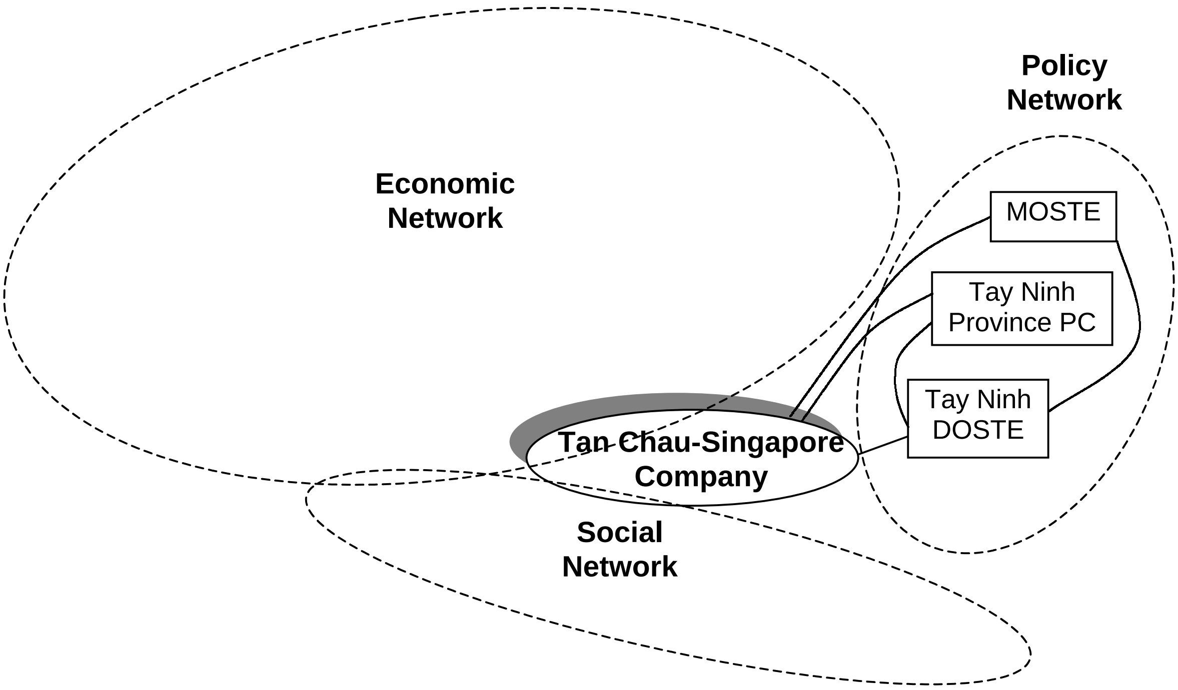


Fig. 6.23 Policy network embedding Tan Chau-Singapore Company.

Administratively, the state environmental management agency at national level is MOSTE and at provincial level is Tay Ninh DOSTE, which is linked to Tay Ninh PC in political, administrative and financial aspects. In general, the role played by MOSTE is mainly on EIA appraisal and promulgation of legislation related to environmental protection. The only role MOSTE played in the initial stage of Tan Chau-Singapore Company was by appraising environmental impact assessment report, but it was not so serious at that time. Consequently, the company was put into operation two years (in 1994) before its EIA report was approved (in 1996). As described in the appraised EIA report, all mitigation measures mainly emphasized on end-of-pipe treatments to meet the environmental standards, for instance the installation of the pond system to treat wastewater, while cleaner production and waste minimization options were not mentioned. This is not only the case of Tan Chau-Singapore

[74] Cheng Vi Starch enterprise (100% Taiwan owned capital, locates in Thanh Duc Village, Go Dau District), Heng Chang Tapioca Co. Ltd. (100% Malaysia owned capital, locates at Chau Thanh Town) (IDECO, 2003).

Company, but for most approved EIA reports until 2001[75]. It should not surprise us because until now, neither specific regulations nor incentives for a company to reuse and recycle its processing wastes were available. The current method of handling hard roots and wood shells illustrate that. No clear definition on what organic solid wastes can be disposed on a sanitary landfill at what disposal fee is one of the reasons why most industrial organic wastes have been disposed together with municipal solid waste. Vietnamese governmental environmental authorities should consider suitable incentives to force the reuse of organic waste as raw material for composting. For instance, experiences on management of farm wastes in the Netherlands show that farmers try to reuse generated wastes from their farms as much as they can to reduce or avoid payment for disposal. In addition, the Dutch government encourages farmers to reuse and recycle wastes, for instance livestock manure, by organizing training courses every year to introduce proper ways to deal with wastes. The monitoring program to ensure proper implementation is also carried out strictly. Familiarizing farmers with the use of compost instead of chemical fertilizers is not only very helpful for the industrial ecosystem of tapioca but also for many other food processing industries or other industrial sectors generating biodegradable organic matters as well. Of course, it will take a lot of time for promulgating, implementing regulation and sufficient resources for monitoring are needed, but the benefit of such activities make it really important to be considered and done. In general, current environmental legislation and regulation have forced the company to do something, such as storing wastewater in earth ponds, to comply with environmental standard, but does not push it towards a more ecological sound production. New standards for industrial effluents to be discharged into a river (TCVN 6980-2001), which is set up based on both loading of contaminants and flow rate of the receiving water body, could serve as a trigger for the company to consider the benefits of applying the proposed options on waste reuse, recycling and treatment.

Tay Ninh DOSTE is responsible for the pollution control of individual enterprises (including Tan Chau-Singapore Company) and industrial zones (IZs). The DOSTE organizes an environmental inspection at the company once every year. The company is also requested to conduct environmental quality measurements themselves at least once a year and submit such an environmental monitoring report to the DOSTE. Compared to other provinces in the South Key Economic Regions of Vietnam, the number of enterprises and IZs in Tay Ninh Province is rather low. At present, Tay Ninh DOSTE has to manage about 550 enterprises outside IZs and 1 IZ, which up till now locates 17 enterprises[76] in total. Therefore, the Environmental Management Department of Tay Ninh DOSTE knows all about the environmental situation of each enterprise in this area. However, attracting industrial investment has been the first priority of the province in recent years, so Tay Ninh DOSTE always tries to balance between requirements on industrial development and pollution control. This might be a reason why Tay Ninh DOSTE decided to approve the use of earth pond systems to store tapioca wastewater for all tapioca producers in Tay Ninh Province. Tan Chau-Singapore Company and other tapioca processing households always have spare earth ponds for this purpose, because they do not want troubles with the DOSTE. Besides, by doing so, Tay Ninh DOSTE can easily monitor environmental protection activity of these enterprises by observing whether wastewater overflows the existing earth ponds. Thus, replacement of the pond system to mechanical WWTS will cause difficulties not only in financial and manpower investment of Tan Chau-Singapore Company, but also in environmental monitoring and management by Tay Ninh DOSTE. In addition, implementation of the proposed model requires an additional

[75] Personal experiences gained from working in different projects (for instance project on "Development of A Guideline for Environmental Impact Assessment of Landfill", "Development of A Guideline for Environmental Impact Assessment of Petroleum Storage Projects", in which re-evaluation of the approved EIA reports is one of the research objectives).

[76] Interview with Mr. Hoang, Vice Director of Tay Ninh DOSTE.

monitoring program for the composting plant/biogas, fishponds, livestock feed production enterprise and cassava cultivation fields to ensure their environmental compliance. Thus with scarce resource for monitoring and effective enforcement, it is uncertain whether Tay Ninh DOSTE has sufficient capacity to push Tan Chau-Singapore Company towards a zero waste industrial ecosystem is a little uncertain.

Tan Chau-Singapore Company itself does not have a separate environmental management section in its organizational structure. Chief of the technical section is also responsible for the environmental issues of the company. So far, all environmental protection activities he did consist of ensuring tapioca wastewater to be discharged into earth pond system properly and selling fibrous residues, hard roots and wood shells to farmers. The chief of technical section of Tan Chau-Singapore Company, said that from the start (1994) until now (2002), these activities have been conducted for along time and quite simple; he is not interested in making any changes unless it is requested by the company management board[77]. However, for future implementation and operation of the proposed model, which is more complicated than the current tapioca production system, it is believed that the establishment of an environmental management system for the company is essential. This section can have an important impact on the implementation of the model as it may redirect all relevant activities and procedures of the company towards a zero waste industrial ecosystem in more a systematic way.

6.4.3 Societal Network

The societal networks of the physical-technological model of a zero waste industrial ecosystem at Tan Chau-Singapore Company consist of resident communities (mainly farmers), mass media, Youth Union and Women Association (Fig. 6.24).

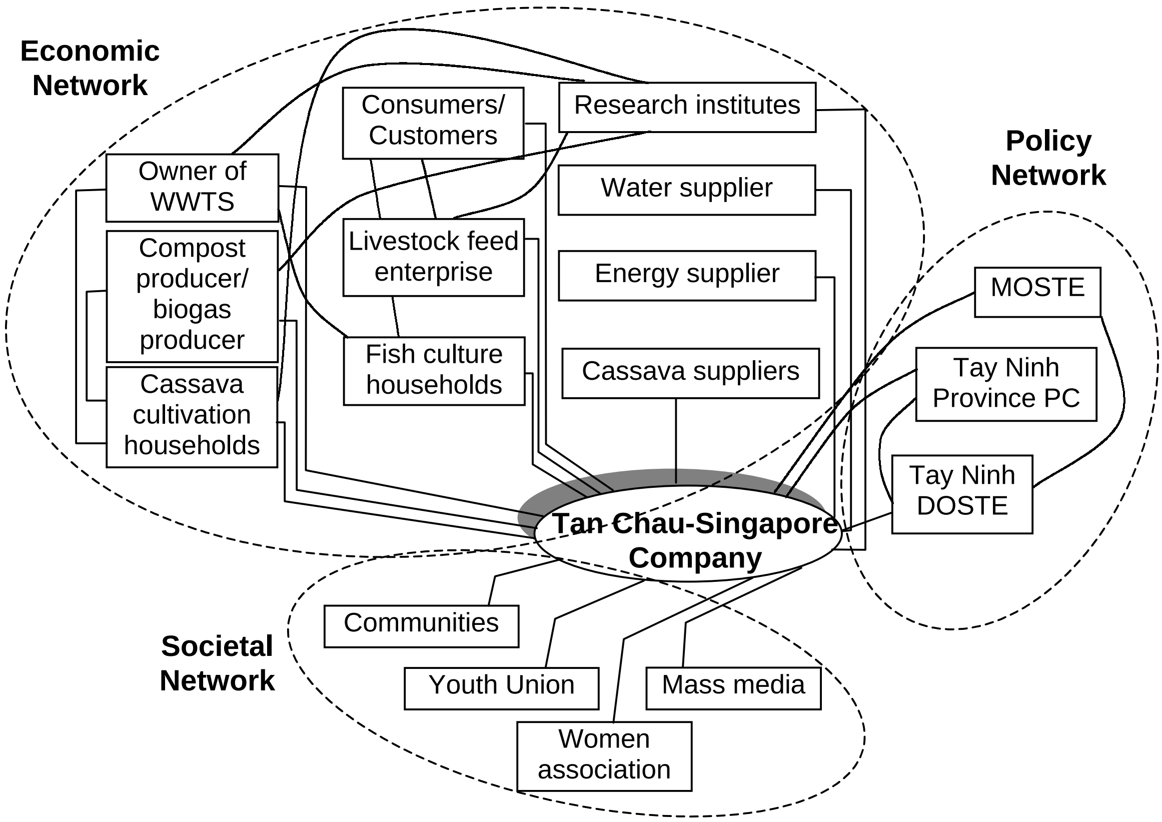


Fig. 6.24 Networks embedding Tan Chau-Singapore Company.

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[77] Interview with Mr. Tu, Chief of Technical Section of Tan Chau-Singapore Company.

The influences of a societal network are not exerted via the market nor via administrative regulation but by means of public pressure, often via the media, in case of Tan Chau-Singapore Company, public pressure has not shown its effectiveness. So far, Tan Chau-Singapore Company has a friendly relationship with local residents, who sell cassava roots to the company and buy with preferential prices both wet fibrous residues and hard roots and wood shells. Therefore, though the earth pond system of the company causes foul odor, there are no complaints from the local residents. Some households stated that their families have lived here for a long time, so they are familiar with that odour nuisance. In addition, households with family members being employees of Tan Chau-Singapore Company gave nothings but positive opinions. Thus, in this case, community driven regulation seems to play no role. In addition, social organizations such as the Youth Union, the Women Association and the Veterans have shown no interest in environmental issues yet, while these actors could help the farmers to complain by putting systematic pressure on the company.

Though mass media such as television, radio and newspapers are available and popular in the residential areas, these mass media have not played any role in environmental improvement of the Tan Chau-Singapore Company yet. Therefore, it is suggested that Tay Ninh environmental agencies and authorities should collaborate with the television station or newspaper editorial office to develop a program to introduce good practices in reuse and recycling of waste, cleaner production and environmental performance. This is a good way to demonstrate and encourage the producers to consider both production and environmental improvement and to educate residents on the possibility to reduce environmental pollution at little costs. This is also an effective way for tapioca companies and other industrial producers to be informed about experiences and involved on environmental protection activities. Existing publication prepared by Vietnam Cleaner Production Centre such as guidance manuals on cleaner assessment and video tapes, brochures and leaflets on cleaner production are useful media for Tay Ninh DOSTE to disseminate cleaner production for industries in the province[78]. Creation of a Waste Exchange Information program by the Section of Research on Environmental Technology and Management of Tay Ninh DOSTE would be useful to enlarge the waste exchange program for different industries in the province.

6.5 CONCLUSIONS

From this case study, we conclude that cleaner production, waste exchanges and ideas of industrial ecology are valuable in greening tapioca production industry. The technological options and organizational schemes are different compared to the case study on family-scale tapioca production units at Tra Co Village (chapter 5). This case study has revealed an excellent combination between industry (tapioca, livestock feed, compost production/biogas production) and agriculture (fish culture, cassava cultivation) to approach a zero waste industrial ecosystem for tapioca industry.

The physical-technological model developed at the large scale Tan Chau-Singapore Company has several advantages compared to the case of Tra Co Village. First, convincing one company to participate as an anchor in the model is easier than to get agreement from all 60 tapioca production households in Tra Co Village. Second, the implementation of a Cleaner Production Program (to conduct the proposed cleaner production measures) for one company

[78] From 1998 to the end of 2002, in addition to several activities on promotion of cleaner production, the following public media were conducted by the Vietnam Cleaner Production Centre: (1) brining about 12 articles; 20 presentation for both national and regional workshops seminars and roundtable; (2) translating, editing and printing three guidance manuals on cleaner assessment; (3) news reports, interviews and films on the Center and its activities have been broadcasted; (4) video tapes, brochures and leaflets have also been prepared (VCPC, 2003).

is much easier than in case of a number of tapioca production households. Cleaner production training in one company is surely not difficult compared to training a whole village. Third, the company has better skilled staffs for specific tasks, for instance production technology, machine reparation, administration, etc. In other words, it is easier to train workers to become adapted to new technology or installations. Though treatment is the final selected option of the model and costly, treatment of wastewater in this case seems to be attractive to the company because it is a possibility for the company to achieve self-sufficient in energy by biogas recovery from proper operation of the proposed WWTS. Finally, the company has sufficient area available for onsite reuse and recycling options, which requires land for new installation and operation. Reusing wastewater for fish culture and reuse of treated wastewater and compost for cassava cultivation is not only meaningful in the reduction of generated wastes and production of new products, but also in natural resource conservation, especially water.

While in the case of Tra Co Village, the environmental pollution of the household-scale tapioca producing units has only been discovered recently and been put on the agenda by the provincial environmental authorities, Tay Ninh DOSTE seems not to have any plan nor activities for environmental innovation within Tan Chau-Singapore Company. The pressure put on the company at the initial stage was on treatment of wastes rather than orienting them to optimize their material flow within the production process and paying attention on onsite and offside reuse and recycling of non-product materials. Lack of manpower, expertise and experience of Tay Ninh DOSTE is debit to today’s neglect. Moreover, the current national regime of environmental regulation does not encourage the company to look towards the implementation of cleaner production and waste exchange. Thus, the barriers that current environmental authorities meet in greening tapioca production in this case study, are similar to that of Tra Co Village.

Community driven regulation does not seem to play any role at present and might also be limited in the future if no adverse environmental impacts affect the interest of local communities directly. Looking into the future, mass media such as television, newspapers and radio might be helpful to spread information on practical application of the ideas and notions of industrial ecology in environmental protection and natural resource conservation. Thus, as a consequence, we should put all our hope at the company to start with implementation of the model.

CHAPTER 7

INDUSTRIAL ECOSYSTEM FOR A GROUP OF DIFFERENT FOOD PROCESSING INDUSTRIES
A Case Study at Bien Hoa 1 Industrial Zone, Vietnam

In this chapter, an integrated model of pollution prevention is again applied to a group of food processing companies located in Bien Hoa 1 Industrial Zone to push it towards a zero waste industrial ecosystem. The chapter starts with a brief introduction to Bien Hoa 1 IZ and its environmental implications (section 7.1) in order to give an overview on establishment and development of Bien Hoa 1 IZ and current environmental problems. Focussing on food processing industry, section 7.2 described the production processes in more detail, material inputs, products, byproducts and wastes of individual companies and its environmental implications. Data from this section are used as foundation for further development of physical-technological model of a zero waste industrial ecosystem in section 7.3. Roles of actors and institutions in implementation of the model are analyzed in section 7.4. The final section presents concluding remarks of the case study.

7.1 BIEN HOA 1 INDUSTRIAL ZONE AND ITS GENERAL ENVIRONMENTAL IMPLICATIONS

7.1.1 Introduction to Bien Hoa 1 Industrial Zone

Answering the demand of Vietnam's economic development and industrialization, Bien Hoa IZ (now called Bien Hoa 1 IZ) has been established in the early 1960s named Bien Hoa Industrille des Zone (SONADEZI, 1997). It covers an area of 551 ha in Bien Hoa City, about 6 km from the city center, 25 km from Northeast of Ho Chi Minh City and 90 km from Vung Tau City. The North is close to the residential area of An Binh and Binh Da Wards, the Southeast and South are near Ha Noi highway, the Southwest and West nearby Cai River (Dong Nai River branch). In the first designs, there were no residential areas planned inside Bien Hoa IZ. However, the war in the South of Vietnam caused immigration and made people settle into An Binh and Binh Da Wards, resulting in a change of the IZ area.

At the beginning, 52 enterprises in Bien Hoa IZ were equipped modernly with advanced facilities made in the United States, Germany, France, Japan, etc. Their products consisted of paper, detergent, wool, wood, construction materials, food processing products, etc., which had competitive prices compared to other neighboring countries. Most enterprises in Bien Hoa IZ belong to private companies, so producers mainly emphasize on using the facilities and labor effectively. Infrastructures such as internal transportation roads, water supply, and electricity network, etc. were constructed quite completely. However, the industrial waste collection and treatment (including exhausted air, wastewater, and solid wastes) were not given much attention, resulting in the discharge of wastewater into Dong Nai River directly, without any treatment (CENTEMA, 1997). This attributed to serious deterioration of the surface water quality. Huge amounts of industrial wastes were generated for many years and accumulated beyond the self-purification capacity of nature.

From 1975 up to now, Bien Hoa 1 IZ is still an important IZ of Vietnam with 90 enterprises (Dong Nai Industrial Department, 2002a)[94], (of which 56 enterprises are state owned),

[94] Presently, there are 90 projects, of which 88 are in operation and 2 in preparation.

benefiting the national and Dong Nai Province budget for billions VND a year. Differing from other IZs, industrial development in Bien Hoa 1 IZ occurred simultaneously with the development of residential area engaged by local communities. Therefore, at present, the industrial zone covers only about 335 ha, of which 231 ha are for rent. The 231 ha rented area in Bien Hoa 1 IZ have been filled for 100% (Fig. 7.1) by different kinds of industry such as food processing, livestock feed, chemical, textile and dying, leather and leather products, wood and wood products, pulp and paper, metallurgy, construction materials, electronics industry, etc. (Dong Nai Industrial Department, 2002a). Among them, 6 food processing companies including Bien Hoa Sugar Company, Bien Hoa Confectionery Corporation (BIBICA Company), Bien Hoa Coffee Factory, DIELAC Powder Milk Factory, Dong Nai Ice Enterprise, and DONA NEWTOWER Joint Venture Company are the companies researched in this case study.

Though infrastructure had been repaired and upgraded many times, the current environmental situation of Bien Hoa 1 IZ has still not been improved. Old technologies and facilities, less attention to environmental protection, unqualified cadres, etc. have caused serious impacts on the environment.

7.1.2 Environmental Implications of Bien Hoa 1 Industrial Zone

So far, there is no common WWTS installed in Bien Hoa 1 IZ. Surveys carried out in May to June 1999 and February to March 2000[95] showed that only 12 of 77 enterprises have own WWTSs, but the qualities of effluents are not consistent with Vietnamese standards for discharging into Dong Nai River yet. Additionally, the sewer network of the industrial zone has not been installed yet, therefore most wastewater from enterprises is discharged into existing ditches or natural drainage basins freely. For instance, Bien Hoa Sugar Company, BIBICA Company, Dong Nai Paper Factory, DIELAC Powder Milk Factory, Bien Hoa Chemical Factory, etc. have discharged large amounts of heavy polluted wastewater into Dong Nai River. Concentrations of organic pollutants in terms of BOD_5 and COD of these wastewaters are in the range of 580-1350 mg/L and 730-1940 mg/L, respectively. Suspended solid concentrations vary from 120-450 mg/L and pH values in the range of 4.6 – 11.4. At the discharge points, where wastewater, including industrial wastewater and domestic wastewater, mixes with river water, organic pollutant concentrations are still 6-18 times higher than that of the maximum allowed values in the discharged wastewater (EPC, 1992; CENTEMA 1997, 1999 and 2000). Qualitatively, it is easy to recognize the subjected area by the difference in river's water color.

Air pollution is mainly caused from utilization of diesel or fuel and oil during processing. The surveys carried out in March 2000 showed that dust, SO_x and NO_x are the main air pollutants in Bien Hoa 1 IZ. Statistical monitoring data provided by the Environmental Monitoring Division of Dong Nai DOSTE showed that at some enterprises dust contents were 3-6 times higher than the maximum allowed value (0.3 mg/m^3). SO_2 concentrations at the same sampling locations were also about 1.3-3.3 times higher than the standard (0.5 mg/m^3).

Solid wastes generated from enterprises in Bien Hoa 1 IZ can be classified into 3 categories: domestic, non-hazardous industrial and hazardous industrial solid waste. Enterprises have to sign contracts with Bien Hoa Urban Environmental Company for collection and treatment of the domestic solid waste (it is dumped at Trang Dai dumping site). Non-hazardous industrial solid waste can also be collected by Bien Hoa Urban Environmental Company or stored within the enterprises (such as slag from VICASA Company, SADAKIM Company).

[95] Surveys were carried by CENTEMA for different projects related to the environmental quality and environmental pollution caused by Bien Hoa 1 IZ. The survey was lead by me.

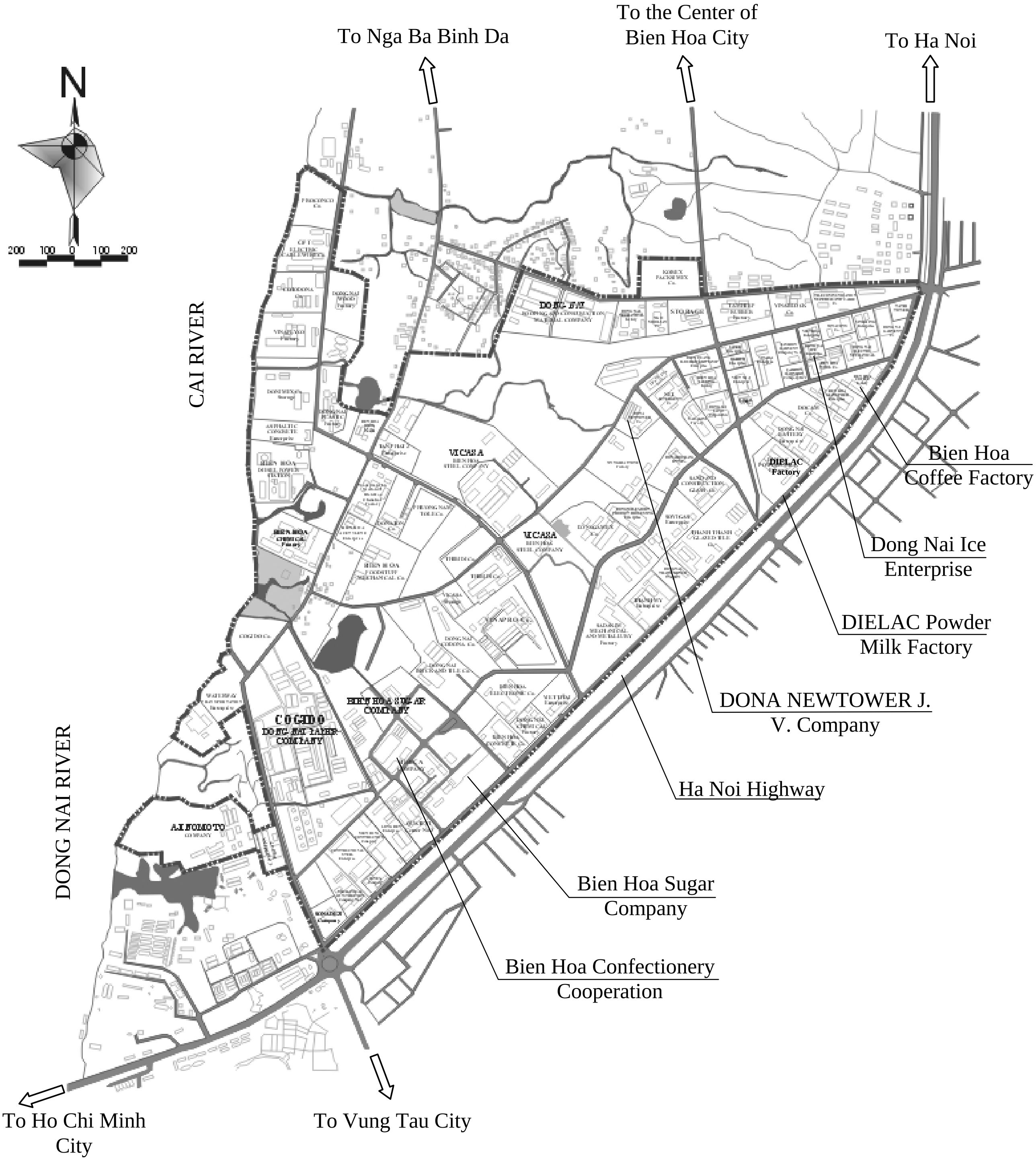

Fig. 7.1 Locations of enterprises in Bien Hoa 1 IZ (CENTEMA, 2002).

Some non-hazardous industrial solid wastes, which consist of recyclable materials, such as clean wrappings (by hard paper, cardboard boxes, metal scraps, spent coffee grounds, calcium carbonate, etc.), are sold or given free of charge to recyclers. Hazardous solid wastes or liquid wastes are mainly stored and waited the availability of Giang Dien Industrial Waste Treatment Plant. In recent years (2002 and 2003), SONADEZI[96] has installed a pilot scale industrial and hazardous waste treatment plant on an area of 2 ha as a demonstration plant to gain experience on operating such a system. A full-scale plant will be constructed based on the experiences of the pilot scale plant and will be extended up to 100 ha at Giang Dien

[96] Infrastructure Development Company of Bien Hoa 1, Bien Hoa 2, Go Dau industrial zones.

Commune. Some hazardous wastes are treated by hazardous waste treatment companies such as Tan Phat Tai Company[97].

Some of the pollution sources causing environmental problems in Bien Hoa 1 IZ are from the production activities of food processing companies, which will subsequently be discussed in the next section.

7.2 FOOD PROCESSING COMPANIES: Production and Environmental Implications

In line with the purpose of the research, only food processing companies in Bien Hoa 1 IZ were included in the inventory, consisting of Bien Hoa Sugar Company, BIBICA Company, Bien Hoa Coffee Factory, DIELAC Powder Milk Factory, Dong Nai Ice Enterprise and DONA NEWTOWER Joint Venture Company. The production technology and environmental problems of each company are described briefly in the following sections.

7.2.1 Bien Hoa Sugar Company

Introduction to the Company

Bien Hoa Sugar Company[98] was established in 1962 and is located in an area of 201,216 m^2 (of which, the production area occupies 145,455 m^2). The total staff and workers, working in the company consist of 520 persons, of which the administrative cadres consist of 57 persons. The products of the company are refined cane sugar and wine.

Bien Hoa Sugar Company

Inputs. The raw materials needed for both production processes are raw sugar, lime, activated carbon, filter aid powder, salt, resin, food alcohol, acid, and sodium hydroxide (Table 7.1). The company consumes diesel fuel oil (DO), fossil fuel oil (FO), gasoline, lubricant and electricity (Table 7.2). From the city water supply system, about 214,000 m^3 is consumed each year, of which 186,000 m^3/year is directly used in the production processes.

Table 7.1 Raw materials and chemicals required for production of Bien Hoa Sugar Company

Raw materials and chemicals	Unit	Consumption			
		1995	1996	1997	1998
Raw sugar	tons/year	69,880	77,819	83,860	87,915
Lime	kg/year		257,395	489,598	551,477
Powder activated carbon	kg/year			137,260	121,000
Filter aid powder	kg/year			45,000	53,500
Salt (NaCl)	kg/year		440,082	838,310	1,000,842
Ion exchange resin	kg/year		1,175	10,000	5,000
Food alcohol	L/year				311,889
Phosphoric acid (H_3PO_4)	L/year		2,325	3,211	5,397
Sodium hydroxide (NaOH)	kg/year		33,090	535,283	666,932

Source: Bien Hoa Sugar Company, 2000.

[97] Interview with Mr. Diep and Mr. Vu Van Thang, managers of Tan Phat Tai Hazardous Waste Treatment Company, Dong Nai Province.

[98] Until March 2001, Bien Hoa Sugar company was cooperated with BIBICA Company. Under decision 44/2001/QD-TTg of March 27, 2001, this company was split into Bien Hoa Sugar Joint Stock Company and Bien Hoa Confection Corporation (BIBICA Company). The Bien Hoa Sugar Joint Stock Company received a registration license No. 4703000014 on May 16th, 2001 issued by the Dong Nai Service of Planning and Investment. (ASEM Connect, 2002a).

Table 7.2 Demands of fuel and energy for production of Bien Hoa Sugar Company

Fuel and Energy	Usage Purposes	Unit	Demand
Diesel Fuel Oil	Furnace burning and transportation	L/year	375,089
Fossil Fuel Oil	Burning in boiler	L/year	14,845,778
Gasoline	Sugar shovel vehicle, cleaning equipment	L/year	9,354
Lubricant	Lubricating vehicle and equipment	L/year	6,253
Electricity*	Lighting and production	KWh/year	9,019,650

Source: Bien Hoa Sugar Company, 2000.

* 15% of electricity demand is supported by the national electricity network and the remaining 85% are supported from the company generator.

Products and Capacity. Total production capacity of refined sugar and wine by Bien Hoa Sugar Company is summarized in Table 7.3.

Table 7.3 Capacity of Bien Hoa Sugar Company

Products	Unit	Capacity			
		1995	1996	1997	1998
Refined sugar	tons/year	57,723	72,739	79,080	83,455
Wine	L/year	1,149,000	787,225	1,024,388	1,025,000

Source: Bien Hoa Sugar Company, 2000.

Refined Cane Sugar Production Technology. The cane sugar refining process mainly focusses on removing colored compounds, which influence the quality of the final product (Cartier, et al., 1997). Refined sugar production technology of Bien Hoa Sugar Company follows traditional refining processes including affination, re-melting, phosphatation, carbonation, physical refining and crystallization. Microfiltation and ultrafiltration techniques are also applied to realize the production of very high quality sugar. In general, the production process of refined sugar of Bien Hoa Sugar Company with different waste sources is briefly described in Fig. 7.2.

Affination is a process of washing raw sugar to remove colored impurities using relatively saturated molasses. By mixing raw sugar with the molasses, the surface layer of sugar crystals, which contain colored impurities, will gradually dissolve into the molasses until saturated molasses is achieved, called magma liquor. Temperature is controlled at around 40-45^oC by hot steam in order to speed up the dissolution. Washed sugar crystals are separated from magma liquor by centrifugation. Thereafter, the sugar crystals are dissolved into fresh water to yield a 65% by weight washed sugar liquor. This process is called re-melting.

Phosphatation treatment is applied to clarify washed sugar liqour. This process produce calcium phosphate precipitate, which entraps suspended and colloidal material such as bagasse particles, proteins and polysaccharides. In addition, 20-35% of the color can be removed depending on the amount of phosphoric acid used (Chen and Chou, 1993). The milk of lime and phosphoric acid are added to the washed sugar liquor to form calcium phosphate by the following reactions:

$$Ca(OH)_2 + C_{12}H_{22}O_{10} \rightarrow H_2O + CaO.C_{12}H_{22}O_{11}$$
$$2\ H_3PO_4 + CaO.\ C_{12}H_{22}O_{11} \rightarrow 3\ C_{12}H_{22}O_{11} + Ca_3(PO_4)_2 + H_2O$$
$$2\ H_3PO_4 + 3\ Ca(OH)_2 \rightarrow Ca_3(PO_4)_2 + H_2O$$

Temperature is maintained at around 70-75^oC in order to reduce viscosity of the solution, sterilize bacteria and avoid caramelization. This defecation process needs 30% less lime compared to cold defecation (Oerlemans, 1985). Carbonation occurs successively by adding carbon dioxide to this mixture. Formed flocs of calcium carbonate are very voluminous, so that it absorbs much of the impurities present. All flocs are then filtrated. To curb inversion, carbonation is applied only to heated sugar liquor.

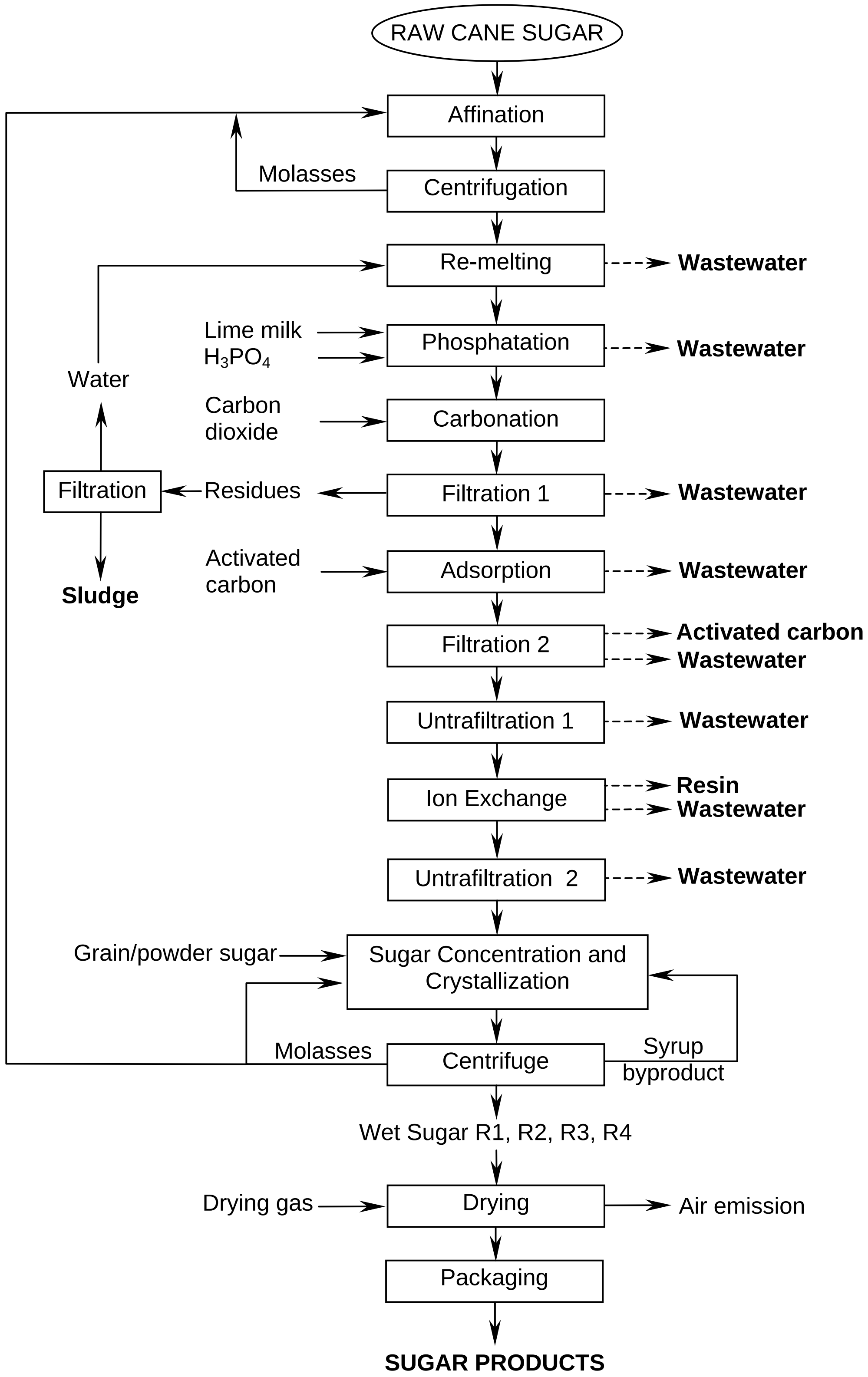

Fig. 7.2 Refined sugar production process of Bien Hoa Sugar Company.

Physical refining consists of an adsorption process by activated carbon and ion exchange. Powder activated carbon is mixed with water before adding to the sugar solution. Adsorption happens within 30-45 minutes, at pH 7.0-7.2 and temperature of 80-90^{o}C. Besides, filtration aid powder is also added into the mixture of sugar solution in this stage to increase the filtration efficiency. Combining micro-filtration and ultrafiltration after adsorption result in the production of sparkling syrup with reduced color and increased purity, which could be further decolorized through ion exchange resin. In general, ion exchangers remove colored substances and inorganic impurities.

The clarified sugar liquor is firstly concentrated in evaporator. A very important factor in the evaporation process is the retention time of the sugar liquor. A long retention time in combination with a high temperature leads to inversion of sugar, decomposition of organic non-sugars leading to formation of ammonia and colored products and scaling. Scaling will hinder the transfer of heat. However, it is not completely preventable. The main component of the scales is calcium phosphate and calcium carbonate. Therefore, the evaporators have to be cleaned periodically. Thereafter, resulting syrup is pumped to the vacuum-pans, which are in fact evaporators working under reduced pressure. Most of the remaining water in the syrup is evaporated here. The result is a certain degree of super-saturation in the liquid, leading to the crystallization. The process of crystallization is started up by adding grain or powder sugar to the syrup, called “seeding”. After a certain boiling time, the semi-solid mass of crystals and syrup, called massecuite, is dropped in a trough and led to the centrifugal machines, that yield sugar and a liquid byproduct, molasses. There are several systems for recovering as much sugar as possible from the syrup. The main difference in these systems is the distribution of syrup flows and molasses flows to the different pans. In the case of Bien Hoa Sugar Company, the crystallization produces 4 types of refined sugar called R1, R2, R3 and R4. Refined sugar R1 is of the highest quality and R4 has the lowest quality. After centrifugation, the sugar is dried by hot air (at 90^oC). Strict process control is required because too high moisture content of the product will lead to caking or bacterial degradation. Finally, the product is packed and stored. Syrup generated from the process of refined sugar R4 will be reused in the wine production process.

Wine Production Technology. In general, the production process of wine is briefly described in Fig. 7.3.

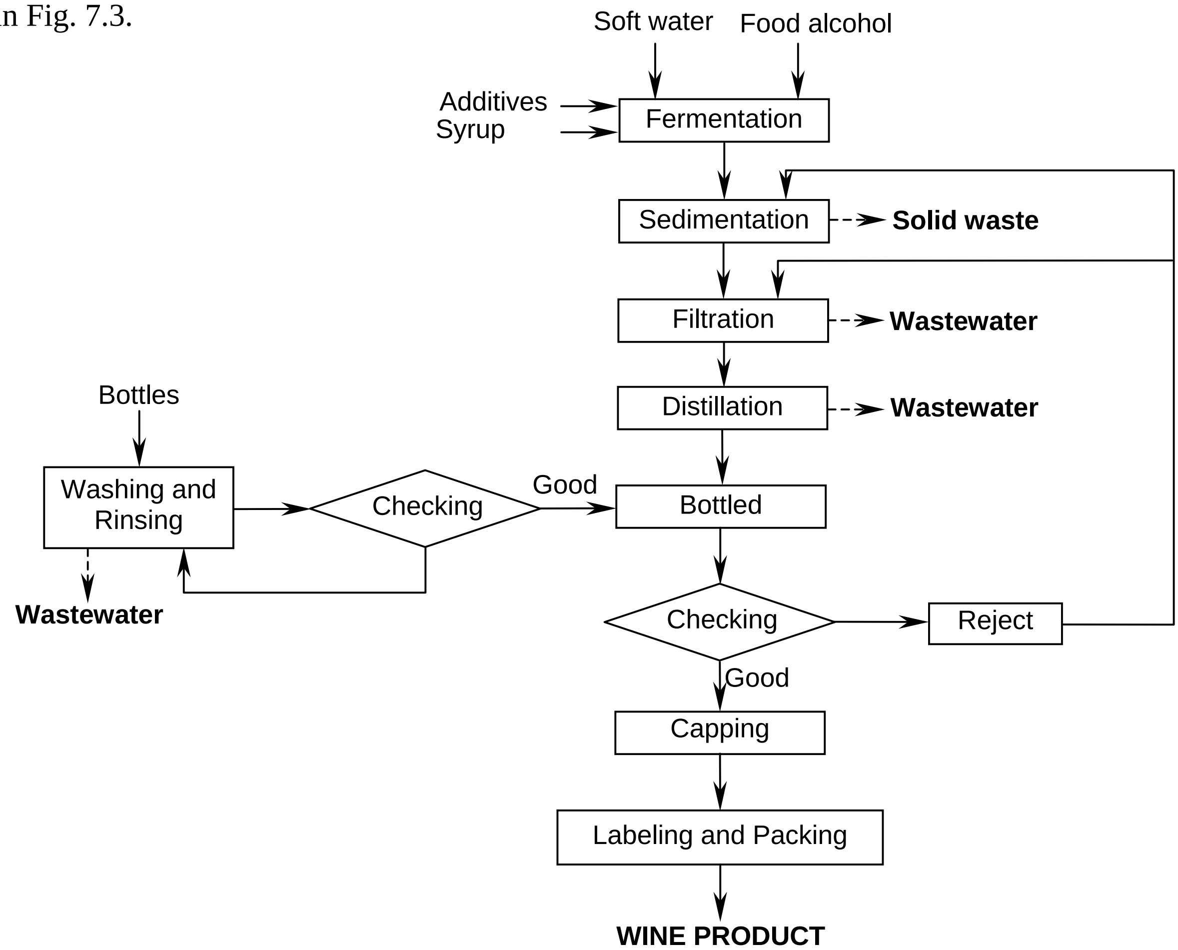

Fig. 7.3 Wine production process of Bien Hoa Sugar Company.

Syrup byproduct from the refined sugar production process is mainly raw material for wine production. Syrup byproduct, food alcohol, additives, and water is mixed and fermented to produce wine. The resulted mixture is then passed the sedimentation and filtration stage to remove suspensions before entering distillation. Distilled wine is then bottled and checked before capping. Unqualified wine bottles are returned back to the filtration stage for re-processing, while qualified bottles are labeled and packaged.

Environmental Implications

Wastewater of the company is generated from micro-filtration, ultrafiltration, filter back washing, resin regeneration, machine and bottles washing, all together accounting for approximately 500 m^3/d of industrial wastewater (excluding cooling water). Besides, about 30 m^3/d of domestic wastewater is generated from toilets and canteens. The cooling water flow is as high as 2,000 m^3/d, which is supplied by surface water of Dong Nai River. In general, wastewater from the cooling stage is not highly contaminated (BOD_5 is only about 4 mg/L), therefore it can be discharged directly into the receiving without treatment. Observations at Bien Hoa Sugar Company, Dong Nai (CENTEMA, 1999), Binh Duong Sugar Company, Song Be (CENTEMA, 1996), Phung Hiep Sugar Company, Can Tho (Can Tho DOSTE, 1995) showed that wastewater from the cooling process of these companies are discharged directly into Dong Nai River, Ba Lua Canal, and Muong Lo Canal, respectively. This reflects that in fact, most refineries are located near rivers and canal systems in major cities.

Wastewater generated from the other production stages are treated by the existing wastewater treatment system (WWTS) of the company using a conventional activated sludge process (Fig. 7.4). Wastewater is firstly released in a primary sedimentation tank to remove suspended solids. The wastewater then enters an equalization tank to create a wastewater, which has uniform concentrations of contaminants and a constant wastewater flow rate before going to the neutralization tank.

The existing wastewater treatment system of Bien Hoa Sugar Company

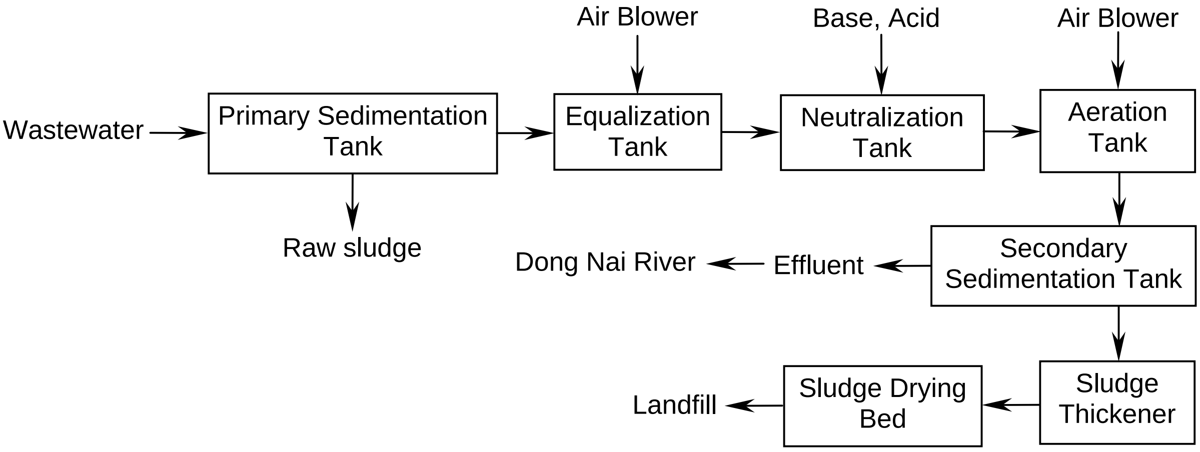

Fig. 7.4 Current WWTS of Bien Hoa Sugar Company.

Alkalinity and pH is adjusted and nutrients are added to the wastewater in the neutralization tank in order to create suitable conditions for aerobic biodegradation in the aeration tank.

Biological sludge generated from the aeration tank is removed from the secondary sedimentation tank, dewatered in sludge thickener and further removed water by sludge drying bed. Effluent from the secondary sedimentation tank is discharged into Dong Nai River. However, quality of the effluent at the discharging point is still not consistent with Class A of Vietnamese standard (Table 7.4). Organic matters in term of COD and BOD_5 are about 6 times and about 8 - 10 times higher than those of COD and BOD_5 standards, respectively (indicated by the bold number in Table 7.4). Ammonia ($N\text{-}NH_3$) concentrations are also 3 - 5 times higher than the standard. Thus, with wastewater flow rate of about 500 m^3/d, Bien Hoa Sugar Company discharges about 150 kg COD/d or 100 kg BOD_5/d into Dong Nai River. This is one of the important pollution sources from Bien Hoa 1 IZ, which requires special consideration in order to reduce the effects to Dong Nai River, an important water source for both Ho Chi Minh City as well as Dong Nai Province.

Table 7.4 Quality of effluent from Bien Hoa Sugar Company[99]

Parameter	Unit	Sampling period						TCVN (A) 5945-1995[100]
		May 99	June 99	July 99	August 99	October 99	November 99	
pH	-	6.57	6.70	6.69	6.69	6.78	6.82	6 - 9
TDS	mg/L	140	148	152	133	142	157	-
Turbidity	FTU	99	94	90	88	90	90	-
COD	mgO_2 /L	**305**	**296**	**289**	**294**	**299**	**287**	50
BOD_5	mgO_2 /L	**185**	**188**	**162**	**185**	**170**	**185**	20
$N\text{-}NH_3$	mg/L	**0.40**	**0.32**	**0.35**	**0.50**	**0.33**	**0.35**	0.1
$N\text{-}NO_3^-$	mg/L	Trace	Trace	Trace	Trace	Trace	Trace	-
SO_4^{2-}	mg/L	Trace	Trace	Trace	Trace	Trace	Trace	-
$P\text{-}PO_4^{3-}$	mg/L	0.15	0.06	0.08	0.06	0.07	0.06	4
Total Fe	mg/L	0.05	0.15	0.09	0.08	0.09	0.08	1

Source: CENTEMA, 1999.

Solid waste generated from the sugar refining process consists of $CaCO_3$ and $Ca_3(PO_4)_2$ (1,050 tons/year), activated carbon (121 tons/year), filter aid powder (53.5 tons/year), ion exchange resin (5 tons/year), and molasses (500 tons/year). During the wine production process, solid waste is mainly generated during the sedimentation and bottle washing stages. At present, biodegradable solid waste is dumped in an earth hole, while the non-biodegradable parts (5%) are stored separately before burning them within the company.

Polluted air is mainly emitted from the boiler, which uses fossil fuel oil (FO). Gas emitted from combustion of fuel in the boiler contains CO_2, SO_x, NO_x and dust. The amounts of generated CO_2, SO_x and NO_x vary depending on the composition of fuel, especially contents of carbon, sulfur[101] and nitrogen. Approximate loading of air pollutants generated from fuel combustion can be estimated based on pollution coefficients proposed by WHO (1993) as presented in Table 7.5.

[99] Influent of the WWTS of the company is a mixture of wastewater of Bien Hoa Sugar and of BIBICA Companies.

[100] Industrial wastewater with concentrations of substances equal to or lower than the values specified in this column are allowed to be discharged into water bodies as well as domestic water supply sources (appendix 4).

[101] FO of Vietnam normally contains 1.5-2.9% S (interview with Mr. Nguyen Danh Hung, Vice Director and Mr. Nguyen Phi Hoa, Chief of Technical Section of Nha Be Petroleum Storage (PETROLIMEX) and refers from the article of Dang and Nhue, 2003).

Table 7.5 Air pollution coefficients for FO combustion (kg/ton FO)

Parameters	Pollution coefficients
SO_2	19.8 (for FO contains 3% S)
NO_2	9.6
SO_3	2.75
Dust	0.238

Source: WHO, 1993.

7.2.2 Bien Hoa Confectionery Corporation (BIBICA Company)

Introduction to the Company

BIBICA Company and Bien Hoa Sugar Company

Bien Hoa Confectionery Corporation (BIBICA Company) was established under Decision No. 234/1998/QD-TTg dated December 1st 1998 by the Prime Minister and officially operated since Jane 16th 1999 under the trading license No. 059167 by the Service of Planning and Investment of Dong Nai Province (BIBICA, 2002). BIBICA Company is located on the land of Bien Hoa Sugar Company as this company belonged to Bien Hoa Sugar Company until 1998. This company produces starch syrup, hard candy, soft candy and cakes. Total productivity of the company is 16,000 tons/year, of which, 2% is exported. A total of 600 workers directly operate the production process.

Inputs. Raw materials needed are enzymes (2.25 kg/year), tapioca starch (2,050 tons/year), food salt (855 tons/year), sugar (8,250 tons/year), butter (400 tons/year), milk (2,100 tons/year), eggs (2,300 tons/year), activated carbon (2.75 tons/year), filter aid powder (1.2 tons/year) and wrapping materials (such as cardboard boxes). The water consumption is about 7,700 m^3/year and is drawn from the city water supply system. Electricity is the main energy source required for the production.

Production Technology. Production processes of the four different products of BIBICA Company namely starch syrup, hard candy, soft candy and cake are briefly described in Fig. 7.5, Fig. 7.6, Fig. 7.7 and Fig. 7.8, respectively.

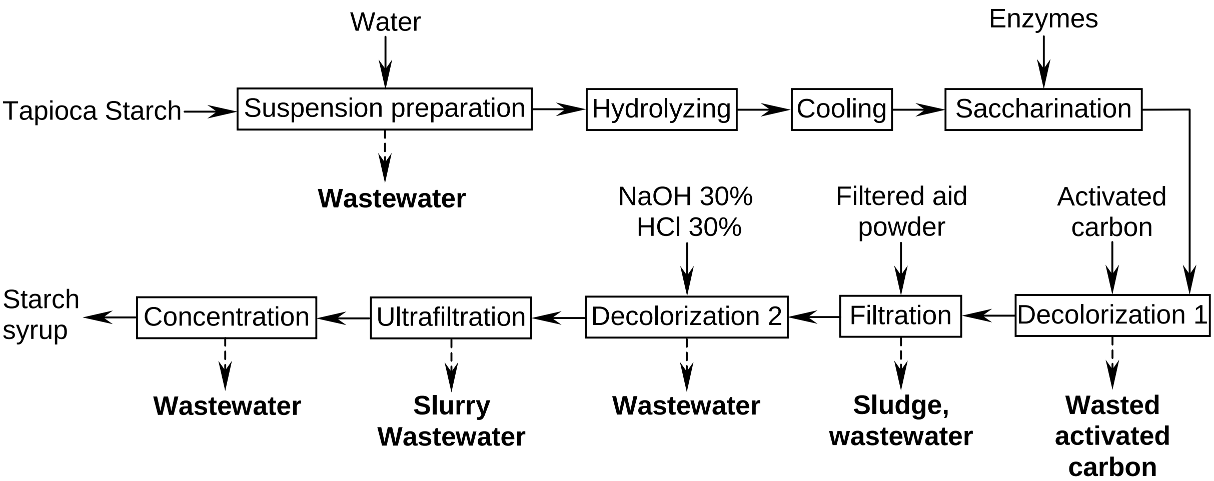

Fig. 7.5 Starch syrup production process of BIBICA Company.

Tapioca starch is the main raw material of starch syrup production. The starch is first mixed with water to form a suspension mixture before entering the hydrolyzing process. The hydrolyzed starch mixture is then cooled down before adding enzymes for the saccharination process. Decolorization and purification is conducted using a combination of activated carbon adsorption, micro-filtration and ultrafiltration. Finally, the clarified solution is concentrated and stored for further use in the candy production.

In order to manufacture hard candy, sugar and malt is dissolved in water and boiled before it is mixed with additives and aromatic spices. Different aromatic spices added classify different kinds of candy. The resulted mixture is then cooled down and shaped. Candies are cooled again before wrapping and packaging.

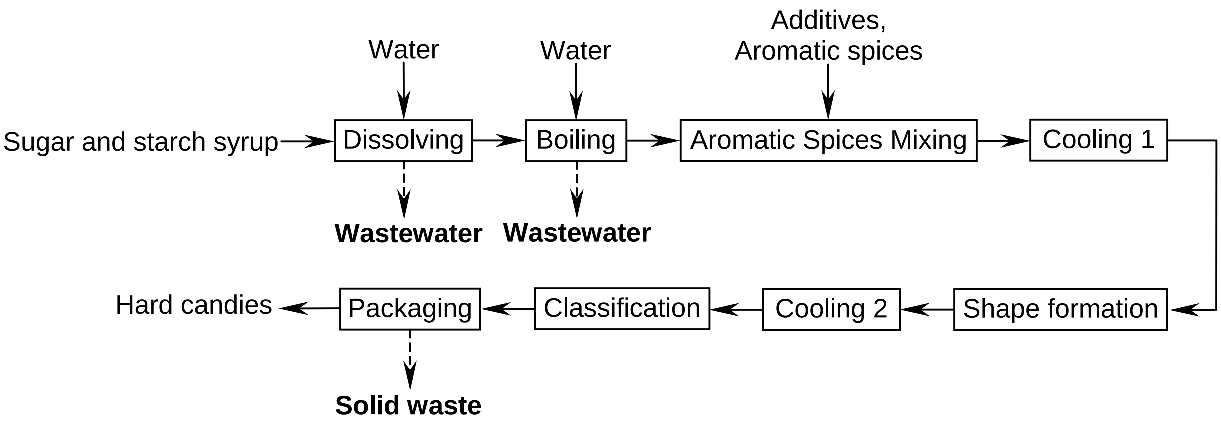

Fig. 7.6 Hard candy production process of BIBICA Company.

In soft candy production (Fig. 7.7), sugar, malt, butter and milk are dissolved in water and boiled. Aromatic spices and additives are mixed with the boiled solution and then cooled to knead. The resulting mixture is then cooled down again and shaped before wrapping and packaging.

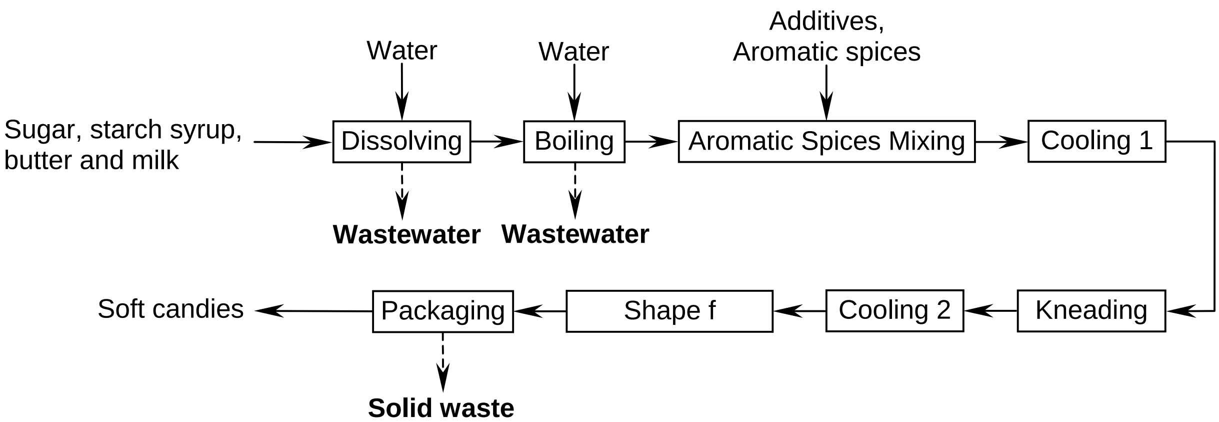

Fig. 7.7 Soft candy production process of BIBICA Company.

Sugar, tapioca starch, eggs, butter and milk are raw materials for the cake production process (Fig. 7.8). These materials are mixed together with water and then shaped before grilling. After cooling down, cakes are wrapped and packed.

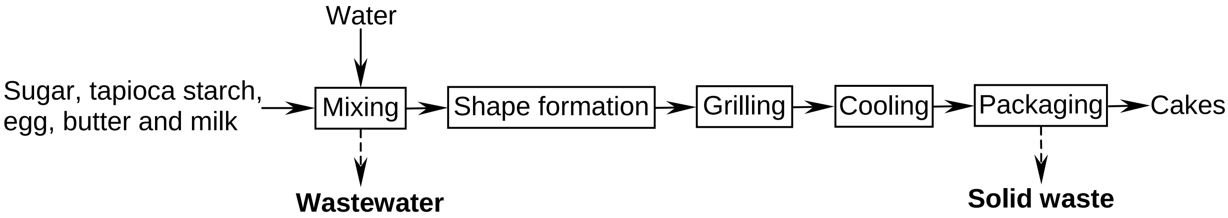

Fig. 7.8 Cake production process of BIBICA Company.

Environmental Implications

Wastewater is generated from the suspension preparation, filter back washing, ultrafiltration and during the concentration stage in starch syrup production process; from dissolving, boiling, and machine washing in hard and soft candy production; and from mixing and machine washing in the cake production process. The production activities of the company generate about 150 m^3 of industrial wastewater daily, which is treated together with wastewater of Bien Hoa Sugar Company. Quality of the treated wastewater is presented in Table 7.4.

Crushed tins, broken wrappings, wrapping paper and boxes are the main solid wastes of BIBICA Company, which are mostly sold for recycling and reuse. Eggshells (253 tons/year), wasted activated carbon (2.75 tons/year), filter aid powder (1.2 tons/year), and sludge from filtration and ultrafiltration are disposed as domestic solid waste.

7.2.3 Bien Hoa Coffee Factory

Introduction to the Factory

As a member of the Vietnam National Coffee Corporation (ASEM Connect, 2002b), Bien Hoa Coffee Factory-state owned business, was established in 1969 and is located in an area of 11,000 m^2 of Bien Hoa 1 IZ. Total staff and workers working at the factory consist of 120 persons, of which 40 persons are working in the administrative cadres. The factory is specialized in the production of instant coffee (52 tons/year), instant coffee mix (940 tons/year), and ground coffee (97 tons/year).

Bien Hoa Coffee Factory

Inputs. Raw materials needed for the production processes are green coffee beans (600 tons/year), sugar (300 tons/year) and powder milk (300 tons/year). Diesel fuel oil (288,000 L/year), gasoline (14,000 L/year), lubricant (1,000 L/year) and electricity (35,000 KWh/year) answer to the fuel and energy demand of the company. Water consumption is about 25,000 m^3/year from wells in the factory.

Products and Capacity. Total production capacity of instant coffee, instant coffee mix and ground coffee by Bien Hoa Coffee Factory is summarized in Table 7.6.

Table 7.6 Capacity of Bien Hoa Coffee Factory

Products	Capacity (tons/year)			
	1995	1996	1997	1998
Instant coffee	46.0	44.8	49.0	51.8
Instant coffee mix	253.0	556.0	824.4	943.9
Ground coffee	37.6	92.9	98.0	96.5

Source: Bien Hoa Coffee Factory, 1999.

Production Technology. The production processes of Bien Hoa Coffee Factory are, per product, briefly described in Fig. 7.9, Fig. 7.10 and Fig. 7.11.

Instant coffee production starts at sieving to remove dust, stones and other strange elements. This step is important to avoid detriment to the quality and flavor of the instant coffee. After sieving, coffee beans are roasted. Roasting is the most important process as the coffee flavor is actually developed at this stage. The degree of roast will to a large extent determine the color and the final taste of the product. The temperature while roasting is normally set between 180^{o}C and 200^{o}C and it takes about 30 minutes in general. Outer-skins of coffee beans are removed after roasting by a force fan. Thereafter, coffee beans are ground to reduce the coffee to the most suitable particle size for subsequent extraction. The granulated coffee is then extracted with water at a certain temperature below 100^{o}C and the grounds are separated from the liquor. The liquor is then spray-dried in a conventional spray-drying tower. The dried coffee is then recovered from the base of the dryer and cooled before packaging. The soluble coffee in the final stage is packed into a seal bin, from which the product is conveyed to hoppers that feed vacuum filling machines, suited either to tins or jars. Because of the hydroscopic nature of instant coffee, packaging must be carried out in a room, which is controlled at low temperature, low humidity and has air condition. The filled tins or jars are then sealed and labeled.

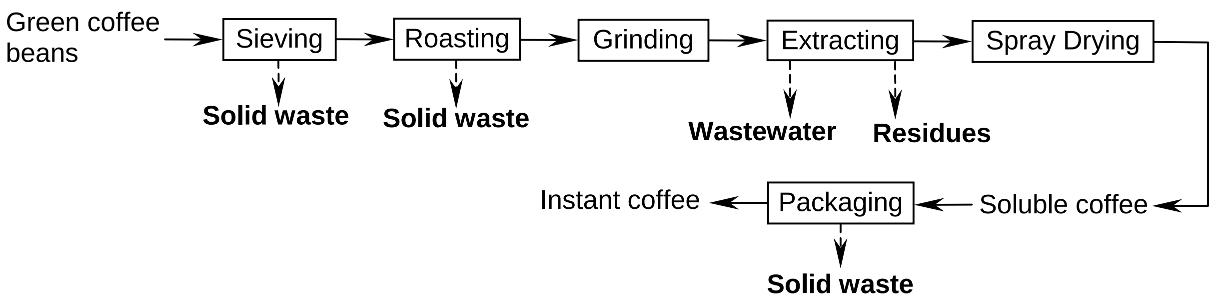

Fig. 7.9 Instant coffee production process of Bien Hoa Coffee Factory.

Instant coffee mix is manufactured by blending soluble coffee with powder milk, creamer and sugar at certain proportions of the mix. The result mixture is then packaged and labeled.

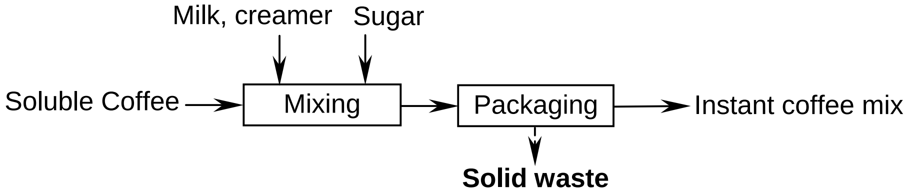

Fig. 7.10 Instant coffee mix production process of Bien Hoa Coffee Factory.

Ground coffee is manufactured simply by roasting green coffee beans and then soaking them in a cooked sugar solution and butter.

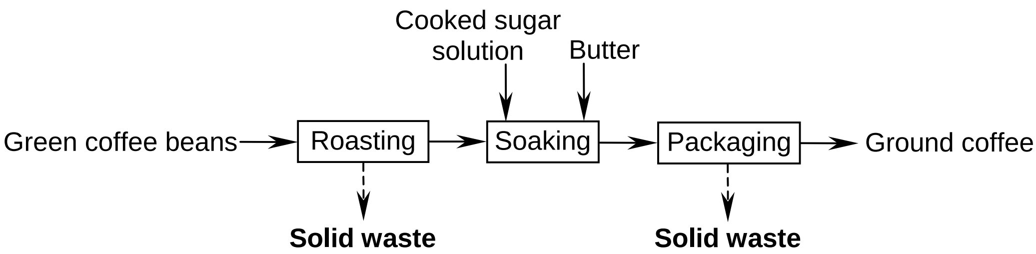

Fig. 7.11 Ground coffee production process of Bien Hoa Coffee Factory.

Environmental Implications

The amount of industrial wastewater generated from this company is only about 7 m^3/day. It is just generated when the extractor and mixer are cleaned. Main industrial solid waste source are the coffee grounds generated from the extracting stage, which are partly sold to farmer to reuse as nutrient soil amending material. Total amount of coffee grounds and wastes from sieving and grilling stages is about 348 tons/years, which are disposed as domestic solid waste. Broken wrapping paper, bags, and boxes are sold for recycling and reuse.

CO_x, NO_x, SO_x, C_xH_y are being emitted from the boiler and coffee beans roasting machine, which both use DO as fuel. Currently, there is no air treatment system installed, except for some stacks.

7.2.4 DIELAC Powder Milk Factory

Introduction to the Factory

DIELAC Powder Milk Factory is located in an area of 40,000 m^2. Total workers and staff are 270 persons, of which 220 workers are working in shifts, 3 per day. Products of the company are powder milk, nutrient powder and biscuits.

DIELAC Powder Milk Factory

Inputs. The needed raw materials for the production processes consist of milk powder, butter, vegetable oil, tapioca starch, rice powder and sugar (Table 7.7). Diesel oil (194,000 L/year), fossil fuel oil (1,327,000 L/year) and electricity (18,080 KWh/year) are demanded as fuel and energy by the company. Water consumption is about 188,000 m^3/year and is supplied by Thu Duc Water Supply Factory.

Table 7.7 Required raw materials and chemicals of DIELAC Powder Milk Factory

Raw materials and chemicals	Demand (tons/year)			
	1995	1996	1997	1998
Powder milk	4,391	4,962	5,697	7,297
Butter	701	809	927	945
Vegetable oil	244	275	316	360
Tapioca starch	192	224	230	262
Rice powder	468	546	562	527
Sugar	1,191	1,355	1,413	1,474

Source: DIELAC Milk Company, 2000.

Products and Capacity. Total production capacity of powder milk, nutrient powder and biscuits by DIELAC Powder Milk Factory is summarized in Table 7.8.

Table 7.8 Capacity of DIELAC Powder Milk Factory

Products	Capacity (tons/year)			
	1995	1996	1997	1998
Powder milk	4,000	4,500	5,200	7,050
Nutrient powder	2,500	2,750	2,800	2,950
Biscuits	500	600	710	820

Source: DIELAC Powder Milk Factory, 2000.

Production Technology. Powder milk and nutrient powder production process is briefly described in Fig. 7.12 and for biscuits in Fig. 7.13. Imported powder milk is either filled into tins or jars, sealed and labeled to sell as powder milk products or to mix with sugar, butter and malt to produce nutrient powder. However the blending is a secret operation and the manufacturer did not disclose the proportion of the mix.

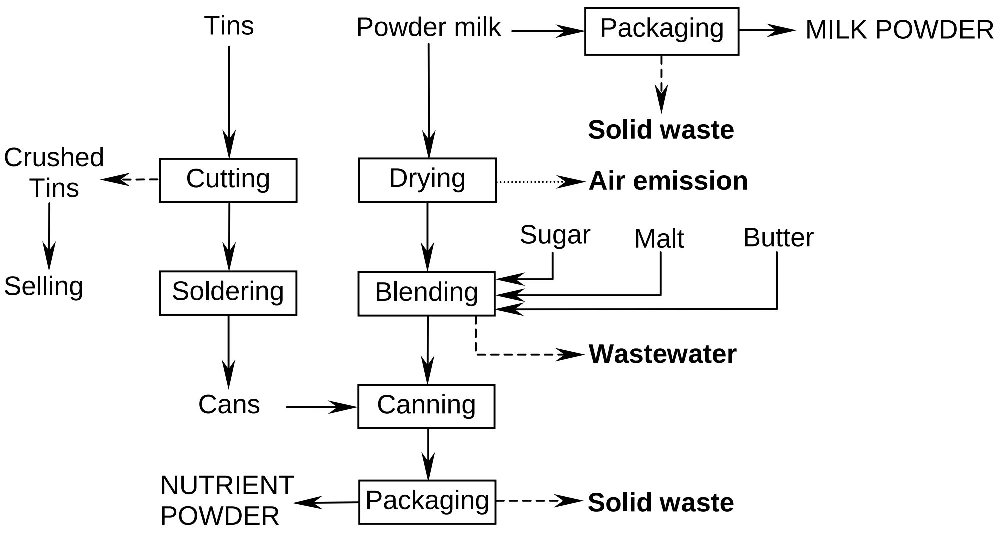

Fig. 7.12 Power milk and nutrient powder production process of DIELAC Powder Milk Factory.

In the biscuits production process, sugar, tapioca starch, rice powder, vegetable oil, butter and milk are blended and mixed with water. The resulted mixture is then shaped and grilled. After cooling, biscuits are packaged and labeled.

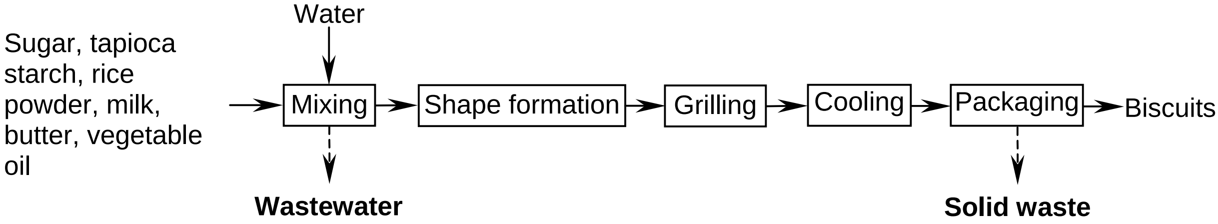

Fig. 7.13 Biscuits production process of DIELAC Powder Milk Factory.

Environmental Implications

The processes and other activities that generate industrial wastewater at DIELAC Milk Company include:

- Rinsing and washing of bulk tank or cans in receiving operations;
- Rinsing of residual product remaining in or on the surface of all pipelines, pumps, tanks, vats, processing equipment, filling machines, etc.
- Washing of all processing equipment (note that rinsing and washing operations are performed routinely every processing cycle, and at least once per day);
- Powder deposited to discharges from the drier.

About 400 m^3/d of the generated wastewater is treated onsite. However, the quality of the effluent is still not consistent with the Class A of Vietnamese standard (TCVN 5945-1995) (Table 7.9). Concentrations of organic pollutants in wastewater in terms of COD (736 mg/L) and BOD_5 (585 mg/L) are still about 15 and 29 times higher than the standard, respectively. Ammonia concentration is 1.75 mg/L, about 17.5 times higher than the standard (CENTEMA, August 2000). Thus, with a flow rate of 400 m^3/d, about 294 kg COD/d or 234 kg BOD_5/d is discharged from the production process of the company. This pollution source contributes significantly to the deterioration of Dong Nai River.

Table 7.9 Quality of effluent from DIELAC Powder Milk Factory

Parameter	Unit	Value	TCVN 5945-1995 Class A
pH	-	4.6	6-9
COD	mg/L	736	50
BOD_5	mg/L	585	20
SS	mg/L	186	50
$N\text{-}NH_3$	mg/L	1.75	0.1
$N\text{-}NO_2^-$	mg/L	2.45	-
$N\text{-}NO_3^-$	mg/L	0	-
Total Fe	mg/L	1.0	1

Source: CENTEMA, 2000.

Crushed tins, broken wrapping paper and boxes are the main industrial solid waste sources from the production process of DIELAC Powder Milk Factory, which are sold separately for recycling and reuse.

About 1,327 m^3/year of FO and 194 m^3/year of DO are used by the boiler, calorifire and oven. Emitted gas containing SO_x, NO_x, CO_2 and dust is exhausted into the atmosphere freely.

7.2.5 Dong Nai Ice Enterprise

Introduction to the Enterprise

Dong Nai Ice Enterprise was established under Decision No. 1136/QD.UBT dated September 1st, 1992 by the Chairman of the Dong Nai Province People's Committee (Chien, 2002). The enterprise is located in an area of 4,550 m^2 at Bien Hoa 1 IZ. The total staff and workers of the enterprise consist of 46 persons. The products of the enterprise are ice and chocolate candy, which are processed as presented in Fig. 7.14 and Fig. 7.15.

Inputs. The raw materials needed for the production processes consist of salt, sugar, peanut, malt, powder milk and cocoa (Table 7.10). The energy demand causes a consumption of diesel fuel oil (12,000 L/year), gasoline (8,400 L/year), lubricant (6,000 L/year), coal dust (46 tons/year) and electricity (1,200,000 KWh/year). Water consumption is about 23,000 m^3/year.

Dong Nai Ice Enterprise

Products and Capacity. Total production capacity of ice and chocolate candy by the enterprise is summarized in Table 7.11.

Table 7.10 Raw materials and chemicals required for production of Dong Nai Ice Enterprise

Raw materials and chemicals	Consumption (kg/year)			
	1995	1996	1997	1998
Salt	72,100	63,120	84,410	92,913
Sugar	114,800	29,705	7,855	15,177
Peanut	190,136	48,073	75,254	27,988
Malt	10,415	2,383	845	1,337
Powder milk	3,449	947	239	533
Cocoa	3,700	947	258	539

Source: Dong Nai Ice Enterprise, 1999.

Table 7.11 Capacity of Dong Nai Ice Enterprise

Products	Capacity (tons/year)			
	1995	1996	1997	1998
Ice	11,167	14,651	15,487	16,327
Chocolate candy	307.22	82.00	29.44	48.05

Source: Dong Nai Ice Enterprise, 1999.

Production Technology. Ice production process is very simple as presented in Fig. 7.14. Water is added into mould to freeze for a certain period. Ices are pulled out the moulds by hot water.

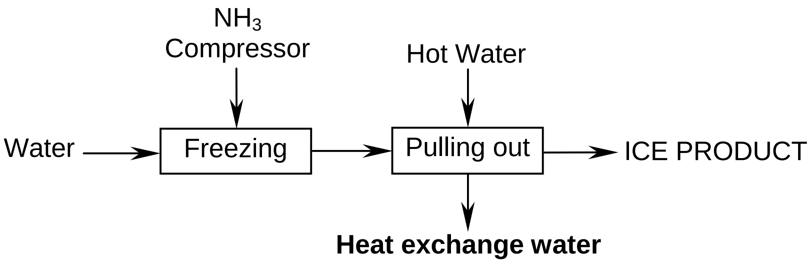

Fig. 7.14 Ice production process of Dong Nai Ice Enterprise.

The chocolate candy production process starts at roasting peanuts and removing its outer skins. Thereafter, peanuts are covered by chocolate and then polished before drying. Finally, candies are wrapped, packaged and labeled.

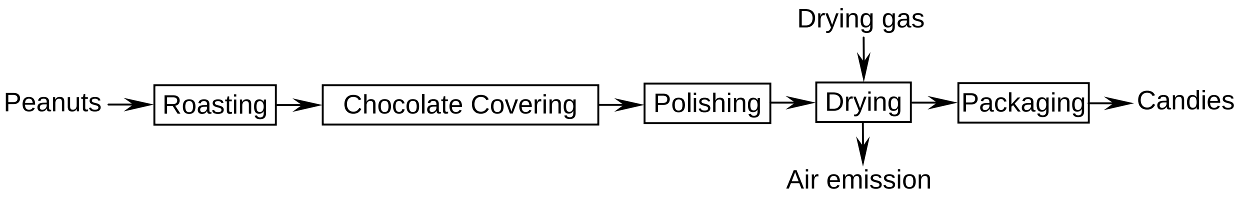

Fig. 7.15 Chocolate candy production process of Dong Nai Ice Enterprise.

Environmental Implications

About 3 m^3/d of wastewater is generated from washing the machines of the chocolate candy production process. Another 30 m^3/d of heat exchange water from the ice production process does not need to be treated.

Industrial solid wastes generated from the production process of the enterprise consist of peanut skins, ash from candy kiln, broken plastic bags and carton boxes, which are disposed as domestic solid waste or sold for recycling and reuse.

7.2.6 DONA NEWTOWER Joint Venture Company

Introduction to the Company

DONA NEWTOWER Joint Venture Company (DONA NEWTOWER J. V. Company) is located in an area of 15,229 m^2 (Dong Nai Industrial Department, 2002). Total staff and workers, working in the factory consist of 257 persons, of which 25 work in the administrative cadres. The products of the factory are canned fruits (including apple, mango, pineapple, etc.) and swallow drink. Total productivity of the factory is 3,000 tons/year, of which 60% is sold at the national market, and 40% is exported.

DONE NEWTOWER J. V. Company

Inputs. Raw materials needed for fruit juice/soft drink are pure sugar, fruits, swallow and “snow” mushroom. Diesel fuel oil (6.5 tons/year, equivalent to 7,900 L/year), fossil fuel oil (250 tons/year, equivalent to 304,878 L/year) and electricity (90,000 KWh/year) cover the fuel and energy demand of the factory. Water consumption is about 30,000 m^3/year, which is supplied by the city water supply system.

Production Technology. The production processes of canned fruit/soft drink are briefly described in Fig. 7.16. Fruits such as mango, orange, apple, etc. are first segregated to remove unqualified ones and other strange elements. Segregated fruits then enter the first rinsing stage before further treatment (such as skin removal, seed removal, etc.). Treated fruits are then re-rinsed before canning. Cooked sugar solution is added to fruit cans. The cans are then capped to pasteurize at 121^{o}C. Pasteurized cans are cooled before packaging. The factory itself produces cans using imported steel sheets as presented in Fig. 7.17.

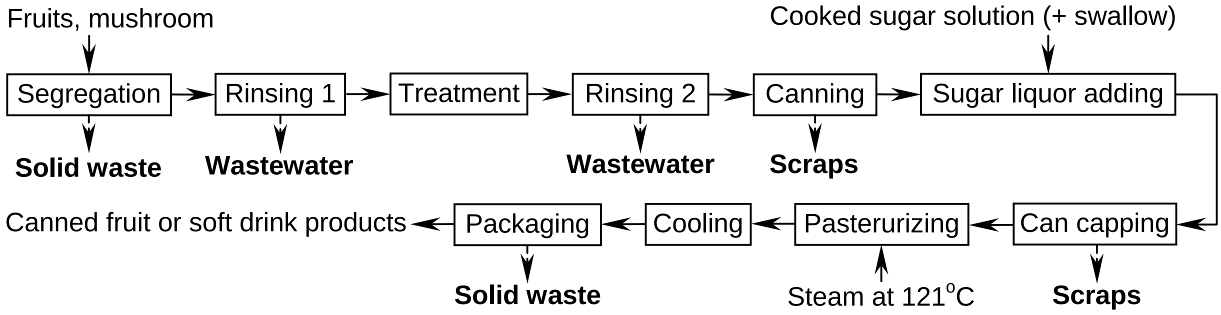

Fig. 7.16 Canned fruit and soft drink production process of DONA NEWTOWER J. V. Company.

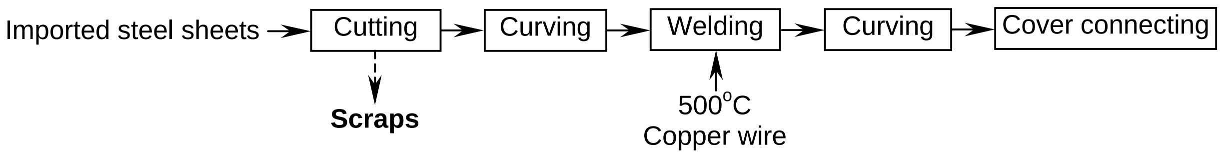

Fig. 7.17 Can production process of DONA NEWTOWER J. V. Company.

Environmental Implications

Production activities of the factory generate about 60 m^3/d of industrial wastewater from rinsing and machine washing. Currently, the generated wastewater is treated by the existing WWTS of the factory as described in Fig. 7.18. Wastewater is released into an equalization tank to create an uniform wastewater flow rate and organic contaminant concentration before entering the anaerobic fermentation tank. Wastewater is then passed through a sedimentation tank to remove suspended solids before discharging into the sewer network of the industrial zone. Settled solids from the sedimentation tank are transferred to a sludge drying bed for dewatering and then disposed together with domestic solid wastes.

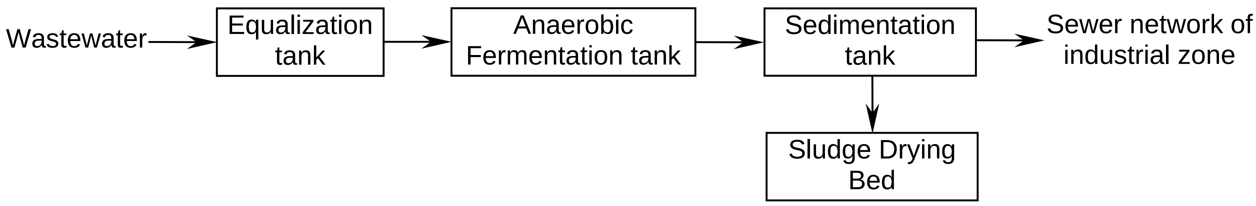

Fig. 7.18 Current WWTS of DONA NEWTOWER J. V. Company.

Solid wastes are mainly generated from outer skin treatment of fruit. Can scraps contribute for 2-3% to the generated solid waste, however, this waste source is sold for recycling and reuse. The industrial solid waste loading coefficient in this case is approximately 60 kg of fruit skin and residues per ton product (equivalent to about 180 tons/year), that are disposed as domestic solid waste. The use of FO and DO as fuel for the boiler and generator again causes air pollution as exhausted gas is emitted into the atmosphere freely.

7.2.7 Material and Energy Balances of Food Processing Companies in Bien Hoa 1 IZ

Material balances are carried out around the boundary of the studied food processing companies in Bien Hoa 1 IZ with three main routes: balance of input and output materials (without water and energy), water balance and energy balance. These balances are summarized in Fig. 7.19, 7.20 and Table 7.12, respectively.

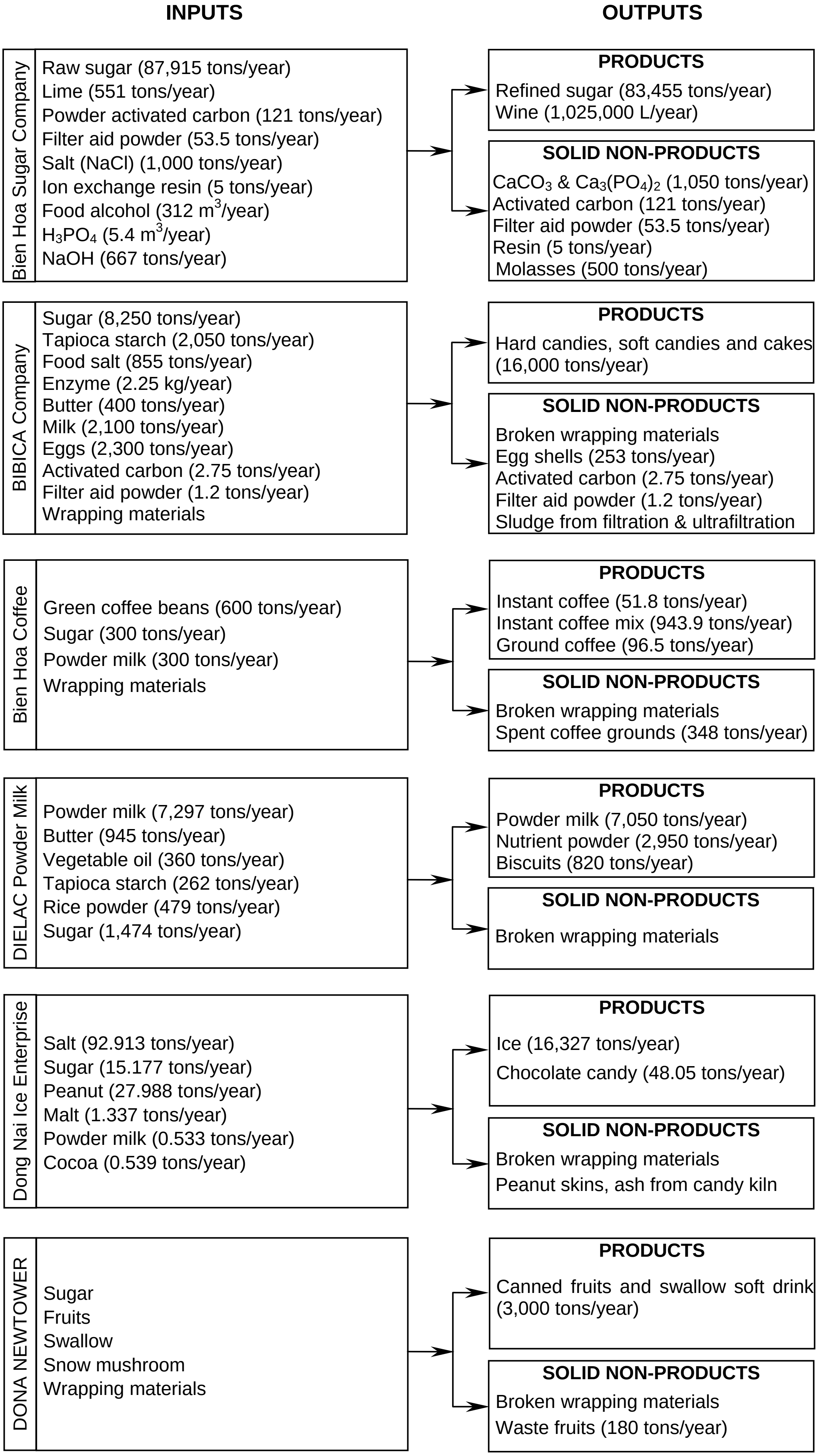

Fig. 7.19 Balance of input and output materials (without water and energy) of food processing companies in Bien Hoa 1 IZ.

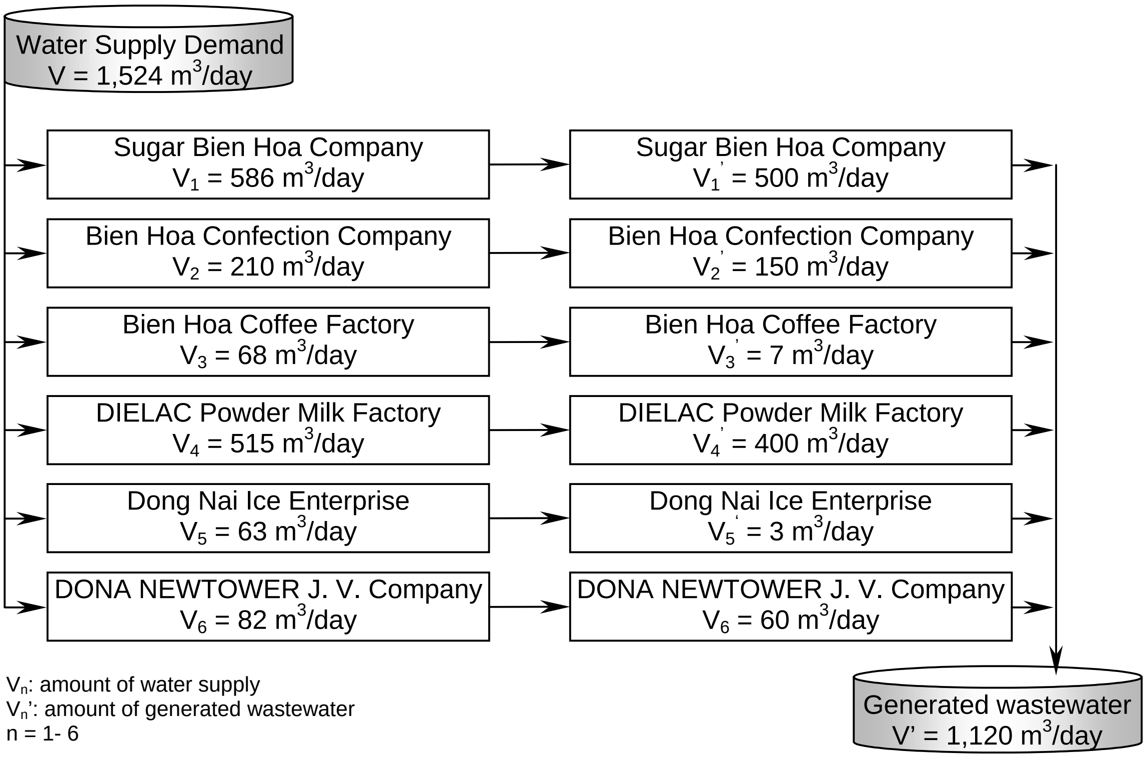

Fig. 7.20 Water balance for food processing companies in Bien Hoa 1 IZ.

Table 7.12 Energy balance of food processing companies in Bien Hoa 1 IZ

Company	**Energy supplied and consumed**					**Generated energy**
	Electricity (KWh/year)	Fuel (L/year)				
		DO	FO	Gasoline	Lubricant	
Bien Hoa Sugar Company BIBICA Company	9,019,650	375,089	14,845,778	9,354	6,253	NONE
Bien Hoa Coffee Factory	35,000	288,000	0	14,000	1,000	
DIELAC Powder Milk Factory	18,080	194,000	1,327,000	0	0	
Dong Nai Ice Enterprise	1,200,000	12,000	0	8,400	6,000	
DONA NEWTOWER J.V. Co.	90,000	7,900	304,878	0	0	
Total	**10,362,730**	**876,989**	**16,477,656**	**31,754**	**13,253**	

7.3 PHYSICAL-TECHNOLOGICAL MODEL OF A GROUP OF FOOD PROCESSING COMPANIES IN BIEN HOA 1 INDUSTRIAL ZONE

Based on the existing production technologies and balances of input and output of materials, water and energy presented in section 7.2, this section continues to develop a physical-technological model of a zero waste industrial ecosystem for food processing companies in Bien Hoa 1 IZ. Consequently, sub-section 7.3.1 seeks for possibilities to prevent and minimize the generation of non-products within these companies. In the successive sub-section, offsite reuse and recycling of unavoidable non-products is the core object of the discussion. After all, treatment of the remaining wastes to avoid their adverse impacts on the environment is proposed in subsection 7.3.3. This section ends with an integration of the selected options from the previous subsections to propose the physical-technological model.

7.3.1 Preventing and Minimizing the Generation of Non-products

Similar to chapter 5 and chapter 6, one can identify detailed prevention and minimization options for each company. However, I will not repeat this step here for all 6 companies, but rather focus on the most suitable options for all these companies. These options can be found in two areas:

Liquid Non-Products (Wastewater)

Wastewater is currently generated from the production processes, machines and equipment washing, bottles and bulk tanks cleaning, floor washing, etc. It is well known that all these factories fall in the food manufacturing for human consumption class, in which food hygienic condition is the first priority. The need for cleanliness and hygiene at all stages of the process leads to heavy demand for cleaning water and consequent wastewater generation. Beside this reason, observations in practice showed that in all cases, water is used wastefully due to poor management supervision of waste-generating practices. Proper management control to implement water use optimization is a possibility to reduce the generation of wastewater. Reusing water from the final stage of bottles cleaning for the first step of bulk tank cleaning or floor washing is another possibility. Again, counter current principle, which is suggested to reduce fresh water used in rinsing stage of tapioca processing (chapter 5 and chapter 6), is very helpful in reduction of water use and wastewater generation from cleaning bottles and machines.

Solid Non-Products

Major amount of solid non-product materials originates from molasses, coffee grounds, broken wrappings, and sludge from WWTSs. With the current production processes of Bien Hoa Sugar Company and Bien Hoa Coffee Factory, the only solution to reduce the amount of generated molasses and coffee grounds is by replacing the existing machines that are used in the centrifugation of affination stage (in case of the sugar company) and coffee extracting stage (in case of the coffee factory) by more modern machines. Onsite reuse of coffee grounds is a possibility to minimize the generation of such solid non-product. In the 1980s coffee grounds began to be utilized as fuel in the soluble coffee processing plants in Brazil (Silva et al., 1998). Silva et al. (1998) state that coffee grounds can be considered an excellent fuel in comparison to other biomass, because they have a heat of combustion higher than others usually used. As indicated in Table 7.13, the heat value of coffee grounds is similar to coal and is higher than wood and other biomass. The coffee grounds with a humidity of 50% (w.b.) can be burned directly in the boiler (Pfluger, 1975) or alternatively, burned after drying to reduce the humidity to 30% (Sivetz and Desrosier, 1977; Adams, 1985), or even to 25% (Sivetz, 1963). Approximately 18 kg of coffee grounds at 50% of humidity (w.b.) produces the same quantity of vapor as 1 gallon of fuel oil (Silva et al., 1998). Therefore, for the typical process of the production of soluble coffee, 75% of the energy required by the plant can be supplied (Pfluger, 1975). Thus, with some technological effort to improve the conditions of utilization of this fuel in the boilers, the soluble coffee industry could become self-sufficient in thermal energy (Silva et al., 1998). Besides that, good training of workers is a possibility to reduce the amount of broken wrappings.

Table 7.13 Heat value of diverse biomass residues

Material	Heat value		References
	(Kcal/kg dry)	(KJ/kg dry)	
Jute stems	4619.10	19307.84	Kumar et al., 1984
Rice husks	3805.30	15906.15	Kumar et al., 1984
Coconut fiber	4707.83	19678.73	Kumar et al., 1984
Wheat straw	4185.02	17493.38	Kumar et al., 1984
Cotton twigs	3750.00	15675.00	Kumar et al., 1984
Corn ears	3804.35	15902.18	Kumar et al., 1984
Sugar cane bagasse	4600.00	19228.00	Anon, 1971
Wood	5450.00	22781.00	Anon, 1971
Coffee grounds	5960.00	24912.80	Anon, 1971

7.3.2 Material Flow Network Creation

For non-products that are unavoidable from these companies, possible solutions for reducing and eliminating their impacts on the environment are reuse and recycling in other suitable processes. In this line, this section emphasizes on analyzing possibilities for offsite reuse and recycling of non-products and the creation of a material flow network.

Solid Non-Products

Unavoidable solid non-products from these companies include molasses, coffee grounds, chicken eggshells, wasted fruits and sludge from the used WWTSs, other inorganic (or non-biodegradable) non-products and broken wrapping materials. Possibilities for offsite reuse and recycling of these non-products are the object of discussion within these paragraphs.

Molasses. Principal uses of molasses are presented in Fig. 7.21. It is worth to remind that different kinds of molasses are generated during the refining process of Bien Hoa Sugar Company. Molasses from refined sugar class R1 is used to produce refined sugar class R2 and so on. At present, a proportion of good quality molasses is reused in wine production process. The generated molasses as solid non-product from this company is blackstrap molasses. A typical analysis of this molasses includes sucrose (34.1%), reducing sugars (16.5%), ash (11.3%), water (21.8%) and various sugar, gums and acids (16.3%). The ash includes calcium, magnesium, potassium, silicon, iron, phosphorous and other elements in the form of inorganic salts (Australian Sugar Industry, 2003). At present, this molasses is stored in an earth hole within the company, while possibilities to reuse it as fertilizer and animal feed are found in several scientific articles (Abbott, 1990; Ranjban et al., 1973; Wythes and Ernst, 1983; Perston, 1987; Pettersson, 1992; Verma et al., 1994, 1995; M'ncene et al., 1999; Sundhagul and Atthasampunna, 2003).

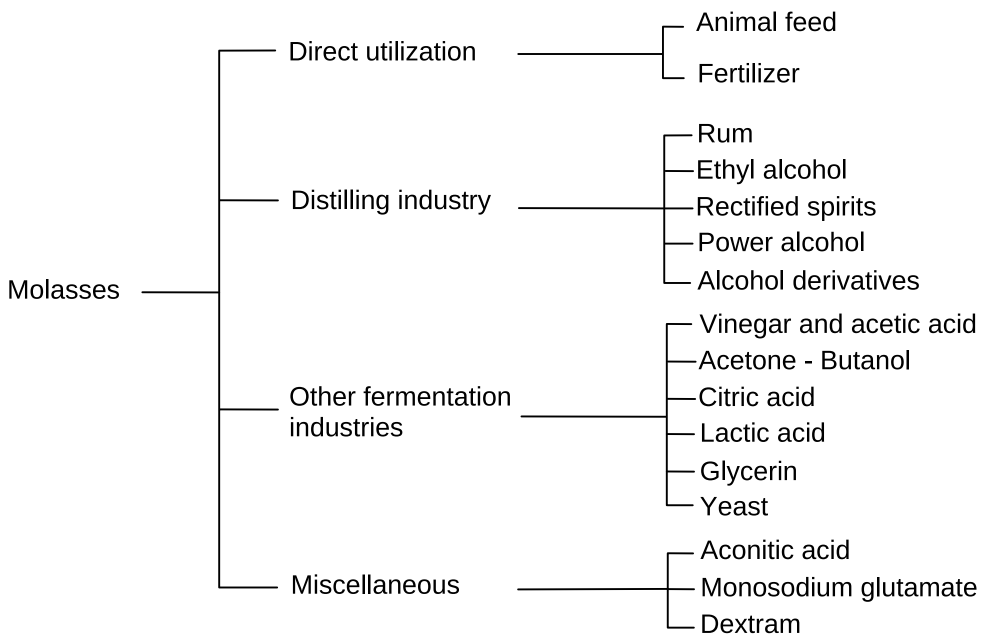

Fig. 7.21 Principal uses for molasses (Abbott, 1990).

The value of molasses as feed for livestock has been known almost since sugar was first manufactured (Patrurau, 1989). The work of nutritionists has indicated the feed value of molasses, especially for milking dairy cows. The effects of increasing the proportion of molasses in the diet of milking dairy cows on milk production and composition were investigated by Murphy (1999). The results from his research indicated that including molasses in the silage proportion of the diet up to 150 g/kg of silage fresh weight significantly increases the milk yield, milk protein, and casein concentration and protein yield. Survival feeds based on urea, molasses along with various combinations have used experimentally in India (Ranjban et al., 1973; Pathak et al., 1976; Daniel et al., 1984, 1986; Mehra et al., 1994a, 1994b; Verma et al., 1994, 1995; Sengaar et al., 1995; Dass et al., 1996a, 1996b) and in the other countries (Elias et al., 1967; Butler, 1971; Wythes and Ernst, 1983; Gulbransen, 1985 a, 1985b; Perston, 1987). A research of Vu et al. (1999) also shows that a supplementary of urea-molasses-multi-nutrient block, consisting of 40% molasses, 45% rice bran, 8% lime, 5% urea and 2% salt in diet of dairy cows, caused significantly improvement of the productivity of dairy cows in Vietnam. Possibilities of substitution of molasses in swine diets has also been reported by Gohl (1981), Pettersson (1992) and M'ncene et al. (1999). For feeding, blackstrap molasses is diluted with water to a standard Brix of 79.5 (Gohl, 1981). A high level of blackstrap molasses in rations causes diarrhea in monogastric animals. However the rates of gain and feed conservation may still be acceptable despite scouring. The sugars present in the molasses have a high digestibility when fed to pigs of all ages, except during the first 21 to 30 days after birth when the secretion of the enzyme sucrose is not well developed in the piglets (Gohl, 1981; Pettersson, 1992).

The practice of applying molasses to cane soils as a fertilizer dates back to about 1850 (Patrurau, 1989). Utilization of molasses as fertilizer in Mauritius for the period of 1956-1985 and experiments in Hawaii were described in the book *"By-products of the Cane Sugar Industry"* of Patrurau (1989). Their experimental results indicated that the application of molasses in the field should be restricted to not more than 1 tons per hectare annually, otherwise the amount applied will far exceed the absorption by the crop or will be lost by leaching during heavy rains. Thus, total amount of molasses produced by Bien Hoa Sugar Company (500 tons/year) is sufficient to enhance soil conditions of about 500 ha of sugarcane fields. Though nowadays, the utilization of molasses as fertilizer is no longer applied in Mauritius, this does not mean that molasses are not suitable for reusing as fertilizer. For countries like Mauritius, where the incentive of an increasing export price for molasses and the constraint of high cost of labor for handling the molasses to agricultural fields, molasses utilization as fertilizer is not an economic proposition anymore.

Utilization of molasses in distilling industry and other fermentation industries are rather complicated technologies[102] and need high investment both for facilities and manpower. Therefore, these options are less attractive.

Coffee grounds. Coffee grounds are a major solid waste source generated from production processes of Bien Hoa Coffee Factory. Coffee grounds are highly pollutant due to the presence of organic material that demands a great quantity of oxygen in order to degrade (Dinsdale et al., 1996; Silva et al., 1998; Nogueira et al., 1999). Simply piled up, they can ferment and produce spontaneous combustion, as has occurred in some storage sites. They can thus not be thrown away untreated (Adams and Dougan, 1985).

Several researches indicate possibility to reuse coffee grounds as fuel (Sivetz, 1963; Pfluger, 1975; Sivetz and Desrosier, 1977; Sivetz, 1977; Adams, 1985; Silva et al., 1998), fertilizer (Kao et al., 1974; Pfluger, 1975; Lane, 1983; Raetz, 1990; Kieda et al., 1992; Kostenberg and Marchaim, 1993; Nogueira et al., 1999; Kitou and Okuno, 1999), animal feed (Tango, 1971); a polisher for painting and a carrier for insecticides and herbicides (Silva et al., 1998); raw material for activated carbon manufacture (Evans et al., 1999) and for cultivation Pheurotus Ostreatus (Fan et al., 2000). However, Silva et al. (1998) stated that all authors are in agreement on utilization of coffee grounds as fuel is the likeliest option. It is estimated that thermal energy

[102] For extended information about utilization of molasses in distilling industry and other fermentation industries, see appendix 7.

supplied by 348 tons spent coffee grounds/year of Bien Hoa Coffee Factory equals to that of 73,080 L of fuel oil[103]. In other words, reuse spent coffee ground as fuel can provide about 25% annual DO demand of the factory. Moreover, the ashes from burning are good fertilizers, because of their composition having a high content of phosphorus, calcium and magnesium (Sivetz and Desrosier, 1977).

Currently, coffee grounds of Bien Hoa Coffee Factory are sold to farmers for reuse as nutrient soil amendment. In literature, both aerobic and anaerobic composting of coffee grounds is possible. Nogueira et al. (1999) found that there is a great applicability of the composting process through the static pile using force positive aeration to coffee grounds provided that vegetable wastes are mixed to avoid the negative effects of high humidity and fine grounds. Anaerobic solid digestion of coffee grounds has been studied at mesophilic temperature by Lane (1983) and Raetz (1990) and at thermophilic temperature by Kieda et al. (1992), Raetz (1990) and Kostenberg and Marchaim (1993). Biodegradation varied from 20 to 87% reduction in volatile solids. Dinsdale et al. (1996) found that mesophilic continuous digestion was achieved for 99 days with supplementation of $Ca(OH)_2$, nitrogen, phosphorus, trace metals and inoculum from a pilot plant treating settled coffee grounds. Investigation carried out by Kitou and Okuno (1999) confirmed that decomposition of coffee grounds containing about 20 g N/kg is slower than that of other organic materials. Besides, decline in gas production after 80 days might be occurred due to some inhibitory compounds in coffee grounds or pH problems (Lane, 1983; Raetz, 1990; Kida et al., 1992; Kostenberg and Marchaim, 1993).

Chicken eggshells. So far, Chicken eggshells generated from the confectionery production of BIBICA Company are disposed together with domestic solid wastes of the company, though this is an excellent Ca source for livestock feed (see chapter 5 and Table 5.15 and 5.16). In a study on mineral composition of Slovakian and Dutch chicken eggshells, Schaafsma et al. (2000) found that the major elements in chicken eggshells are Ca and Mg (Table 7.14).

Table 7.14 Mineral composition of Clovakian and Dutch eggshell powder

Component	Unit	Slovakian eggshell	Dutch eggshell		
			"Four cereal"	"Grass"	"Battery"
N	mg/g	3.96	4.01	3.90	4.02
NH_3	mg/g	0.38	0.65	0.66	0.68
Ca	mg/g	401.00	385.00	393.00	387.00
Mg	mg/g	4.50	3.60	3.60	3.50
Total P	mg/g	0.99	1.50	0.20	1.90
Sr	µg/g	372.00	380.00	880.00	320.00
Zn	µg/g	5.13	5.00	5.00	0
Fe	µg/g	22.40	23.00	23.00	22.50
Cu	µg/g	7.70	10.00	13.00	7.50
B	µg/g	≤ 0.50	0.50	0.50	0.80
Cr	µg/g	0.12	0.20	0.40	0.25
F	µg/g	3.75	6.00	5.50	3.00
V	µg/g	< 0.50	< 0.50	< 0.50	< 0.50
Pb	µg/g	< 0.50	1.10	1.30	0.53
Al	µg/g	< 5.00	2.00	2.00	2.00
Hg	µg/g	< 0.20	< 0.20	< 0.20	< 0.20
Cd	ng/g	< 50.00	18.00	24.00	3.00
Se	ng/g	23.50	45.00	50.00	53.00

Source: Schaafsma et al., 2000.
- "Four cereal" chickens were fed a mix of four cereals and were kept inside (with outside light) on a litter of sand and wood chips.
- "Grass" chickens could walk outside (enjoy fresh air and sun), were able to eat grass and green vegetables and received an additional feed consisting of cereals and leguminous plants.
- "Battery" chickens received standard feed for laying hens.
- Slovakain eggshells are also from battery eggs.

[103] This estimation is based on data provided by Silva et al. (1998). Approximately 18 kg of coffee grounds at 50% humidity (w.b.) produces the same quantity of vapor as 1 gallon of oil fuel.

With regard to calcium content, a chicken eggshell is equal to purified $CaCO_3$, which is widely used because of its high calcium content (Kärkkäinen et al., 1997). A piglet study (Schaafsma and Beelen, 1999) showed that calcium from chicken eggshells was as well absorbed as Ca from purified $CaCO_3$ or even better when both calcium sources were given in combination with Soya protein. Low levels of Pb, Al, Cd and Hg provide an advantage for chicken eggshells, because the natural Ca source may be polluted with these elements (Whiting, 1994; Faine, 1995). Thus, with high percentage of calcium and low levels of heavy metals, chicken eggshells are useful ingredient for calcium enrichment of livestock feed.

Based on swine diet ingredients presented in Table 5.15, it is estimated that 253 tons eggshells from BIBICA Company is sufficient for production of about 90,357 tons swine feed/year. This amount of Ca source is also sufficient to provide about 25% calcium demand of PROCONCO Livestock Feed Production Company, which locates within Bien Hoa 1 IZ.

Wasted fruits and sludge from the existing wastewater treatment systems. Wasted fruits consisting of unqualified fruits, outer skins, etc. and sludge from the existing WWTSs are all biodegradable organic in nature. Therefore, composting seems to be a promising option. A study of Suh and Rousseaux (2001) on “An Life Cycle Assessment of Alternative Wastewater Sludge Treatment Scenarios” shows that anaerobic digestion and land application is the most environmental friendly method considering less emission and less energy consumption. Paredes et al. (2002) conclude from their study on bio-degradation of olive mill wastewater sludge by co-composting it with agriculture wastes that the composting can be an environment-friendly alternative to recycle sludge and that it can help to solve the disposal problem. Several articles identify that composting wastewater sludge for agricultural use is a feasible and perfect solution (Perttu, 1995; Elvira et al., 1996; Hackett et al., 1999; Rantala et al., 2000; Suh and Rousseaux, 2001; Paredes, 2002). Composting seems the likeliest option for organic solid wastes because the technique is rather simple compared to others and already known in Vietnam. In addition, there is a big demand of fertilizer in Vietnam. The potentials of composting products for agriculture cultivation can be seen in the cultivated areas in Vietnam as follows:

- Cultivation area of cereals in the whole country in 2000 was about 8,368,900 hectares, of which the South-East region including Ho Chi Minh, Ninh Thuan, Binh Phuoc, Tay Ninh, Binh Duong, Dong Nai, Binh Thuan and Ba Ria-Vung Tau occupied about 645,100 hectares (General Statistic Office, 2001). These values of paddy are about 7,654,900 and 526,700 hectares, respectively.
- Cultivation areas in 2000 of main annual industrial crops like cotton, jute, rush, sugarcane, peanut, soya-bean, and tobacco in the whole country were about 18,900; 5,700; 8,600; 302,900; 243,900; 122,300; and 24,400 hectares, respectively.
- Cultivation areas in 2000 of main multi-year industrial crops as tea, coffee, rubber, pepper and coconut in the whole country were 89,500; 516,700; 406,900; 24,500; 163,200 hectares, respectively.

Agricultural production and development resulting in a shortage of soil’s nutrient led to increased use of chemical fertilizers during the last two decades. Together with soil decaying problems through erosion, due to deforestation combined with tropical climate conditions, this results in the acidification and hardening of the soil. Therefore, using composting products can be a way to supply nutrients and based-soil for agricultural production.

Besides composting, several authors suggest to apply anaerobic digestion of these wastes to recover energy from biogas production (Saha, 1994; Augenstein et al., 1994; Mæng et al., 1999; Al-Masri, 2001; Castro-González et al., 2001; Lastella et al, 2002; Bouallagui et al., 2003). Based on experiences of biogas plants in Denmark (Mæng et al., 1999), it is estimated that about 5,400 m^3 biogas are annually produced from 180 tons waste fruits of DONA NEWTOWER J. V. company. Electric energy generated from this amount of biogas equals 34,500 KWh. Similarly, approximately 130 tons/year[104] of sludge from WWTS (either existing WWTSs or proposed common WWS) can produce about 3,900 m^3 of biogas or 24,917 KWh electricity. Thus, total electricity produced from these wastes (about 59,417 KWh) can support a part of electrical energy demand of these companies.

Inorganic (or non-biodegradable) non-products. This class of non-products consists of solid material containing $CaCO_3$ and $Ca_3(PO_4)_2$, activated carbon, filter aid powder and ion exchange resin from Bien Hoa Sugar Company and BIBICA Company. Thanks to the characteristics of these non-products, it is suggested to give the solid material containing $CaCO_3$ and $Ca_3(PO_4)_2$ to Dong Nai Chemical Factory for reproduction of $CaCO_3$ and $Ca_3(PO_4)_2$. Waste activated carbon, filter powder aid and ion exchange resin can be incinerated[105] and recovered the generated heat.

Broken wrappings. Broken wrappings such as cardboard boxes, plastic bags, crushed tin cans, paper, etc. are all sold as scraps for reproducing. However, it seems better to sell these scraps to corresponding companies within the industrial zones, such as selling waste paper to COGIDO Paper Company, plastic bags to Dong Nai Plastic Company, crushed tin cans to Viet Thai Enterprise.

In general, the material flow network proposed for solid non-products from food processing companies of Bien Hoa 1 IZ can be described as illustrated in Fig. 7.22.

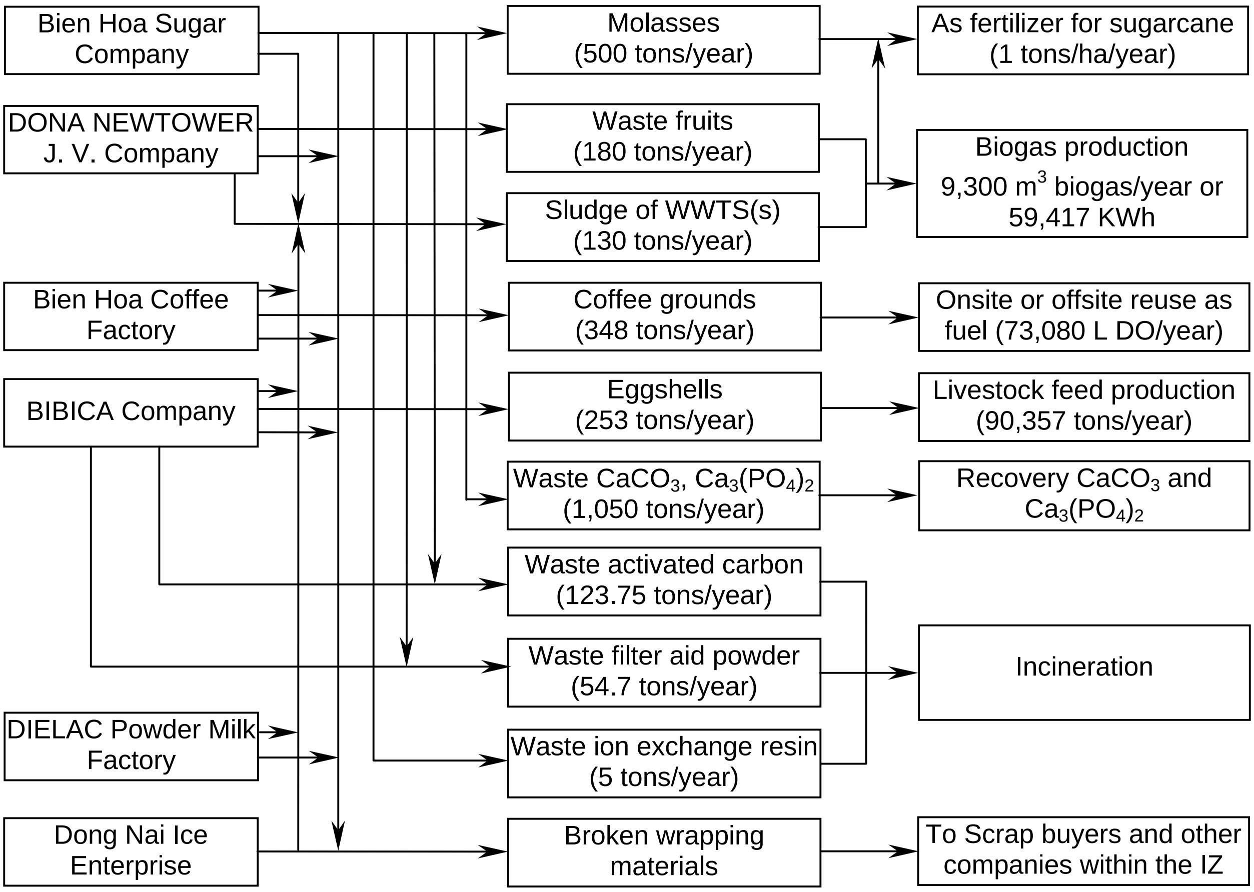

Fig. 7.22 Material flow network of solid non-products of food processing companies in Bien Hoa 1 IZ.

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[104] This is calculated based on the following assumptions and data: (1) wastewater is treated using an activated sludge process, (2) average BOD_5 concentration of influent is 1,000 mg/L, (3) efficiency of the aerobic biological process is 80%, (4) yield coefficient is 0.4 kg VSS/kg BOD_5 removed and (5) wastewater flow rate is 1,120 m^3/day (Fig. 7.20).

[105] Incineration is one of treatment technologies used in Giang Dien Industrial Waste Treatment Plant, which is constructed and operated by SONADEZI.

Liquid Non-Products (Wastewater)

Different kinds of industrial wastewater are generated from these studied companies. Among these companies, Bien Hoa Sugar Company, BIBICA Company, DIELAC Powder Milk Factory and DONA NERTOWER J. C. Company contribute to the large amount and high organic strength wastewater. There are hardly any possibilities for direct reuse of these kinds of industrial wastewater known in practice. However, some authors report that it is possible to use refinery sugar wastewater as a carbon source for bacterial growth. In general, bacterial growth was determined under aerobic conditions in standard growth media (Biebl and Pfenning, 1981) containing L-malic acid and sodium glutamate in 7.5/10 and 15/2 molar ratios (Eroglu et al., 1997). However, Yetis et al. (1998) found that wastewater from sugar refinery can partially replace the carbon source of the bacterial growth medium. This was proved by a study of Yigit et al. (1999) on the production of Poly-β-hydroxy butyric acid (PHB) using a medium containing 30% wastewater from a sugar refinery. PHB accumulation in different grow media as summarized in Table 7.15 shows that the use of the wastewater increased the yield of PHB and the production in anaerobic conditions is higher compared to aerobic condition (Yigit et al., 1999). Though this utilization converts wastewater into a valuable substrate for microorganism, its application can reduce very small proportion of generated wastewater and requires specific conditions and experts in this field. Besides, large amounts of remaining wastewater still have to be treated before discharging or reusing. These reasons make this option to be unattractive today. However, because of the important role of PHB in producing a biodegradable carrier for long term dosage of herbicides and insecticides, packing containers, bottles and bags (Anderson and Dawes, 1990), of drugs and in producing surgical pins, sutures, staples, swabs (Abe and Doi, 1992; Sang, 1996), this option might become very attractive in the future.

Table 7.15 Poly-β-hydroxy butyric acid accumulation in different media

Growth media	Time (h)	Max PHB concentration (g/L)	%PHB (w/w)
15/2	96	0.2	19.8
7.5/10	96	0.2	16.8
30% refinery sugar wastewater (aerobic)	84	0.3	52.4
30% refinery sugar wastewater(anaerobic)	96	0.5	70.4

Source: Yigit et al., 1999.

Irrigation with wastewater is common in both beet and cane sugar industries (McNeil, 1984). One half of the cane sugar factories in Queensland irrigate sugar cane or cattle pasture with untreated wastewater and a number of others use irrigation together with other methods of treatment. Irrigation with cane wash-water and factory wastewater is widely practiced in Hawaii (Train et al., 1975). Parkhomenko (1964), Bereznikov and Novikov (1976), McNeil (1984) indicate that about 15-20 m^3 wastewater is required for irrigating 1 ha of sugar beet, oats, corn per day. Thus, if all generated wastewater from the company is reused (excluding cooling wastewater) for irrigation, a sugar cane field of about 45 – 60 ha is required. However, Bien Hoa Sugar Company produces sugar from raw sugar imported from other companies and is located far from sugar cane fields, so it is impossible to reuse wastewater for irrigating sugar cane. The only possibility is to reuse effluent from the wastewater treatment system for watering and planting trees in the green area of the company and other surrounding companies.

Reuse of dairy wastewater for irrigation has also been reported. Spray irrigation is widely used in New Zealand, where effluents from 45 to 81 dairy plants, representing 52% of dairy products manufacture, are disposed of by spray irrigation (Galpin, 1981). The practice of spray irrigation disposal of dairy factory effluent was reviewed by EPA (1971) and Parkin and Marshall (1976). Similar to many other authors, they conclude that spray irrigation is a successful low cost method to dispose dairy factory effluent, which provides a positive benefit to farming (Marshall and Harper, 1984). Experiences from New Zealand indicate that it can be applied on 3,000 m^3/ha to 15,000 m^3/ha yearly. The rate of wastewater spraying is equivalent to a rainfall of between 2.5 mm/h and 30 mm/h or in average of 9 mm/h (Marshall and Harper, 1984). Even relatively strong wastes, such as whey (McDowall and Thomas, 1961; Parkin and Marshall, 1976; Watson et al., 1977), can be applied to land at rates up to 100 m^3 per ha dose (i.e., an average of 7 m^3/ha.d when the return cycle was 14 days). Thus, in order to reuse about 400 m^3/d of wastewater generated from DIELAC Milk Company, about 57 ha for irrigating are required. Again, this faces the difficulty of limited agricultural land surrounding the industrial zone.

7.3.3 Waste Treatment

The remaining non-products including wastewater and air emission have to be treated properly before discharging them into the environment. Selection of end-of-pipe treatment technology options for these wastes are described in this section.

Wastewater

Limitation of reusing wastewater for irrigation leads to the need of treatment of wastewater properly for watering the green area within and surrounding companies and before returning it to Dong Nai River. At present, Bien Hoa Sugar company, BIBICA company, DIELAC Milk company, and DONA NEWTOWER company have their own WWTSs, but effluents of the WWTSs still do not meet Vietnamese standards for discharged wastewater. Therefore, there is still a need for further treatment of these effluents. It is possible to treat the total wastewater flow rate of 1,120 m^3/day (Fig. 7.20) from these companies with the existing common wastewater treatment plant of Bien Hoa 2 IZ. The designed capacity of this plant is 8,000 m^3/day, but up till now, the used capacity of the plant is only 2,000 m^3/day[106]. In addition, biological treatment technology of this plant, applying activated sludge continuous sequence batch system, is quite suitable to treat wastewater from the food processing companies. The current treatment process of common wastewater treatment plant of Bien Hoa 2 IZ is described in Fig. 7.23. Thus, in order to implement this option, there is only need for installation of sewer pipes from these companies to a receiving pit of the plant and these companies have to pay for the treatment. Besides, their existing WWTSs will play the role of pretreatment before discharging into the common WWTS.

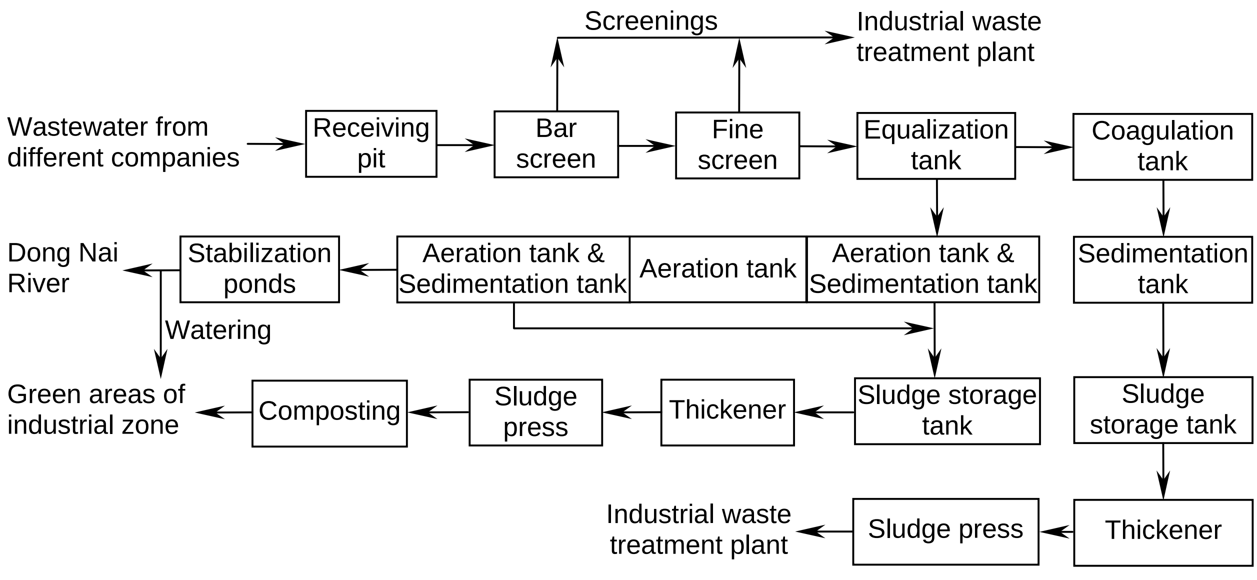

Fig. 7.23 Scheme of the wastewater treatment plant of Bien Hoa 2 IZ.

[106] Interview with Mr. Nguyen Quang Thoa, Vice Director of SONAEMS (Environmental Service Enterprise of SONADEZI). Two main reasons attributed to this problem are (1) the common wastewater treatment plant was constructed after several enterprises were settled down and some have their own WWTSs, (2) over estimation of wastewater flow rate due to differences in assumptions of industrial sectors to be located in the IZ and practice.

Treated wastewater can be used for watering the green area within the enterprises and the IZ, the remaining can be discharged into Dong Nai River. Sludge from WWTSs is transferred to the composting or biogas plant.

Air Pollutants

Exhausted gas from furnace, boiler, candy kiln, etc. needs to be treated properly before releasing into the atmosphere. As presented in section 6.4.3, exhausted gas mainly consists of acid gases such as SO_x, NO_x, CO_x and dust. These air pollutants can be treated by (1) wet scrubbing of flue gases, in which liquid solutions are used to scrub and neutralize acid gases and (2) dry scrubbing, in which neutralizing slurries are injected directly into the flue gas stream.

7.3.4 Physical-Technological Model of a Zero Waste Industrial Ecosystem

Based on the former sections, a physical-technological model can be developed for the food processing companies of Bien Hoa 1 IZ, which aims at the reduction of environmental impacts and natural resource consumption. Cleaner production, waste minimization and waste exchange are put to work in the model in order to achieve efficient utilization of resources, maximal reduction of generated non-product and feasible reuse and recycling of non-products. The relationships between the studied food processing companies and other proposed units involved in a complex flow of material inputs and outputs is specified in Fig. 7.24. Compared to the existing situation, implementation of this model would reduce coffee grounds disposal (348 tons/year) by direct reuse as fuel within its production process. Instead of disposing it together with the domestic solid wastes, eggshells from BIBICA Company (253 tons/year) are an excellent calcium source for livestock feed production and waste fruits from DONA NEWTOWER J. V. Company (180 tons/year) and sludge from the existing WWTSs (130 tons/year) are input materials for biogas production (about 9,300 m^3 biogas/year) and energy recovery (about 59,417 KWh). Besides, together with molasses of Bien Hoa Sugar Company, these organic non-products are suitable materials for composting. The other inorganic or non-biodegradable non-products such as broken wrapping materials, $CaCO_3$ and $Ca_3(PO_4)_2$, waste activated carbon, ion exchange resin could be recycled in other corresponding companies such as paper, plastic, chemical companies or incinerated to recover the heat. Effluents from the existing WWTSs and untreated wastewater from Bien Hoa Coffee Factory and Dong Nai Ice Enterprise, which do not have own WWTSs, are further treated in the common WWTS of Bien Hoa 2 IZ for complete remove of contaminants. Practical experience from Bien Hoa 2 IZ shows that reuse of treated wastewater for watering green areas within the IZ is a possible solution to reduce treatment costs and at the same time save an equal amount of water needed for watering. In this model, the output of non-products or waste materials from six food-processing factories are pretreated and mostly reused. This principle is also applied to reuse and recovery processes, therefore, the developed model almost realizes a closed material flow system. Every output can be used as input in other production system, so no waste is released. The final product (sugar) from Bien Hoa Sugar Company can be distributed directly to the other five factories and help to reduce transportation costs, while other products can be exchanged with the outside through the market.

The main boundary of the developed model is Bien Hoa 1 IZ. However, some elements, which are not located within the Bien Hoa 1 IZ, such as the composting plant, biogas production plant, incinerator (in Giang Dien Industrial Waste Treatment Plant of SONADEZI) and common WWTS (in Bien Hoa 2 IZ), are also included. Therefore the boundaries of Bien Hoa City and Dong Nai Province are used to indicate the operation area of these elements. The market serves as an exchange center to receive and distribute products within the model and the outside. Dong Nai River green areas of both Bien Hoa 1 and Bien Hoa 2 IZ close the water cycle by receiving proper treated wastewater from the common WWTS.

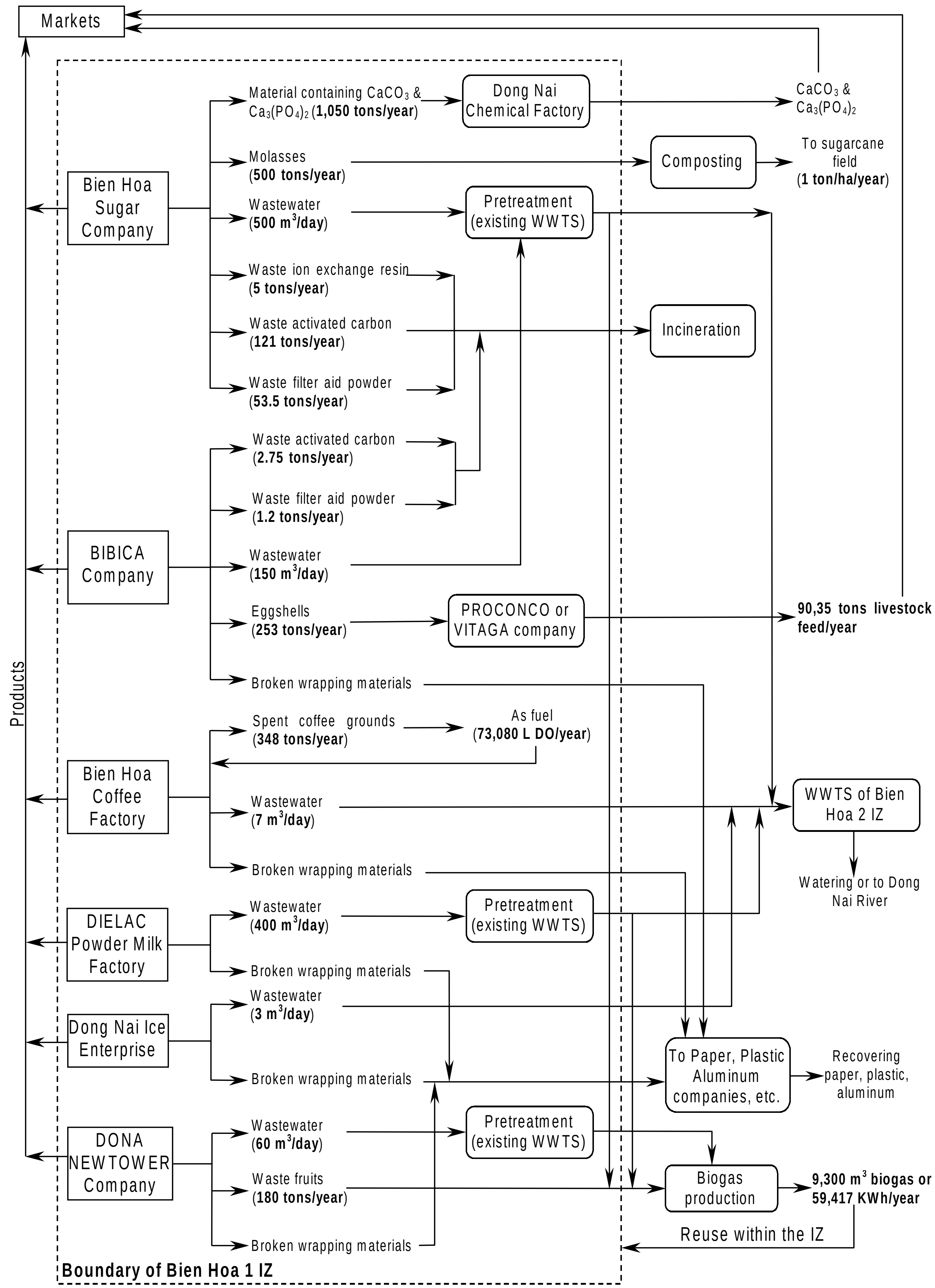

Fig. 7.24 Material flow network of the physical-technological model of a zero waste industrial ecosystem of food processing companies in Bien Hoa 1 IZ.

7.4 ACTORS AND INSTITUTIONS IN AN INDUSTRIAL ECOSYSTEM OF FOOD PROCESSING COMPANIES IN BIEN HOA 1 INDUSTRIAL ZONE

The developed physical-technological model of a zero waste industrial ecosystem of food processing companies in Bien Hoa 1 IZ is a theoretical system. It is developed based on theoretical pollution prevention approaches without analyzing the feasibility in terms of actors and institutions that could trigger, facilitate, enforce or sustain the implementation of the various options. Actual application of the model might face severe difficulties since the current industrial system of these companies is related to and embedded in complex social-economic conditions. Therefore, it is again important to analyze the actors and institutions governing the food processing companies and identify how these might enable and constrain the further implementation of the whole or parts and options of the proposed model. Consequently, this section focuses on an analysis of economic (section 7.4.1), policy (section 7.4.2) and societal networks (section 7.4.3), in which the food processing companies of Bien Hoa 1 IZ are engaged.

7.4.1 Economic Network

In this section, the following interactions and relations will be analyzed: (i) relationships between food processing companies of Bien Hoa 1 IZ with their input suppliers, recyclers and consumers/customers; (ii) the relationships between these companies and other companies or via branch association; and (iii) the interactions between these companies and other economic agencies and research institutes. In general, the economic network of the proposed physical-technological model of a zero waste industrial ecosystem of food processing companies at Bien Hoa 1 IZ is presented in Fig. 7.25.

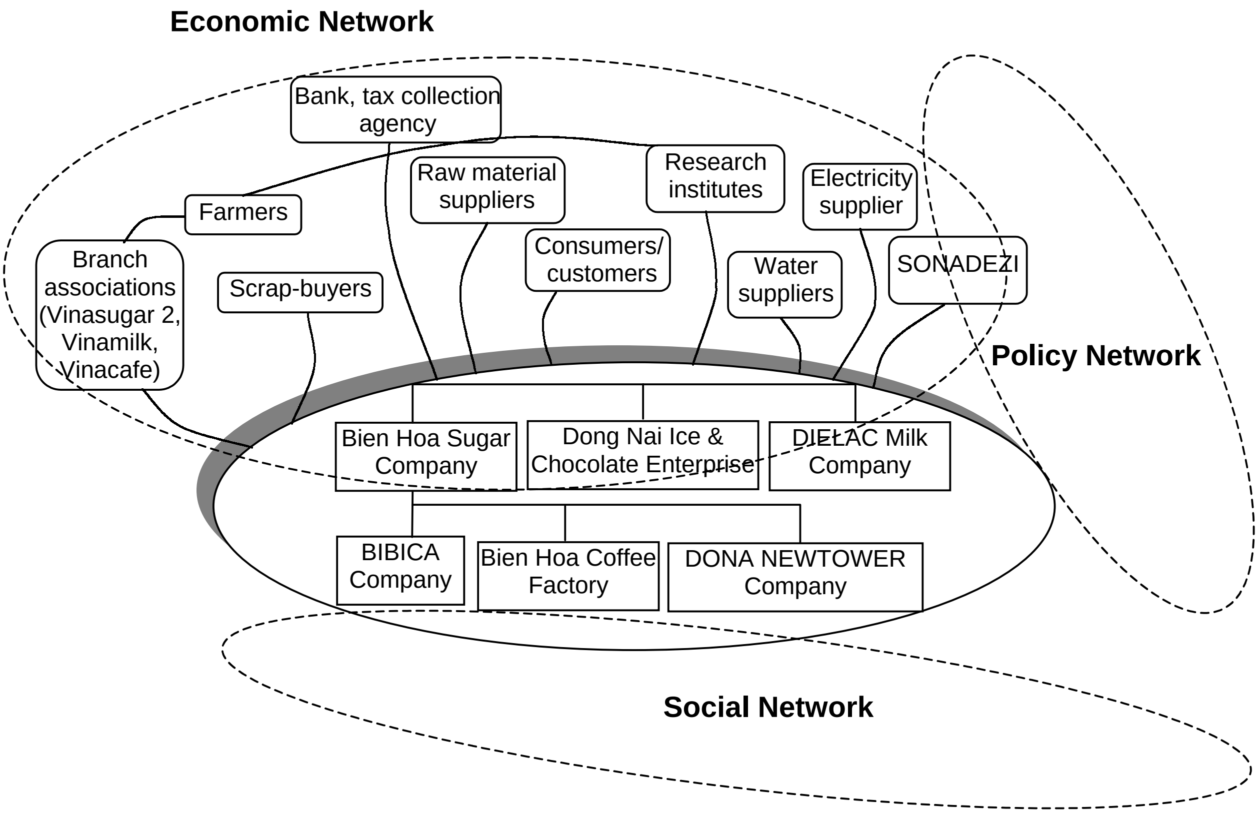

Fig. 7.25 Economic network embedding food processing companies in Bien Hoa 1 IZ.

Vertical Interactions from Input Suppliers to Producers, Recyclers and Consumers/Customers

Input Suppliers. Inputs of these six companies include raw materials and chemicals, electric and thermal energy, and water. As presented in section 7.2, raw materials and chemicals of these companies are quite multifarious and purchased from different suppliers. Therefore, the detailed discussion below will not be equal for all raw materials and chemical suppliers, but rather focus on the main suppliers that be strongly influence the operation of these companies.

*Raw materials and chemical suppliers***.** Except for DONA NEWTOWER J.V. Company, which uses local raw materials (fruits and sugar) for its production process, other companies have to import some raw materials that require specific quality. About 45% of raw sugar needed to manufacture refined sugar in Bien Hoa Sugar Company is imported from Australia and New Zealand. The remaining 55% is purchased from Binh Duong Sugar Company (Binh Duong), La Nga (Dong Nai) and Hiep Hoa Sugar Company (Tay Ninh)[107]. High import ratio of raw sugar is attributed to stable supply and higher quality of raw sugar from foreign companies[108] compared to unstable productivity and supply from domestic raw sugar companies. Relation between Bien Hoa Sugar Company and other raw sugar companies are maintained by economic contracts, in which the amount and quality of raw sugar, the supplying schedule and the price are indicated. Prices vary depending on purity of raw sugar and are negotiated between Bien Hoa Sugar Company and its suppliers. Certainly, the higher the purity degree of raw sugar, the higher the efficiency of refine sugar production and the lower the amount of generated non-products from the sugar refining processes. By setting the buying price of raw sugar based on the degree of purity, Bien Hoa Sugar Company creates a kind of economic incentive to force raw sugar producing companies to improve their product quality. Consequently, Bien Hoa Sugar Company is able to not only reduce the generation of molasses, a non-product from the refining process, but also reduce the demand on other materials needed for processing such as ion exchange resins, filter aid powder, fresh water and energy for filter back-washing, etc. However, import of large amounts of cheap raw sugar from other countries leads to a lower price for raw sugar from the local companies and of course a lower price for sugarcane from the farmers. The price drop made the farmers stop growing sugarcane and change to growing something else. This leads to the lack of sugarcane for raw sugar production and the fluctuation in the production program of the raw sugar companies. More permanent relations between farmers and sugar companies may overcome mistakes in supply and demand. Lam Son Joint Stock Corporation, for instance, gives each farmer a yearly loan to help them develop raw material (LASUCO, 2002). Moreover, the governmental program “one million tons of sugarcane” has increased both sugarcane area (from 131 thousand ha in 1990 to 350.8 thousand ha in 1999) and output (5.4 million tons in 1990 to 17.8 million tons in 1999) all over the country (MARD, 2002a).

Activated carbon, filter aid powder, ion exchange resins (Bien Hoa Sugar Company), enzymes (BIBICA Company), powder milk (Bien Hoa Coffee Factory[109], DIELAC Powder Milk Factory[110] and Dong Nai Ice Enterprise[111]) are imported for 100%. This should not surprise us because until now (the end of 2002) industry of Vietnam is still not able to manufacture high-tech products as ion exchange resins[112] and enzymes. Activated carbon[113], filter aid powder and

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[107] Interview with Ms. Pham Thi Lan, Director of Bien Hoa Sugar Company, Bien Hoa 1 IZ.
[108] Interview with Mr. Hai, Chief of Technical Section, Bien Hoa Sugar Company, Bien Hoa 1 IZ.
[109] Interview with Ms. Pham Thi Bich Ha, Expert, Quality Assessment Section of Bien Hoa Coffee Factory, Bien Hoa 1 IZ.
[110] Interview with Mr. Tam, Engineer, Technical Section of DIELAC Milk Company, Bien Hoa 1 IZ.
[111] Interview with Mrs. Thu, Manager, Dong Nai Ice and Chocolate Enterprise, Bien Hoa 1 IZ.
[112] Experiences from different projects carried out by Center for Environmental Technology and Management (CENTEMA) on demineralization of water for laboratory use and pharmaceutical production using ion exchange technology, in Vietnam.

powder milk made in Vietnam does not satisfy quality requirements for production processes of these companies, so they have to be imported. In general, Vietnam imports most materials and products required for the food manufacturing and food service sectors (Australian Trade Commission, 2002). These companies were established for a long time (the earliest is Bien Hoa Sugar Company in 1962), so they have good and long relationships with foreigner suppliers. Imported raw materials are all required to be of high quality, thus quality control is a major factor in the relation between the companies and contractors. High quality of raw materials imported leads to reduced waste generation. Higher quality of activated carbon or ion exchange resins results in higher capacities of contaminant removal.

Other raw materials including sugar, fruits, green coffee, food salt, food alcohol, rice powder, vegetable oil, peanut, phosphoric acid, lime and sodium hydroxide are purchased on the domestic market. Again, different contracts are conducted for different suppliers. Except for coffee suppliers, raw material supply meets no difficulties. For instance, though fruits needed for the production processes of DONA NEWTOWER J.V Company vary seasonally, there is still no problem about fruit supply. At present, only about 5-7% of the fruits are processed, even though the fruit cultivation area of the country has increased 6.7%/year, from 282,000 ha to 496,000 ha in the period of 1990 to 1999 (MARD, 2002c). By contrast, Bien Hoa Coffee Factory has faced fluctuation in coffee supply from farmers in Daklak and Lam Dong. When the supply of coffee is large, the price of coffee falls, sometimes to levels below the actual cost of growing coffee. Many farmers then shift to other products. Consequently, the supply of coffee falls and prices rise again. Once again, this makes it worthwhile for farmers to produce coffee instead of other crops. As they do so, the supply rises and prices fall again. Though coffee growers faced lean times last year as oversupply on world markets saw prices plunge, Vietnam's coffee growers indicate their fate is changing partially thanks to a campaign by Oxfam[114] (Lam, 2002). Different with the two previous case studies, coffee cultivation farmers play a crucial role in the physical model but only as suppliers, not as reusers of compost and/or treated wastewater.

Water suppliers. Water for production activities of these companies is mainly supplied by the city water supply system, except for Bien Hoa Coffee Factory, who gets it from wells in the factory. However, for cooling water, the companies can use surface water of Dong Nai River. Though industrial producers have to pay for water consumption, the current price does not really seem to force the producers to minimize wastage of water. Water use has only been recorded because the producers have to pay for water consumption. No companies have carried out an auditing or monitoring program to assess whether the water flow within their production processes is optimal. Instead of minimizing the generation of wastewater, companies that have their own WWTSs, believe that they are already performing much better than many others in environmental protection, so they feel no need to do anything else. Workers, who directly operate the production processes, state that they are too familiar with their jobs to think about any change in their operation behavior. Some workers thought that little wastage of water might be necessary as it helps to achieve the discharged effluent standards.

In order to enforce these producers to pay attention to saving fresh water, pricing of both water supply and wastewater treatment is necessity. For pricing of water supply, it is better to apply the progressive principle of electricity pricing. If the amount of used water is higher than a certain level, the water supply price will increase. With recorded data on water, the producers themselves are able to estimate how much money they can save from saving water use. In addition, setting treatment fees based on loading of contaminants, instead of concentration, will

[113] Experiences on laboratory researches on treatment of textile wastewater in CENTEMA, Vietnam and in the Sub-department of Environmental Technology, Wageningen University, The Netherlands.

[114] Oxfam International is a confederation of 12 organizations working together in more than 100 countries to find lasting solutions to poverty, suffering and injustice.

force producers to minimize the generation of wastewater, because adding fresh water will no longer help to reduce treatment cost while it does waste money for the added fresh water.

Electricity supplier. Electricity is produced and distributed by Electricity of Vietnam. The government decides on the electricity price via electricity purchase contracts directly signed between electricity use-partners and Electricity of Vietnam[115]. Different from the water supply, the price of electricity varies depending on the voltage level and demand hours[116]. The higher the voltage level, the cheaper the price and the lower the demand hour, the cheaper the price. This makes producers pay attention to saving electricity.

Consumers/Customers. Depending on their food products, these studied companies have different consumers/customers. Except for Dong Nai Ice Enterprise, the other studied companies participate in foreign markets. Refined sugar from Bien Hoa Sugar Company is mainly exported to Asian, China, Iraq and Eastern European countries (ASEM Connect, 2002a). Bien Hoa Coffee Factory exports its products to the USA, Taiwan, China, Malaysia, Singapore, South Korea, Eastern European countries and is getting prepared to export to Middle East countries in the coming years (ASEM Connect, 2002b). Products of DIELAC Milk Powder factory satisfy markets of the USA, Asia and Middle East countries (Vinamilk, 2002). About 40% of the products of DONA NEWTOWER J.V Company are mainly sold to Hongkong, China, Singapore and South Korea. However, so far, influences of both domestic and foreign consumers and customers on environmental issues of these producers are rather poor. None of these companies have an ISO 14000 certificate. However, two of them, BIBICA Company and DIELAC Powder Milk Factory, were granted the Certificate of Quality Management System ISO 9000 (Dong Nai Industrial Department, 2002). This guarantees that they only manufacture and market the highest quality products, ready to satisfy all requirements of customers and maintain their leading positions in Vietnam's confectionery and milk industry. The good production management system is an advantage for them to develop an environmental management system following ISO 14000. In addition, starting at Eastern European and USA markets might be instrumental in an ISO 14001 accreditation process for Bien Hoa Sugar Company and Bien Hoa Coffee Factory in future.

Horizontal Interactions between the Producers and Other Companies or via Branches

Vietnam Sugarcane and Sugar Corporation 2 (Vinasugar 2), Vietnam National Coffee Corporation (Vinacafe) and Vietnam Dairy Products Company (Vinamilk) are branch associations of Bien Hoa Sugar Company, Bien Hoa Coffee Factory and DIELAC Powder Milk Factory, respectively. They own several factories of the same food processing industrial sub-sector and contribute significantly to industrial and economic development of the country. Vinasugar 2 comprises 7 of 15 large-scale state owned sugar companies (Box 7.1) and contribute to production capacity of about 12,400 tons sugar/year (MARD, 2002a). Vinacafe is the biggest state owned corporation specializing in coffee production, processing and export-import in Vietnam and plays an important role in Vietnam coffee industry development (Lai, 2002). Vinamilk currently dominates the domestic market with a market share of 75-80 percent and an annual growth rate of 15-20 percent (Australian Trade Commission, 2002). So far, efforts of these companies have been on improvement of processing technologies and quality of products, especially for export. These have revealed, for instance through the production technology upgrading plan of Vinacafe by focussing on investment in new machinery as well as gradual replacement of old and backward ones (Vinacafe, 2002b). This has resulted in a new investment

[115] Said by Mr. Dinh Quang Tri in Vietnam Leading's International Business Newspaper, No. 532, December 24-30, 2001

[116] Decision No. 20/VGCP-TLSX dated July 26, 1994 by Mr. Tran Quang Nghiem, Chief of the Government Committee for Price of Goods

to in modernize the processing line of instant coffee and roast coffee with a capacity of 1,000 tons/year at Bien Hoa Coffee Factory since 2001 (ASEM Connect, 2002b). With the new modern production process, Bien Hoa Coffee Factory contributes significantly to the annual coffee export of Vinacafe and Vietnam (Vinacafe, 2002a)[117]. In the case of Vinamilk, continual effort to improve management and product quality has been a key focus of its strategy (Vinamilk, 2002). Vinamilk support DIELAC Powder Milk Factory as well as the other factories by investing in advanced technologies, applying quality management system ISO 9000, providing staff training (Sai Gon Economic Times, 2002)[118] and laboratory for testing quality criteria (Vietnam News, 2002)[119].

Box 7.1 State Owned Sugar Companies in Vietnam

VINASUGAR 1	VINASUGAR 2
Son Duong Sugar Company Son Duong District, Tuyen Quang Province	Bien Hoa Sugar Joint Stock Company Bien Hoa 1 IZ, Bien Hoa City, Dong Nai Province
Tra Vinh Sugarcane and Sugar Company Luu Nghiep Anh Commune, Tra Cu District, Tra Vinh Province	Binh Duong Sugar Company Vo Minh Duc St., Phu Tho Ward, Thu Dau Township 1, Binh Duong Province
Van Diem Sugar Company (VASUCO) Phu Xuyen District, Ha Tay Province	Hiep Hoa Sugar Company Hiep Hoa Town, Duc Hoa Dist., Long An province
19-5 Foodstuff Technology Company Son Tay Town, Ha Tay Province	Khanh Hoi Sugar Company 147 Nguyen Tat Thanh, Ward 13, District 4, HCM City
Lam Son Sugar Company Tho Xuan District, Thanh Hoa Province	La Nga Sugarcane and Sugar Joint Stock Company Km 102, National highway 20, La Nga Town, Dinh Quan District, Dong Nai Province
Viet Tri Sugar, Wine, Beer Company Viet Tri Town, Phu Tho Province	Quang Nam Cane Sugar Company Que Cuong Hamlet, Que Son District, Quang Nam Province
Nong Cong Sugar Company Nong Cong District, Thanh Hoa Province	Tuy Hoa Sugarcane and Sugar Company Hoa Phu Hamlet, Tuy Hoa District, Phu Yen Province
Quang Binh Sugar Company Bo Trach District, Quang Binh Province	

Source: ASEM Connect, 2002c.

BIBICA Company has three branches in Ho Chi Minh City, Da Nang, Can Tho and Bien Hoa Confectionery II Factory with branch office in Ha Noi. They follow the quality policy of ‘continuously study, innovate, improve product quality and serve at best’ as well as ‘make conditions to enhance the quality of manpower resources, working environment and the opportunity of equal promotion for laborers’ (BIBICA, 2002). Though environmental protection is not the first priority of these activities, improvement of production technology will probably contribute to reduce the generation of wastes from their production processes and hence increase their environmental performances. Besides, these companies can also help to improve the efficiency of agricultural production and to create relationship (based on material exchange) between food processing industrial producers and agricultural producers. The industrial producers use products of agricultural producers as inputs for their production processes and return non-products (in the forms of treated wastewater for irrigation and compost for soil enhancement) back to the agricultural producers. While the agricultural producers use the non-products from the industrial producers and produce products to supply to the industrial producers. Though so far, none of the activities of Vinasugar 2, Vinacafe nor Vinamilk have aimed at developing this relationship, their attempts to improve the agricultural production

[117] Vinacafe’s annual coffee export account for 30-40% of the export of Vietnam.

[118] The company’s director Mai Kieu Lien spoke exclusively to Sai Gon Economic Times Newspaper on the 26th birthday of Vinamilk. She said that Vinamilk originally started the staff-training program in 1991 for the company’s junior staff.

[119] Deputy general director of Vinamilk, Nguyen Thi Thanh Hoa spoke to Vietnam News on Friday, July 5, 2002.

efficiency[120] are important for maintaining the operation and development of agricultural sector and relationships between the agricultural (as suppliers) and industrial producers (as consumers). Vinasugar 2, Vinacafe and Vinamilk should learn from the experiences of Lam Son Joint-Stock Company in material flow network creation among their members. The network of Lam Son company consist of 13 members (Box 7.2), which produce cane sugar, reuse molasses for alcohol production, reuse sugar mud for bio-fertilizer production, have an enterprise to serve raw materials and transportation and have a center for research on cane cultivation. In the co-operatives, input and output service for their members, such as the transport of to be sold sugarcane, the supply of fertilizer, the strains, soil working, irrigation, adsorption and transfer of biotechnology into production, the making of production plans and so on have been implemented satisfactory (Linh, 2001). What Lam Son Sugar Cane Joint-Stock Company has done reflects the picture of the alliance between farmers, workers and scientists, the combination of a material supplier, producer and consumer link and consolidation of the production relationship. This could be used as a demonstration to not only convince Vinasugar 2 and all sugar production members (including Bien Hoa Sugar Company), but also similar organizations of other food processing industrial sectors to improve its network towards a zero waste industrial ecosystem.

Box 7.2 Members of Lam Son Sugar Cane Joint-Stock Company

Members	Capacity
Lam Son Sugar Factory No. I	2,500 tons sugarcane/day
Lam Son Sugar Factory No. II	4,500 tons sugarcane/day
Plant for production of alcohol made from molasses	1,5 millions liters/year
Alcohol Plant No. 1	15 million liters of alcohol/year for export
Dinh Huong Confectionery Factory	5,000 tons/year
Bio-fertilizer Producing Factory No. 1 (from sugar mud)	20,000 tons/year
Bio-fertilizer Producing Factory No. 2 (from sugar mud)	30,000 tons/year
Center for research on cane cultivation, providing high-yield and quality strain of cane	150 hectares
Fodder Processing Plant	180 hectares
Agricultural mechanized enterprise	
Raw Materials And Transport Enterprise	
Mechanical repair workshop	
New product center	

Source: LASUCO, 2002b.

The Interaction between the Producers and Economic Agencies and Research Institutes

Economic agencies. Economic agencies include banks, tax agencies, and the infrastructure company. At present, these companies are responsible for paying tax including corporate income tax, value added tax (VAT) depending on the classification and types of business (Box 7.3), special consumption tax (only to few items as alcohol, cigarettes, cars and petrol), import duty, export duty, personal income tax and production royalty (VASC, 2002). Among these taxes, only production royalty is a tax to industries exploiting natural resources, but mainly focussed on the exploitation of minerals, forests and fisheries, which is not the case in the studied industrial sector. Besides, those companies, which import raw materials and equipment or expert products,

[120] Vinamilk has planned to assist dairy farmers in running model dairies, each having at least 10 head of cattle and initially start at 5 (in 2002), to obtain experience. Vinamilk also brief dairy farmers on milking methods to improve the quality. Vinamilk has signed long-term contracts with farmers to buy fresh milk at a stable price (Vietnam News, 2002). In the case of Vinacafe, this company is implementing a project on growing 40,000 ha of Arabica coffee in the North provinces of Vietnam. By developing coffee cultivation area, the company contribute actively to the implementation of the National social-economic program such as poverty alleviation, reforestation, generation of jobs for millions of people who are now living in the remote areas and carrying out permanent agriculture and settlement policy, etc (Vinacafe, 2002c).

have also complied with the Law on Export Tax and Import Tax[121]. However, so far, there seems to be no articles of these existing laws and regulations on taxation indicating any incentive to encourage producers to improve their production efficiencies or environmental performances. Preferential corporate income tax was also promulgated by the General Department of Taxation in the Official Letter 1866 TCT/CS dated May 10, 2002, but tax exemption or reduction only aims to push firms into operation (Saigon News, 2002). This again shows that the tax system in Vietnam does not provide any incentive for industrial producers to consider resource conservation nor environmental protection.

Box 7.3 The Value Added Tax Rates for Industrial Zone Enterprises

Type of business	Tax rates (%)
Exported goods	0
Water supply plant	5
Fertilizer, pharmaceutical and medical products, toys, animal feed, scientific and technical service	5
All kinds of industrial products, construction, transport, housing storage berths, equipment, transportation for rent, and service consultant for legal instrument on laws	10
Jewellery gemstone and broking	20

Source: VASC, 2002.

These studied companies are located in Bien Hoa 1 IZ, which now belongs to SONADEZI – the first state-owned company associated with the development of an industrial zone in Dong Nai province, Vietnam (SONADEZI, 2002). SONADEZI was approved to be established following Decision No. 1713/QD-UBT dated 15 December 1990 by Dong Nai PC. The main missions of SONADEZI are described in Fig. 7.26. So far, SONADEZI has been working with the following objectives: (1) carrying out the construction, management and business development of Bien Hoa 2 IZ, Go Dau IZ, An Phuoc IZ, An Binh residential property, (2) carrying out the maintenance, up-grading and development of facilities and utilities of Bien Hoa 1 IZ, (3) providing the environmental management service, (4) providing one-stop investment consultant services and helping the investor in their IZs to carry out their projects after the investment licenses are granted, (5) providing building design and construction of civil and industrial projects and leasing the ready-built factories.

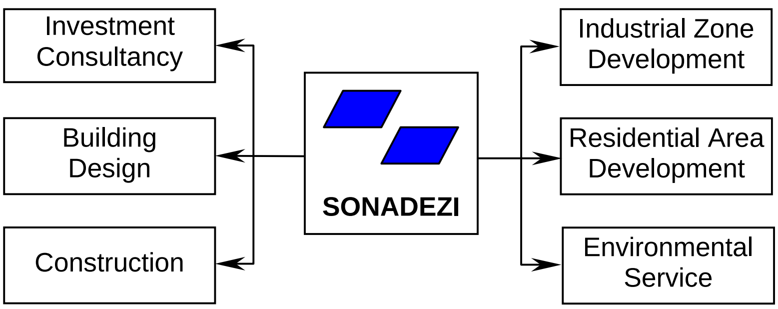

Fig. 7.26 Missions of SONADEZI (SONADEZI, 2002).

With current administrative organization (Fig. 7.27), the Environmental Management Service Enterprise (called SONAEMS) is responsible to SONASEZI for providing environmental protection services such as the common wastewater treatment system, industrial waste treatment plant, consulting enterprises in preparation of application documents to get the license of Registration for Securing Environmental Standard. At present, SONAEMS manages the common WWTS of Bien Hoa 2 IZ, which was designed to serve all enterprises in Bien Hoa 2 IZ with a designed capacity of 8,000 m^3/day, but the practical capacity, until now (end of 2002) is

[121] Law No. 4/1998/QH10, the Law amending and supplementing a number of articles of the Law on Export Tax and Import Tax.

only 2,000 m^3/day. In fact, SONADEZI does not have the right to compel enterprises to make use of the common WWTS unless they are willing to do so. Enterprises with own waste treatment systems are managed directly by Dong Nai DOSTE. Therefore, it is impossible for SONADEZI to ensure the performance of environmental protection of the whole IZ. This is exactly the case of these food processing companies.

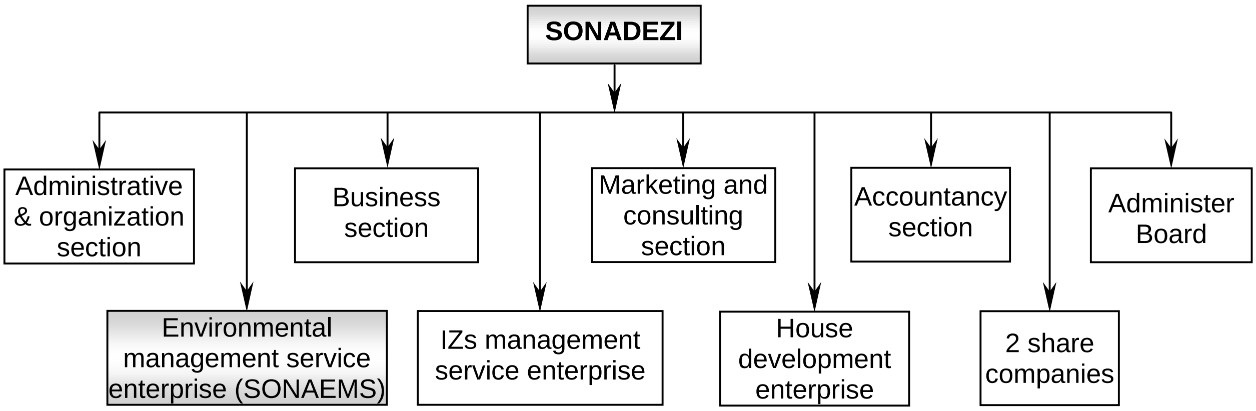

Fig. 7.27 Current administrative organization of SONADEZI (2002)[122].

Nevertheless, having the strategy to develop sustainable industrial zones, SONADEZI has invested significantly for environmental protection activities. SONADEZI is the first IZ Infrastructure Development Company (IIDC), which is capable of investing in an industrial and hazardous waste treatment plant (IHWTP). Composting or biogas production from organic solid non-products, complete treatment of wastewater, incineration of other non-biodegradable wastes are major components of this IHWTP located in an area of 2 ha at Giang Dien Commune[123], Dong Nai Province (Dong Nai PC and SONADEZI, 2001). Besides, SONADEZI has conducted several programs to strengthen the capacity of its staff on waste treatment and management, cleaner production, hazardous waste handling, etc. For instance, some staff members have graduated at master degree on environmental technology and management, others participated in short trainings or excursions in Taiwan, Malaysia, USA, etc. and several staff members participated in training courses, which were organized by SONADEZI in collaboration with the United State Asian Environmental Partnership (US EPA) or by other environmental centers. In other words, with the assistance of SONADEZI, the implementation of other proposed technological options seem to be feasible.

So far, with respect to environmental protection, SONADEZI or SONAEMS only plays the role of environmental service company. SONADEZI supports the companies located within its owned industrial zones with all infrastructural and environmental protection facilities if these are requested. Their relations (between SONADEZI and serviced companies) are maintained via contracts, for instance on treatment of wastewater or consult to apply for an environmental license. SONADEZI is not in charge of environmental management of all companies located within its own industrial zones, but only for the companies, which use its environmental service. For instance, only the companies, which discharge wastewater into the central wastewater treatment plant (in Bien Hoa 2 IZ) have to pay SONADEZI for treatment. While SONADEZI will have to carry out monitoring (flow rate and characteristics of wastewater), treat and has responsibility about effluent before discharging. Only if Dong Nai DOSTE request, SONADEZI will collaborate with the DOSTE in conducting the annual environmental monitoring program of

[122] Interview with Mr. Nguyen Quang Thoa, Vice Director of SONAEMS and Ms. Vu Thuy Linh, Environmental Expert of SONAEMS.
[123] The full-scale project will be conducted on an area of 100 ha in Giang Dien after evaluating the demonstration projects (said by Md. Chu Thi Thu, Director of SONADEZI).

the companies. SONADEZI will not carry out any environmental monitoring nor improvement at other companies than the serviced ones.

Thus, in order to make use of the available environmental service facilities and environmental management capacity of SONADEZI to solve environmental pollution caused by improper treatment and management of generated wastes from producers in Bien Hoa 1 IZ, it is suggested that:

- In order to enhance environmental awareness among producers, SONADEZI should organize in collaboration with Dong Nai DOSTE and DIZA to organize short training courses on cleaner production and waste minimization not only for their staff (as it is often conducted) but also for enterprises. In addition, as SONAEMS has started a program on consulting enterprises within IZs belonging to SONADEZI in preparation of application documents to get the license of Registration for Securing Environmental Standard[124], SONAEMS can also add cleaner production and waste minimization into this program.

- In order to encourage producers to participate in a reusing and recycling program, SONADEZI should include “environmental credit” in treatment fee. For instance, with proper segregation of broken wrapping materials, producers can earn money instead of payment; with proper separation of biodegradable organic solid non-products for composting or biogas production, producers only pay for the collection and transportation to the IHWTP.

- Dong Nai DOSTE should carry out a special monitoring program to assess whether existing waste treatment systems are able to completely treat the wastes and operate properly. Data from this monitoring program is the basis for DOSTE to convince and enforce enterprises, which do not comply with Vietnamese discharge standards, to cooperate with SONADEZI for further treatment of their wastes. Additionally, in order to estimate the treatment fee, SONADEZI has to monitor both flow rate and composition of wastes (effluents) from these enterprises more frequently. This can serve as an incentive for enterprises to pay more attention to waste prevention and minimization. By doing so, Dong Nai DOSTE could save a lot of time for monitoring individual enterprises within industrial zones.

Research Institutes. All sugar companies belonging to Vinasugar 2 can have technical service and investment consultancy on cane sugar production from the Sugar Investment Consulting and Technical Service Company. Manufacturing of wine from high-grade molasses in Bien Hoa Sugar Company is attributed to the role of this company. Besides, one of the major activities set by VINASUGAR 2 is “to conduct scientific and technological research on issues relating to industrialization and modernization of the sugar industry, development of new sugarcane varieties and sugarcane planting technique” (ASEM Connect, 2002c). This promises a chance for Bien Hoa Sugar Company to improve its production efficiency and environmental performance. Besides, cooperation with other research institutes/centers such as the research center of Lam Son Sugar Cane Joint Stock Company, Research Institute of Agriculture, Scientific Research Centers, universities, top-class of scientists and experts in sugar industry, etc. are always helpful for improvement of sugarcane cultivation, cane sugar production and byproduct reuse and recycling.

In case of Bien Hoa Coffee Factory, all activities related to the production improvement are governed by Vinacafe. The production process of Bien Hoa Coffee Factory is gradually modernized as in fact a new instant coffee production process was installed last year. So far, no research on reuse of coffee ground as fuel within coffee processing is conducted or considered to

[124] Interview with Mr. Nguyen Quang Thoa, Vice Director of SONAEMS.

be studied[125]. However, as Vinacafe emphasizes on keeping Vietnamese coffee to be highly competitive with respect to price by high productivity, high quality and low production cost (Vinacafe, 2002a), they might be interested in doing and applying research on self-sufficient in thermal energy by onsite reuse of coffee ground. It is also worth to know that Vietnam is facing problem due to over cultivation of Robusta coffee[126], so at present all efforts are firstly focussing on improving the quality of coffee bean production[127]. This is important for the coffee processing industry, as the quality of coffee beans will affect the quality of coffee processing products. In addition, Vietnamese Government also has a plan to improve the technique of coffee harvesting, drying, processing and storing, etc. All of these activities will indirectly influence coffee processing companies like Bien Hoa Coffee Factory.

Similar to Bien Hoa Sugar Company and Bien Hoa Coffee Factory, the product standard of DIELAC Powder Milk Factory is set by Vinamilk. In other words, the production improvement program of DIELAC Powder Milk Factory is included in the general program of Vinamilk. So far, with mechanized production processes and using imported powder milk, DIELAC Powder Milk Factory seems to achieve a high production efficiency with a high quality product as any other in the world. The only thing missing at present is that the factory has not carried out any auditing program or monitoring on waste material flow, in this case especially preferred for wastewater, to see whether it is possible to reduce the generation of wastes. If Vinamilk expects to keep prices of its products as cheap as they are[128] or even cheaper, Vinamilk and its milk production factories as DIELAC factory have to pay attention on saving costs by saving water use and reducing wastewater generation. To some extent, the role of Vinamilk as a research institute has showed in fresh milk production, for instance by guiding farmers on milking methods to improve the fresh milk quality and in milk processing factories as considering in investment of advanced technologies and application of ISO 9000 (Vietnam News, 2002). Therefore it seems to be possible to convince Vinamilk to include environmental protection into their production efficiency. Vinamilk or DIELAC Powder Milk Factory can consult SONADEZI or environmental centers in both training of staff and carrying out demonstration on waste minimization programs for the milk production processes.

So far, Dong Nai Ice enterprise and DONA NEWTOWER J.V. company have no contact with scientific research centers or institutes for neither production nor environmental issues. This is attributed to the simple production technologies and low waste generation due to its small productivity.

Composting or biogas production and reuse from organic wastes is an element of the proposed physical-technological model and will be implemented by SONAEMS. In recent years, SONAEMS itself has carried out pilot scale researches on composting some organic industrial wastes such as sludge from Fujisu Company and sludge from the wastewater treatment plant of Bien Hoa 2 IZ[129]. SONADEZI can also consult the Center for Environmental Technology and

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[125] Interview with Ms. Pham Thi Bich Ha, expert of Bien Hoa Coffee factory.

[126] In the last few years, Vietnam coffee growers have expanded their coffee plantations in a spontaneous way without complying with Government's guideline and plans. Robusta coffee is grown everywhere possible, from hillsides to hilltops. And Robusta is chosen because growing Arabica coffee needs more seedlings and is not resistant to diseases, so it requires more investment, more care and a more complicated processing method. That is the reason for the undiversification of Vietnam coffee product (speech by Mr. Doan Trieu Nhan, Chairman of Vietnam Coffee and Cocoa Association, at International Coffee Conference, May 17-19, 2001 in London, UK).

[127] Vietnam's coffee industry has carried out studies for the adjustment on area and production of Robusta-Arbica in the whole country.

[128] In a conversation with Sai Gon Economic Times on the occasion of the 26th birthday of Vinamilk, the company's director Mai Kieu Lien stated that "Vinamilk product standard is as high as any other in the world... We have dominated the market because our products have reached the international standard and our costs are suitable for domestic consumers".

[129] Observation in Wastewater Treatment Plant of Bien Hoa 2 IZ.

Management (CENTEMA)[130] and the University of Agriculture and Forestry[131], which have conducted several laboratory and pilot scale-researches on composting and biogas production, to implement and improve both processes.

7.4.2 Policy Network

The policy network involving food processing companies in Bien Hoa 1 IZ is described in Fig. 7.28. The roles of actors and policy institutions at different level (including national, provincial, industrial zone, and enterprise level) will be analyzed to see how these actors and institutions can push the existing industrial system of food processing industry in Bien Hoa 1 IZ towards a zero waste industrial ecosystem.

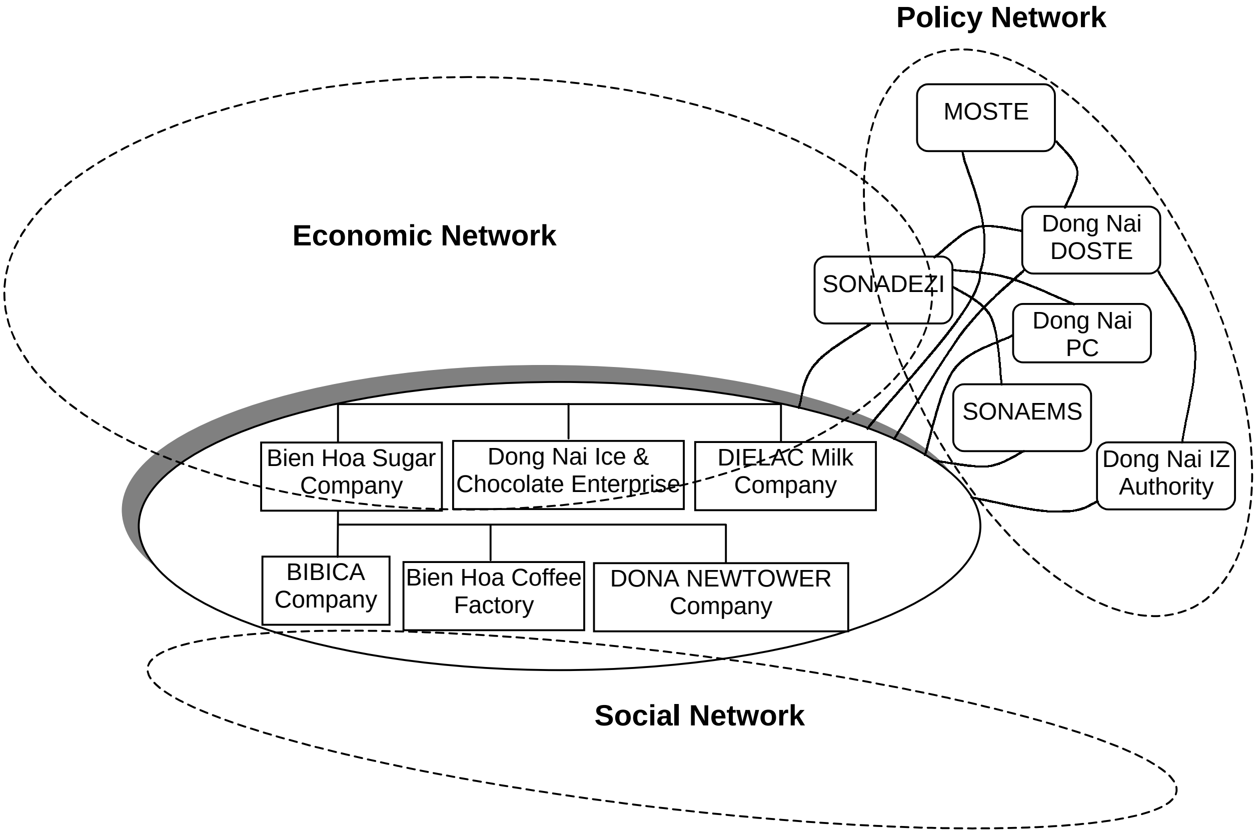


Fig. 7.28 Policy network embedding food processing companies in Bien Hoa 1 IZ.

At national level, MOSTE is the highest governmental environmental agency in Vietnam. It influences environmental protection of industrial zones via EIA appraisal and promulgation of legislation related to environmental protection. After being established 34 years ago, MOSTE demanded an environmental impact assessment report (EIA report) of Bien Hoa 1 IZ, which was conducted and approved by MOSTE in 1997 (SONADEZI, 1997). At that time, companies located in Bien Hoa 1 IZ were also requested to prepare an EIA report and submit these to Dong Nai DOSTE for appraisal[132]. However, in the approved EIA reports, proposed environmental protection methods strongly emphasized on conventional end-of-pipe treatment technologies.

130 Personal experiences from working in several research projects of CENTEMA such as semi-composting of organic municipal solid wastes, reuse of organic matter from old landfills, effect of enzyme on biodegradation of organic municipal solid wastes.

131 Interview with Dr. Tran Tien Viet, lecturer of the University of Agriculture and Forestry, who is ascertaining the role of "black solder fly" in degradation of organic municipal solid wastes and vermi-composting.

132 This regulation is no longer applied for companies located in industrial zones.

That is why the companies, which cause heavy environmental pollution, especially due to generation of large amounts of wastewater, have to install a wastewater treatment system.

At provincial level, Dong Nai People Committee (Dong Nai PC) has the highest political responsibility. Dong Nai DOSTE and DIZA are accountable to Dong Nai PC for IZ environmental management. However, with the current organizational structure, Dong Nai DOSTE is a crucial organization, which is responsible for policy-making, control and enforcement of environmental management activities of IZs in Dong Nai province. Dong Nai DOSTE is responsible for implementing national environmental laws and regulations, participates in the decision-making about IZs' locations, plays an important role in environmental impact assessments of IZs, approves Environmental Standard Registrations and issues environmental licenses for enterprises, and carries out inspections of the environmental performances of enterprises and IZs. At present, Dong Nai DOSTE has to manage and inspect the environmental performance of all 10 existing IZs in Dong Nai Province. With limited human resources, it is not surprising that (illegal) discharging of (untreated or improper treated) wastewater or free emission of air pollutants into the environment still takes place. In addition, applied regulations are strongly based on environmental standards for water, wastewater, air, soil and the environmental inspection program, while more modern environmental protection solutions such as cleaner production, industrial ecology and an industrial development master plan have hardly been considered yet[133]. Companies are requested to install WWTSs rather than to consider waste reduction and waste minimization measures. So far, although effluents from these studied companies have not met the Vietnamese standard of discharged wastewater, they all have not been fined yet. This is attributed to two main reasons: first, Dong Nai DOSTE promulgates a regulation that enterprises have to be informed about environmental inspection 7 days in advance. Therefore environmental protection activities such as the operation of wastes' treatment facilities of these companies will always function when facing inspections. Second, until 2001, all Vietnamese environmental standards are based on concentration of contaminants and utilization purpose of receiving resources without any consideration on the total discharged loads of contaminants. This often leads to dilution of effluents or stopping the production processes to reduce the amount of waste to be treated or disposed during the inspection period. This again confirms that with a heavy reliance on command-and-control regulation but scarce resources for monitoring and effective enforcement, pushing these food processing companies or the whole Bien Hoa 1 IZ towards more environmentally sound production by environmental authorities in future is unsure. However, it is worth to remind that new promulgated standards for industrial effluents discharged into a river (TCVN 6980-2001) based on both contaminant loads and flow rate of the receiving resources, could serve as an incentive for the company to consider the benefit of applying waste reuse and recycling. One of the obvious constraints of waste reuse and recycling is that Vietnam has not yet implemented any specific policies to encourage this activity. All organic industrial solid wastes from these companies can be disposed as domestic solid wastes, which are currently collected by Bien Hoa Urban Environmental Company[134]. This not only creates a bad habit in dealing with industrial wastes from producers (dumping industrial wastes together with domestic solid wastes), but also increases the amount of land required for landfilling, while a good resource for soil enhancement is wasted. This is attributed to unclear regulations and lack of control on what kinds of solid waste should be collected and disposed in sanitary landfills, as well as lack of a waste disposal fee.

Dong Nai DOSTE normally collaborates with SONADEZI and Dong Nai Industrial Zone Authority (DIZA) to organize environmental inspections at companies, which locate in SONADEZI owned industrial zones (including Bien Hoa 1 IZ). However, so far, SONADEZI and DIZA only participate in the inspection program as team members. The role of DIZA in

[133] Interview with Mr. Phan Van Het, Vice Director of Dong Nai DOSTE.
[134] Interview with managers and staff members of several companies in Bien Hoa 1 and Bien Hoa 2 IZ.

environmental management of the existing companies in Dong Nai industrial zones is very vague. The Department of Planning and Environment of DIZA has initial information of invested projects (on production process, machines, energy, water demand, raw materials, products and wastes, proposed treatment methods, etc.), while actual information of these projects, as they are put into operation, is often lacking. Though DIZA has the right to retrieve investment licenses of non-complying companies, this has not been done yet because investment attraction is their first priority[135]. However, establishment of professional industrial zone in Dong Nai (such as Textile and Garment IZ in Nhon Trach District) to overcome difficulties of central waste treatment systems of the existing IZs shows that DIZA can have an influence on planning the establishment of new IZs following the model of a zero waste industrial ecosystem.

SONADEZI is responsible to Dong Nai DOSTE for proper operation of the central waste treatment systems of industrial zones, such as central wastewater treatment plants of its owned IZs or Industrial (Hazardous) Waste Treatment Plant. SONADEZI can only provide environmental services to companies, which have the demand and are able to pay for such service. SONADEZI does not have a right to force companies, which are not complying with environmental standards to use its services. Thus, if Dong Nai DOSTE, which is a state environmental authority, and SONADEZI, which has sufficient available facilities to handle generated wastes, collaborate in environmental management of companies within IZs, they can not only enforce policies, but also provide proper solutions for the companies to follow.

With respect to environmental issues, the studied companies only have contact with Dong Nai DOSTE, especially via annual environmental inspection program. Submitting of annual environmental monitoring reports to Dong Nai DOSTE has only been obligatory from last year onwards (2002)[136]. In order to force the companies to pay more attention to their production efficiency and environmental performance, Dong Nai DOSTE should request them to include information related to material and energy inputs in each production stage and corresponding outputs (including wastes) in the environmental reports. This information is necessary for Dong Nai DOSTE to convince the companies to conduct cleaner production, waste exchange, reuse or treatment to gradually improve their environmental performance. By doing so, Dong Nai DOSTE is more trusted by the companies as a guide and source of information on environmental protection activities, and not only as their inspector. This makes the companies feel free to explain their problems in carrying out environmental protection activities, so that Dong Nai DOSTE can guide them or introduce professional organizations to help them. Alternatively, these kind of tasks could also be performed by the environmental branch of SONADEZI, if it is preferred to keep inspection, control and enforcement separated from assistance, information exchange and services.

7.4.3 Societal Network

The social network involving food processing companies in Bien Hoa 1 IZ consist of resident communities, social organizations such as the Youth Union, Women Association, Veterans Union and Retired People Association and mass media (Fig. 7.29).

So far, there are no direct complaints from surrounding residents on pollution caused by these food processing companies, for several reasons. First, these companies are not located close to residential areas (Fig. 7.1). Second, compared to other existing companies in Bien Hoa 1 IZ, such as Dong Nai Battery enterprise, Dong Nai Paint factory, Dong Nai Paper company, Bien Hoa Chemical factory, and NET Detergent factory, these companies cause less serious and acute environmental problems. Third, though production activities of these companies generate large

[135] Interview with Mr. Phan Van Yen and Ms. Phung, Planning and Environmental Department of DIZA.
[136] Interview with Mr. Phan Van Het, Vice Director of Dong Nai DOSTE

amounts of wastewater and their effluents are not meeting Vietnamese standards, the wastewater is discharged into the sewer system and lead to Dong Nai River. Therefore, only people who live along Dong Nai River or earn money from fishing or fish culture, are affected by the deteriorating water quality of Dong Nai River along Bien Hoa 1 IZ during the growth of industrial zone[137]. However, they face difficulties in indicating which pollution sources are important contributors to deterioration of the water quality.

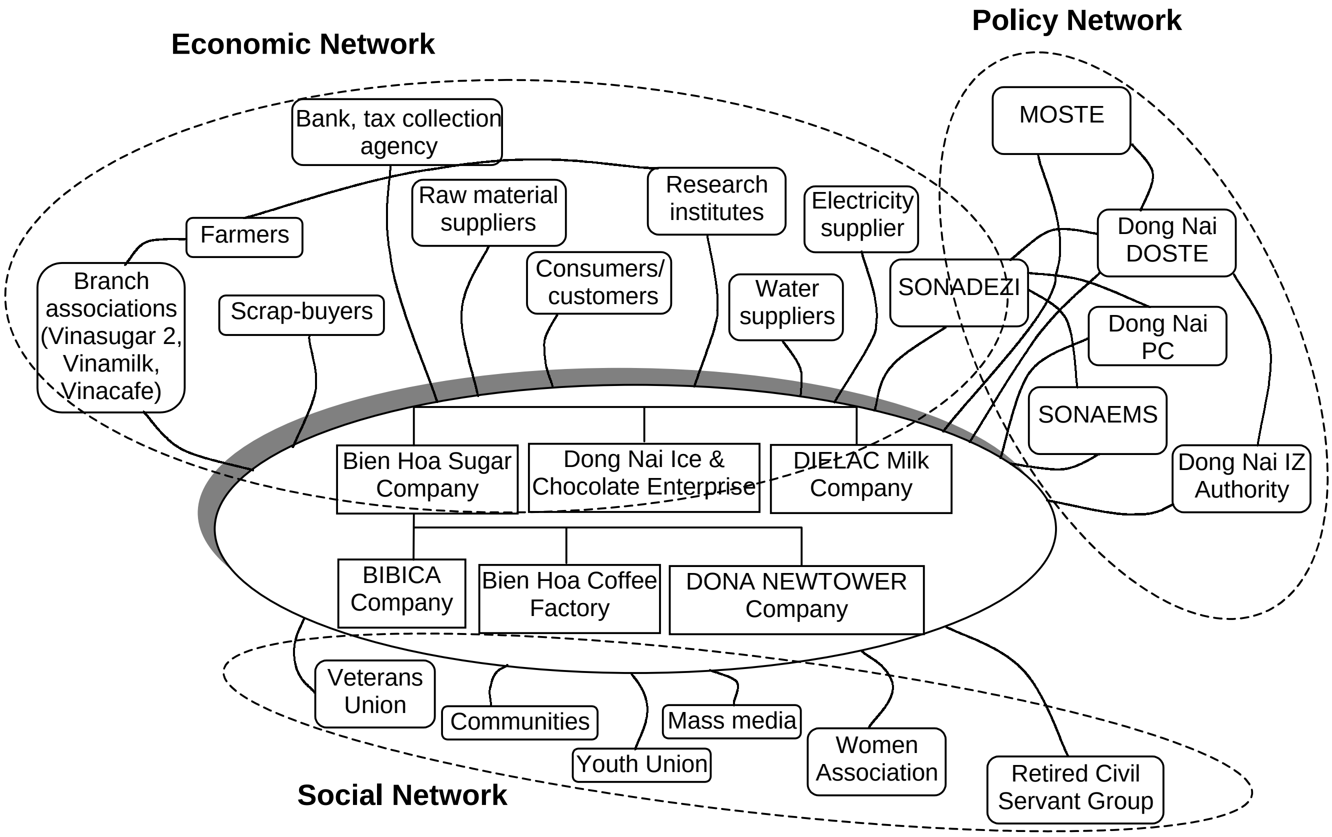


Fig. 7.29 Networks embedding food processing companies in Bien Hoa 1 IZ.

Surrounding residents have complained in various ways pollution problems caused by (other factories in) Bien Hoa 1 IZ, that they have to face. For instance, during monthly meetings, residents complain to the head of the quarter and to the representatives of the Women's Association, the Veterans' Association, the Retired Civil Servants' group, etc (see also Phuong, 2002). Though these actors and organizations do not have the power to solve environmental problems themselves, they usually have better access to higher authorities and they have more respects and esteem, which can help in passing the problems to higher levels and getting them on the political agendas. The Decision of the Prime Minister on reconstruction, management and development of Bien Hoa 1 IZ[138] is attributed to a consequence of environmental complaints by local community. Other environmental activities that took place, such as companies raising their chimney to reduce nuisance of air emission, Dong Nai DOSTE monitoring the water quality of Dong Nai River, residents getting compensation for the loss of fish, etc., are also the result of community complaints. However, in general, the community is not or ill informed about the environmental improvements or changes related to their problems, as there is usually no feed back. "They do not know if the government is taking their complains seriously or not, nor if they are working on a solution" (Woltjer, 2001: 57). This lack of communication between Dong Nai DOSTE, PCs and the community might result in distrust of people in the governmental

[137] Interview with some boatmen, who provided transportation by boats along Dong Nai river for surface water sampling.
[138] In Directive No. 217/TTg dated April 15, 1996 by the Prime Minister.

environmental management agencies and will not stimulate the role communities play as driving force for environmental innovation. If Dong Nai DOSTE would inform the complainant (such as representative of the Women's Association, the Veterans' Association, head of the quarter, etc.) about their progress in dealing with these problems, the information would probably reach local community. This not only encourages local communities to continue detecting environmental problems and to push polluters to change their behavior, but also forms a good example for other local communities. Only if the community understands that their complaints are taken serious and solved where possible, residents will show their neighbors how to transfer their complaints to the right organizations.

At present, the main mass media in residential areas surrounding Bien Hoa 1 IZ includes television, radio and newspapers. Internet access is low and therefore does not play a major role. Though there are special programs on television, radio and in newspapers on environment, the environmental protection and monitoring activities of Bien Hoa 1 IZ have not been introduced through these media yet. That explains why residents do not know whether Dong Nai DOSTE has paid close attention to the complaints of residents or plays an important role as representative of governmental agency in environmental protection, though Dong Nai DOSTE actually has carried out several activities to improve environmental quality of the province[139]. Dong Nai DOSTE can easily take advantage of its annual and quarter magazines on science, technology and environment of the province to introduce such environmental protection activities to the people. It can also use local newspapers as a way of disseminating information to residents. Independent reporting on environmental problems related to industrial pollution of Bien Hoa I industries in the mass media is still rare, and does not play a major role in triggering authorities and industries to take action.

7.5 CONCLUSIONS

This case study shows that approaching a zero waste industrial ecosystem needs the combination and integration of various pollution prevention and treatment methods. Cleaner production measures (e.g. optimization of water flow within the production process), onsite reuse (e.g. using spent coffee grounds as fuel) and waste exchange methods are all environmental friendly solutions that are put to work to get rid of generated non-products and to build a zero waste industrial system. The non-products of these studied companies are mainly organic non-products. Solutions for reusing and recycling organic non-products are: (1) use as raw material for livestock feed production (e.g. from chicken eggshells); (2) composting (e.g. from molasses); (3) biogas production and energy recovery (e.g. from waste fruits and sludge from existing WWTSs); (4) watering (e.g. from treated wastewater). Other non-biodegradable or inorganic non-products (such as broken wrapping materials, waste containing $CaCO_3$, $Ca_3(PO_4)_2$, waste activated carbon, ion exchange resin, etc.) are also partly recyclable. For instance, waste wrapping-paper/cardboard, -plastic can be remanufactured in paper or plastic factories. $CaCO_3$ and $Ca_3(PO_4)_2$ can be recovered from waste in a chemical factory. The other non-products can be incinerated and the generated heat can be reused for other purposes. In short, cleaner production, waste exchange and the ideas of industrial ecology prove valuable elements for developing the physical-technological model of zero waste industrial systems. Certainly, operation of the proposed model developed for six companies of different food processing industrial sub-sectors

[139] Mr. Phan Van Het, Vice Director of Dong Nai DOSTE responded to the interview that for IZs' environmental management, Dong Nai DOSTE conducted environmental inspection of whole Bien Hoa 2 IZ in 1999, Bien Hoa 1 IZ in 2000, and Nhon Trach 1, 2, 3 IZ in 2001. In addition, Mr. Duc, Head of the Environmental Monitoring Section of Dong Nai DOSTE answered the interview that the air quality monitoring program of the IZ as a whole has been implemented at IZs as Bien Hoa 1, Bien Hoa 2, Loteco, Go Dau, Nhon Trach 1, Nhon Trach 2 and Nhon Trach 3 every two months at 2 sampling locations for each IZ. Surface water quality of Dong Nai river, Thi Vai river, Thao river and some other lakes such as Tri An, Le, which receive effluents from IZs are also monitored.

will be more complicated than a model for only one industrial sub-sector (such as tapioca industrial system of Tan Chau-Singapore Company or Tra Co Village).

Participation of SONADEZI plays an important role on the implementation of various technical options. These studied companies can benefit from collective environmental services provided by SONADEZI. Availability of livestock feed production companies (such as PROCONCO Company, VITAGA Company), chemical factories (Dong Nai Chemical Factory, Bien Hoa Chemical Factory), COGIDO Paper Company, and Dong Nai Plastic Factory within Bien Hoa 1 IZ, is another advantage for proper re-manufacturing other non-products. However, as Bien Hoa 1 IZ is located at large distance from crop fields, the developed model face a disadvantage due to the limited possibility to reuse treated wastewater for agricultural irrigation.

I have identified various actors, institutions and relations that play - or can play - a crucial role in introducing these technological options and innovations. First, collaborative relations between Dong Nai DOSTE and SONADEZI in environmental management can help to push the companies to implement environmental protection activities more properly. It is the combination of these two organizations that has the authority, capacity and access to companies in environmental management and technology, that are essential in not only enforcing but also providing ideas, information and proper solutions for the companies (polluters). Second, to completely introduce a model of a zero waste industrial ecosystem in practice (for instance in the case of re-construction existing IZs or development of new IZs), involvement and participation of the Planning and Environmental Department of DIZA is necessary and important because this organization is responsible for industrial (zones) planning in Dong Nai Province. It goes without saying that DIZA should link up with other organizations to fulfil such a task. Third, general corporations such as Vinasugar 2, Vinamilk, Vinacafe can be important actors in developing new production technologies, pushing for new organizational models and designing environmental management schemes for their member companies. In that way they may be able to minimize the generation of non-products and enhance environmental performances of the studied companies. Fourth, achievements in ISO 9000 certification for some companies were directly triggered by their operation on European and USA markets. We might expect that (further) expansion to European and USA markets will force companies to take both product and environmental qualities into account and extent their certification to ISO 14000 series. Fifth, appropriate pricing of both water and wastewater, adding financial sanction on existing environmental regulations, and proper implementation of new promulgated standards (TCVN 2001) on wastewater dischargement and air emission, would encourage the companies to apply cleaner production and waste reuse and recycling. On these points state organizations, both provincially and nationally, have major role to play in the policy networks. Finally, community driven regulation has contributed to some extent in forcing the implementation of Bien Hoa 1 IZ Upgrading Program (it is not so much at the companies studied in this research). Improvement of the communication between state environmental authorities (such as DOSTE) and the community is necessary to encourage local communities in detecting environmental problems and changing the behavior of polluters.

CHAPTER 8

GREENING FOOD PROCESSING INDUSTRY IN VIETNAM: CONCLUSIONS

8.1 INTRODUCTION

The role of food processing industry in Vietnam's economic development (as introduced in chapter 1) is evident. However, it is also obvious that production activities of this industrial sector contribute significantly to environmental deterioration. This will not only damage the environment, but also restrain the industrial development process in future. Though several pollution prevention approaches have been developed and practiced in developed and developing countries, each approach can only be applied successfully in some circumstances and is limited in others (see chapter 2). Additionally, we can clearly envision that various strong points of these approaches are able to overcome each other's weaknesses. This arises the question how to make use of the strong points of the existing pollution prevention approaches for greening agro-industry, in this case especially for food processing industry in Vietnam. This potential is analyzed and assessed in this study to seek for possibilities and potency to move the existing food processing industrial system in Vietnam to a more sustainable (or a zero waste) industrial ecosystem. More specific, this study seeks to fulfil the questions on: how to apply and adapt the existing experiences of industrial ecosystem practices from highly industrialized Western countries in order to develop food processing industrial ecosystems with the existing institutions, technological and socio-economic conditions of Vietnam? Whether it is possible to apply the model for large stand-alone firms as well as small (household) and medium sized companies? What would be core features of a zero waste industrial ecosystem model of food processing industry in Vietnam? Which actors, institutions and relations are crucial or potentially crucial to introduce the proposed model in practice? What are their specific roles and contribution? In order to answer these questions, we investigated, in chapter 3, the strong points of the existing pollution prevention approaches and integrated them in the development of a methodology for moving to a zero waste industrial ecosystem. Taking into account the diversity of the industrial system situations in Vietnam and its differences compared to highly industrialized countries, in chapter 5, 6 and 7, this methodology was tested by three different settings: (1) tapioca processing industry at household-scale in a village, (2) tapioca processing industry at a large-scale company and (3) different types of food processing companies, other than tapioca, in an industrial zone.

This chapter first returns to the integrated approaches and methodology that was developed for greening food processing industries and evaluate the possibilities of moving in a direction of zero waste industrial ecosystems in Vietnam. The second section will discuss similarities and differences between the three case studies. Constraints and opportunities in implementing a zero waste industrial ecosystem of food processing industry in Vietnam will be elaborated in the third section. General conclusions on applicability of the developed methodology and approaches for greening the food processing industrial sector and other industrial sectors are presented in the fourth section. The chapter closes with a general, overall conclusion and a reflection on the applicability of the Industrial Ecology Concept in Vietnam.

8.2 LEARNING FROM THE CASE STUDIES

8.2.1 Similarities from the Case Studies

In general, the scope of food processing industry extends from farms, where raw materials as crops (such as cassava, sugarcane, coffee, vegetables and fruits) and livestock (chickens, cattle, swine) are grown, to factories, where these raw materials are processed and then brought to the markets, where the final products are sold. At present, the food processing industry in Vietnam is a combination of industry and agriculture in such a way that the industry consumes agricultural products for its operation and the production of new products. More precisely, the industry extracts raw materials from farms, fresh water from natural resources and electrical and thermal energy for its operation, but it does little to compensate for the amounts of consumed energy, used fresh water and soil nutrients, which are utilized to grow agricultural products. In addition, its production activities contribute to the deterioration of the environment due to improper discharge, disposal and emission of the generated wastes. This study tries to overcome the un-sustainability of this system by developing a physical-technological model focussed on a zero waste industrial ecosystem.

The three case studies show that excessive generation of non-products (including reusable/valuable materials, wastes and air pollutant emission) arises due to:

- Inefficient technology, as in the case of household tapioca processing units at Tra Co Village.
- Inadequate processing, resulting from a poor knowledge of the process by operators, like during the cassava root rinsing stage at tapioca producing households in Tra Co Village or the current application of water and processing wastewater circulation in Tan Chau-Singapore Company.
- Inadequate consideration on onsite reuse and recycling, such as selling spent coffee grounds to farmers to reuse as soil conditioner instead of onsite reuse as fuel to provide thermal energy (Bien Hoa Coffee Factory), releasing hot gases to the atmosphere instead of recovering its excess heat for drying fibrous residues (Tan Chau-Singapore Company).
- Inadequate offsite reuse and recycling, which could be done by food processing companies in Bien Hoa 1 IZ and Tan Chau-Singapore Company.
- Cheap natural resources (such as the free of charge availability of ground water, cheap water supply).
- Lack of knowledge about waste(water) treatment and recovery of valuable materials from non-products.
- Financial limitation for environmental investment.
- No strict enforcement on pollution prevention and environmental protection, lack of incentives to encourage the implementation of waste reuse and recycling.
- No active civil society on environmental issues.

Seeking possibilities to overcome the mentioned causes of excessive generation of non-products, these case studies have revealed that cleaner production, waste exchanges and ideas of industrial ecology are valuable in greening food processing industry, though the feasible technical options and organizational schemes are different in the three cases as we will see in the next section.

Characteristics of food processing industry lead to the generation of three types of non-products, which are mainly organic in nature. First, liquid non-products that normally consist of three types of wastewater: (1) process wastewater (rinsing wastewater and settling wastewater from household-scale tapioca processing units, wastewater from the starch extracting stage of large-scale tapioca processing company, wastewater from machine cleaning of other processes, etc.); (2) cooling and heating wastewater; and (3) domestic wastewater. Second, solid non-products, which are unqualified raw materials (such as cassava hard roots and wood shells, unqualified vegetable and fruits, etc.); generated residues from the processes (cassava fibrous residues and pulp, spent coffee grounds, molasses, etc.) and unqualified packaging materials (broken cardboard boxes, plastic bags, tin cans, etc.). Finally, air pollutants and surplus heat are generated from boilers and heaters, which use diesel oil and fossil oil as fuel. Except for air pollutants, surplus heat and unqualified packaging materials, the other major non-products are organic in nature and it is difficult to avoid their generation completely due to the importance of maintaining food hygiene and product quality. However, the case studies have revealed that for putrescible and biodegradable non-products, the logical solutions with respect to environmental, economic and technological feasibility, include:

- Prevention and minimization at source as much as possible;
- Wherever possible, the continuing use as raw materials for livestock feed production (for instance fish feed from tapioca wastewater, swine feed from cassava fibrous residues and pulp);
- Where appropriate, the application of composting to convert organic waste materials (such as cassava hard roots and wood shell, residues from fruits and vegetable, spent coffee grounds, etc.) to soil conditioners and fertilizers; or production/ recovery of biogas for self-generation of energy by application of anaerobic digestion of organic non-products or recovering methane gas from anaerobic wastewater treatment process;
- Treatment of the remaining un-reusable non-products for further reuse, like use of treated wastewater for irrigation and watering;
- Proper treatment of wastes (including wastewater, air pollutants and solid wastes) before discharging to avoid adverse impacts on the natural environment.

It proved in all three case studies that these are possibilities to transform the current food processing industrial system (closer) to a zero waste industrial ecosystem, in which the food processing industry (and other related industries, which use its products and byproducts as raw materials) and agriculture are integrated.

Analysis on current actors and institutions aims at understanding the existing relations of the industrial systems with, among others, governmental agencies, other economic entities and social actors, which might hamper the implementation and introduction of some or all of alternatives of the proposed industrial ecosystem model. Several similar points have arisen from the three case studies. First, state environmental management authorities, especially the provincial DOSTEs, face difficulties of high workload, lack of expertise and scare resources for monitoring and enforcement. To some extent, provincial DOSTEs have forced producers to implement environmental protection activities, for instance the installation of wastewater treatment systems or chimneys. However, the current environmental monitoring and enforcement programs of the DOSTEs have not been competent enough to force producers to keep on operating the systems properly in order not to deteriorate the environment with their effluents. This explains why tapioca producing households in Tra Co Village not even take notice of environmental pollution caused by wastewater from their production processes. Second, specific regulations and incentives for producers to make their production processes more ecologically sound as well as reuse and recycle wastes are completely lacking at the moment. Therefore, it should not surprise us that all studied companies have not carried out auditing programs, which is the first important step to implement a cleaner production program. The current activities of waste reuse and recycling are conducted not with the purpose to protect the environment, but mainly because of economic saving of producers. Fish culture farmers in Tra Co Village use tapioca wastewater from tapioca producing households, but in fact they have no idea about environmental protection or waste exchange, reuse and recycling. Their reason to do so is just because they can reduce the cost of buying fish feed. Though eggshells from BIBICA Company are an excellent calcium source for livestock feed production, they are disposed together with the domestic solid waste because the profit increase from this source is insignificant for such a large-scale company. Third, influence from economic agents does not seem to encourage producers to improve their production efficiencies and environmental performances. Except for some demonstration projects on the implementation of cleaner production in Ha Noi and Ho Chi Minh City, banks in general provide credit with short payback periods and without preferential interest rates for environmental investment. Therefore producers, who have financial limitations, face difficulties in getting a loan from a bank for environmental investments. Fourth, there is hardly any enduring relation between research institutes and the producers in neither production nor environmental protection. Finally, the civil society is not actively involved in environmental issues. This is especially where the local community is equal to the producers and profiteers of environmental problems as the case of Tra Co Village. In addition, this is the case, where social organizations are not interested in environmental issues and non-governmental organizations that could focus on environmental issues are non-existent.

8.2.2 Dissimilarities in the Case Studies

Beside similarities found in the case studies as mentioned in section 8.2.1, several dissimilarities can also be indicated. The diversity of industrial systems in Vietnam in terms of scale (household, large), size (one enterprise and group of enterprises), industrial sector (one food processing industrial sector and different food processing industrial sector) and location (within and outside IZ) are causing the dissimilarities. Therefore, it is made clear in these case studies that any general or national approach to green food processing industry is doomed to fail in practice if in its operationalisation these differences are not taken into account.

Dissimilarities between household- and large scale company

To compare household-scale and large-scale companies, the case studies on tapioca processing industry were conducted at Tra Co Village (chapter 5) and Tan Chau-Singapore Company (chapter 6). Though these case studies were conducted for one industrial sector, the proposed options and implementations to approaching a zero waste industrial ecosystem are not the same. First, the proposed technological options for household-scale units differ from that of a large-scale company. The traditional tapioca production technology at households in Tra Co Village is not suitable for the proposed cleaner production measures like a more modern tapioca production technology as applied in Tan Chau-Singapore Company. For instance, though using the same countercurrent principle to reduce the amount of used fresh water and generated wastewater, the existing tapioca production technology of the households in Tra Co Village does not suit the proposed water circulation option of Tan Chau-Singapore Company. Whereas it is a possibility for Tan Chau-Singapore Company to reuse heat from high temperature emission to dry their fibrous residues, this is impossible for the households. In addition, because of the continuous operation during ten months a year, it is easier to convince large-scale tapioca processing company to implement cleaner production measures to minimize the generation of wastes. But it is difficult to do so in the case of households, which usually put their tapioca production processes in operation for three months every year. With respect to reuse and recycling options, it is feasible to install as well as facilitate a livestock feed production enterprise, composting plant, biogas plant and fishponds within the boundaries of Tan Chau-Singapore Company reducing transportation costs, it is impossible to do so for each individual tapioca producing household. Installation of a wastewater treatment system to treat tapioca wastewater for irrigation and to recover biogas for self-sufficiency in energy seems an attractive option for Tan Chau-Singapore Company, but is also impossible to apply for the households. However, this does not mean that it is completely impossible to improve the environmental situation of these tapioca producing households. The case study at Tra Co Village has revealed that the limitations of individual households in implementing waste exchange options can be overcome by co-operating among the production households. Installation of a central composting plant, a central biogas production plant and a central wastewater treatment plant to reuse and treat non-products from all tapioca producing households of the village would help to solve the existing environmental problems in this case in an economically and environmental friendly way. By doing so, the group of tapioca producing households can benefit from the collective offsite reuse and recycling and environmental services (waste collection and treatment system).

Second, difference in size (in terms of employees and production capacity) of producers leads to differences in organization of the cleaner production program. For a large-scale firm like Tan Chau-Singapore Company, it is possible to organize a study team itself to conduct a cleaner production program, but it is not feasible for each household in Tra Co Village, which have 3-5 workers. Again, one cleaner production study team could be organized for all tapioca producing households in the whole village. But, without economic incentives, it is not easy to get all 65 households in Tra Co Village to participate voluntary in the cleaner production program. In addition, the company has better skilled staff for specific tasks, for instance production technology, machine reparation, administration, etc., so it is easier to train workers to become adapted to new technologies or installations.

Third, differences in the existing organizational structure of the industrial systems also lead to differences in the organizational structure of the proposed industrial ecosystem. While Tan Chau-Singapore Company is responsible for the installation and operation of the wastewater treatment system, the households can only pay the (public or private) owner of a central wastewater treatment system to treat tapioca wastewater generated from their production process after it has been installed and put into operation. In other words, in the case of household-scale producers, it is necessary to have a third actor, who is responsible for treatment of un-reusable non-products. Tan Chau-Singapore Company is able to manage the proposed industrial ecosystem, but it is obviously impossible for each tapioca producing household to do so.

Finally, relations between these industrial systems and the current actors and institutions are partly different. For a large-scale company like Tan Chau-Singapore Company, Ministry of Science, Technology and Environment (MOSTE) played its role in the initial stage of the company by appraising the environmental impact assessment report. So far, MOSTE has not directly influenced the environmental improvement at Tra Co Village. While Tay Ninh DOSTE has monitored the environmental situation of Tan Chau-Singapore Company from its initial stage (1996), environmental problems at Tra Co Village have just started to receive attention by Dong Nai DOSTE in 2001. By applying regulations in compliance with environmental discharge standards, Tay Ninh DOSTE has at least succeeded in forcing Tan Chau-Company to store tapioca wastewater in ponds without discharging it into Tha La River. However, it is very difficult for Dong Nai DOSTE to use strong enforcement instruments such as fine, administrative punishments or closure to all 65 tapioca producing households that violate environmental regulations, because this will create significant social problems. The role of customers in pushing producers to take into account both product qualities and environmental qualities only seem to be relevant in the case of large-scale companies that participate in international markets.

Dissimilarities between one large scale enterprise and a group of enterprises

Compared to a group of enterprises (for instance 65 tapioca producing households in Tra Co Village), the designing and implementation of a proposed zero waste industrial ecosystem for one company (for instance Tan Chau-Singapore Company) is much easier, for several reasons. First, collection of non-products from a group of enterprises is certainly more difficult than that of one company. For instance, in order to collect tapioca wastewater of Tan Chau-Singapore Company for further handling, we only have to design a sewer network within the company, but in case of Tra Co Village, it has to be done for the whole village. Second, convincing one company to participate as an anchor in the model is easier than to get agreement from all 65 tapioca producing households in Tra Co Village. Third, the implementation of a cleaner production program (to conduct the proposed cleaner production measures) for one company is much easier than in case of a number of tapioca production households. Cleaner production training in one company is surely less difficult compared to training a whole village.

Dissimilarities between a group of enterprises from one food processing industrial sub-sector and a group of enterprises from different food processing sub-sectors

The case studies at Tra Co Village (chapter 5) and Bien Hoa 1 IZ (chapter 7) have revealed that the operationalization (or application) of the developed methodology for a group of enterprises from one food processing industrial sub-sector also differs from that of a group of enterprises from different food processing industrial sub-sectors. A group of enterprises from one food processing industrial sub-sector will generate almost the same non-products. This leads to two main advantages:

- Benchmarking can be done by these enterprises themselves. It is possible to compare the production efficiency (for instance unit of product per unit of input or unit of non-products per unit of input) and environmental performance (for instance unit of waste per unit of product or input) among these enterprises. This is not only helpful in selecting feasible solutions to reduce the generation of non-products but also in convincing producers to learn experiences from each other.
- By a group of enterprise, the same kinds of non-products are generated in larger amounts making it worthwhile to reuse, recycle or treat them. It is possible to gather the non-products from the different enterprises and handle it by the same method. Additionally, it is easier and more economic to handle large amounts of one non-product by one method than to handle small amounts of different non-products using different methods.

The disadvantage of having a group of enterprises from only one food processing industrial sub-sector is that these enterprises can not use each other’s products and reuse byproducts (or non-products). In other words, the material flow network, which is often essential to reach a zero waste industrial ecosystem, can only be created by adding new enterprises that use and produce different inputs and outputs. However, because food processing industry manufactures food for human beings, it is usually only possible to use each other products as raw materials (for instance sugar and tapioca starch for confectionery company, milk for instant coffee mix production, etc.) and impossible to reuse non-products from each other. Except for some non-products, like wrapping materials, which have to be re-manufactured in other processes (such as paper or plastic processing), most organic non-products from food processing industry are suitable for producing one of the following non-food products: livestock feed, fish feed, industrial grade alcohol, biogas, compost and irrigation water. Organic non-products (usually the largest part of all non-products in the food processing industry) generated from different food processing enterprises, are of course not uniform though they are all organic in nature. For instance, molasses of Bien Hoa Sugar Company contain different organic compounds and contents compared to waste fruits from DONA NEWTOWER J. V. Company or spent coffee grounds of Bien Hoa Coffee Factory. Wastewater from all food processing companies in Bien Hoa 1 IZ certainly contain biodegradable organic contaminants. However, the concentrations of organic contaminants in terms of COD or BOD_5 of wastewater from these companies are totally different. This makes reuse and recycling processes more complicated than in the case of uniform non-products from one food processing industrial sub-sector.

Dissimilarities between industrial system located inside and outside industrial zone

Beside several dissimilarities discussed above, the developed industrial ecosystem model for enterprises located within an industrial zone also differs from that of enterprises located outside the industrial zone in several points. First, enterprises located within an industrial zone can benefit from collective environmental services (such as a common wastewater treatment system, composting, collection and handling other wastes) of the Industrial Zone Infrastructure Development Company. Second, these enterprises can reduce transportation costs for non-products to recyclers, which are also located within the industrial zone. However, if the industrial zone is located far away from available agricultural fields, food processing enterprises located in the industrial zone face a large disadvantage. Because agriculture provides raw materials for these enterprises and also serves as an environmental friendly receiving body for wasted materials, close physical distance between the enterprises and agricultural lands can be an important condition for successful implementation of the developed industrial ecosystem model. This brings several potential economic and environmental advantages:

- Reduction in costs and time to transport raw materials from the fields to the enterprises;
- Minimizing loss of quantities and qualities of raw materials due to long distance transport from the agricultural fields to industrial processing enterprises;
- Reduction in costs of wastewater treatment, because only pretreatment is necessary to use wastewater for irrigation, instead of complete treatment;
- Water resource conservation thanks to the possibility of reusing wastewater for irrigation, instead of using (surface or ground) water;
- Providing a clear life-cycle benefit by returning composted organic solid wastes into soil (of crop fields) as conditioners;

Finally, actors and institutions involved in the policy network of enterprises located within an industrial zone (as presented in chapter 4) are different with those located outside. Enterprises located within an industrial zone are normally under an administrative management of the Industrial Zone Infrastructure Development Company or Industrial Zone Management Board and District Industrial Zone Authority. These institutional and policy actors can play a significant role in creating the conditions that support the development of the proposed model, educating and advising (potential) participants on the opportunities to improve their production efficiency and environmental performance as well as monitoring the last. These actors can also cooperate intensively with environmental authorities on various levels.

8.3 CONSTRAINTS AND OPPORTUNITIES TO APPROACH A ZERO WASTE INDUSTRIAL ECOSYSTEM OF FOOD PROCESSING INDUSTRY IN VIETNAM

The case studies have revealed several constraints hampering the implementation of cleaner production, waste exchange and even end-of-pipe treatment approaches, which play important roles in moving the current food processing industrial system in Vietnam to a more sustainable industrial ecosystem. However, besides these constraints, there are also opportunities to approach a more sustainable development of food processing industry in Vietnam. Discussions on these constraints and opportunities will focus on the following main aspects: (1) technical dimensions, (2) environmental policy, (3) economic aspects and (4) public participation. Of course, not all constraints and opportunities are of equal relevance for all situations.

8.3.1 Technical Constraints and Opportunities

Constraints

Technical constraints refer to the lack of five needed facilities: (1) know-how, (2) willingness to change the current techniques, (3) information dissemination, (4) advanced equipment, and (5) monitoring facilities. First, the case studies have revealed that producers often do not know how to implement cleaner production measures, to conduct reuse and recycling and to treat waste properly. So far, it is hard to find any plan or even ideas to implement cleaner production programs in the studied companies. Implementation of cleaner production does not seem to have any urgency in their development strategy. Several economic and technological feasible possibilities for onsite and offsite reuse and recycling of non-products have not been practiced in the studied areas. For instance, Bien Hoa Coffee Factory has not considered onsite reuse of spent coffee grounds to approach self-sufficiency in thermal energy. BIBICA Company does not know that it is wasting an excellent calcium source for livestock feed production. DONA NEWTOWER J. V. Company does not seem to realize that waste fruits are raw materials to produce bio-fuel. Recovery of biogas from anaerobic treatment of tapioca wastewater to generate energy is a new idea for Tan Chau-Singapore Company. Concentration levels of substances in the effluent from the existing wastewater treatment system of the studied companies, which are often higher than allowed following Vietnamese discharge standards, give evidence that these companies do not pay attention nor know how to treat it properly.

Second, technical constraints also refer to lack of willingness of producers to change the current techniques. They all do believe in the current production efficiency and do not want to modify their operational habit. They have the prejudice that any change in the processes takes too long to be implemented and may affect the product quality, especially in case of food, this may be a strong barrier. Additionally, extra investment adds to their unwillingness to any change.

Third, lack of information dissemination is also attributed to be a technical constraint. This explains why not all producers know about the existing technical solutions to improve production efficiency and environmental performance fitting to their cases. Reuse of tapioca wastewater, as fish feed is one of the evidences for that. Though this technique is applied successfully in Tra Co Village, it is unknown in Tay Ninh Province. All case studies show that it is hard to find enduring or even incidental cooperation between research institutes and producers. This limits opportunities of producers in accessing new techniques to improve their production efficiency and environmental performance. In addition, due to little demonstration and full-scale application of the laboratory studies, it is also difficult to convince producers to carry out waste reduction and minimization.

Fourth, lack of advanced equipment for the production process, such as in the case of tapioca processing households in Tra Co Village is one thing causing high amounts of generated non-products and wastes. Finally, lack of monitoring facilities and continuous measurement and assessment of environmental performance of producers is another constraint, which is attributed to improper implementation of environmental protection activities of several producers for a long time. All three case studies show that none of the producers have data on material flows of their production processes, though these data are very important for them to know whether their processes are operated efficiently.

Opportunities

There are several opportunities to overcome these constraints and to further implement a zero waste industrial ecosystem for greening food processing industry in Vietnam. First, cleaner production and waste exchange are actually not completely unknown in Vietnam. Successful demonstration projects on cleaner production in Ha Noi and Ho Chi Minh City do not only illustrate the potentials and possibilities to implement cleaner production in Vietnam, but also provide at least the know-how on cleaner production. The experiences of these projects can serve as the foundation for further multiplying to other enterprises. The case studies also show that waste exchange is not completely lacking in Vietnam. This is illustrated by several existing activities such as selling non-products to other producers instead of throwing it away (tapioca producers sell fibrous residues, other food processing companies sell broken cardboard boxes, plastic bags, etc.), or reusing non-products in agriculture (Tra Co Villagers reuse tapioca wastewater as fish feed). In other words, future implementation of waste exchange or reuse and recycling in Vietnam is possible, provided that precaution is taken into account in order to avoid secondary pollution from reuse and recycling processes.

Second, successful cleaner production demonstration projects convince producers that it is not difficult to improve their production efficiency in terms of technical modification and costs. Third, the establishment and achievements of the Vietnam Cleaner Production Center (VCPC) in recent years (from 1998 to now) can play a role in overcoming the lack of technical information dissemination and lack of awareness on the importance of cleaner production. Several activities carried out by VCPC such as organizing training and awareness-raising seminars; editing guidance manuals on cleaner assessment; preparing reports, video tapes, brochures and leaflets; conducting cleaner production assessment at companies; etc., (VCPC, 2003) have been efficient ways to expand and disseminate cleaner production technologies to producers. It is necessary to have intermediary organizations as a bridge to transfer information from VCPC to companies. These intermediary organizations might be branches of the VCPC in each key economic region of Vietnam, Division of Science and Technology of provincial DOSTEs, environmental centers, general cooperation, branch association, etc. In the same way, provincial DOSTE in collaboration with environmental centers or research institutes can conduct and disseminate cleaner production measures for household production units, which are currently not among the targets of VCPC. Similarly, the limitation on technical information related to waste exchange could be overcome by either integrating this program in the activities of VCPC and its branches[140] or establish waste information exchange centers as sub-sections of the Division of Science, Technology and Information belonging to provincial DOSTEs and Industrial Zone Infrastructure Development Companies.

[140] Burnside Cleaner Production Center plays an important role in providing information on waste reduction and prevention, and cleaner production to existing industrial estates (Smolenaars, 1996).

Fourth, Vietnam can learn experiences on production technologies, cleaner production, waste reuse and recycling from other countries and adapt them for use in the technological conditions of the country. Openness to trade and investment alongside with industrialization might offer opportunities for enterprises to take advantage of newer and cleaner technologies imported from other industrialized countries (Rock, 2000, 2001). Growing of foreign investments in industrial development might help Vietnam modernizing the industrial system and achieving more sustainable development.

Finally, in order to force producers to conduct auditing programs, provincial DOSTEs or industrial zone authorities need to give a clear and specific content of environmental reports and material manifests so that producers have to carry out measurements and give more detailed data on their production processes and waste generation. By doing so, environmental management authorities can compare and recognize whether production processes of those producers are operated efficiently and environmental friendly to advise them in conducting a cleaner production program.

8.3.2 Environmental Policy Constraints and Opportunities

Constraints

Environmental policy constraints refer to four main points: (1) strong emphasis on end-of-pipe treatment; (2) lack of incentives to encourage investment and implementation of cleaner production and waste exchange, (3) low or no price for using natural resources and absence of waste treatment fees, and (4) lack of environmental management (division) within the company.

First, as discussed in chapter 4, the existing environmental legislation strongly emphasizes on end-of-pipe solutions, while cleaner production and waste reuse and recycling is mentioned briefly without concrete and practical incentives and guidelines for implementation. This is shown through all three case studies (chapter 5, 6 and 7). For instance, to overcome environmental pollution due to tapioca processing in Tra Co Village, Dong Nai DOSTE and the People Committee planned to install a new sewer system[141], in stead of seeking solutions to reduce the generation of wastes. In case of Tan Chau-Singapore Company (chapter 6), the pressure put on the company at the initial stage was on treatment of wastes rather than orienting them to optimize their material flow within the production process and paying attention to onsite and offsite reuse and recycling of non-products. This is also the case of food processing companies in Bien Hoa 1 IZ. These companies installed wastewater treatment plants just to fulfil the requirements from environmental authorities without proper care on treatment efficiencies. That is the reason why concentrations in these effluents from these plants are usually above the Vietnamese standards and contribute to the deterioration of surface water.

Second, there is no incentive to encourage investment and implementation of cleaner production and waste exchange. Disposal of wastes (such as waste fruits from DONA NEWTOWER J. V. Company, eggshells from BIBICA Company, etc.) together with domestic solid waste is an evidence of this constraint. Third, low resource pricing and non-existing pollution treatment fees are among the major regulatory constraints in encouraging the implementation of cleaner production and waste exchange. This is illustrated by the case of tapioca producing households in Tra Co Village, where the producers can use ground water free of charge for their production activities. They do not care about minimizing water losses,

[141] Including a sewer network and wastewater treatment plant.

because it costs almost nothing. In addition, they do not have to pay for discharging their wastewater and generated wastewater finally does not end up in their own yards.
Finally, most producers do not have a separate environmental management division. Therefore, so far, except for the operation of wastewater treatment systems and selling non-products for recycling, hardly any other activity focussing on improvement of environmental performance are carried out by producers themselves.

Opportunities

In order to promote the implementation of cleaner production and pollution prevention as well as further approaching to a zero waste industrial ecosystem for food processing industry in Vietnam, the following key measures should be taken into account. First, it is important to establish financial incentives to encourage the implementation of cleaner production and waste exchange in the environmental regulation system. By setting a waste treatment and disposal fee based on unit of generated waste (amount of waste per unit product), for instance the higher the unit generated waste, the higher the fee, will encourage producers to minimize the generation of wastes from their production processes.

Second, appropriate pricing of natural resources and materials and removal of subsides for water and electricity supply as well as for the waste collection and disposal service is essential. It is of course of great importance to determine suitable charging rates. Too high charging rate will affect the economic performance and competitiveness of business, while a too low rate will discourage producers to pay attention to environmental protection. For electricity and water supply, the Government Pricing Committee in collaboration with Electricity of Vietnam and Water Supply Companies have to carry out studies to estimate appropriate prices of electricity and water supply for industrial producers and submit them to the Government to make a decision about. Similarly, in the case of treatment and disposal fee of wastes, it is the task of MOSTE and DOSTEs in collaboration with environmental centers and waste treatment companies to estimate proper prices. The implementation of such a pricing system can only be done after promulgation by the Government.

Finally, without continuous maintaining environmental protection activities of participated companies, all attempts to approach more sustainable development are meaningless. In addition, because “cleaner” is a comparative expression and “cleaner” today may not be “cleaner” tomorrow (Sakurai, 1995: 2) and industrial development is a dynamic process, establishment of a permanent system or institutions to facilitate and implement proper environmental pollution prevention activities is necessary. This can be done in different ways at different levels. For companies above a certain size (such as medium- and large-scale companies), it is suggested to establish a separate environmental management section, which is able to conduct environmental monitoring, auditing, designing cleaner production measures as well as properly operate the waste treatment systems. For small-scale or household-scale production units, where it is difficult and impossible to establish separate environmental management sections for each unit, Environmental Management Sections of District Urban Management Divisions will play important roles.

8.3.3 Economic Constraints and Opportunities

Constraints

Economic constraints refer to three main points: (1) lack of incentives from economic agents; (2) poor influence from customers and consumers, and (3) financial limitation. First, all three case studies show that so far, economic agencies such as banks, tax agencies and insurance companies have not provided companies any incentives to apply cleaner production and pollution prevention measures. No tax exemption or tax reduction is applied for environmental investment of companies. Insurance companies have only emerged recently in Vietnam and are mainly related to health insurance rather than risk insurance for industries.

Second, the case studies also show that national customers and consumers play no role yet in pushing food processing companies in Vietnam to both qualities of product and environment take into account nor have a role in triggering companies to get interested in ISO certifications. No products among the studied companies having eco-labels or are in a stage of working towards a labeling system. Unfamiliarity with eco-labeling of Vietnamese customers and consumers give further evidence of this constraint. The industrial grade alcohol producing from reusable materials (such as high quality molasses of sugar companies) has not been specified, in terms of environmental protection, compared to that from original raw materials (such as wood). It is attributed to the common situation in Vietnam because environmental performance is not taken into account by customers and consumers in selecting their products or suppliers.

Last but not least, lack of capital for environmental investment is always a challenge for the implementation of cleaner production measures as well as end-of-pipe treatment, especially in the case of household-scale units. So far, there is a limited financial assistance for implementing cleaner production measures (only for some demonstration projects).

Opportunities

There are several opportunities to overcome these economic constraints. First, cleaner production demonstration projects, that have recently been established in Ho Chi Minh City and Ha Noi, show that environmental funds with a preferential interest rate could help to facilitate the implementation of cleaner production (Nhan, 2001). This shows that companies are willing to borrow money from credit institutions for environmental investments. Vietnam can also learn from experiences of other Asian countries in applying soft loans and special schemes giving benefit on taxes (Chandak et al., 1995; Roestamsjah and Cahyaningsih, 1995; Rock, 1996) to make cleaner production and environmental pollution prevention more attractive.

Second, except for household-scale production units (as in the case of Tra Co Village), large-scale companies increasingly export part of their products to several foreign countries in the world (as the cases of food processing companies in Bien Hoa 1 IZ and Tan Chau-Singapore Company). Starting at Eastern European and USA markets might be instrumental in an ISO 14000 accreditation process for companies, which were granted the Certificate of Quality Management System ISO 9000 (such as Bien Hoa Sugar Company, Bien Hoa Coffee Factory, DIELAC Powder Milk Factory). In other words, customers and consumers will be able to push these companies to pay more attention to their environmental performance. Moreover, achievement of ISO 9000 of some companies (such as BIBICA Company, DIELAC Powder Milk Factory) directly triggered by their operation in European and USA martkets, is a good start for these companies to move further into the implementation of proper environmental management system (EMS). Because from this position, the steps towards an EMS according to ISO 14000 might be smooth as these companies already have experience with the necessary internal organization and reporting and with accreditation procedures (Magno, 2001).

Finally, besides establishment of financial incentives as mentioned in section 8.3.2, those companies, which face financial limitations, should start with cost-effective low and no-cost cleaner production measures that are easy to implement. The savings from these low- or no-cost solutions could then be used to fund the applications of other more costly options.

8.3.4 Constraints and Opportunities on Public Participation

Constraints

A key catalyst for adoption of environmental-friendly production practices is a strong public preference for them. In several cases in Vietnam, environmental reforms are triggered by local community complaints (O'Rourke, 1999; Woltjer, 2001; Phuong, 2002). However, the case studies indicate existence of several constraints that hamper community action with respect to the studied companies. First, the overall level of environmental awareness of residents remains low. The local community hardly knows anything on long term impacts caused by (industrial) wastes nor do they pay attention to that. This is especially the case where the community is equal to the producers and profiteers of the environmental problems. For instance in Tra Co Village, villagers can earn income from tapioca wastewater as fish feed or from recovery of fibrous residues and pulp, so they do not complain about the dischargement of tapioca wastewater into the environment. Farmers living in the surrounding of Tan Chau-Singapore Company can sell cassava roots to the company and buy with preferential prices both wet fibrous residues and hard roots and wood shells. In addition, some households have family members that are employees of the company. So there is no reason for them to complain about environmental problems caused by these production activities.

Second, limited access to environmental agencies also contributes to restrain the role of the community. In several cases, the community members do not know DOSTE or its functions. Therefore, they usually need help from other social organizations such as the Retired Civil Servants' group, the Veterans' Association, the Women's Association, or the media to transfer their complaints to higher authorities. This is illustrated through the case study at Bien Hoa 1 IZ. Thus, the lack of interest in environmental issues of these social organizations (as indicated in the case studies at Tra Co Village and Tan Chau-Singapore Company) is another constraint for public participation.

Finally, lack of local and national independent NGOs working on pollution issues is also among the most significant constraints. In other (developed and developing) countries, domestic environmental NGOs link to international environmental NGOs, and in that way succeed to mobilize concerned citizens to participate in policy-making and support social movements to push state organizations and industrial polluters towards radical environmental reform (Phuong, 2002). In the absence of such NGOs, citizens in Vietnam lack a powerful source of support.

Opportunities

In order to enhance the role of communities in detecting environmental pollution and changing behavior of the polluters, it is important that the communities become more aware and get more knowledge about the environment and environmental quality in their livelihood. The Government can help to increase environmental awareness among citizens by including environmental issues in curriculum of primary schools and widening opportunities for the establishment and functioning of domestic, national environmental NGOs as well as international NGOs. Supporting of the Government in establishment of special programs on science and education focussing on environment of television, radio and newspaper is an other effective way to disseminate environmental information to citizens. Finally, in order to facilitate community action, the state environmental authorities have to provide specific guidelines, so that citizens know on how, where and to whom their complaints can be sent.

8.4 APPLICABILITY OF THE POLLUTION PREVENTION METHODOLOGY IN APPROACHING A ZERO WASTE INDUSTRIAL ECOSYSTEM

This section evaluates the applicability of the developed pollution prevention methodology (chapter 3) in approaching a current industrial system towards more sustainable system after testing through three case studies (section 8.4.1). Proposed physical-technological models to approach zero waste industrial ecosystems of food processing industrial sector and other industrial sectors are discussed in section 8.4.2 and section 8.4.3, respectively.

8.4.1 Applicability of the Developed Pollution Prevention Methodology

Though several similarities and dissimilarities arose from three case studies, it is possible to draw some general conclusions on the proposed methodology for developing a zero waste industrial ecosystem. First, the methodology to design a physical-technological model of a zero waste industrial ecosystem following four basic steps proved feasible and applicable in any industrial system. No matter how large or small the industrial system, where it is located, what kind of production processes are used, how homogenous or heterogeneous, none influences the logic of investigating the process flow data, waste generations and solutions to prevent, minimize, and treat wastes. By following the four basic steps of the developed methodology (analysis of the existing material flows, selection of appropriate possibilities for prevention and minimization of waste generation, material flow network creation, and waste treatment), one can screen and select suitable technical solutions to move an existing industrial system to a more sustainable system.

Second, the case studies show that without an analysis of actors and institutions, any physical-technological model remains a theoretical possibility at best. Without understanding the existing relations of the industrial systems with governmental organizations, other economic entities and social actors, we can not identify the existing barriers that hamper the implementation and introduction of (options of) the developed physical-technological model. Further more, we have no basis to give adequate solutions to change these existing relations in order to facilitate, support and enhance the possibilities of implementing some or all proposed options of the model. An analysis of actors and institutions following a triad-network model proved useful in all case studied industrial systems.

8.4.2 A Zero Waste Industrial Ecosystem Model of Food Processing Industry

The possibilities and approaches for greening food processing industry in Vietnam are drawn from three case studies and generalized in a general physical-technological model as presented in Fig. 8.1. Though operationalization of this model will vary due to the diversity of (food processing) industrial systems, this generalized model is the foundation for governmental authorities, planners, policy makers and environmentalists in reforming existing industrial systems and establishing new industrial systems as well.

In this model, the agricultural sector supplies raw material for both the food processing industrial sector and livestock sector, for instance sugarcane for sugar processing, green coffee beans for instant coffee production or cassava for tapioca starch processing and for pig breeding. The industrial sector receives major input from agricultural fields, supplies products to the market and other enterprises, and returns biomass back to the agricultural lands after a composting process as well as to the aquacultural sector (such as tapioca wastewater as fish feed). The livestock sector also supplies manure to the composting plant or biogas production plant. Other related industrial sectors (for instance enterprise B, a livestock feed production enterprise or enterprise C, which use product of enterprise A as raw material) exist to process products or byproducts from the food processing enterprise (for instance enterprise A in the model), which requires virgin materials from agricultural fields for processing (see Fig. 8.1). Thus, onsite transfers of energy and materials exist among agricultural fields, industrial enterprises, livestock and fish breeding. Besides, each sector also has to connect to the outside for delivering products to the market and importing other inputs to the industrial ecosystem. By doing so, food processing industry and agriculture can cooperate for environmentally sound development of both.

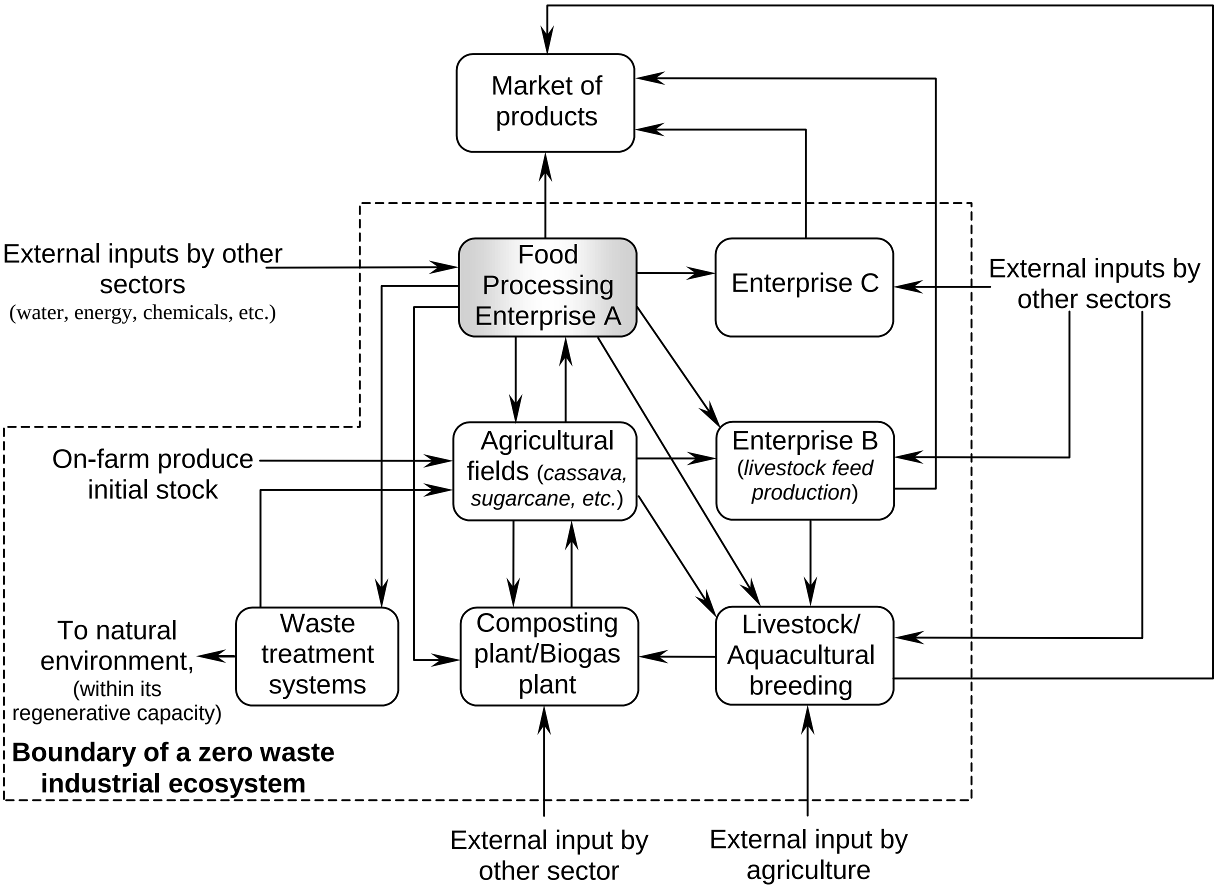


Fig. 8.1 General recommended physical model of a zero waste industrial ecosystem for food processing industry.

Non-products of the food processing industry are mainly organic materials, which can be reused as raw materials for livestock feed production, composting, biogas production, fish feed, and few specific products such as industrial grade alcohol. The companies (livestock feed company, composting plant, biogas production plant, fish culture households, alcohol company) do not face high risks of losing supply or market if the food processing company closes down or changes its product for any reason. First, as discussed in the case study chapters (chapter 5, 6 and 7), each of these companies usually uses non-products from the food processing company to substitute a proportion of one of its, often virgin, raw materials. By doing so, they reduce their spending and simultaneously help to reduce requirements on treatment of non-products and avoid damage to the natural environment due to improper treatment and disposal. In case the food processing company closes down, reduces capacity or changes its product, these companies can fall back to the originally used raw material. Second, the biodegradable characteristics of non-products from the food processing industry always makes them suitable raw materials for composting or biogas production. Third, even in case the food processing company changes its production process to produce different food products, it is still possible to reuse its organic non-products for composting, biogas production and irrigation (after pre-treatment). Finally, variation in the quality of the organic non-products does not cause significant effects on the quality of products (for instance compost, biogas, water for irrigation, etc.), because it is always possible to adjust mixtures of these non-products with other available materials (such as rice straw, sawdust, livestock faeces, etc.) before entering the recycling processes. Thus, in the case of food processing industry, offsite reuse and recycling could help to complete the prevention of organic non-products from becoming wastes.

From the case studies we conclude that this physical-technological model can be applied for different existing food processing industrial systems: one company, small/household-scale or medium- and large-scale companies, a group of enterprises from one food processing industrial sub-sector or from different food processing industrial sub-sectors, enterprises located within or outside industrial zones. Of course, this model is designed and applied for food processing industrial sub-sectors that use agricultural products as raw materials. In some cases food processing companies do not use agricultural products as raw materials (such as seafood processing companies, confectionery companies, Coca-cola company), so they do not have to be located close to agricultural fields. In those cases, some of the proposed elements in the developed physical model might not play the role of recylers of non-products from the food processing company. However, this does not mean that these elements do not have to be involved in the system. For instance, if enterprise A in the proposed model is a seafood processing enterprise, two main non-products from its production process will be organic solid non-products (including residues of fish, shrimp, cuttle-fish, etc.) and wastewater. Certainly, these organic solid non-products can be reused as raw materials for livestock feed production, while wastewater has to be treated properly before discharging or reusing for watering or irrigation (if possible). In this case, agricultural fields and the composting plant/biogas production plant will not recycle non-products from seafood processing enterprise, but these elements can be important in recycling non-products from the livestock breeding sector as well as supplying raw materials to the livestock feed production enterprise. In other words, though relations among the proposed elements of the model of a zero waste industrial ecosystem of food processing industry might differ in different food processing industrial systems, the main proposed elements creating cooperation between industry and agriculture remain similar. The relationships between food processing industrial sub-sectors, which do not use agricultural products as raw materials, and other elements in a proposed physical-technological model of a zero waste industrial ecosystem is described in Fig. 8.2.

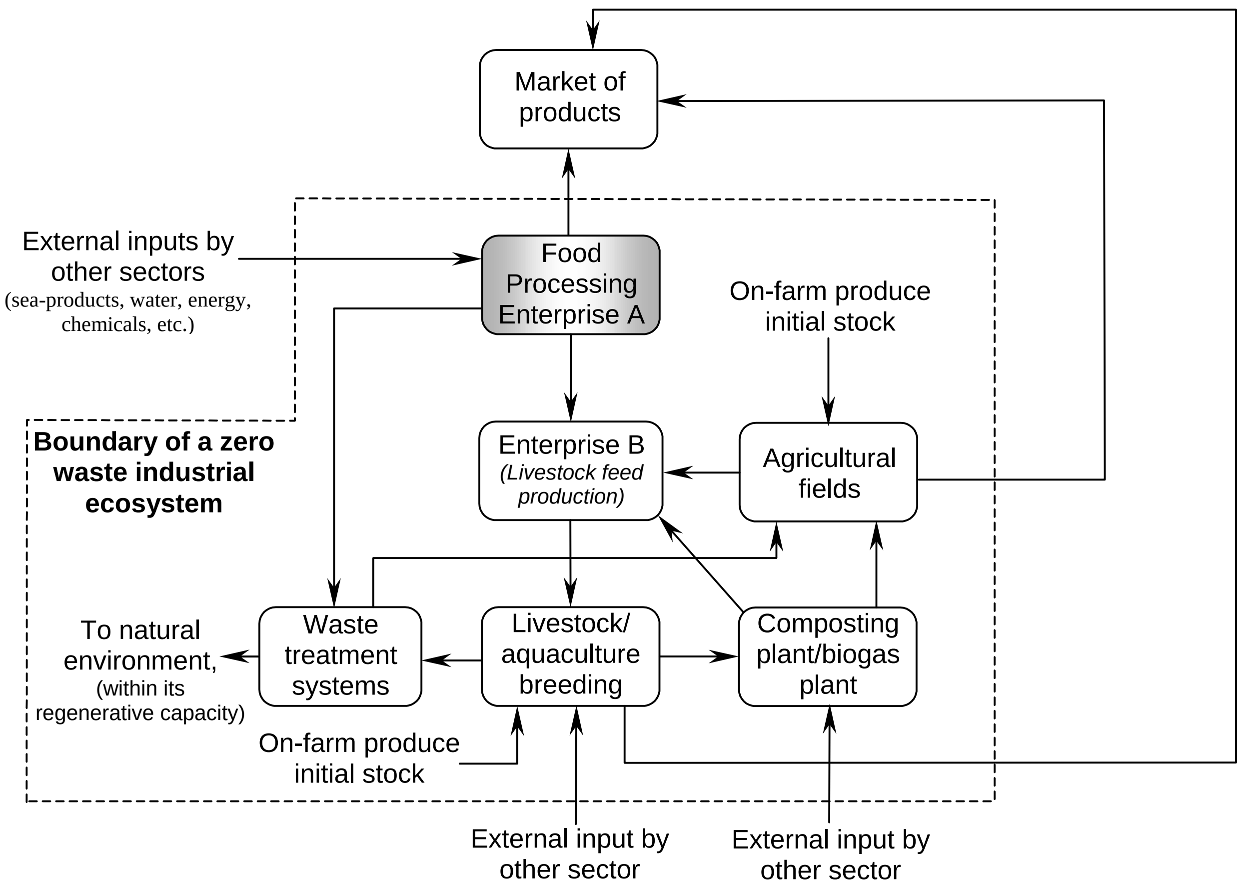


Fig. 8.2 A Proposed physical model of a zero waste industrial ecosystem of food processing industrial sub-sectors, which do not use agricultural products as raw materials.

8.4.3 Approaching a Zero Waste Industrial Ecosystem: a Physical Model of General Industries

In this section, we will in general terms discuss what a physical-technological model of a zero waste industrial ecosystem look like (compared to that of food processing industry) when it is developed for other agro-industrial sectors and other industrial sectors, which do not use agricultural products as input. As discussed in section 8.3 and section 8.4.1, operationalization of a developed physical-technological model will be different due to the variation in the complex social, economic and political networks between the industrial system and other actors. Therefore it is impossible to generalize these relations for any industrial system. The discussions in this section focus on the physical-technological model, which can be used as a guidance for moving the industrial system into a sustainable direction. In addition, the proposed material network flow is developed with the hypothesis that all industrial enterprises participating in the model carry out cleaner production measures to prevent and minimize the generation of non-products from their production processes.

Agro-Industries

In order to be able to come to a general physical model of a zero waste industrial ecosystem for agro-industries, it is logical to indicate typical characteristics of these industrial sectors, inputs needed for their production processes and potential generated non-products. Moreover, these are the foundation to evaluate differences between the physical model of food processing industry and other agro-industries.

In general, agro-industries are industries, which use agricultural products as raw material input. More precisely, agro-industries comprise four main industrial sectors: (1) food processing industry, (2) crop processing industry, (3) livestock feed processing industry, and (4) slaughter industry[142]. Because these industrial sectors require agricultural products for their production processes, again integration between agricultural cultivation, livestock breeding and agro-industrial manufacturing seems to be the most likely strategy. The crop processing industry receive products of agricultural fields (such as paddy, corn, cassava, etc.) to produce foods for human consumption or raw materials for other production processes (such as rice, maize powder, cassava chips or powder etc.). Several products and byproducts of crop processing industry are raw materials for livestock feed production, for instance bran, maize powder, cassava powder, etc. Products of the livestock feed industry supply of course to the livestock breeding sector. Products of livestock breeding include (1) milk for the dairy industrial sector, (2) eggs for confectionery industrial sector, or (3) meat from slaughterhouses. Non-products from these industrial sectors mainly consist of organic solid and liquid (wastewater) materials, which are recyclable back to agricultural fields, and air emissions, which have to be treated. Thus, a general approach towards a zero waste industrial ecosystem of agro-industries can be specified in Fig. 8.3. This model is similar to the proposed model for a food processing industrial ecosystem (as presented in Fig. 8.1 and 8.2), but it is an integration of all agro-industrial sectors and also implies the model of a zero waste industrial ecosystem of food processing industry.

[142] This classification is based on the definition of agricultural products in Vietnam. Therefore, industrial sectors such as wood processing, pulp and paper, etc. which use forestry products as raw materials for processing, are not categorized among agro-industries.

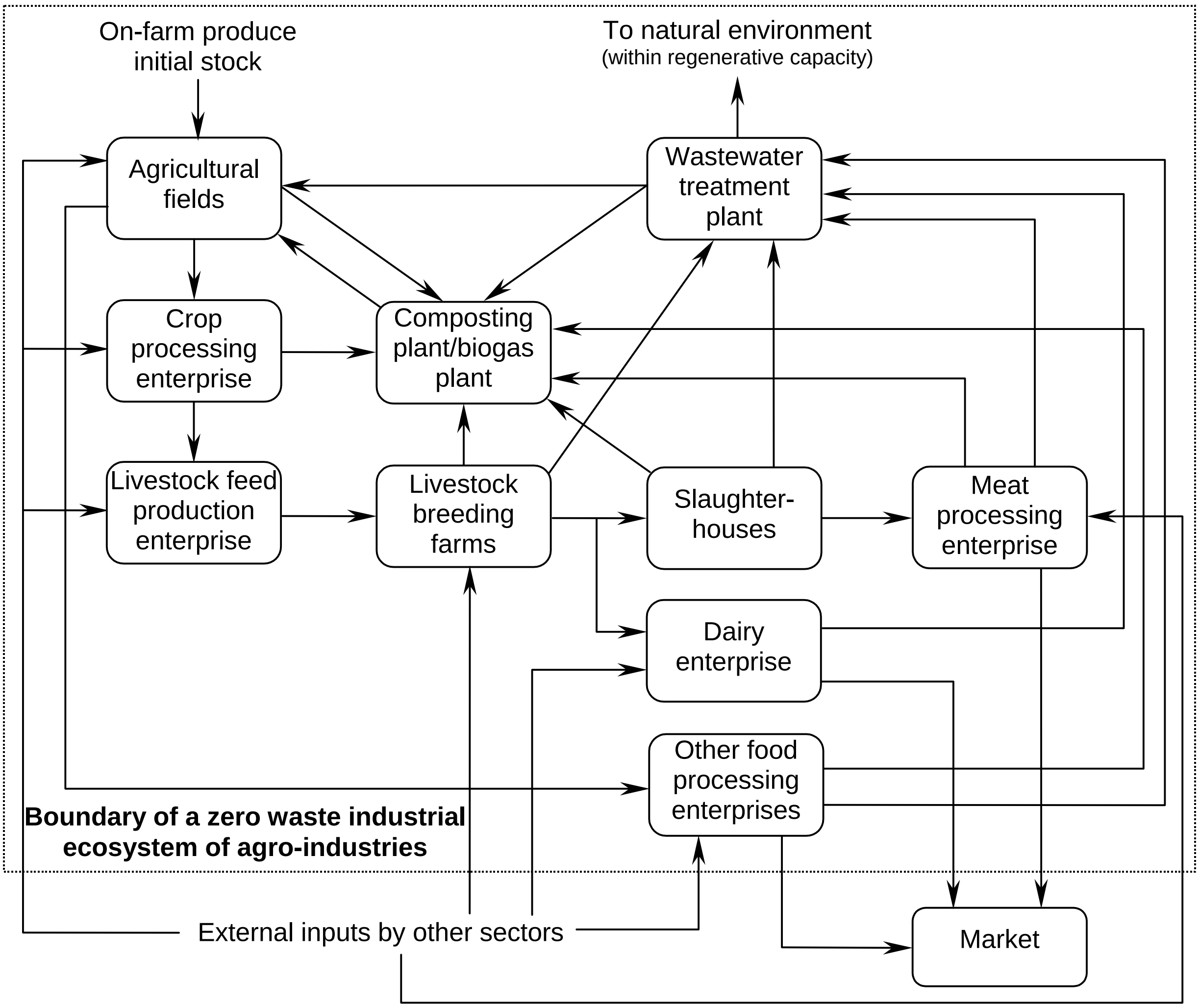


Fig. 8.3 A Proposed physical model of a zero waste industrial ecosystem of agro-industries.

Non-Agro-Industries

Several industries do not use agricultural products as raw materials in their production processes, for instance for the production chemicals, construction materials, electric and electronic equipment, petroleum, energy, etc. Because their required inputs are not from agricultural products, it is less crucial to locate these industrial enterprises close to agricultural fields. Because non-products from these industrial sectors often contain potential toxic compounds (for instance heavy metals, chemicals, acid and base contaminants, etc.), reuse of waste streams for agricultural purpose is often impossible. However, these industrial sectors can have symbiotic relationship, in which wastes from one company are utilized by another, as it is illustrated by several experimental industrial ecosystems in the world (as presented in section 2.4.3 and appendix 1). In other words, the kind of the industrial sector does not restrain the development of a zero waste industrial ecosystem and the developed methodology can be a good starting point to analyze and assess possibilities and approaches. The discussion in section 8.4.1 has revealed that this methodology is feasible and applicable in any industrial system. Therefore, application of this methodology to analyze and asses possibilities and approaches to achieve a zero waste industrial ecosystem of other industrial sectors is strongly suggested because: (1) there is an advantage of availability of the methodology, which has been proved its applicability through case studies in food processing industries; (2) application of this methodology in other industrial sectors will help to prove again that it is possible to apply the same methodology for different industrial sectors; and (3) by doing so, there is a possibility to improve this methodology, so that it can be applied for any existing industrial system. It is worth to emphasize that in the case of non-agro-industries, the basic symbiotic relationship of the system is not based on industry and agriculture as the case in food processing or agro-industrial sectors, but it is rather based on industry-industry coexistence. This means that if for instance producers from only one kind of industrial sector (which produce the same product) are located in an area (for instance an industrial zone), there is no opportunity to create a material flow network or symbiotic relationships among producers by making use of products or non-products from each other. This also means that concentration of any kind of industrial sector in an area is not a preferable configuration from the industrial ecology point of view. Only coexistence between certain industrial sectors that helps to increase both economic and environmental benefits and leads to approaching a zero waste industrial ecosystem is expected to develop.

8.5 REFLECTIONS ON INDUSTRIAL ECOLOGY CONCEPTS IN VIETNAM

This section returns to the evaluation to what extent the very Western ideas of Industrial Ecology (IE) fit a developing and state dominated country like Vietnam, following five crucial points. First, the industrial ecology concept has especially been applied in European and USA market countries all having advanced technological systems, while Vietnam is a less technological developed country. Therefore, for a similar industrial sector the application of IE in Vietnam will differ from European and USA ones in several points:

- Production processes of Vietnam often generate higher amounts of non-products per unit of output, which contain higher proportion of valuable (reusable) materials compared to the production processes in developed countries. Thus, in this situation, there are more opportunities to create a non-product material flow between different production processes.

- The application of IE in Vietnam depends less heavily on very advanced technological solutions to link material flows between production units and to limit the openness of the industrial system. This means that the system will have to rely on relative simple measures. This varies of course depending on the kind of Vietnamese industrial system being studied and is influenced by for instance the degree of joint venture, the number of foreign owned companies, the size of the companies, etc.

- Avoidance of secondary pollution, which might be generated from the re-manufacturing processes, is somewhat uncertain in Vietnam. In some cases, unavailability of suitable technology or improper operation of waste-processing systems may create more pollution than was caused by the original production process. This will destroy the whole idea of closing material loops for more sustainable development.

Second, in Vietnam, the organizational and institutional structures around industry and industrial systems are in general simpler than what we see in Western countries. It is clear that environmental protection in Vietnam appears to be a state responsibility and environmental policy is implemented on a top-down basis without modern management practices, for instance corporate (environmental) policy formulation, systematic monitoring and reporting, participation at various levels, etc. This means that an operationalisation of IE can rely less on all kinds of advanced organizational models, as for instance is needed when industrial ecology practices stretch among long distances and complicated communication, data-processing and just-in-time delivery systems are required.

Third, a number of socio-institutional conditions that have been crucial for advancing and implementing IE models in practice in advanced industrialized societies are absent or less developed in Vietnam, for instance market pull (such as customers and consumers), strong pressures of the environmental state management, environmental monitoring institutions, strong civil society or a system of branch associations. On other instances, Vietnam has favorable institutional conditions for IE, such as the advanced system of industrial estates with their industrial infrastructure development companies. This means that feasible options that have a high chance to succeed in Vietnam will be different from those developed in advanced industrialized countries.

Fourth, being related to the third point, compared to advanced countries where ideas of IE firstly emerged and were experimented with, Vietnam still has a large number of reuse and recycling practices that are not so much motivated by environmental considerations but rather by economic ones. This of course offers better opportunities to develop an IE model. Probably IE practices in Vietnam will more heavily rely on recycling and reuse than those in Europe and the USA. Development of the economy in Vietnam shows that these existing recycling and reuse practices might come under pressures and need to be ‘protected’: that is an active IE policy needs to be developed to continue these practices.

Finally, the large agro-(food processing) industrial sector together with the large proportion of the land used for agricultural production opens favorable conditions for agro-industrial ecology models and practices in Vietnam.

REFERENCES

Abass, A. and Bokanga, M. (2001), *Rural Cassava Processing and the Development of the Food Industry in West Africa,* International Institute of Tropical Agriculture, Ibadan, Nigeria.

Abbott, G. C., 1990. *Sugar.*

Abe, H. and Doi, Y. (1992), Controlled Release of Lastet, an Anti-Cancer Drug, from Poly (3-hydroxybutyrate) Microspheres Containing Acyclycerols Macromolec, *Rep. A29,* pp. 229-235.

Abram, J. C. and Ramage, J. T. (1979), Sugar Refining: Present Technology and Future Developments, *Sugar Science and Technology,* Birch, G.G. and Parker, K.J. (Eds), London : Applied Science.

Adams. M. R. and Dougan, J. (1985), *Waste Products, Coffee,* Lodon: Elsevier Applied Science Publisher.

Adegbola, A. A. (1977), Methionine as Additive to Cassava-Based Diets, *Cassava as Animal Feed,* Proc. Workshop Univ. of Guelph, 18 – 20 April 1977, IDRC 095e.

Agu, R. C., Amadife, A. E., Ude, C. M., Onyia, A., Ogu, E. O., and Okafor, M. (1997), Technical Note: Combined heat Treatment and Acid Hydrolysis of cassava Grate Waste (CGW) Biomass for Ethanol Production, *Waste Management,* 17 (1): 91-96.

Agu, R. C., Amadife, A. E., Ude, C. M., Onyia, A., Ogu, E. O., and Okafor, M. (1997), Technical note: Combined heat Treatment and Acid Hydrolysis of cassava Grate Waste (CGW) Biomass for Ethanol Production, *Waste Management,* 17 (1): 91-96.

Allen, D. T., and Behmanesh, N. (1992), Wastes as Raw Materials. *The Greening of Industrial Ecosystems,* Washington: National Academy of Engineering, pp. 69-89.

Allenby, B, R. (1999), *Industrial Ecology: Policy Framework and Implementation,* New Jersey: Prentice Hall.

Allenby, B. R. (1991), Design for Environment: A Tool whose Time Has Come, *SSA Journal September,* 5-9.

Allenby, B. R. (1992a), Achieving Sustainable Development through IE, *International Environmental Affairs,* 4 (1): 62.

Allenby, B. R. (1992b), Integrating Environment and Technology: Design for Environment, *The Greening of Industrial Ecosystems,* Washington: National Academy of Engineering, pp. 137-148.

Al-Masri, M. R. (2001), Changes in Biogas Production due to Different Ratios of Some Animal and Agricultural Wastes, *Bioresource technology* 77 (2001): 97-100.

Amoa-Awua. W. K. A. (1996), *The Dominant Microflora and Their Role in the Fermentation of 'Agbelima' Cassava Dough.*

An, D. (1998), Solutions and Orientations of IZs in 1998, *The Vietnam Industrial Zone Bulletin 2-1998*: 5-7.

An, L. Q. (1997a), Environmental Protection Law and Regulations in Vietnam, *Environmental Policy and Management in Vietnam*.

An, L. Q. (1997b), Vietnamese Policy on the Environment and Sustainable Development, *Environmental Policy and Management in Vietnam*.

Anastas, P. T. and Breen, J. J. (1997), Design for the Environment and Green Chemistry: the Heart and Soul of Industrial Ecology, *J. Cleaner Production,* 5 (1-2): 97-102.

Anderberg, S. (1999), Industrial Metabolism and the Linkages Between Economics, Ethics and the Environment, *Ecological Economics,* 24 (1998): 311-320.

Andersen, S. M. (1994), *Governance by Green Taxes: Making Pollution Prevention Pay,* Manchester: Manchester University Press.

Anderson, A. J., and Dawes, E. A. (1990), Occurrence, Metabolism, Metabolic Role, and Industrial Uses of Bacterial Poly Hydroxy Alkanolates, *Microbiol. Rev.,* 54: 450-472.

Andrews, C. J. (1999), Putting Industrial Ecology into Place: Evolving Roles for Planners, *Journal of the American Planning Association,* 65 (4): 364-375.

Andrews, J. W. (1977), Protein Requirements, Nutrient and Feeding of Channel Catfish, *South. Soop. Ser. Bull.,* 218: 10-13.

Andrews, J. W., and Murai, T. (1975), Studies on the Vitamin C Requirements of Channel Catfish, *J. Nutr.,* 105: 557-561.

Andrews, J. W., and Murai, T. (1978), Dietary Niacin Requirements of Channel Catfish, *J. Nutr.* 108: 1508-1511.

Andrews, J. W., and Murai, T. (1979), Pyridoxine Requirements of Channel Catfish, *J. Nutr.,* 109: 533-537.

Anon, X. (1971), Let Residue Disposal Pay for Itself, *Power,* 115: 60-61.

Anonymous (1998), Regional Implementation and Monitoring of Cleaner Production, *UNEP-Industry and Environment,* 21 (4): 9-11.

Aoe, H., Masuda, I., Sato, T., and Komo, A. (1967), Water-soluble Vitamin Requirements of Carp-I. Requirement for Vitamin B_2, *Bull. Hpn. Sci. Fish.,* 33: 355-360.

Arai, S., Nose, T., and Hashimoto, Y. (1972), Qualitative Requirements of Young Eels *Anguilla Japonica* for Water – Soluble Vitamins and Their Deficiency Symptoms, *Bull. (Tokyo) Freeshw. Fish. Res. Lab.,* 22: 69-83.

Ashford, N. A. (1997), Industrial Safety: the Neglected Issue in Industrial Ecology, *J. Cleaner Prod.* 5 (1-2): 115-121.

Asmus, P. (1998), A Template for Transition: How Mitsubishi and the Rainforest Action Network Found the Natural Step, *Summer,* 5 (4): 50-59.

Augnstein, D., Benemann, J., Hughes, E. (1994), Electricity from Biogas, *Six National Bioenergy Conference,* 2-6 October, Reno, NV, US.

Axaopoulos, P. And Panagakis, P. (2002), Energy and Economic Analysis of Biogas Heated Livestock Building, *Biomass and Bioenergy, Article in Press.*

Ayalon, O., Avnimelech, Y., Shechter, M. (2000), Application of a Comparative Mulidimensional Life Cycle Analysis in Solid Waste Management Policy: the Case of Soft Drink containers, *Environmental Science & Policy,* 3 (2000): 135-144.

Ayres, R. U. (1992a), Industrial Metabolism: Theory and Policy, *The Greening of Industrial Ecosystems,* Washington: National Academy of Engineering, pp. 23-37.

Ayres, R. U. (1992b), Toxic Heavy Metals: Materials Cycle Optimization, *Proceedings of the Nation Academy of Sciences,* 89: 812-820.

Ayres, R. U. (1994), Industrial Metabolism: Theory and Policy, *Industrial Metabolism: Restructuring for Sustainable Development,* pp. 3-20.

Ayres, R. U. (1996), Creating Industrial Ecosystem: A Viable Management Strategy?, *UNEP-Industry and Environment,* 19 (4): 7-13.

Ayres, R. U. and Simonis, U. E. (1994), *Industrial Metabolism: Restructuring for Sustainable Development,* United Nations: University Press.

Ayres, R. U., and Ayres, L. W. (1994), Consumptive Uses and Losses of Toxic Heavy Metals in the United States, 1880-1980, *Industrial Metabolism: Restructuring for Sustainable Development,* pp. 259-298.

Ayres, R. U., and Ayres, L. W. (1996), *IE: Towards Closing the Materials Cycle,* Edward Elgar.

Ayres, R. U., and Ayres, L. W. (1998), *Accounting for Resources, 1: Economy-Wide Applications of Mass-Balance Principles to Materials and Waste,* Edward Elgar.

Ayres, R. U., Ayres, L. W., and Tarr. J. A. (1994), A Historical Reconstruction of Carbon Monoxide and Methane Emissions in the United State, 1880-1980, *Industrial Metabolism: Restructuring for Sustainable Development,* pp. 194-238.

Baas, L. (1998a), Reflections on Cleaner Production Technology, *UNEP-Industry and Environment,* 21 (4): 28-29.

Baas, L. (1998b), Cleaner Production and Industrial Ecosystem, a Dutch Experience, *Journal of Cleaner Production,* 6 (1998): 189-197.

Bajracharya, P. (1995), National Reports Nepal on Cleaner Production for Green Productivity, *Cleaner Production for Green Productivity: Asian Perspectives,* Asian Productivity Organization.

Baker, K. H. and Herson, D. S. (1994), *Bioremediation,* New York: McGraw-Hill.

Balagopalan, C., Padmaja, G., Nanda, S. K., Tech, M., and Moorthy, S. N. (1988), *Cassava in Food, Feed, and Industry,* CRC Press, Inc. Boca Raton, Floria.

Balagopalan, C., Ray, R. C., Sheri, J. T., Rajalekshmy, L. (1994), Biotechnology for the Value Addition of Wastewaters and Residues from Cassava Processing Industries, *Proceeding of the Second International Scientific Meeting of the Cassava Biotechnology Network,* Bogor, Indonesia, 22-26 Aug 1994.

Barbosa, R. A., and Anna, S. G. L. Jr. (1989), Treatment of Raw Domestic Sewage in an UASB Reactor, *Water Research,* 30 (1): 183-189.

Barton, J. R., Dalley, D., Patel, V. S. (1996), Life-Cycle Assessment for Waste Management. *Waste Manag.,* 16: 35-50.

Beck, U. (1994), The Reinvention of Politics: Towards a Theory of Reflexive Modernization, *Reflexive Modernization. Politics, Tradition and Aesthetics in the Modern Society Order.* Cambridge: Polity Press, pp. 1-55.

Behling, E., Diaz, A., Colina, G., Herrera, M., Gutierrez, E., Chacin, E., Fernandez, N., and Forster, C. F. (1997), Domestic Wastewater Treatment Using a UASB Reactor, *Bioresource Technology,* 61 (1997): 239-245.

Berg, N.W.V.D., Dutilh, C.E., Huppes, G. (1992), *Beginning LCA: A Guide into Environmental Life Cycle Assessment,* Rotterdam: Humanitas.

Berkel, C. W. M. V. (1996), Cleaner Production in Practice: Methodology Development for Environmental Improvement of Industrial Production and Evaluation of Practical Experiences, *PhD Dissertation,* University of Amsterdam.

Berkel, R. E., Willems, and Lafleur, M. (1997), The Relationship Between Cleaner Production and Industrial Ecology, *Journal of Industrial Ecology,* 1 (1): 51-65.

Berkel, R. V., and Lafleur, M. (1997), Application of an Industrial Ecology Toolbox for the Introduction of Industrial Ecology in Enterprises-II, *J. Cleaner Prod.,* 5 (1-2): 27-37.

Berkel, R. V., Willems, E., and Lafleur, M. (1997), Application of an Industrial Ecology Toolbox for the Introduction of Industrial Ecology in Enterprises-I, *J. Cleaner Prod.,* 5 (1-2): 11-25.

Bhaskaran, T. R. and Chakraborty, R. N. (1966), Pilot Plant for Treatment of Cane Sugar Waste, *J. Water Pollution Control Fed.,* 38: 1160-1169.

Bhaskaran, T. R., Chakraborty, R.N., Das, N. and Sinha, S.N. (1961), Treatment and Disposal of Sugar Factory Effluents, *Indian Counc, Med. Res, Tech. Rep. Ser.,* 39: 1-19.

Bhaskaran, T. R., Chakraborty, R.N., Das, N. and Sinha, S.N. (1963), Sugar Factory Effluents, *Effluent Water Treat. J.*, 33: 323-325.
Bhat, V. N. (1996), *The Green Corporation: the Next Competitive Advantage*, London: Quorum Books.
Bi, G., and Guozhen, Y. (1996), Commercial-Scale Production of Ethanol from Cassava Pulp, *Cassava, Starch and Starch Derivatives: Proceedings of the International Symposium held in Nanning, Guangxi, China. Nov 11-15, 1996.*
Bien, P. V. and Kim, H. (1990), Cassava Production and Research in Vietnam – Historical Review and Future Direction, *Cassava breeding, agronomy and utilization research in Asia – CIAT 1990.*
Bieske, G. C. (1979), Agricultural Use of Dunder, *Proc. 1st Conf. Aust. Soc. Sugar Cane Technol.*, pp. 139-141.
Bilitewski, B., Hardtle, G., Marek, K., Weissbach, A., and Boeddicker, H. (1992), *Waste Management*, Springer.
Binh Duong DOSTE (2002), Status of Hazardous Waste Management in Binh Duong Province, *Findings of the Baseline Study on Hazardous Waste in the Southern Economic Focus Zone in Vietnam*, Workshop hold in HCMC, on 19 June 2002.
Bogte, J. J., Breure, A. M., van Andel, J. G., and Lettinga, G. (1993), Anaerobic Treatment of Domestic Wastewater in Small Scale UASB Reactors, *Water Science and Technology*, 27 (9): 75-82.
Bogte, J. J., van Andel, J. G., and Breure, A. M. (1988), Application of Small UASB Reactor for Treatment of Domestic Wastewater of Individual Households at Isolated Locations, *Fifth International Symposium on Anaerobic Digestion (Poster-papers)*, Bologna, Italy, Eds A. Tilche & A. Rozzi, pp. 725-729.
Bond, J. F. and McNeil, K. E. (1976), Treatment of Sugar Mill Waste by Shallow Ponding, *Proc. 43 rd Conf. Qd. Soc. Sugar Cane Technol.*, pp. 317-318.
Boons, F. A. A. and Baas, L. W. (1997), Types of Industrial Ecology: the Problems of Co-ordination, *J. Cleaner Prod.*, 5 (1-2): 79-86.
Bouallagui, H., Cheikh, R. B., Marouani, L., and Hamdi, M. (2003), Mesophilic Biogas Production from Fruit and Vegetable Waste in a Tabular Digester, *Bioresource Technology* 86 (2003): 85-89.
Boushy, A. R. Y. El. and van der Poel, A. F. B. (1994), *Poultry Feed from Waste: Processing and Use*, Chapman & Hall.
Brand, E., and de Bruijn, T. (1999), Shared Responsibility at the Regional Level: the Building of Sustainable Industrial Estates, *European Environment*, 9 (6): 221-231.
Brattebø, H. (1996), Industrial Ecology and Sustainable Product Design, *Proceeding of the Seminar and Workshop*, Trondheim (Norway): Norwegian Academy of Technology Sciences, February 1-2, 1996.
Brieger, F. O. (1977), Observations on the Distribution of Vinasse or Distillery Juice in Sao Paulo Stare, *Bras. Acucarerio*, 90: 23-30.
Brieger, F. O. (1979), Observations on the Distribution of Vinasse or Distillery Juice in Sao Paulo Stare, Brazil, *Sugar Azucar*, 74: 42-49.
Brunner, P. H., Daxbeck, H., and Baccini, P. (1994), Industrial Metabolism at the Regional and Local Level: A Case Study on a Swiss Region, *Industrial Metabolism: Restructuring for Sustainable Development*, pp. 163-193.
Burgos, C. F. (1980), Soil Related Intercropping Practices in Cassava Production, *Proceeding of a Workshop held in Salvador*, Brazil, 18 – 21 March 1980.
Burns, S. (1999), The Natural Step: A Compass for Environmental Management Systems, *Corporate Environmental Strategy*, 6 (1999): 329-342.
Burström, F and Korhonen, J. (2001), Municipalities and Industrial Ecology: Reconsidering Municipal Environmental Management, *J. Sustain Devel.*, 2001, 9 (1).
Butler, T. M. (1971), Molasses as a Supplement to Silage and Straw, *Farm Food Res.*, 2: 105-106.
Buttel, F. H. (2000a), Reflections on the Potentials of Ecological Modernization as a Social Theory, *Natures Sciences Sociétés*, 8 (2000): 5-12.
Buttel, F. H. (2000b), Ecological Modernization as Social Theory, *Geoforum*, 31 (2000): 57-65.
Byrom, D. (1987), Polymer Synthesis by Microorganisms, Technology and Economics, *Trend Biotechnol.*, 5: 246-250.
Can Tho DOSTE (1995), *Environmental Impact Assessment Report of Hiep Hoa Sugar Company.*
Cantlon, J. E., and Koenig, H. E. (1999), Analysis: Sustainable Ecological Economies, *Ecological Economics*, 31 (1999): 107-121.
Carawan, R. E. (1989), Environmental Issues Facing Food Processors in the 1990s, *Proc. Food Processing Waste Conf.*, Georgia Tech. Res. Inst., Atlanta, 217-237.
Carr, A. J. P. (1998), Choctaw Eco-Industrial Park: an Ecological Approach to Industrial Land-Use Planning and Design, *Landscape and Urban Planning*, 42 (1998): 239-257.
Cartier, S., Tatoud, L., Théoleyre, and Decloux, M. (1997), Sugar Refining Process by Coupling Flocculation and Cross-flow Filtration, *Journal of Food Engineering*, 32 (1997): 155-166.
Castillo, L. S. (1974), The Cassava Industry of the Philippines, *Proceedings of an Interdisciplinary Workshop on Cassava: Processing and Storage*, Pattaya, Thailand, 17-19 April 1974.
Castro-González, A., Enríquez-Poy, M., and Durán-de-Bazúa, C. (2001), Design, Construction and Starting-up of Anaerobic Reactor for the Stabilization, Handling, and Disposal of Excess Biological Sludge Generated in a Wastewater Treatment Plant, *Anaerobe* 7 (3): 143-149.

Cenpukdee, U., Thiraporn, C. and Sinthuprama, S. (1991), Cassava Processing and Utilization in Thailand, *Product Development for Root and Tuber Crops - CID, CIAT, IITA, ViSCA.*

CENTEMA (1996), *Environmental Impact Assessment Report on Expanding Sugar Production Workshop of Binh Duong Sugar Company.*

CENTEMA and SONADEZI (1997a), *Environmental Impact Assessment Report of Bien Hoa 1 Industrial Zone.*

CENTEMA and SONADEZI (1997b), *Environmental Impact Assessment Report of Bien Hoa 2 Industrial Zone.*

Chaan-Ming, L. (1995), National Reports of Hongkong on Cleaner Production for Green Productivity, *Cleaner Production for Green Productivity: Asian Perspectives,* Asian Productivity Organization.

Chandak, S. P., Kuttiapan, N. K., and Gupta, P. K. (1995), National Reports: India, *Cleaner Production for Green Productivity, Asian Perspective,* Tokyo: Asian Production Organization, pp. 114-194.

Chen, J. C. P and Chou, C. C. (1993), *Cane Sugar Handbook*. 12th Edn, New York: Wiley-Interscience.

Chen, J. C. P., Walters, C.O., Blanchard, F. J., Caballero, M.P. and Picou, R. (1971), Handling of Sugar Factory waste Streams, *Proc. 14th Congr. Int. Soc. Sugar Cane Technol.*, 1537-1543.

Chen, Z. S. (1999), Selecting Indicators to Evaluate Soil Quality, *Food & Fertilizer Technology Center, Extension Bullentin 473.*

Chermicharo. C. A., de L., and Borges, J. M. (1997), Evaluation and Start up of a Full Scale UASB Reactor Treating Domestic Sewage Case Study, *Proceedings of the 8th International Conference on Anaerobic Digestion*, Sendai, Japan, 2: 192-199.

Chertow, M. R. (1999), The Eco-Industrial Park Model Reconsidered, *Journal of Industrial Ecology* 2, 3: 8-10.

Cheung, P. S. (1995), National Reports of Republic of China on Cleaner Production for Green Productivity, *Cleaner Production for Green Productivity: Asian Perspectives*, Asian Productivity Organization.

Cheva-Isarakul, B. (1990), Non-Conventional Feeds for Ruminants in Thailand, *Food & Fertilizer Technology Center, Extension Bullentin 307.*

Chi, D. K. (1993), General Situation of Air Pollution from the Industry of Vietnam, *Report of the Project KT-02-06.*

Chiu, S. Y. and Peters, B. (1994). *Industrial Pollution Prevention,* Asian Development Bank.

Cho, C. Y., Slinger, S. J., and Bayley, H. S. (1976), Influence of Level and Type of Dietary Protein, and of Level of Feeding on Feed Utilization by Rainbow Trout, *J. Nutr.,* 106: 1547-1556.

Christoff, P. (1996), Ecological Modernization, Ecological Modernities, *Environmental Politics,* 5 (3): 476-500.

Clift, R. (1994), Life Cycle Assessment and Eco-labeling, *J. Cleaner Production*, 1: 155-159.

Clift, R. and Longley, A. J. (1995), Introduction to Clean Technology, *Clean Technology and the Environment,* Blackie Academic & Professional, pp. 174-198.

Coats, J. A., and Halver, J. E. (1958), Water- Soluble Vitamin Requirements of Silver Salmon, *US. Fish. Wildl. Serv. Sci. Rep. Fish.,* pp. 281.

Cock, J. H. (1985), *Cassava New Potential for a Neglected Crop.*

Cohen, M. J. (1997), Risk Society and Ecological Modernization: Alternative Visions for Post-Industrial Nations, *Futures,* 29 (2): 105-119.

Collicignarelli, C., Urbini, G., Farneti, A., Bassetti, A., and Barbaresi, U. (1991), Economic Removal of Organic and Nutrient Substances From Municipal Wastewaters with Full Scale UASB Fluidized- and Fixed-Bed Reactors, *Water Science and Technology,* 24 (7): 90-95.

Commoner, B. (1997), The Relation Between Industrial and Ecological System, *J. Cleaner Prod.,* 5 (1-2): 125-129.

Connelly, L., Koshland, C. P. (1997), Two Aspects of Consumption: Using an Exergy-Based Measure of Degradation to Advance the Theory and Implementation of Industrial Ecology, *Resources, Conservation and Recycling,* 19 (1997): 199-217.

Cooper, B. R. (1975), Distillery Waste as a Fertilizer, *Annu. Rep. Res., Caroni Research Station,* cited in *Sugar Ind. Abstr.,* 8: 76-1271.

Corcoran, C. M. (1997), An Appetite Efficiency, *Food Science and Technology Today,* 11: 91-92.

Cote, R. and Hall, R. (1995), Industrial Park as Ecosystem, *J. Cleaner Prod.,* 3 (1-2): 41-46.

Côté, R. P. (1994), *Designing and Operating Industrial Parks as Ecosystems,* School for Resource and Environmental Studies, Faculty of Management, Dalhousie University, Halifax, Nova Scotia.

Côté, R. P. and Cohen-Rosenthal, E. (1998), Designing Eco-Industrial Parks: a Synthesis of Some Experience, *Journal of Cleaner Production,* 6: 181-188.

Côté, R. P. and Smolenaars, T. (1997), Supporting Pillars for Industrial Ecosystems, *J. Cleaner Prod.,* 5 (1-2): 67-74.

Côté, R. P., and Cohen-Rosenthal, E. (1998), Designing Eco-Industrial Parks: a Synthesis of Some Experiences, *Journal of Cleaner Production,* 6 (1998): 181-188.

Côté, R. P., and Smolenaars, T. (1997), Supporting Pillars for Industrial Ecosystems, *J. Cleaner Prod.,* 5 (1-2): 67-74.

Côté, R. P., Ellison, R., Grant, J., Hall, J. Klynstra, P., Martin, M., and Wade, P. (1994), *Designing and Operating Industrial Park as Ecosystem.* School for Resource and Environmental Studies. Dalhousie University, Halifax, Nova Scotia, Canada.

Côté. R. P. (2001), The Evolution of an Industrial Park: the Case of Burnside, *UNEP Environmental management for Industrial Estates: Information and Training Resource, presented at International Conference & Workshop on Industrial Park Management,* Manila, Philippines, April, 2001.

Cowey, C. B. (1976), Use of Synthetic Diets and Biochemical Criteria in the Assessment of Nutrient Requirements of Fish, *J. Fish. Res. Board Can.,* 33: 1040-1045.

Cowey, C. B. (1979), Protein and Amino Acid Requirements of Finfish, *Finfish Nutrition and Fishfeed Technology,* 1: 3-16.

Cramer, J. J.,van den Akker, S. F., and Geesteranus, G. M. (1990), Stimulating Cleaner Technologies through Economic Instruments: Possibilities and Constraints, *UNEP Industry and Environment*, 13 (2): 45-53.

Crittenden, B. D. and Kolaczkowski, S. T. (1992), *Waste Minimization Guide,* Institution of Chemical Engineers, Rugby.

Dahlgren, M. and Nilsson, A. (2001), *Potential of Market Waste from Vegetables and Fruit as Livestock Feed in Urban Areas of Vietnam,* Swedish University of Agricultural Sciences.

Damron, B. L., Randel, P. F., and Soldevilla, M. (1980), Condensed Molasses Soluble in Poultry Feeds, *Poultry Sci.,* 59: 673-675.

Danalewich, J. R., Papagiannis, T. G., Belyea, R. L. (1998), Characterisation of dairy waste Streams, Current Treatment Practices, and Potential for Biological Nutrient Removal, *Wat. Res.*, 32 (12): 3555-3568.

Dang, P. N. (1988), Pollution at Thuong Dinh Industrial Are, *Report of the Project 52D.05.01*

Dang, P. N. (2001), Existing Status and Challenges or Urban Environment during Process of Industrialization and Modernization in Vietnam, *International Conference Industry and Environment in Vietnam*, Ho Chi Minh City, April 2001, REFINE-project.

Dang. P. N. and Nhue, T. H. (2003), *Domestic and Industrial Waste Management in Vietnam*.

Daniel, S. J., Hasan, Q. Z., Nath, K. (1984), Urea Molasses Liquid Diet as a Feed for Calves, *Indian J. Anim. Sci.,* 50: 149-151.

Daniel, S. J., Hasan, Q. Z., Nath, K. (1986), Compensatory growth in Crossbred Calves Fed on urea Molasses Liquid Diet, *Indian J. Anim. Sci.,* 56: 979-981.

Dash, S.S., and Misra, M. K. (2001), Studies on Hill Agro-Ecosystem of Three Tribal Villages on the Eastern Ghats of Orissa, India, *Agriculture Ecosystem of Environment,* 86 (2001): 287-302.

Dass, R. S., Verma, A. K., Mehra, U. R. (1996a), Compensatory Growth and Nutrient Utilization in Crossbred Heifers During Revival Period fed Urea Molasses Liquid Diet, *Asian Australiansian J. Anim. Sci.,* 9: 563-566.

Dass, R. S., Verma, A. K., Mehra, U. R. (1996b), Effect of Feeding Urea Molasses Liquid Diet on Nutrient Utilization, Rumen Fermentation Pattern and Blood Profile in Adult Male Buffaloes, *Buffalo J.,* 12: 11-22.

De Bruijn, J. N. M., and Hofman, P. S. (2000), Pollution Prevention and Industrial Transformation Evoking Structural Changes within Companies, *Journal of Cleaner Production,* 8 (2000): 215-223.

De Man, A. W. A., Grin, P. C., Roersma, R. E., Grolle, K. C. F., and Lettinga, G. (1986), Anaerobic Treatment of Municipal Wastewater at Low Temperatures, *Anaerobic Treatment: a Grown up Technology, Conference Papers (Aquatech '86),* Amsterdam, pp. 451-466.

De Man, A. W. A., van der Last, A. R. M., and Lettinga, G. (1988), The Use of EGSB and UASB Anaerobic Systems or Low Strength Soluble and Complex Wastewaters at Temperatures Ranging from 8 to 30^0C, *Proceedings of the 5^{th} International Symposium on Anaerobic Digestion,* Bologna, Italy, eds, E. R., Hall & P. N. Hobson, pp. 197-208.

Del Re, G., Di Giacomo, G., Alisio, L., and Terreri, M. (1998), RO Treatment of Wastewater from Diary Industry, *Desalination,* 119 (1998): 205-206.

Delong, D. C., Halver, J. E., and Mertz, E. T. (1958), Nutrition of Salmonids Fishes. IV. Protein Requirements of Chinook Salmon at Two Water Temperature, *J. Nutr.,* 65: 589-599.

Desrochers, P. (2000), Market Processes and the Closing of ‘Industrial Loops’: A historical Reappraisal, *Journal of Industrial Ecology,* 4 (1): 29-43.

Devendra, C. (1977), Cassava as a Feed Source for Ruminants. *Proceedings of a Workshop on Cassava as Animal Feed,* held as the University of Guelph, 18-20 April 1977.

Di Giacomo, G., Del Re. G., Spera, D. (1997), Milk Whey Treatment With Recovery of Valuable Products, *Desalination,* 108 (1-3).

Diem, N. V. (1998), The Law on IZs – A Much - Needed One, *The Vietnam Industrial Zone Bulletin,* August-1998.

Dillon, P. S. (1992), Implications of IE for Firms, *The Greening of Industrial Ecosystems*, Washington: National Academy of Engineering, pp. 201-207.

Dimitroff-Regatschnig, H. and Schnitzer, H. (1998), A Techno-Economic Approach to Link Waste Minimization Technologies with the Reduction of Corporate Environmental Costs: Effects on the Resource and Energy Efficiency of Production, *Journal of Cleaner Production*, 6 (1998): 213-225.

Dinsdale, R. M., Hawkes, F. R., and Hawkes, D. (1996), The Mesophilic and Thermophilic Anaerobic Digestion of Coffee Waste Containing Coffee Grounds, *Wat. Res.,* 30 (2): 371-377.

Draaijer, H., Maas, J. A. E., Schaapman, J. E., and Khan, A. (1992), Performance of the 5 MLD UASB Reactor for Sewage Treatment at Kanpur, India, *Water Science and Tecnology,* 25 (7): 123-133.

Duc, M. (2002), Sugar Industry: Tackling Poor Competitiveness, *Vietnam Business Forum No. 18 (107), September 25, 2002.*

Duchin, F. (1992), Industrial Input-Output Analysis: Implications for IE, *Proceedings of the National Academy of Sciences*, 89: 851-855.

Duchin, F., Lange, G. M., Kell, G. (1995), Technical Change, Trade and the Environment, *Ecological Economics,* 14 (1995): 185-193.

Dung, L. T. (2002), A Brief Overview on Food Processing in Vietnam During the Last Decade, *Available in* http://www.vietbiotech.com/publish/index.php/article/articleview/, *January 10, 2003.*

Dung, N. T. (1999), Report of VIZA presented by the Vice Chairman, Mr. Nguyen Tat Dung at the Meeting Reviewing Operation of Vietnam Industrial Zones In the First 6 Months of 1999, held on June 29th and 30th, 1999 in Quy Nhon city, Vietnam.

Dunn, S. V. (1997), *Eco-Industrial Parks: A Common Sense Approach to Environmental Protection,* Yale University, Online Internet, 4 April, 1997.

Dupree, H. K. (1966), Vitamins Essential for Growth of Channel Catfish, *U.S. Bur. Soort Fish., Wildl. Tech. Pap. 7.*

Dupree, H. K. (1969), Influence of Corn Oil and Beef Tallow on Growth of Channel Catfish, *U.S. Bur. Soort Fish., Wildl. Tech. Pap. 27.*

Eccleston, B and Potter, D. (1996), Environmental NGOs and Different Political Contexts in South East Asia: Malaysia, Indonesia and Vietnam, *Environmental Change in South East Asia: People, Politics and Sustainable Development,* London and New York, pp. 49-66.

Eckersley, R. (1995), *Markets, the State and the Environment: Towards Integration,* London: MacLillan.

Edwards, P. (1985), *Aquaculture: a Component of Low Cost Sanitation Technology,* World Bank Technical Paper – ISSN 0253-7494, no. 36.

Edwards, P., Pullin, R. S. V., Gartner, J. A. (1988), *Research and Education for the Development of Integrated Crop-Livestock-Fish Farming System in the Tropics.*

Ehrenfeld, J. R. (1992), IE and Design for Environment: the Role of Universities, *The Greening of Industrial Ecosystems,* Washington: National Academy of Engineering, pp. 228-240.

Ehrenfeld, J. R. (1992), IE and Design for Environment: the Role of Universities, *The Greening of Industrial Ecosystems,* Washington: National Academy of Engineering, pp. 228-240.

Ehrenfeld, J. R. (1997), Industrial Ecology: a Framework for Product and Process Design, *J. Cleaner Prod.,* 5 (1-2): 87-95.

Ehrenfeld, J. R. (1997), Industrial Ecology: a Framework for Product and Process Design, *J. Cleaner Prod.,* 5 (1-2): 87-95.

Ehrenfeld, J. R. and Gertler, N. (1997), The Evolution of Interdependence at Kalunborg, *Industrial Ecology,* 1 (1): 67-80.

Elias, A., Preston, T. R., Willis, M. B., Sutherland, T. M. (1967), By-products of Sugarcane and Intensive Beef Production. 4. Fatting Bulls with Molasses and Urea in Place of Grain in Diets with Little Fibre, *Rev. Cub. Cienc. Agric.,* 5: 59.

Elvira, C., Sampedro, L., Dominguez, J., and Mato, S. (1996), Vermi-composting of Wastewater Sludge from Paper-Pulp Industry with Nitrogen Rich Materials, *Soil. Biol. Biochem.,* 29 (3-4): 759-792.

Environmental Protection Center (EPC) (1992), *Report on the Survey of Bien Hoa Industrial Zone.*

Enriquez, F. Q. and Ross, E. (1967), The Value of Cassava Root Meal for Chicks, *Poultry Sci.* 46: 622-626.

EPA (1996), *Report on Integrated Waste Strategy for Metropolitan Adelaide 1996-2015.*

Erkman, S. (1997), Industrial Ecology: An Historical View, *J. Cleaner Prod.,* 5 (1-2): 1-10.

Erkman, S. (2001), Industrial Ecology: a New Perspective on the Future of the Industrial System, *Official Journal of the Swiss Society of Infectious Disease, the Swiss Society of Internal Medicine, the Swiss Society of Pneumology,* 131 (37-38): 531-538.

Esty, A.C. and Porter, M.E. (1998), IE and Competitiveness: Strategic Implications for the Firm, *Journal of IE Contents,* 2: 35-43.

European Commission (1997), *Final Report on Cleaner Technologies for Waste Minimization.*

Ezumal, H. C., Lal, R. and Okigbo, B.N. (1980), Soil and Water Conservation and Management for Cassava Production in Affrica, *Proceeding of a workshop held in Salvador,* Brazil, 18 – 21 March 1980.

Faine, M. P. (1995), Dietay Factors Related to Preservation of Oral and Skeletal Bone Mass in Women, *J. Prosthet. Dent,* 73: 65-72.

Fan, L., Pandey, A., Mohan, R., and Soccol, C. R. (2000), Use of Various Coffee Industry Residues for the Cultivation of Pleutotus Ostreatus in Solid State Fermentation, *Acta Biotechnologica,* 20 (1): 41-52.

Fava, J. A., and Smith, J. K. (1998), Integrating Financial and Environmental Information for Better Decision Making, *Journal of Industrial Ecology* 2 (1): 9-11.

Freeman, H. M. (1990), *Hazardous Waste Minimization,* New York: McGraw-Hill.

Fresner, J. (1998), Cleaner Production as a Means for Effective Environmental Management, *Journal of Cleaner Production,* 6 (1998): 171-179.

Friedlander, S. K. (1992), The Two faces of Technology: Changing Perspectives in Design for Environment, *The Greening of Industrial Ecosystems,* Washington: National Academy of Engineering, pp. 217-227.

Frijns, J. (2001), Pollution Control of Small Scale Industry in Ho Chi Minh City: to Relocate or to Renovate?, *The Journal of Corporate Environmental Strategy and Practice*, 34: 55-73.

Frijns, J. and Malombe, J.M. (1997), *Cleaner Production and Small Enterprise Development in Kenya.*

Frijns, J., Phuong, P. T., and Mol, A. P. J. (2000), Ecological Modernization Theory and Industrializing Economies: the Case of Vietnam, *Ecological Modernization Around the World: Perspectives and Critical Debates*, London, Portland: Frank Cass, pp. 257-292.

Frijns. J., Kirai, P, Malombe, J. and van Vliet, B. (1997), *Pollution Control of Small-Scale Metal Industries in Nairobi*, Wageningen University.

Frijns. J., Phuong, P. T., and Mol, A. P. J. (2000), Ecological Modernization Theory and Industrializing Economics: the Case of Vietnam, *Ecological Modernization around the World: perspectives and Critical Debates*, Frank Cass, pp. 257-292.

Frosch, R. A. and Gallopoulos, N. E. (1989), Strategies for manufacturing, *Managing Planet Earth*, pp. 97-108.

Fryer, P. (1995), Clean Technology in the Food Industry, *Clean Technology and the Environment*, London: Blackie Academic & Professional, pp. 254-276.

General Statistical Office of Vietnam (2001), *Statistical Year Book 2000*, Statistical Publishing House, Ha Noi, Vietnam.

Gertler, N. (1995), Industrial Ecosystem: Developing Sustainable Industrial Structures, *Dissertation for Master of Science in Technology and Policy and Master of Science in Civil and Environmental Engineering*, Massachusetts Institute of Technology, Cambridge, MA.

Gertler, N. and Ehrenfeld, J. R. (1996), A Down-to-Earth Approach to Clean Production, *Technology Review February-March*, pp. 48-54.

Ghosh, S. P. and Nair, R. G. (1984), Improving Productivity of Cassava in India, *Cassava in Asia, its Potential and Research Development Needs – CIAT 1984.*

Gibbs, D. (2000), Ecological Modernization, Regional Economic Development and Regional Development Agencies, *Geoforum*, 31 (2000): 9-19.

Gill, S. S., Duggal, D., Gill, R. K. (1999), By-production of whey for the Production of Yeast, *Journal of Industrial Pollution Control*, 15 (1): 9-20.

Gnanadipathy, A., and Polprasert, C. (1993), Treatment of Domestic Wastewater with UASB Reactors, *Water Science and Technology*, 27 (1): 195-203.

Gohl, B. (1981), Tropical Feeds, *FAO-Food and Agriculture Organization of the United Nations.*

Goletti, F., Rich, K., and Wheatley, C. (2001), The Cassava Starch Industry in Vietnam: Can Small Firms Survive and Prosper?, *International Food and Agribusiness management Review*, 2 (3/4): 345-357.

Gomez, G. G. (1977), Life-Cycle Swine Feeding Systems with Cassava, *Proceedings of a Workshop on Cassava as Animal Feed*, held as the University of Guelph, 18-20 April 1977.

Gonzalez, F. B., Randel, P. F., Soldevilla, M. (1980), Dried Rum Distillery Stillage in Broiler Rations, *J. Agric. Univ. Puerto Rico*, 64: 194-203.

Gough, R. H., Samkutty, P. J., McGrew, P., Arauz, J., Adkinson, R. W. (2000), Prediction of effluent Biochemical Oxygen Demand in a Dairy Plant SBR Wastewater, *Jurnal of Environmental Science and health, Part A: Toxic/Hazardous Substances and Environmental Engineering*, 35 (2): 169-175.

Gouldson, A and Murphy, J. (1996), Ecological Modernization and the European Union, *Geoforum*, 27 (1): 11-21.

Gouldson, A. and Murphy, J. (1997), Ecological Modernization: Economic Restructuring and the Environment, *The Political Quarterly*, 68 (5): 74-86.

Government of the Socialist Republic of Vietnam (1994), *Government Decree on Providing Guidance for the Implementation of the Law on Environmental Protection.*

Government of the Socialist Republic of Vietnam (1996), *Government Decree No. 26/CP Providing Regulations on Punishment of Administrative Violation of Environmental Protection.*

Graedel, T. E. And Allenby, B. R. (1995), *Industrial Ecology*, Englewood Cliffs, New Jersey 07632: Prentice Hall.

Grant, J. (1997), Planning and Designing Industrial Landscapes for Eco-Efficiency, *J. Cleaner Prod.*, 5 (1-2): 75-78.

Grant, J. (2000), Industrial Ecology: Planning a New Type of Industrial Park, *Journal of Architectural and Planning*, 17 (1): 64-81.

Gray, W. B. and Shadbegian, R. J. (1995), *Pollution Abatement Costs, Regulation and Plant-Level Productivity, National Bureau for Economic Research Working Paper Series # 4994*.

Guillen-Jimenez, E., Alvarez-Mateos, P., Romero-Guzman, F., and Pereda-Marin, J. (2000), Bio-Mineralization of Organic Matter in Dairy Wastewater as affected by pH: The Evolution of Ammonium and Phosphates, *Wat. Res.*, 34 (4): 1215-1224.

Gulbransen, B. (1985a), Survival Feeding of Cattle with Molasses. 1. Feeding of Non-Pregnant Heifers with Molasses Plus Urea and Roughage, *Aust. J. Expt. Agric.*, 25: 1-3.

Gulbransen, B. (1985b), Survival Feeding of Cattle with Molasses. 2. Feeding Steers with Molasses/Urea Plus either Sorghum Grain (Sorghum Vulgare) or Cotton Seed Meal (Gossipum Hirsutum), *Aust. J. Expt. Agric.*, 25: 4-8.

Gupta, S. C. (1965), Problem of Industrial Waste Treatment with Particular Reference to the Treatment of Wastes from Sugar Factories, *Proc. 33rd Conv. Sugar. Technol. Assoc. India,* 59-67.

Hackett, G. A. R., Easton, C. A., and Duff, S. J. B. (1999), Composting of Pulp and paper Mill Fly Ash with Wastewater Treatment Sludge, *Bioresource Technology,* 70 (1999): 217-224.

Haga, K. and Harada, Y. (1990), *Production of Compost from Organic Wastes. Composting and Application of Animals Wastes.*

Hai, D. and Bo, N. V. (1997), Results of Applying New Generic Cassava Type in Thong Nhat District, *Vietnam Cassava Workshop* held at HCMC 4-6 March 1997, (Ket Qua Dua Giong San Moi Vao San Xuat Tren Dia Ban Huyen Thong Nhat. *Hoi Thao San Viet Nam 4-6/3/1997).*

Hajer, M. (1996), Ecological Modernization as Cultural Politics, *Risk, Environment and Modernity: Towards a New Ecology*, Lasash, B, Szerszynski and B, Wynne (Eds). Sage, London, pp. 247-266

Hajer, M. A. (1995), *The Policies of Environmental Discourse: Ecological Modernization and the Policy Process,* Oxford.

Halver, J. E. (1957), Nutrition of Salmonids Fishes. III. Water – Soluble Vitamin Requirements of Chinook Salmon, *J. Nutr.,* 62: 225-243.

Halver, J. E. (1972), The Role of Ascorbic Acid in Fish Disease and Tissue Repair, *Bull. Jpn. Soc. Sci. Fish.,* 38: 79-92.

Halver, J. E., and Coates, J. A. (1957), A Vitamin Test Diet for Long-Term Feeding Studies, *Prog. Fish-Cult.,* 19: 112-118.

Halver, J. E., Ashley L. M., and Smith, R. R. (1969), Ascorbic Acid Requirements of Coho Salmon and Rainbow Trout, *Trans. Am. Fish. Soc.*, 98: 762-771.

Hara, K. (1990), Production of Compost From Organic Wastes, *Food & Fertilizer Technology Center, Extension Bullentin 311.*

Harada, Y. (1990), Composting and Application of Animal Wastes, *Food & Fertilizer Technology Center, Extension Bullentin 311.*

Hartl, R. F. And Kort, P. M. (1997), Optimal Input Substitution of a Firm Facing an Environmental Constraint, *European Journal of Operation research,* 99 (1997): 336-352.

Haskoning Consulting Engineers and Architects (1996), 14 MLD UASB Treatment Plant in Mirzaur, India, *Evaluation Report on Process Performance, Internal Report.*

Haskoning Consulting Engineers and Architects (1996), 36 MLD UASB Treatment Plant in Kanpur, India, *Evaluation Report on Process Performance, Internal Report.*

Hedlund, A. and An, B. X. (2000), A Theorretical Integrated Nutrient Flow on a Farm with Three Sub-systems in a Village in Southern Vietnam, *Material Flow Analysis of Integrated Bio-System (2000), Available in http://www.ias.unu.edu/proceedings/icbs/ic-mfa/hedlund,* January 24, 2003.

Henningsson, S., Smith, A., and Hyde, K. (2001), Minimizing Material Flows and Utility Use to Increase Probability in the Food and Drink Industry, *Trends in Food Science & Technology,* 12 (2001): 75-82.

Henry, G., and Westby, A. (1996), Global Cassava Starch Markets: Current Situation and Outlook, *Cassava, Starch and Starch Derivatives: Proceedings of the International Symposium* held in Nanning, Guangxi China, Nov. 11-15, 1996.

Hertwich, E. G., Pease, W. S., Koshland, C. P. (1997), Evaluating the Environmental Impact of Products and Production Process: a Comparison of Six Methods, *The Science of the Total Environment,* 196 (1997): 13-29.

Hien, P. G., Oanh L.T.K., Viet, N.T. and Lettinga, G. (1999), Closed Wastewater System in the Tapioca Industry in Vietnam, *Wat. Sci. Tech.*, 39 (5): 89-96.

Hilson, G. (2000a), Pollution Prevention and Cleaner Production in the Mining Industry: a Analysis of Current Issues, *Journal of Cleaner Production,* 8 (2000): 199-126.

Hilson, G. (2000b), Barriers to Implementing Cleaner Technologies and Cleaner Production (CP) Practices in the Mining Industry: a Case Study of the Americas, *Minerals Engineering,* 13 (7): 699-717.

Hilson, G. and Nayee, V. (2002), Environmental Management System Implementation in the Mining Industry: a Key to Achieving Cleaner Production, *Int. J. Miner. Process,* 64 (2002): 19-41.

Hin, D. H. K., Chong, R. T. Y., Wai, T. K., and Briffett, C. (1997), The Greening of Singapore's National Estate, *HABITAT INTL,* 21 (1): 107-121.

Hitoshi, M., Susumu, A., Koji, S., Yasunari, K. (2000), Water Recycling by Floating Media Filtration and Nanofiltration at a Soft Drink Factory, *Desalination,* 131 (91-3): 47-53.

Ho Chi Minh City DOSTE (2002), Status of Hazardous Waste Management in Ho Chi Minh City, *Findings of the Baseline Study on Hazardous Waste in the Southern Economic Focus Zone in Vietnam,* Workshop hold in HCMC, on 19 June 2002.

Ho Chi Minh City People Committee (2001), *Environmental Protection Activities in Ho Chi Minh City.*

Ho Chi Minh City People Committee (2002), *Draft Statutes on State Management of EPZs and IZs Environmental Protection in Ho Chi Minh City.*

Hoang, N. (2001), New Industrial Zones: How to Strengthen Investment, *Sai Gon Giai Phong Saturday Newspaper (10 March 2001).*

Holderbeke, M. V. and Timmermans, V. (2002), Integrated Chain Management by Applying Substance Flow Analysis in the Flemish Region of Belgium, *International Journal of Corporate Sustainability – Corporate Environmental Strategy,* 9 (3): 297-304.

Holzer, Z., Aharoni, Y., Lubimov, V., and Brosh, A. (1997), The Feasibility of Replacement of Grain by Tapioca in Diets for Growing-Fattening Cattle, *Animal Feed Science and Technology,* 64 (1997): 133-141.

Houdijk, J. (1998), *Effects of Non-digestible Oligosaccharides in Young Pig Diets*.

Housman, R. F. (1992), International Environmental Law and IE, *The Greening of Industrial Ecosystems,* Washington: National Academy of Engineering, pp. 108-122.

Howeler, R. H., Dang, N. T., and Vongkasem, W. (1999), *Farmer Participatory Selection of Vetiver Grass as the Most Effective Way to Control Erosion in Cassava-based Cropping Systems In Vietnam and Thailand.*

Howeler. R. H. (1980), Soil Related Cultural Practices for Cassava, *Proceeding of a Workshop held in Salvador,* Brazil, 18 – 21 March 1980.

Howes, R., Skea, J., Whelan, B. (1997), *Clean and Competitive*, UK: Earthscan Publications.

Hrishi, N. (1974), Problems and Prospects in Cassava Production in India, *Proceedings of an Interdisciplinary Workshop on Cassava: Processing and Storage*, Pattaya, Thailand, 17-19 April 1974.

Huesemann, M. H. (2001), Can Pollution Problems be Effectively Solved by Environmental Science and Technology? An Analysis of Critical Limitations, *Ecological Economics*, 37 (2001): 271-287.

Hui, J. K., Chan, H. S. A., and Fun, K. F. (2001), A Study of the Environmental Management System Implementation Practices, *Journal of Cleaner Production,* 9 (2001): 269-276.

Huisingh, D. (1989), Cleaner Technologies through Process Modifications, Material Substitutions and Ecologically Based Ethical Values, *UNEP Industry and Environment*, 4-10, Paris, France.

Hung, N. T. (1997), Industrial Development and Natural Environmental Protection, Environmental Auditing, *Workshop on "Mitigation of Industrial Pollution"* held on September 1997, Economic Development Institute, World Bank.

Husar, R. B. (1994a), Ecosystem and the Biosphere: Metaphors for Human-Induced Material Flows, *Industrial Metabolism: Restructuring for Sustainable Development*, pp. 21-30.

Husar, R. B. (1994b), Sulphur and Nitrogen Emission Trends for the United States: An Application of the Materials Flow Approach, *Industrial Metabolism: Restructuring for Sustainable Development*, pp. 239-258.

Huss, L. (1979), Treatment of Sugar Factory Wastewater, *Sugar J.,* 2 (8): 9-12.

Hutagalung, R. I., Phuah, C. H., and Hew, V. F. (1973), *The Utilization of Cassava Tapioca (Manihot Utilization) in Livestock Feeding,* Third Proc. Int. Symp. Trop. Root and Tuber Crops.

Hwa, T. J. (1995), National Reports of Republic of Singapore on Cleaner Production for Green Productivity, *Cleaner Production for Green Productivity: Asian Perspectives*, Asian Productivity Organization.

Hyde, K., Henningsson, S., Smith , M. and Smith, A. (2000), Waste Minimization in the Food and Drink Industry, *Project Report from the East Anglia, Waste Minimization in the Food and Drink Industry*, University of Hertfordshire, Hatfield.

Hyde, K., Smith, A., Smith, M., and Henningsson, S. (2001), The Challenge of Waste Minimisation in the Food and Drink Industry: a Demonstration Project in East Anglia, UK. *Journal of Cleaner Production,* 9 (2001): 57-64.

Ichhponani, J. S., Kakkar, V. K., Makkar, G. S. (1993), Feasibility of Raising Dairy Animals on Urea Molasses Liquid Feeds as a Famine Ration, *Proceeding of the 6th Animal Nutrition Research Workers Conference* 13-16 September, Orissa University of Agriculture and Technology, Bhubaneswar, India.

Ilomaki, M., and Melanen, M. (2001), Waste Minimisation in Small and Medium-Sized Enterprises – Do Environmental Management System Help?, *Journal of Cleaner Production,* 9 (2001): 209-217.

International Food Policy Research Institute (IFPRI) (1998), *Starch Industry Development as a Strategy for Agro-food Based Rural Industrialization*, Washington, D. C.: Markets and Structural Studies Division, IFPRI.

Irvin, G. (1997), Vietnam: Adjustment, Growth and Poverty, *Journal of International Development*: 9 (6): 783-801.

Isidro, R. G. (1980), CO_2 Recovery Plant of Central Don Pedro, *Proc. XVII Congress ISSCT (Philippines)* 3.

Jackman, E. A. (1977), Distillery Effluent Treatment on the Brazilian National Alcohol Program, *Chem. Eng. (London),* 319: 239-242.

Jackson, T and Clift, R. (1998), "Where's the Profit in Industrial Ecology?", *Journal of Industrial Ecology,* 2 (1): 3-5.

Jackson, T., and Clift, R. (1998), Where's the Profit in Industrial Ecology?, *Journal of Industrial Ecology,* 2 (1).

Jänicke, M. (1991), *The Political System's Capacity for Environmental Policy,* Berlin: Department of Environmental Polictics, Free University Berlin.

Japan International Cooperation Agency (JICA), Ha Noi People's Committee (1995), *Master Plan of Industrial Development in Hanoi Area.*

Jorgenson, D. W. and Wilcoxen, P. J. (1990), Environmental Regulation and US Economic Growth, *Rand Journal of Economics,* 21: 314-340.

Kamath, J. (1973), *The Small Scale Manufacture of Soluble Coffee.*

Kanbour, F. (1996), The Regional Seminar on Cleaner Production in Abu Ahabi, *UNEP IE* 19 (3): 52.

Kao, G. N., and Nataraan, C. P. (1974), Utilization of Coffee By-products, *Indian Coffee*, 38: 3-5.
Karamanos, P. (1995), Industrial Ecology: New Opportunities for the Private Sector, *J. Industry and Environment*, 18 (4): 38-44.
Kärkkäinen, M. U. M., Wiersma, J. W., and Lamberg-Allardt, C. J. E. (1997), Postprandial Parathyriod Hormore Respones to Four Calcium-Rich Foodstuff, *Am. J. Chin. Nutr.*, 65: 1726 – 1730.
Ketola, H. G. (1979), Influence of Dietary Zinc on Cataracts in Rainbow Trout, *J. Nutr.*, 109: 965-969.
Khajarern, S., Khajarern, J. M., and Muller, Z. O. (1977), Cassava in the Nutrition of Swine, *Proceedings of a Workshop on Cassava as Animal Feed*, held as the University of Guelph, 18-20 April 1977.
Khan, F. I., Natrajan, B. R., Revathi, P. (2001), GreenPro: a New Methodology for Cleaner and Greener Process Design, *Journal of Loss Prevention in the Process Industries*, 14 (2001): 307-328.
Khatijah, I. and Isa, M. (1990), Cassava Processing and Utilization in Malaysia, *Cassava Breeding, Agronomy and Utilization Research in Asia – CIAT 1990.*
Khoa, L. V. and Boot, S. (1998), Industrial Environmental Management: The Case Study of the Tapioca Starch Processing Industry in Vietnam, *MSc Thesis, Department of Sociology – Wageningen University, the Netherlands.*
Kida, K. I., and Sonada, Y. (1992), Treatment of Coffee Wastewater by Slurry State Anaerobic Digestion, *J. Ferment. Bioenergy,* 73: 390-395.
Kim, H., Bien, P. V., and Howeler, R.H. (2003), Status of Cassava in Vietnam: Implications for Future Research and Development, *Available in* http://www.globalcassavastrategy.net/Asia/vietnam/v0000e01.htm, *January 13, 2003.*
Kirkwood, R. C. and Longley, A. J. (1995), *Clean Technology and the Environment,* Blackie Academic & Professional.
Kirschner, E. (1995), Eco-Industrial ParkFind Growing Acceptance, *Chemical and Engineering News*, February 20: 15.
Kitou, M. and Okuno, S. (1999), Decomposition of Coffee Residue in Soil, *Soil Science and Plant Nutrition,* 45 (4): 981-985.
Klimisch, R. L. (1992), Designing the Modern Automobile for Recycling, *The Greening of Industrial Ecosystems,* Washington: National Academy of Engineering, pp. 165-170.
Koenig, H. E., and Cantlon, J. E. (1999), Quantitative Industrial Ecology and Ecological Economics, *Journal of Industrial Ecology,* 3 (2-3): 63-83.
Kooijmans, L., J and van Velsen, E. M. (1986), Application of the UASB Process for Treatment of Domestic Sewage under Sub-Tropical Conditions, the Cali Case, *Anaerobic Treatment, A Grown up Technology, Conference Papers (Aquatech '86),* pp. 423-436.
Korhonen, J. (2001), Co-production of Heat and Power: an Anchor Tenant of a Regional Industrial Ecosystem, *Journal of Cleaner Production,* 9 (2001): 509-517.
Korhonen, J. (2001), Four Ecosystem Principles for an Industrial Ecosystem, *Journal of Cleaner Production,* 9 (2001): 253-259.
Korhonen, J. (2001), Industrial Ecosystems-Some Conditions for Success, *International Journal of Sustainable Development and World Ecology,* 8 (1): 29-39.
Korhonen, J., Wihersaari, M., and Savolainen, I. (1999), Industrial Ecology of a Regional Energy Supply System – a Case of Jyväskylä Region, Finland, *Journal of Gender Management International,* 26: 57-67.
Korhonen, J., Wihersaari, M., and Savolainen, I. (2001), Industrial Ecosystem in the Finnish Forest Industry: Using the Material and Energy Flow Model of a Forest Ecosystem in a Forest Industry System, *Ecological Economics,* 39 (2001): 145-161.
Kostenberg, D. and Marchaim, U. (1993), Anaerobic Digestion and Horticultural Value of Solid Waste from Manufacture of Instant Coffee, *Envir. Technol,* 14: 973-980.
Krrishnamohan, K., and Herat, S. (2000), Industrial Ecology and Sustainable Development – A Viewpoint, *International Journal of Environmental Studies,* 57 (4): 387-400.
Kujaha, P., Hull, R., Engstrom, F. and Jackman, E. (1976), Alcohol from Molasses as a Possible Fuel, *Sugar Azucar,* 71 (3): 28-39.
Kumar, K., Bal, S. and Ojha, T. P. (1984), Fuel Characteristics of Agricultural Residues, *Agricultural Mechanism in Asia, Africa and Latin America,* 15: 61-64.
Lagrega, M. D., Buckkingham, P. L., Evans, J. C. (1994), *Hazardous Waste Management,* McGraw-Hill Inc.
Lam, T. D. T. (2002), Vietnam's Coffee Growers See Hope, *World Press Review, December 2002.*
Lambert, A. J. D. and Boons, F. A. (2002), Eco-Industrial Parks: Stimulating Sustainable Development in Mixed Industrial Parks, *Technovation* 22 (2002): 471-484.
Lanari, D. and Franci, C. (1998), Biogas Production from Solid Wastes Removed from Fish Farm Effluents, *Aquat. Living Resour.* 11 (4): 289-295.
Lane, A. G. (1983), Anaerobic Digestion of Spent Coffee Grounds, *Biomass,* 3: 247-268.
Langenhoff. A. A., Intrachandra, N., and Stuckey, D. C. (2000), Treatment of Dilute Soluble and Colloidal wastewater Using an Anaerobic Baffled Reactor: Influence of Hydraulic Retention Time, *Wat. Res.,* 34 (4): 1307-1317.

Lastella, G., Test, C., Cornacchia, G., Notornicola, M., Voltasio, F., and Sharma, V. K. (2002), Anaerobic Digestion of Semi-Solid Organic Waste: Biogas Production and Its Purification, *Energy Conversion and Management* 43 (2002): 63-75.

Lave, L., Schempf, N. C., Harvey, J., Hart, D., Bee, T., and MacCracken, C. (1998), Recycling Postconsumer Nylon Carpet, *Journal of Industrial Ecology,* 2 (1): 117-126.

Lee, C. H. (1995), National Reports of Republic of Korea on Cleaner Production for Green Productivity, *Cleaner Production for Green Productivity: Asian Perspectives,* Asian Productivity Organization.

Leontief, W. (1986), *Input-Output Economics,* New York: Oxford.

Lettinga, G., de Man, A., Grin, P., and Hulshoff Pol, L. (1987), Anaerobic Wastewater Treatment as an Appropriate Technology for Developing Countries, *Trib. Cebedeau* 40 (519): 21-32.

Lettinga, G., de Man, A., van der Last, A. R. M., Wiegant, W., van Knippenberg, K., Frijn, J., and van Buuren, J. C. L. (1993), Anaerobic Treatment of Domestic Sewage and Wastewater, *Water Science and Technology,* 27 (9): 67-73.

Lettinga, G., Roersma, R., and Grin, P. (1983), Anaerobic Treatment of Raw Domestic Sewage at Ambient Temperatures Using a Granular Bed UASB Reactor, *Biotechnology and Bioengineering,* 25: 1701-1723.

Levine, S. H. (1999), Products and Ecological Models: A Population Ecology Perspective, *Journal of Industrial Ecology,* 3 (2-3): 47-62.

Lewicki, W. (1978), Production, Application and Marketing of Concentrated Molasses-Fermentation-Effluent (Vinasses), *Proc Biochem.,*13 (6): 12-13.

Lewis, J. W. V. and Ravnoe, A. B. (1976), Effluent Treatment at Felixton Mill, *Proc. 50 th Anni. Congr. S. Afr. Sugar Technol. Assoc.*, pp. 242-245.

Lian,T. S., Khen, C. S. (1984), Improving Productivity of Cassava in Peninsular, Malaysia, *Cassava in Asia, its Potential and Research Development Needs – CIAT 1984.*

Linda, G. and Robert, F. (1999), Environment of IZs: Experiences of Canada. *The paper at "The First Asian Environmental Forum",* Hanoi, Vietnam, 20-24 September, 1999.

Loan, N. T. K. (1994), Environmental Protection and Industrialization in Developing Countries: The Case of Vietnam, *RSPR. no. SM 94-1, AIT.*

Lohm, U., Anderberg, S. and Bergbäck, B. (1994), Industrial Metabolism at the National Level: A Case Study on Chromium and Lead Pollution in Sweden, 1880-1980, *Industrial Metabolism: restructuring for Sustainable Development*, pp. 103-118.

Lorenzen, K. H., Perdersen, M. L., Thompson, H. and Klemmesen, B. (1994), Voluntary Strategies in Pollution Prevention: Experience from Denmark and the Netherlands, *European Environment*, 4 (4): 18-21.

Lovell, R. T. (1978), Dietary Phosphorus Requirement of Channel Catfish, *Trans. Am. Fish. Soc.* 107: 617-621.

Lowe, E. A. (1997), Creating By-products Resource Exchanges: Strategies for Eco-Industrial Parks, *J. Cleaner Prod.,* 5 (1-2): 57-65.

Lowe, E. A., and Evans, L. K. (1995), Industrial Ecology and Industrial Ecosystem, *J. Cleaner Prod.*, 3 (1-2): 47-53.

Lowe, E. A., Warren, J. L., and Moran, S. R. (1997), *Discovering Industrial Ecology: an Executive Briefing and Sourcebook*, Columbus: Battelle Press.

Lowe, E., Moran, S., and Holmes, D. (1996), *Eco-Industrial Parks: a Guidebook for Local Development Team*, Indigo Development Vol. 2, Final Report.

Lowenthal, M. D., and Kastenberg, W. E. (1998), Industrial Ecology and Energy Systems: a First Step, *Resources, Conservation and Recycling,* 24 (1998): 51-63.

Luken, R. A. and Freij, A. C. (1995), Cleaner Industrial Production in Developing Countries: Market Opportunities for Developed Countries, *J. Cleaner Prod.,* 3 (1-2): 71-78.

M'ncene, W. B., Tuitoek, J. K., Muiruri, H. K. (1999), Nitrogen Utilisation and Performance of Pigs Given Diets Containing a Dried or Undried Fermented Blood/Molasses Mixture, *Animal Feed Science and Technology,* 78 (1999): 239-247.

Maaskant, W., Magelhaes, C., Maas, J., and Onstwedder, H. (1991), The Upflow Anaerobic Sludge Blanket (UASB) Process for the Treatment of Sewage, *Environmental Pollution*, 1: 647-653.

Machietto, S. (1992), Controlling the Environmental Impact of the Food Processing Pilot Plant, *IchemE Symp. Ser.,* 126: 179-190.

Macia, V. (1996), Cleaner Production in the Mediterranean Region, *UNEP IE* 19 (3): 53-56

Mæng. H., Lund, H., and Hvelplund, F. (1999), Biogas Plants in Denmark: Technological and Economic Developments, *Applied Energy* 64 (1999): 195-206.

Magno, B. O. (2001), Environmental Management System and Pollution Prevention in Small and Medium Enterprises: International Valuable Experiences for Vietnam, *International Conference: Industry and Environment in Vietnam,* April 20-21, 2001, Ho Chi Minh City, Vietnam.

Magro, J. A. and da Gloria, N. A. (1977), Fertilizer of Sugar Cane Ratoons with Vinasse Complemented with Nitrogen and Phosphorus, *Bras. Acucareiro,* 90: 31-34.

Mai, H. N. P., Thai, L. N., Viet, N. T., and Lettinga, G. (2001), Effect of Organic Loading Rate on Treatment Efficiency for Tapioca Processing Wastewater Using UASB, *International Conference: Industry and Environment in Vietnam,* April 20-21, 2001, Ho Chi Minh City, Vietnam.

Manahan, S. E. (1999), *Industrial Ecology: Environmental Chemistry and Hazardous Waste,* Lewis Publishers.

Maner, J. H. (1973), *Cassava in Swine Breeding.*

Mara, D. D., and Cairncross, A. M. (1989), *Guidelines for the Safe Use of Wastewater and Excreta in Agriculture and Aquaculture,* World Health Organization, Geneva.

Marder, R. C., and Trim, D. S. (1996), Water Conservation and Effluent Reduction in the Cassava Starch Extraction Industries Using Hydrocyclone Technology, *Proceedings of the International Symposium on Cassava, Starch and Derivatives,* held in Nanning, Guangxi, China, Nov. 11-15, 1996.

Mariscal, A. (1984), Improving Productivity of Cassava in Philippines, *Cassava in Asia, its Potential and Research Development Needs – CIAT 1984.*

Marstrander, R. Brattebo, H., Roine, K., Storen, S. (1999), Teaching Industrial Ecology to Graduate Students: Experiences at the Norwegain University of Science and Technology, *Journal of Industrial Ecology,* 3 (4): 117-130.

Mba. C. C. (1996), Treated-Cassava Peel Vermicomposts Enhanced Earth Activities and Cowpea Growth in Filed Plots, *Resources, Conservation and Recycling,* 17 (1996): 219-226.

McCartney, T. H. (1971), The Comparative Utilization of Glucose, Fructose, and Galactose by Fingerling Brook Trout, *State N. Y. Conserv. Dep. Fish. Res. Bull.,* 39: 43-52.

McGrath, C. (2001), Waste Minimisation in Practice. *Resources Conservation & Recycling,* 32 (2001): 227-238.

McLaren, B. A., Keller, E., O'Donnell, J, and Elvehjem, C. A. (1947), The Nutrition of Rainbow Trout. I. Studies of Vitamin Requirements, *Arch. Biochem. Biophys., 1*5: 169-178.

McNeil, K. E. (1984), The Treatment of Wastes from the Sugar Industry, *Surveys in Industrial Wastewater Treatment: Food and Allied Industries,* USA: John Wiley & Sons.

Mehra, U. R., Dass, R. S., Varshney, V. P., Verma, A. K. (1994a), Response of Urea Molasses Liquid Diet on the Performance and Thyroid Gland Activity in Crossbred Heifers (Bos Indicus x Bos Taurus), *J. Nuclear Agric. Biol.,* 23: 33-38.

Mehra, U. R., Verma, A. K., Varshney, V. P., Kumar, H., Dass, R. S. (1994b), Urea Molasses Liquid Diet as Sole ration: Along Term Feeding Experiment on Crossbred Heifers to Study Nutrient, Growth and Thyroid Gland Activity, *World Rev. Anim. Prod.,* 29: 65-71.

Migiro, C. L. C. (1996), Cleaner Production Regional Perspectives: Africa Region, *UNEP IE,* 19 (3): 48-51.

Millikin, M. R. (1982), Qualitative and Quantitative Nutrient Requirements of Fishes: A Review, *Fishery Bulllentin,* 80 (4).

Minot, N. (1998), Competitiveness of Food Processing in Vietnam: a Study of the Rice, Coffee, Seafood and Fruit and Vegetables Sub-sectors, *Report prepared for Vietnam Development Strategy Institute, Ministry of Planning and Investment and Medium-Term Industrial Strategy Project of United Nations Industrial Development Organization in Vietnam.*

Misi. S. N., and Forster, C. F. (2001), Batch Co-Digestion of Multi-Component Agro-Wastes, *Bioresource Technology,* 80 (2001): 19-28.

Modak, P., Visvanathan, C., Parasnis, M. (1996), Cleaner Production Audit, *Environmental Systems Reviews No. 38,* Environmental Systems Information Center, Asian Institute of Technology, Bangkok, Thailand.

Mol, A. P. J. (1999), Ecological Modernization and the Environmental Transition of Europe: Between national Variations and Common Denominators, *Journal of Environmental Policy and Planning,* 1: 167-181.

Mol, A. P. J. (2000), The Environmental Movement in an Era of Ecological Modernization, *Goeforum,* 31 (2000): 45-56.

Mol, A. P. J. and Sonnenfeld, D. A. (2000), Ecological Modernization around the World: an Introduction, *Ecological Modernization Around the World: Perspectives and Critical Debates,* Frank Cass, 1-14.

Mol, A.P.J. (1995), *The Refinement of Production: EM Theory and the Chemical Industry.* Utrecht: Van Arket, University of Amsterdam.

Mol, A.P.J. (1997a), Ecological Modernization: Industrial Transformations and Environmental Reform, *The International Handbook of Environmental Sociology,* Michael Redclift and Graham Wood Gate, pp. 138-149

Mol, A.P.J. (1997b), International Experience with Industrial Pollution Abatement. *Cleaner Production and Small Enterprise Development in Kenya.*

Mol, A.P.J. (1998), Globalization and Changing Patterns of Industrial Pollution and Control, *Environmental Risk and the Quality of Life.*

Mol, A.P.J. and Frijns, J. (1998), Environmental Reforms in Industrial Vietnam, *Paper prepared for the Conference of the Ministry of Science, Technology and Environment, Ha Noi, Vietnam, June 1998.*

Mol, A.P.J., and Spaargaren, G. (1993), Environment, Modernity and the Risk-Society: the Apocalyptic Horizon of Environmental Reform, *International Sociology,* 8 (4): 431-459.

Mol, A.P.J., and Spaargaren, G. (1998), Ecological Modernization Theory in Debate: a Review, *Paper presented at the 14th World Congress of Sociology, Montreal, July 1998.*

Molier, T., Willems, E., and van Berkel, R. (1995), Competitive and Employment Effects of Cleaner Production-Working Report, *Report 94/12, IVAM Environmental research.*

Moltaldo, A. (1977), Whole Plant Utilization of Cassava for Animal Feed, *Proceedings of a Workshop on Cassava as Animal Feed,* held as the University of Guelph, 18-20 April 1977.

Monroy, O., Noyola, A., Ramirez, F., and Guyot, J. P. (1988), Anaerobic Digestion and Water Hyacinth as a Highly Efficient Treatment Process for Developing Countries, *Fifth International Symposium on Anaerobic Digestion (Post-papers)*, Bologna, Italy, Eds A. Tilche & A. Rozzi, pp. 747-751.

Monsma, D. and Mazurek, J. (1999), Building a Performance-Based Environmental Management System: EPA's Reinvention Efforts Revisited, *Corporate Environmental Strategy*, 6 (1999): 232-244.

Montilla, J. J. (1977), Cassava in the Nutrition of Broilers, *Proceedings of a Workshop on Cassava as Animal Feed,* held as the University of Guelph, 18-20 April 1977.

Morehouse, E. R. JR. (1994), Preventing Pollution and Seeking Environmentally Preferable Alternatives in the U.S. Air Force, *The Greening of Industrial Ecosystem*, Washington: National Academy Press, pp. 149-164.

Moriguchi, Y. (2000), Industrial Ecology in Japan, *Journal of Industrial Ecology*, 4 (1): 7-9.

MOSTE (1994), *Decision No. 1806/QD-MTg on the Promulgation of the Regulations and Organization of the Appraisal Council on Environmental Impact Assessment and Issuing Environmental License.*

MOSTE (1994), *Instruction No. 1420/QD-MTg for Guiding Environmental Impact Assessment to the Operating Units.*

MOSTE (1994), *Regulation No. 1807/QD-MTg on Organizing and Activities of Appraisal Council on Environmental Impact Assessment Report and Issuing Environmental License*

MOSTE (1997), *Instruction No. 1100/TT-MTg for Guidance on Preparation and Appraisal of Environmental Impact Assessment Report of the Investment Projects.*

MOSTE (1998), *Circular No. 490/1998/TT-BKHCNMT "Guidance on Setting up and Appraising Environmental Impact Assessment Report for Investment Projects".*

MOSTE (2002), *Decision No. 35/2002/QD-BKHCNMT: Promulgation on List of Vietnamese Environmental Standards.*

MOSTE and Ministry of Industry (1997), *Inter-Ministerial Circular No. 1590/1997/TTLT/BKHCNMT-BXD on "Guideline for Implementation of Instruction No. 199/TTg".*

MOSTE and NEA (1999), *Guideline of Environmental Impact Assessment Report Preparation for Industrial Zone Development Projects.*

Muller, Z., Chou, K. C., and Nah, K. C. (1975), Cassava as Total Substitute for Cereals in Livestock and Poultry Rations, *Proceedings of the 1974 Tropical Products Institute Conference,* 1-5 April, pp. 85-95.

Murphy, J and Gouldson, A. (1995), Implementing EU Environmental Policy through Fine Tuning, *European Environment,* 6 (6): 160-164.

Murphy, J. and Gouldson, A. (2000), Environmental Policy and Industrial Innovation: Integrating Environment and Economy Through Ecological Modernization, *Geoforum*, 31 (2000): 33-44.

Murphy, J. J. (1999), The Effects of Increasing the Proportion of Molasses in the Diet of Milk dairy Cows on Milk Production and Composition, *Animal Feed Science and Technology,* 78 (1999): 189-198.

Nataagiin, O. (1995), National Reports of Mongolia on Cleaner Production for Green Productivity, *Cleaner Production for Green Productivity: Asian Perspectives,* Asian Productivity Organization.

National Assembly of the Socialist Republic of Vietnam (1993), *Law on Environmental Protection.*

Nava, C. C. D. (1996), Cleaner Production Perspectives in Latin America and the Caribbean, *UNEP IE,* 19 (3): 57-62.

Navarro, A. R., Sepulveda, M. D. C., and Rubio, M. C. (2000), Bio-Concentration of Vinasse from the Alcoholic Fermentation of Sugarcane Molasses, *Waste Management,* 20 (2000): 581-585.

Nemerow, N. L. (1995), *Zero Pollution for Industry: Waste Minimization through Industrial Complexes*, John Wiley & Son, Inc.

Nestel, B. and Graharm, M. (1977), *Cassava as Animal Feed*.

Netherwood, A. (1998), Environmental Management System, *Corporate Environmental Management*, The European.

Nghiem, Q. (1990), Cassava Processing and Utilization in Vietnam. *Cassava Breeding, Agronomy and Utilization Research in Asia – CIAT 1990.*

Nghiem, Q. (1991), Cassava and Sweet Potato Processing, Marketing and Utilization in Vietnam, Cassava Processing and Utilization in Thailand, *Product Development for Root and Tuber Crops - CID, CIAT, IITA, VISCA.*

Nhan and Nga (1999), *Design of Sewer System.*

Nhan, D. T. (2001), Orientations of Vietnam Coffee Industry, *Speech at International Coffee Conference, May 17-19, 2001 in London, UK.*

Nhan, T. V. (2001), Practice and Challenge for Cleaner Production in Vietnam, *Proceeding of International Conference on Industry and Environment in Vietnam,* REFINE Project, hold at Ho Chi Minh City, Vietnam in April 20-21/2001.

Nhan, T. V. and Nga, N. T. (1993), Wastewater from Several Industries of Vietnam, *Report of the Project KT-02-06.*

Nhue, T. H. (2001), The establishment of the environmental management system in the industrial zones in Vietnam, *Proceeding of International Conference on Industry and Environment in Vietnam*, REFINE Project, hold at Ho Chi Minh City, Vietnam in April 20-21/2001.

Nogueira, W. A., Nogueira, F. N., and Devents, D. C. (1999), Temperature and pH Control in Composting of Coffee and Agricultural Wastes, *Wat. Sci. Tech.,* 40 (1): 113-119.

O' Rourke, D., Connelly, L. And Kosubsuland, C. P. (1996), *Environment and Pollution*, 6 (2/3): 89-112.

O'Hair, S. K. (1995), *Cassava*, Tropical Research and Education Center, University of Floria.

O'Rourke, D. (1999), Community-Driven Regulation: The Political Economy of Pollution in Vietnam, *PhD Dissertation,* Berkeley, CA: University of California.

Oanh, L. T. K., de Jong, K., Mai, H. N. P., and Viet, N. T. (2001), Removing Suspended Solids from Tapioca Processing Wastewater in Upflow Anaerobic Filter (UAF), *International Conference: Industry and Environment in Vietnam*, Ho Chi Minh City, Vietnam.

OECD (1995b), *Technologies for Cleaner Production and Products.*

OECD (Organization for Economic Cooperation and Development) (1995a), *Promoting Cleaner Production in Developing Countries: the Role of Development Co-operation,* OECD Documents.

Oerlemans, A. M. H. M. (1985), *Production of Cane Sugar in Kenya: Developing or Developed?*

Ogino, C., and Takeda, H. (1978), Requirements of Rainbow Trout for Dietary Calcium and Phosphorus, *Bull. Jpn. Soc. Sci. Fish.,* 44: 793-799.

Ogino, C., and Yang, G. Y. (1978), Requirements of Rainbow Trout for Dietary Zinc, *Bull. Jpn. Soc. Sci. Fish.,* 44: 1015-1018.

Oka, T. (1995), National Reports of Republic of Japan on Cleaner Production for Green Productivity, *Cleaner Production for Green Productivity: Asian Perspectives,* Asian Productivity Organization.

Oke, O. L. (1984), The Use of Cassava as Pig Feed. *Nutrition Abstract and Reviews – Series B,* 54 (7): 301-314.

Oldenburg, K. U., and Geiser, K. (1997), Pollution Prevention and … or Industrial Ecology? *J. Cleaner Prod.*, 5 (1-2): 103-108.

Oliveira, M. A., Reis, E. M., Nozaki, J. (2001), Biological Treatment of Wastewater from the Cassava meal Industry, *Environmental Research,* 85 (2): 177-183.

Olson, D. W., Sunde, M. L., and Bird, H. R. (1969), The Metabolizable Energy Content and Feeding Value of Mandioca Meal in Diet for Chicks, *Poultry Sci.,* 48: 1445-1452.

Omole, T. A. (1977), Cassava in the Nutrition of Layers, *Proceedings of a Workshop on Cassava as Animal Feed,* held as the University of Guelph, 18-20 April 1977.

Oron, G., Campos, C., Gillerman, L. and Salgot, M. (1999), Wastewater Treatment, Renovation and Reuse for Agricultural Irrigation in Small Communities, *Agricultural Water Management,* 38 (1999): 223-234.

Ostertag, C. (1996), World Production and Marketing of Starch. *Cassava Flour and Starch: Progress in Research and Development, CIAT-CIRAD, Cali, Colombia,* pp 105-122.

Overcash, M. (1986), *Techniques for Industrial Pollution Prevention – A Compendium Waste Minimization,* USA: Lewis Publishers.

Page, C. A., Diamond, M. L., Campbell, M., Mckenna, S. (1998), Take a Life-Cycle View of Site Remediation, *Chemical Engineering Progress August*, 63-70.

Page, W. J. (1989), Production of Poly-β-hydroxybutyrate by *Azotobacter Vinelandii* Strain UWD During Growth on Molasses and Other Complex Carbon Sources, *Appl. Microbiol. Biotechnol.,* 31: 329-333.

Palm, C. A., Gacherngo, C. N., Delve, R. J., Cadisch, G., and Giller, K. E. (2001), Organic Inputs for Soil Fertility Management in Tropical Agroecosystems: Application of an Organic Resource Database, *Agriculture Ecosystem & Environment,* 83 (2000): 27-42.

Paredes, C., Bernal, M. P., Cegarra, J., and Roig, A. (2002), Bio-Degradation of Olive Mill Wastewater Sludge by its Co-composting with Agricultural Wastes, *Bio-resource Technology,* 85 (2002): 1-8.

Pargal and Wheeler (1996), For Econometric Evidence on Materials Price and Plant-level Pollution Intensity, *Greening Industry: New Role for Communities, Markets, and Government.*

Parkhomenko, A. N. (1964), Irrigation of Field with Sugar Factory Wastewater, *Sakh. Prom-st,* 38: 748-751.

Pathak, N. N., Krishnamohan, D. V. G., Ranihan, S. K., Katiyar, R. C., Bhat, P. N. (1976), Utilization of Urea Molasses Liquid diet Along With Limited Amount of Intact Protein and Cereal Forage for Milk Production in Crossbred (Bos Indicus x Bos Taurus) Cows. 2. Effect on Digestibility Coefficients and Efficiency of Energy and Nitrogen Utilization for Milk Production, *Indian J. Anim. Sci.,* 43: 821-825.

Paturau, J. M. (1989), *By-products of the Cane Sugar Industry: an Introduction to Their Industrial Utilization,* Third, Completely Revised Edition, Amsterdam-Oxford-New York- Tokyo.

Pento, T. (1999), Industrial Ecology of the paper Industry, *Water Science and Technology,* 40 (11-12): 21-24.

Perttu, K. L. (1995), Ecological, Biological Balance and Conservation, *Biomass and Bioenergy,* 9 (1-5): 107-116.

Pette, K.C. (1979), Anaerobic Wastewater Treatment at CSM Sugar Factories, *C.R. 16 Assem. Ge'n. Comm. Int. Tech. Sucr., Amsterdam,* 17-28.

Pettersson, A. (1992), *The Use of Sugar cane Molasses in Diets for Pigs,* Swedish University of Agricultural Sciences, International Rural Development Centre.

Pfahl, R. C. JR. (1992), Design for Environment: An R&D Manager's Perspective, *The Greening of Industrial Ecosystems,* Washington: National Academy of Engineering, 208-213.

Phuong, P. T. (2002), Ecological Modernization of Industrial Estate in Vietnam, *PhD-Thesis, Wageningen University.*

Ping, F. B. (1990), Cassava Production and research in Guangdong Province of China. *Cassava Breeding, Agronomy and Utilization Research in Asia – CIAT 1990.*

Piyachomkwan, K., Oates, C. G. (2000), Processing of Cassava Waste for Improved Biomass Utilisation, *Bioresource Technology,* 71 (2000): 63-69.

Plaut, J. (1998), Industry Environmental Processes: Beyond Compliance, *Technology in Society* 20 (1998): 469-479.

Polprasert, C. (1989), *Organic Waste Recycling,* John Willey & Sons.

Polprasert, C. (1996), *Organic Waste Recycling,* John Willey & Sons.

Polprasert, C., Edwards, P., Pacharaprakiti, C. (1982), *Final Report on Recycling Rural and Urban Night-soil in Thailand.*

Pond, W. G. and Manner, J. H. (1974), *Swine Production in Temperature and Tropical Environments.*

Ponlranz, Y. (1981), Composition of Cereal Grain, *CRC Handbook of Transportation and Marketing in Agriculture Volume 2.*

Poston, H. A. (1967), Effect of Dietary L – Ascorbic Acid on Immature Brook Trout, *State N. Y. Conserv. Dep. Fish. Res. Bull.,* 30: 46-51.

Poston, H. A., Combs, G. F., and Leibovitz, L. (1976), Vitamin E and Selenium Interrelations in the Diet id Atlantic Salmon: Gross, Histological and Biochemical Deficiency Signs, *J. Nutr.,* 106: 892-904.

Potter, S. G., Moya, A., Henry, P. R., Palmers, A. Z., Becker, H. N., Ammerman, C. B. (1985), Sugarcane Condensed Molasses Solubles as a Feed Ingredient for Finishing Cattle, *J. Anim. Sci.,* 69: 839-846.

Preston, T. R. (1987), Molasses as Animal Feed: an Overview, *FAO Expert Consultation on Sugarcane as Feed,* FAO, Rome.

Pretorius, W. A. (1971), Anaerobic Digestion of Raw Sewage, *Water Research,* 5: 681-687.

Price, B. J. (1999), Effective Responses to Public Reviews: An Environmental Manager’s Perspective at Phillips Petroleum Company, *Corporate Environmental Strategy*.

Prime Minister of the Socialist Republic of Vietnam (1997), *Instruction No. 199/TTg on Urgent Measures in Management of Industrial and Municipal Solid Wastes.*

Prime Minister of the Socialist Republic of Vietnam (1999), *Decision No. 152/1999/QD-TTg on Solid Waste Management Strategy for Urban Areas and Industrial Zones in Vietnam up till 2020.*

Pufluger, R. A. (1975), *Solid Waste: Origin, Collection, Processing and Disposal,* Toronto: Wiley Intersciene Publishers, pp. 365-376.

Punra, P. A. (1990), Cassava Processing and Utilization in Thailand, *Cassava Breeding, Agronomy and Utilization Research in Asia – CIAT 1990.*

Quin, G. (1996), *Processing Soybeans of Different Origins: Response of a Chinese and a Western Pig Breed to Dietary Inclusion.*

Quoc, N. P. (1999), Industrial Solid Waste Prevention and Reduction: Circular Metabolism Rubber Products and Footwear Manufacturing Industries, *MSc Thesis Series No. 4, Wageningen University.*

Quy, V. (1997), Environmental Issues in Vietnam: An Overview, *Environmental Policy and Management in Vietnam,* German Foundation for International Development, pp. 5-31.

Quyen, P. B., Nhan, D. D., San, N. V. (1995), Environmental Pollution in Vietnam: Analytical Estimation and Environmental Priorities, *Trends in Analytical Chemistry,* 14 (8): 383-388.

Quynh, N. K. and Cecil, J. (1996), *Sweetness from Starch: a Manual for Making Maltose from Starch,* Food and Agriculture Organization of the United Nations.

Raetz, E. (1990), Anaerobic Digestion of Wastes, Spent Coffee Grounds, *Nestle Research Centre* No. 492.

Ramjeawon, T. (2000), Cleaner Production in Mauritian Cane Sugar Factories, *Journal of Cleaner Production* 8 (2000); 503-510.

Ranjhan, S. K., Sawhwey, P. C., Jayal, M. M. (1973), Application of Live Saving Research in Animal Feeding, *Farm Information Unit, Directorate of Extension,* Ministry of Agriculture, New Delhi, India.

Rantala, P. R., Vaajasaari, K., Juvonen, R., Schultz, E., Joutti, A., and Mäkelä-Kurtto, R. (2000), Composting of Forest Industry Wastewater Sludge for Agricultural Use, *Water Science and Technology,* 40 (11-12): 187-194.

Rasko’, G. (1998), Competition Polities and Market Regulation in the Food Economy in Hungary-The Role of Institution, *The Importance of Institutions for the Transition in Central and Eastern Europe.*

Reginster, J. Y., Halkin, V., Henrotin, Y., and Gosset, C. (1999), Treatment of Osteoporosis: Role of Bone-forming Agents, *Osteoporosis Int.,* 3: 91-96.

Reith, C. (2001), Applying Environmental Management Strategies to the Agricultural Sector: Louisiana’s Model Sustainable Agricultural Complex, *Corporate Environmental Strategy,* 8 (1).

Rice, S. (1999), Five Years of the CES Journal and Strategic Environmental Management: Quantum Leaps, One Step at a Time, *Corporate Environmental Strategy,* 6 (1999): 290-301.

Richards, D.J., Allenby, B.R., and Frosch, R.A. (1992), The Greening of Industrial Ecosystems: Overview and Perspective, *The Greening of Industrial Ecosystems,* Washington: National Academy of Engineering.

Ringrose, R. C. (1971), Calorie – to- Protein Ratios for Brook Trout, *J. Fish. Res. Board Can.,* 28: 1113-1117.

Rock, M. T. (1996), Towards More Sustainable Development: the Environmental and Industrial Policy in Taiwan, *Development Policy Review,* 14: 255-272.

Rock, M. T. (2000), Globalization and Sustainable Industrial Development in the Second Tier Southeast Asian Newly Industrializing Countries, *Paper prepared for Global Change Assessment Report, Centre for Southeast Asia and the Asia Pacific Network for Global Change Research.*

Rock, M. T. (2001), Pathways to Industrial Environmental Improvement in the East Asian Newly Industrializing Economies, *Paper presented at the Ninth International Greening of Industry Conference*, January 21-25, 2001, Bangkok.

Rock, M. T., Angel, D. P., Feridhanusetyawan, T. (1999), Industrial Ecology and Clean Development in East Asia, *Journal of Industrial Ecology,* 3 (4): 29-42.

Roestamsjah, E. M. and Cahyaningsih, S. (1995), National Report: Indonesia, *Cleaner Production for Green Productivity, Asian Perspective,* Tokyo: Asian Production Organization, pp. 195-245.

Roper, H. (1996), Application of Starch and Its Derivatives, *Carbohydrates in Europe*, pp 22-37.

Rosen, K. (1977), Production of Baker's Yeast, *Process Biochem.*, 12 (3): 10-12.

Rosenthal, E. C. (1996), Designing Eco-Industrial Parks: the US Experience", *UNEP-Industry and Environment,* 19 (4): 14-18.

Ruth, M and Dell'Anno, P. (1997), An Industrial Ecology of the US Glass Industry, *Resource Policy,* 23 (3): 109-124.

Sagar, A. D., and Frosch, R. A. (1997), A Perspective on Industrial Ecology and Its Application to a Metals-Industry Ecosystem, *J. Cleaner Prod.*, 5 (1-2): 39-45.

Saha, S. L. (1994), Promoting Use of Biogas in India, *Electrical India* 34: 13-16.

Sakamoto, S., and Yone, Y. (1978), Iron Deficiency Symptoms of Carp, *Bull. Jpn. Soc. Sci. Fish.,* 44: 1157-1160.

Sakurai, K. (1995), *Cleaner Production for Green Productivity,* Asian Productivity Organization.

Salvesen, D. (1996), Making Industrial Parks Sustainable, *Urban Land, February,* pp. 32.

Sanchez, S. (1990), The Use of Cassava as Animal Feed in Developing Countries – Implications on Food Security and Balance of Payments, *Report for the Food and Agriculture Organization of the United Nations,* Rome, Italy.

Sang, C. T. (1999), *Industrial Environmental Management in Vietnam,* The paper at "The First Asean Environmental Forum", Hanoi, Vietnam, 20-24 September, 1999.

Sang, Y. L. (1996), Bacterial Polyhydroxyalkanoates, *Biotechnol. Bioeng.,* 49: 1-14.

Santisopasri, V., Kurotjanawong, K., Chotineeranat, S., Piyachomkwan, K., Sriroth, K., Oates, C. G. (2001), Impact of Water Stress on Yield and Quality of Cassava Starch, *Industrial Crops and Products – an International Journal,* 13 (2001): 115-129.

Sarkis, J. and Cordeiro, J. J. (2001), An Empirical Evaluation of Environmental Efficiencies and Firm Performance: Pollution Prevention Versus End-of-Pipe Practice, *European Journal of Operational Research,* 135 (2001): 102-113.

Sat, C. D., and Deturchk, P. (1999), Cassava Soils and Nutrient Management in South Vietnam, *Paper presented at the Workshop on Cassava in Vietnam, Ho Chi Minh, 5-7 March, 1997.*

Schaafsma, A. and Beelen, G. M. (1999), Eggshell Powder, a Comparable or Better Source of Calcium than Purified Calcium Carbonate: Piglet Studies, *J. Sci. Food Agric,* 79: 1-5.

Schaafsma, A., Pakan, I., Hofstede, G. J. H., Muskiet, F. A. J., Van Der Veer, E., DeVries, P. J. F. (2000), Processing and Products: Mineral, Amino Acid and Hormonal Composition of Chicken Eggshell Powder and the Evaluation of its Use in Human Nutrition, *Poultry Science*, 79: 1833-1838.

Schellinkhout, A., and Collazos, C. J. (1992), Full-Scale Application of the UASB Technology for Sewage Treatment, *Water Science and Technology,* 25 (7):159-166.

Schellinkhout, A., and Osorio, E. (1994), Long term Experience with the UASB Technology for Sewage Treatment on Large Scale, *Proceedings of the Seventh International Symposium on Anaerobic Digestion,* Cape Town, South Africa, pp. 251-252.

Schwarz, E. J. and Steininger, K. W. (1997), Implementing Nature's Lesson: the Industrial Recycling Network Enhancing Regional Development, *J. Cleaner Prod.,* 5 (1-2): 47-56.

Seghezzo, L., Zeeman, G., van Lier, J. B., Hamelers, H. V.M, Lettinga, G. (1998), Review: The Anaerobic Treatment of Sewage in UASB and EGSB Reactors, *Bio-resource Technology,* 65 (1998): 175-190.

Sekutowski, J. (1994), Greening the Telephone: A Case Study, *The Greening of Industrial Ecosystem*, National Academy Press, pp. 171-177.

Sengar, S. S., Verma, A. K., Varhney, V. P., Mehra, U. R. (1995), Effect of Feeding Urea Molasses Liquid Diet Feeding on the Growth Performance, Blood Profile and Thyroid Gland Activity in Buffalo Heifers in early Stage of Growth, *Buffalo J.,* 11: 157-163.

Sharma, V. K., Canditelli, M., Fortuna, F., and Cornacchia, G. (1997), Processing of Urban and Agro-Industrial Residues by Aerobic Composting: Review, *Energy Convers. Mgmt,* 38 (5): 453-478.

Shaub, S. M. and Leonard, J. J. (1996), Composting: an Alternative Waste Management Option for Food Processing Industries, *Trends in Food Science & Technology,* 7: 263-268.

Shiga, H. (1997), The Decomposition of Fresh and Composted Organic Materials in Soil, *Food & Fertilizer Technology Center, Extension Bullentin 447.*

Shuran, J. (1990), Cassava Processing and Utilization in China, *Cassava Breeding, Agronomy and Utilization Research in Asia – CIAT 1990.*

Sikdar, S. K., and Howell, S. G. (1998), On Developing Cleaner Organic Unit Processes. *Journal of Cleaner Production*, 6 (1998): 253-259.

Sikor, T. and O'Rourke, D. (1996), Economic and Environmental Dynamics of Reform in Vietnam, *Asian Survey. Berkeley CA,* 36 (6): 601-617.

Siller, H., and Winter, J. (1998), Treatment of Cyanide-Containing Wastewater from the Food Industry in a Laboratory-Scale Fixed-Bed Methanogenic Reactor, *Appl Microbiol Biotechnol,* 49: 215-220.

Silva, M. A., Nebra, S. A., Machado, Silva, M. J. M., and Sanchez, C. G. (1998), The Use of Biomass Residues in the Brazilian Soluble Coffee Industry, *Biomass and Bioenergy,* 14 (5/6) 457-467.

Simonis, U. (1989), Ecological Modernization of Industrial Society: Three Strategic Elements, *International Social Science Journal,* 121: 347-361.

Sinha, S. N. and Thakur, B. (1967), Anaerobic Digrestion of Cane Sugar Wastes, *Environ. Health,* 9: 118-125.

Sinthupprama, S and Tiraporn, C. (1984), Improving Productivity of Cassava in Thailand, *Cassava in Asia, its Potential and Research Development Needs – CIAT 1984.*

Sinthuprama, S. (1980), Cassava Planting System in Asia: Cassava Cultural Practices, *Proceeding of a Workshop* held in Salvador, Brazil, 18-21 March 1980.

Sivetz, M. (1963) *Coffee Processing Technology Vol 2,* Wesport : AVI Publishing Co.

Sivetz, M., and Desrosier, N. W. (1977), *Coffee Technology,* Wesport: AVI Publishing Co.

Smith, J. B. And Sims, W. A. (1985), The Impact of Pollution Charges on Productivity Growth in Canadian Brewing, *Rand Journal of Economics,* 16 (3).

Smolenaars, T. (1996), Industrial Ecology and the Role of the Cleaner Production Centre, *Industry and Environment,* 19(4): 19-21.

Society of Environmental Toxicology and Chemistry (1991), *A technical Framework for Life Cycle Assessment,* Washington, D. C.: SETAC Foundation.

Soenarjo, R. and Nugroho, J. H. (1984), Improving Productivity of Cassava in Indonesia. *Cassava in Asia, its Potential and Research Development Needs – CIAT 1984.*

Sonnenfeld, D. A. (2000), Contradictions of Ecological Modernization: Pulp and Paper Manufacturing in South-east Asia, *Ecological Modernization around the World: perspectives and Critical Debates,* Frank Cass, pp. 203-234.

South Vietnam Economic Study Center (1996), *The Master Plan for the Southern Economic Focal Zone 1996-2010.*

Spaaragaren, G. (1997), *The Ecological Modernization of Production and Consumption,* Essays in Environmental Sociology, Wageningen University, the Netherlands.

Spaaragaren, G. (2000), Ecological Modernization Theory and Domestic Consumption, *Journal of Environmental Policy and Planning,* 2: 323-335.

Spaaragaren, G., and Mol, A. P. J. (1991), *Sociology, Environment and Modernity: Ecological Modernization as Theory of Social Change,* LUW, Wageningen.

Spaaragaren, G., and Mol, A. P. J. (1992), Sociology, Environment and Modernity: Ecological Modernization as a Theory of Social Change, *Society & Natural Resources,* 5 (4): 323-344.

Spaaragaren, G., and Mol, A. P. J. (1993), Environment, Modernity and the Risk-Society: The Apocalyptic Horizon of Environmental Reform, *International Sociology,* 8 (4): 431-559.

Sriroth, K. (1996), Cassava Industry in Thailand: the Status of Technology and Utilization, *Cassava, Starch and Starch Derivatives, Proceedings of the International Symposium held in* Nanning, Guangxi, China, Nov. 11-15, 1996.

Sriroth, K., Chollakup, R., Chotineeranat, S., Piyachomkwan, K., and Oates, C. G. (2000), Processing of Cassava Waste for Improved Biomass Utilization, *Bioresource Technology,* 71 (2000): 63-69.

Stahel, W. R. (1992), *Waste Minimization and Clean Technology: Waste Management Strategies for the Future,* London: Academic Press.

Stahel, W. R. (1994), The Utilization – Focused Service Economy: Resource Efficiency and Product-Life Extension, *The Greening of Industrial Ecosystem*, Washington: National Academy Press, pp. 178-190.

Stahel, W. R., and Jackson, T. (1993), Developing Preventive Environmental Management in the Industrial Ecosystem, *Clean Production Strategies,* Boca Raton, FL: Lewis Publishers.

Stahel, W. R., and Malvey, R. G. (1981), *Jobs for Tomorrow. The Potential for Substituting Manpower for Energy,* New York: Vantage Press.

Sterner, T. (1994), Environmental Tax Reform: the Swedish Experience, *European Environment,* 4 (6): 20-25.

Stigliani, W. M. and Anderberg, S. (1994), Industrial Metabolism at the Regional Level: the Rhine Basin, *Industrial Metabolism: restructuring for Sustainable Development*, pp. 119-162.

Suh, Y. J. and Rousseaux, P. (2001), An LCA of Alternative Wastewater Sludge Treatment Scenarios, *Resources, Conservation and Recycling,* 00 (2001): 00-000.

Sy, P. C. (2000), Status and Control Measures of Air Pollution in the South Key Economic Regions, *Environmental Workshop 2000 on "Science, Technology and Environment"*, held on 06 June 2000 at Ho Chi Minh City, Vietnam.

Tacon, A. G. J. (1987), *The Nutrition and Feeding of Farmed Fish and Shrimp – A Training Mnual, Nutrient Sources and Composition.*

Takeda, S. (1995), The Task and Challenge for Japan in the 21st Century: An Introduction, *Technological Forecasting and Social Change*, 49: 113-126.

Takeuchi, T., Yazu, Y., and Sakuma, A. (1999), Integrated Environmental Management Process Applying Genetic Algorithm, *International Journal of Production Economic,* 60-61 (1999): 229-234.

Tam, H. (1998), *Scientific Report "Research on Management Measures for Cassava Soil in the Southeast Area".* (*Bao Cao Khoa Hoc "Nghien Cuu Mot So Bien Phap Quan Ly dat Trong Khoai Mi o Mien Dong Nam Bo".*

Tam, T. (2001), Ten Years of Export Processing Zone – Industrial Zones in Vietnam: High Efficiency, but..., *Sai Gon Giai Phong Newspaper (Friday, 16 march 2001).*

Tamayo, C. M. (1996), Colombia: the Cleaner Production National Policy, *UNEP IE,* 19 (3): 59.

Tang, N N., Torres, C. L., and Speece, R. E. (1995), Treatment of Low Strength Domestic Wastewater by Using Upflow Anaerobic Sludge Blanket Process, *50th Purdue Industrial Waste Conference Proceedings,* pp. 437-448.

Tapaneeyangkul, P. (1995), National Reports of Thailand on Cleaner Production for Green Productivity, *Cleaner Production for Green Productivity: Asian Perspectives,* Asian Productivity Organization.

Tchobanoglous, G., Theisan, H., Vigil S. A. (1993), *Integrates Solid Waste Management,* McGraw-Hill International Editions.

Thanh, N. C. (1974), Technology of Cassava Chips and Pellets Processing in Thailand, *Proceedings of an Interdisciplinary Workshop on Cassava: Processing and Storage*, Pattaya, Thailand, 17-19 April 1974.

Thanh, N. C. (1993), Vietnam Environmental Sector Study, *Report in the Workshop on Managment of Environment with Rapid Industrialisation: Lesson from the East Asian Experience,* September 1993, Ha Noi, Vietnam.

Tibbs, H. (1993), *Industrial ecology: An Environmental Agenda for Industry,* Globa; Business Network, California.

Tibbs, H. B.C. (1992), Industrial Ecology: an Environmental Agenda for Industry, *Whole Earth Review*, pp. 4-19.

Tietenberg, T. (1988), Country Papers: Thailand, *ISO 14000 for Small and Medium Enterprises,* Tokyo: Asian Productivity Organization, pp. 82-86.

Todd, R. (1994), Zero-Loss Environmental Accounting Systems, *The Greening of Industrial Ecosystem,* Washington: National Academy Press, pp. 191-200.

Train, R. E., Agee, T.L., Cywin, A. and Dellinger, R. W. (1975), Development Document for Interim Final Effluent Limitations Guidelines and Proposed New Source Performance Standards for the Raw Cane Sugar Processing Segment of the Sugar Processing Point Source Category, *EPA-440/1-75-044, US Environmental Protection Agency,* Washington DC.

Train, R.E., Stelow, P., Cywin, A. and Dellinger, R.W. (1974), *Development Document for Interim Final Effluent Limitations Guidelines and News Source Performance Standards. Cane Sugar Refining Segment of the Sugar Processing Industry, EPA-440/1-74-002-C*, Washington: Environmental Protection Agency.

Triet, L. M., Sinh, N. N., Sang, C. T. (1999), Scientific and Practical Rationales for Development of Regulations on Environmental Protection of Industrial Parks in Vietnam, *the paper at "The First Asean Environmental Forum"*, Hanoi, Vietnam, 20-24 September, 1999.

Trinh, L. X. (1998), Main Activities of IZs in 1997. *The Vietnam Industrial Zone Bulletin 2-1998*: 4, 8-9.

Tu, R. (1996), Promoting Cleaner Production in China: Overview and Outlook, *UNEP IE,* 21 (4): 30-36.

Tu, T. T. (2001), The Environmental Management of Export Processing Zones and Industrial Zones of Ho Chi Minh City: Past Performance, New Objectives and Orientation, *International Conference on Industry and Environment in Vietnam,* held at Ho Chi Minh City, April 20-21/2001, REFINCE PROJECT.

ULI (Urban Land Institute) (1988), *Business and Industrial Park Development Handbook,* Urban Land Institute, Washington, D. C., pp. 95-96.

UNEP (1995), *Incorporating Environmental Considerations into Investment Decision-making in Vietnam, A Special Report for the Government of the Socialist Republic of Vietnam.*

UNEP/ICC/FIDIC (1997), *EMS Training Resource Kit*, Version 1.0, January 1997.

USEPA (1992), *Facility Pollution Prevention Guide,* Office of Research and Development, Washington, D. C., EPA/600/R-92/008, May.

Usher, J. F. and Willington, I. P. (1979), The Potential of Distillery Waste as Sugar Cane Fertilizer, *Proc. 1st. Conf. Aust. Soc. Sugar Cane Technol.,* pp. 143-146.

Van Berkel, R. (1994), *Journal of Cleaner Production,* 2 (3-4): 207-215.

Van Berkel, R. (1995), *Industry and Environment Review,* 18 (1): 8-15.

Van Berkel, R., and Lafleur, M. (1997), Application of an Industrial Ecology Toolbox for the Introduction of Industrial Ecology in Enterprises-II, *J. Cleaner Prod.,* 5 (1-2): 27-33.

Van Berkel, R., Willems, E., and Lafleur, M. (1997), Development of an Industrial Ecology Toolbox for the Introduction of Industrial Ecology in Enterprises-I, *J. Cleaner Prod.,* I5 (1-2): 11-25.

Van der Last, A. R. M., and Lettinga, G. (1992), Anaerobic Treatment of Domestic Sewage Under Moderate Climatic (Dutch) Conditions Using Upflow Rectors at Increased Superficial Velocities, *Water Science and Technology,* 25 (7): 167-178.

Van Koppen, C. S. A and Hagelaar, J. L. F. (2002), Environmental Management and Industry, *Course Book 2002, Wageningen University, Environmental Policy Group and Environmental Science Group.*

Van Koppen, C. S. A. (1999), *The Logic of Environmental Management System.*

Van Koppen, C. S. A. and Mol. A. P. J. (2002), Ecological Modernization of Industrial Ecosystems, *Water Recycling and Resource Recovery in Industry: Analysis, Technologies and Implementation,* IWA Publishing.

Van, N. T. (2001), Environmental Management in Industrial Zones in the First Years of the Modernization and Industrialization Processes in Binh Duong Province, *International Conference on Industry and Environment in Vietnam,* held at Ho Chi Minh City, April 20-21/2001, REFINE PROJECT.

Verma, A. K., Dass, R. S., Mehra, U. R. (1994), Response of Urea Molasses Liquid Diet Feeding on Growth Performance, Nutrient Utilization and Thyroid Gland Activity in Crossbred Heifers, *World Rev. Anim. Prod.,* 29: 101-107.

Verma, A. K., Dass, R. S., Mehra, U. R. (2000), Revival Performance of Growing Buffalo Calves Fed on Urea Molasses Liquid Diet and Roughage as Survival Feed, *Animal Feed Science and Technology,* 87 (2000): 23-261.

Verma, A. K., Mehra, U. R., Dass, R. S., Varhney, V. P., Kumar, H. (1995), Performance of Crossbred Heifers Suring Revival Period after Long Term Scarcity Feeding, *J. Appl. Anim. Res.,* 8: 63-70.

Vieira, S. M. M. (1988), Anaerobic Treatment of Domestic Sewage in Brazil - Research Results and Full Scale Experience, *Proceedings of the 5th International Symposium on Anaerobic Digestion Bologna, Italy,* Eds, E. R. Hall & Hobson, pp. 185-196.

Vieira, S. M. M., and Garcia, Jr. A. D. (1992), Sewage Treatment by UASB Reactor: Operation Results and Recommendations for Design and Utilization, *Water Science and Technology,* 25 (7): 143-157.

Vieira, S. M. M., and Souza, M. E. (1986), Development of Technology for Use of the UASB Reactor in Domestic Sewage Treatment, *Water Science and Technology,* 18 (12): 109-121.

Vieira, S. M. M., Carvalho, J. L., Barijan, F. P. O., and Rech, C. M. (1994), Application of the UASB Technology for Sewage Treatment in a Small Community at Sumare Sao Paulo State, *Water Science and Technology,* 30 (12): 203-210.

Vietnam Industrial Zone Authority (1998), *Industrial Investment Opportunities.*

Vietnam Industrial Zone Authority (1999), Status of Vietnam's IZs Development and Some Environmental Management Problems, The paper at "*The First Asian Environmental Forum*', Hanoi, Vietnam, 20-24 September, 1999.

Vigneswaran, S., Jegatheesan, V., and Visvanathan, C. (1999), Industrial Waste Minimization Initiatives in Thailand: Concepts, Examples and Pilot Scale Trials, *Journal of Cleaner Production,* 7 (1999): 43-47.

Visser, H. D. (1993), *Influence of Carbonhydrates on Feed Intake, Rumen Fermentation and Milk Performance in High-Yielding Dairy Cows.*

Visvanathan, C. (1995), Regulation, Enforcement, Legislation and Licensing of Industrial Plants, *Training Course on Pollution Prevention Techniques*, 13-25 February, 1995, Vietnam.

Visvanathan, C. (1998), *Lecture Note on Industrial Pollution Control.* Asian Institute of Technology, Bangkok, Thailand.

Visvanathan, C. and Kumar, S. (1999), Issues for Better Implementation of Cleaner Production in Asian Small and Medium Industries, *Journal of Cleaner Production,* 7 (1999): 127-134.

Vliet, B.V. and Frijns, S. (1995), Small-scale Industries, Economic Development and Environmental Issues with Reference to Nairobi, Kenya, *The Center for the Urban Environmental (CUE) Internal Working Document 1,* CUE Rotterdam.

Vogt, H. (1966), The Use of Tapioca Meal in Poultry Rations, *World's Poult. Sci. J.,* 22: 113-125.

Vu, D. D., Cuong, L. X., Dung, C. A., and Hai, P. H. (1999), Use of Urea-Molasses-Multinutrient Block and Urea-Treated Rice Straw for Improving Dairy Cattle Productivity in Vietnam, *Preventive Veterinary Medicine,* 38 (1999): 187-193.

Vuc, L. D., and Kim, H. (1997), Research on Fertilizing N-P-K for Cassava in Dong Nai Province, *Vietnam Cassava Workshop* held at HCMC, 4-6 March, 1997. (Nghien Cuu Bon Phan NPK Cho san O Tinh Dong Nai. *Hoi Thao San Viet Nam,* HCMC, 4-3/3/1997).

Waliszewski, K. N., Romero, A., and Pardio, V. T. (1997), Use of Cane Condensed Molasses Soluble in Feeding Broiler, *Animal Feed Science and Technology,* 67 (1997): 253-258.

Wallace, J. S. (2000), Increasing Agriculture Water Use Efficiency to Meet Future Food Production, *Agriculture Ecosystem & Environment,* 82 (2000): 105-119.

Wallner, H. P. (1999), Towards Sustainable Development of Industry: Networking, Complexity and Eco-Clusters, *Journal of Cleaner Production,* 7 (1999): 49-58.

Wang, H. (2002), Pollution Regulation and Abatement Efforts: Evidence from China, *Ecological Economics,* 41 (2002): 85-94.

Watanabe, T., & Takeshima, F. (1977), Effect of α-Tocoperol Deficiency on Carp-IV. Deficiency Symptoms & Changes of Fatty Acid and Triglyceride Distributions in Adult Carp, *Bull, Jpn. Spoc. Sci. Fish.,* 43: 819-830.

Weale, A. (1992), *The New Politics of Pollution.* Manchester University Press: Manchester.
Wei, M. S. and Huang, K. H. (2001), Recycling and reuse of Industrial Wastes in Taiwan, *Waste Management* 21 (2001): 93-97.
Weigand, E., and Kirchgessner, M. (1980), Protein and Energy Value of Vinasse for Pigs, *Anim. Feed. Sci. Technol.*, 5: 221-231.
Weinberg, M., Ayring G., Raguso, J., and Jensen, D. (1992) IE: The Role of Government, *The Greening of Industrial Ecosystems*, National Academy of Engineering, Washington, pp. 123-133.
Wernick, I., and Ausubel, J. H. (1995), National material Metrics for Industrial Ecology, *Resources Policy*, 21 (3): 189-198.
Whiithing, S. J. (1994), Safety of Some Calcium Supplements Questioned, *Nutr. Rev.*, 52: 95-105.
WHO (1989), Health Guidelines for the Use of Wastewater in Agriculture and Aquaculture, *Technical Report Series No. 778*, World Health Organization, Geneva.
WHO (1993), *Handbook on Rapid Assessment Techniques of Industrial Pollution.*
Williams, J. E., Belyea, R. L., Hsieh, F. H., Firman, J. D. (1998), Response of Growing Turkeys to the Dietary Inclusion of Inedible Pasta and Unextruded and Extruded Biosolids from Milk Processing, *Animal feed Science Technology*, 70 (1998): 123-136.
Woltjer, V. (2001), Coping with Industrial Zone: an Analysis of Community Influence on the Environmental Performance of Industrial Zones in Southern Vietnam, *MSc Thesis Series No. 19*, Wageningen University: the Netherlands.
Work Bank (1995), *Vietnam Environmental Program and Policy Priorities for a Socialist Economy in Transition*, Report No. 13200-VN.
Woszczyna, J. (1998), The Privatization of Polish Economy with Emphasis on Agriculture and Food Industry, *The Importance of Institutions for the Transition in Central and Eastern Europe.*
Wythes, J. R., Ernst, A. J. (1983), Molasses as a Drought Feed, *Proc. Aust. Soc. Anim. Prod.*, 15: 213-276.
Xiong, L., Weit, Z., and Xucheng, T. (1984), Improving Productivity of Cassava in China, *Cassava in Asia, its Potential and Research Development Needs – CIAT 1984.*
Yakowitz, H. (1997), Assessing the Cost –Effectiveness of Cleaner Production, *OECD Proceedings on Cleaner Production and Waste Minimization in OECD and Dynamic Non-Member Economies*, France, pp. 163-178.
Yang, S. S. (1997), Preparation of Compost and Evaluation its Maturity, *Food & Fertilizer Technology Center, Extension Bullentin 445.*
Yasunoby, Y., Tuyen, N. Q., and Yamada, R. (1999), Factors Influenced Establishing the VAC Farming Systems in Mekong Delta, Vietnam, *Available in http://www.ifama.org/conferences/1/1999/*, January 24, 2003.
Yetis, M., Gunduz, U., Eroglu, I., Yucel, M., Turker, L. (1998), Photoproduction of Hydrogen from Wastewatr of Sugar Refinery by Rhodobacter Sphaeroides OU 001, *Paper to be presented in Marine Bioporcess Engineering, Noordwijkeerhout, The Netherlands.*
Yigit, D. O., Gunduz, U., Turker, L., Yucel, M., Eroglu, I. (1999), Identification of By-products in Hydrogen Producing Bacteria, Rhodobacter Sphaeroides O. U. 001 grown in the Wastewater of a Sugar refinery, *Journal of Biotechnology*, 70 (1999): 125-131.
Yone, Y. (1975), Nutritional Studies of Red Sea Bream, *Proc. First. Int. Conf. Aquaculture Nutr.*, pp. 36-64.
Yuracko, K. L., Hadley, S. W., Perlack, R. D., Rivera, R. G., Curlee, T. R. (1997), Fernald's Dilemma: Recycle the Radioactively Contaminated Crap Metal, or Bury It?, *Resources, Conservation and Recycling*, 19 (1997): 187-198.
Zakkour, P. D., Gaterell, M. R., Griffin, P., Gochin, R. J., and Lester, J. N. (2001), Anaerobic Treatment of Domestic Wastewater in Temperature Climates: Treatment Plant Modelling with Economic Considerations, *Wat. Res.*, 35 (17): 4137-4149.
Zeeman, G. (1997), Decentralized Sanitation Systems: the Role of Anaerobic Treatment in UASB-Septic Tank Systems, *Paper Presented to the Third Japan-Netherlands Workshop on Integrated Water Quality Management, the Netherlands, 26-30 May 1997.*
Zoebl, D. (2000), Patterns of Input-Output Relations in Agro-Ecosystem, *Agriculture Ecosystem & Environment*, 79 (2000): 233-244.
Zuurmond, T. (1993), *A Financial Analysis of the Managed Futures Industry.*
Zwetsloot, G. I. J. M. (1995), Improving Cleaner Production by Integration into the Management of Quality, Environment and Working Conditions, *J. Cleaner. Prod.*, 3 (1-2): 61-66.

INTERNET REFERENCES

ADB (Asian Development Bank) (1999), Ho Chi Minh City Environmental Improvement Project, *Available in* http://www.adb.org/Documents/News/1999/pi1999089.asp, *January 6, 2003.*
An, B. X. (2002), Biogas Technology in Developing Countries: Vietnam Case Study, *Proceeding Biodigester Workshop, March 2002, Available in http://www.mekarn.org/procbiod/an.htm.*
APFood (Asia Pacific Food Industry) (2003), Vietnam in Transition, *Available in* http://www.apfoodonline.com/magazines/1999/may/art01.htm, *January 14, 2003.*
ASEM Connect (2002a), The Vietnam Business Directory: Bien Hoa Sugar Company, *Available in* http://asemconnectvietnam.gov.vn/hsdn/logo_detail.asp?c_ty=2639, *December 19, 2002.*

ASEM Connect (2002b), The Vietnam Business Directory: Bien Hoa Coffee Factory, *Available in* http://asemconnectvietnam.gov.vn/caphebienhoa/main.htm, *December 19, 2002*.

ASEM Connect (2002c), The Vietnam Business Directory: State Owned Sugar Companies, *Available in* http://asemconnectvietnam.gov.vn/hsdn/activities3.asp?mhkd_code=138, *December 24, 2002.*

Australian Trade Commission (2002), Dairy to Vietnam, *Available in* http://www.austrade.gov.au/print_template, *December 30, 2002.*

Australian Sugar Industry (2003), Sugar Industry Terminology, *Available in* http://www.sri.org.au/terminology2.html, *February 10, 2003.*

BIBICA (Bien Hoa Confectionery Corporation) (2002), Quality Policy of Bien Hoa Confectionery Corporation, *Available in* http://www.bibica.com/qcsystem.php, *December 30, 2002.*

Bien, P. V., Kim, H., Wang, J. J. and Howeler, R. H. (2003), Present Situation of Cassava Production and Research and Development Strategy in Vietnam, *Available in* http://www.danforthcenter.org/iltab/cassavanet/cbnv/abstracts/Session1/S1-24.htm, *January 13, 2003.*

Brownsville Economic Development Council (2003a), Industrial Park, *Available in* http://www.bedc.com/executivesum/05induspaks.html, *February 25, 2003.*

Brownsville Economic Development Council (2003b), Brwonsille Eco-Industrial Park Project Underway, *Available in* http://www.bisn.org/ecopark.html, *February 25, 2003.*

Chien, D. M (2002), Introduction to Dong Nai Ice Enterprise, *Available in* http://www.donaice.com.vn/index_e.html, *December 19, 2002.*

Chinh, B. V., Ly, L. V., Tao. N. H. and Phuc, N. G. (2002), Biogas Technology Transfer in Small-Scale Farms in Northern Provinces of Vietnam, *Proceedings Biodigester Workshop, March 2002, Available in* http://www.mekarn.org/procbiod/chinh.htm, *January 24, 2003.*

Cohen-Rosenthal, E. and McGalliard, T. N. (2003), Eco-Industrial Development: the Case of the United States, *Available in* http://www.jrc.es/iptsreport/vol27/english/COH1E276.htm, *February 25, 2003.*

Cohen-Rosenthal, E., McGalliard, T., and Bell, M. (2003), Designing Eco-Industrial Parks: the North American Experience, *Available in* http://www.cfe.cornell.edu/wei/EIDP/design.html, *February 25, 2003.*

Dong Nai Industrial Department (2002a), Bien Hoa 1 Industrial Zone, Available in http://www.dongnai-industry.gov.vn/english/kcn_cppd_1.html, December 19, 2002.

Dong Nai Industrial Department (2002b), Introduction of Enterprises, Available in http://www.dongnai-industry.gov.vn/english/qtpt-spcy-nam2002, December 19, 2002.

Edward, T. (2003), Doi Moi in Vietnam: a Small Tiger's Growth Spurt Comes to an End, *Available in http://* www.columbia.edu/cu/ccba/cear/issues/fall97/graphics/regional/tran/tran.htm, *January 28, 2003.*

Enden, J. V. (2002), Vietnam Coffee Industry – Learning from the Past, *Available in* http://www.new-agri.co.uk/02-6/develop/dev04.html, *December 20, 2002.*

EUROPEN (1997), Optimal Waste Management Calls for Flexible Choice of Recovery Options (November 1997), *Available in* http://www.europen.be/issues/optiwast.html, *January 16, 2003.*

Euromonior International (2002), The Market for Soft Drink in Vietnam, *Available in http://www.euromonitor.com/report_summary.asp?country=VN&s=deep&docid=12499, January 14, 2003.*

FAO (Food and Agriculture Organization of the United Nation) (2002), *Vietnam Sugar Industry*, *Available in* http://www.fao.org/es/ESC/escr/sugar/sugare.htm, *December 24, 2002.*

FCN Eco-Park (2003), FCN's Eco-Industrial Park Cheney: Washington State, *Available in* http://www.cfe.cornell.edu/wei/EIDP/FCNecopark.htm, *February 25, 2003.*

Food Market Exchange (2003a), World Production Statistics of Tapioca, *Available in* http://www.foodmarketexchange.com/datacenter/product/feedstuff/tapioca/detail, *January 4, 2003.*

Food Market Exchange (2003b), Tapioca Competitors: Vietnam, *Available in* http://www.foodmarketexchange.com/datacenter/product/feedstuff/tapioca/detail, *January 4, 2003.*

German Chamber of Commerce, (2002), Vietnamese Economy 2001 and Its Orientation, *Available in* http://www.ahk.org.hk/Archive/02_02_vietnam/pdf, *January 13, 2003.*

Hao, D. H. (2003), Some Major Contents of the Industrial Development Strategy Towards the Year 2010, *Available in* http://www.un.org.vn/unido/frame4/hao-industry-strategy.pdf, *January 13, 2003.*

IDECO (2003), Overview of Tay Ninh Province, *Available in* http://www.trangbang-iz.com.vn/e_main.htm, *January 4, 2003.*

Incomebank Monthly Bullentin, Issue 1 (2002), Domestic Market, *Available in* http://www.icb.com.vn/e/tpr02.html, *December 19, 2002.*

Lai, T. Do. (2002), Main Activities of VINACAFE, *Available in* http://www.vinacafe.com.vn/vinacafe/about_us.htm, *December 30, 2002.*

Lam, T. D. T. (2002), Vietnam's Coffee Growers See Hope, *World Press Review*, *Available in* http://www.globlexchange.org/economy/coffee/20021203_445.html, *December 20, 2002.*

Lan, N. (2003), Environmental Problems: Development Costs in Vietnam, *Available in* http://www.asiasource.org/asip/nguyen.cfm, *January 10, 2003.*

LASUCO (Lam Son Joint Stock Cooporation) (2002a), Social Cultural and Political Activities, *Available in* http://www.lasuco.com.vn/Eng/aboutus3.htm, *December 20, 2002.*

LASUCO (2002b), Organization of Lam Son Joint Stock Corporation, *Available in* http://www.lasuco.com.vn/Eng/aboutus2.htm, *December 20, 2002.*

Linh, T. T. T. (2002), Lam Son Economic Development Model, *Available in* http://www.geocities.com/tranthithuylinh/07-2001/TTTL-lamsonduong.html, *December 20, 2002.*

Lowe, E. A. (2003), East Bay Eco-Industrial Park, Greater Oakland Region, CA, *Available in* http://www.smargrowth.org/casestudies/ecoin_east_bay.html, February 25, 2003.

MARD (Ministry of Agriculture and Rural Development of Vietnam) (2002a), *Sugarcane, Available in the Official Website of Ministry of Agriculture and Rural Development* http://www/agroviet.gov.vn/en/hang/miaduong.asp, December 19, 2002.

MARD (Ministry of Agriculture and Rural Development of Vietnam) (2002b), *Coffee, Available in the Official Website of Ministry of Agriculture and Rural Development* http://www/agroviet.gov.vn/en/hang/caphe.asp, December 19, 2002.

MARD (Ministry of Agriculture and Rural Development of Vietnam) (2002c), *Fruit and Vegetable, Available in the Official Website of Ministry of Agriculture and Rural Development* http://www/agroviet.gov.vn/en/hang/rauqua.asp, December 19, 2002.

MARD (Ministry of Agriculture and Rural Development of Vietnam) (2002d), Rice, *Available in the Official Website of Ministry of Agriculture and Rural Development* http://www/agroviet.gov.vn/en/hang/luagao.asp, December 19, 2002.

National Environmental Agency of Vietnam (2003), State of the Environment in Vietnam 2001: Environmental Management and Legislation, *Available in* http://www.rrcap.unep.org/report/soe/vietnam/, *January 28, 2003.*

Peters, D., Ngai, D. D. and An, D. T. (2000), Agro-Processing Waste Assessment in Peri-urban Ha Noi, *CIP Program Report 1999-2000, Available in* http://www.cipotato.org/market/PgmRprts/pr99-00/58hanoi.pdf, *January 16, 2003.*

Sai Gon Economic Times - Thursday, August 22, (2002), *After 26 Years, Vinamilk still Laps up the Lessons of the Open Market.*

Saigon News – July (2002), New Legislation, *Available in* http://www.vietnamhost.net/$news/saigonnewsold47.html, *December 30, 2002.*

SONADEZI (2002), Introduction to SONADEZI, *Available in* http://www.sonadezi-vn.com/content_coporate.htm, *December 30, 2002.*

Spitzer, M. A. (1996), *Eco-Industrial Park Workshop Proceeding*, October 17-18, 1996, Cape Charles, Virginia.

Sundhagul, M and Atthasampunna, P. (2003), Bioconversion of Carbohydrate Residues in Thailand, *Available in* http://www.unu.edu/enupress/unupbooks/80362e/80362E0a.htm, *February 10, 2003.*

Tuyen, D. K. and Giao, H. K. (2003), Dairy Cattle Production in Vietnam and Development Plan for 2002-2010, *Available in* http://www.vcn.vnn.vn/sp_pape/_spec_5_11_2002_9.htm, *January 14, 2003.*

UNIDO (2003), UNIODO in Vietnam: Environmentally Sustainable Industrial Development and Urban Management, *Available in* http://www.un.org.vn/unido/frame1/text1c.htm, *January 13, 2003.*

Vacvina (Vietnam's National Horticultural Training Association) (2003), VACVINA Biogas Projects, *Available in* http://www.energyhouse.com/p_vietnam.htm, *January 24,2003.*

VASC (Vietnam Software Development Company) (2002), Industrial Zone Investment Opportunities: Taxation, *Available in* http://www.vnn.vn/province/zones5.htm, *Decemebr 30, 2002.*

VCPC (Vietnam Cleaner Production Center) (2003), News and Events Overview, *Available in* http://www.un.org.vn/vncpc/news/index.html, *January 6, 2003.*

Vina Econet (Vietnam Economic News Service Bullentin) (2002), Vinamilk Invests in Expanding Dairy Production, *Econet-Wednesday, January 8, 2002, Available in http://www.vnagency.com.vn/Econet/English/VE0801003.htm.*

Vina Econet (Vietnam Economic News Service Bullentin) (2003), *New Tapioca Mill Operational in Central Highlands*, Available in http://www.vnagency.com.vn/Econet/English/VE0901005.htm, January 9, 2003.

Vinacafe (Vietnam National Coffee Corporation) (2002a), Vietnamese Coffee to the World, *Available in* http://www.vinacafe.com.vn/vinacafe/index1.htm, *December 30, 2002.*

Vinacafe (2002b), Coffee Processing of VINACAFA, *Available in* http://www.vinacafe.com.vn/vinacafe/index2.htm, *December 30, 2002.*

Vinacafe (2002c), Coffee Plantation of VINACAFA, *Available in* http://www.vinacafe.com.vn/vinacafe/index3.htm, *December 30, 2002.*

Vinamilk (Vietnam Dairy Products Company) (2002), Introduction to VINAMILK, *Available in* http://www.vinamilk.com.vn/en/intro.asp, *December 19, 2002.*

Vietnam News, Friday, July 5, (2002), Vinamilk Rises to Top in Local Market, *Available in* http://vietnamnews.vnagency.com.vn/2002-07/04/Columns/Interview.htm, *December 12, 2002.*

VISTA (2003), Environment in Southern Economic Zones at SOS Level, *Available in* http://www.vista.gov.vn/VistaEnglish/news/3.htm, *January 10, 2003.*

Vu, D. D. and Cai, D. V. (2003), Participatory Research and Extension for Dairy Technology Development and Transfer in Vietnam: a Case Study, *Available in* http://www.ssdairy.org/Programme/, *January 14, 2003.*

Warner, N. (2003), The Riverside Eco-Park, *Available in* http://www.cfe.cornell.edu/wei/EIDP/Burlington.html, *February 25, 2003.*

APPENDICES

APPENDIX 1: INDUSTRIAL ECOSYSTEM PROJECTS

1 KALUNDBORG INDUSTRIAL PARK (referred from Côté and Hall, 1995; Cohen-Rosenthal and McGalliard, 2003)

An unique industrial ecosystem has been slowly evolving in Kalunborg, Denmark and has become a favorite example for industrial ecology enthusiasts. Located roughly 75 miles east of Copenhagen, Kalundborg is a small industrial area on the Danish coast (Cohen-Rosenthal and McGalliard, 2003). The industrial symbiosis began to evolve in the 1970s, as several of the core partners, truing to reduce costs and meet regulatory goal, sought innovative way of managing waste materials and using freshwater more efficiently. The partners making up the Kalunborg system include, among others:

- *Asnaes Power Station.* Commissioned in 1950, the coal-fired plant boasts a 1,500 Mwe capacity. The same company also operates a fish farm.
- *Statoil Refinery.* One of Denmark's largest refineries with a capacity of between 3-4 million tons/year
- *Gyproc.* Manufactures gypsum-based wallboard.
- *Novo Nordisk.* Produces a significant amount of the world's insulin supply and certain industrial enzymes.
- *City of Kalundborg.* Provides district heating services to the town's residents.
- *Local farmers.* Many hundreds of farms producing a variety of crops are located within the area.

A number of symbiotic connections have developed between major and minor partners. The Statoil refinery distributes sulfur byproducts to a sulfuric acid manufacture and hot water to local greenhouses. Waste heat and steam from the Asnaes Power Station are used by Novo Nordisk, which in turn distributes organic sludge from its manufacturing process to locals as fertilizer. The Kalundborg model goes beyond material exchanges and in a limited way towards other types of collaborations in worker training and worker safety (Gertler, 1995). However the primary focus remained on the material and energy exchanges. The symbiotic relationships between the core partners of Kalundborg and others that operate within the system is presented in Fig. A1.1. Energy and waste exchanges were originally designed to find financially rewarding uses for waste material or unused energy. However, over time, business managers discovered that significant environmental benefits were also resulting from the innovative system of exchanges. According to Jorgen Christensen, several principles assisted the symbiotic in Kalundborg:

- the industries fit together;
- the geographical distance waste not too large;
- the 'mental distance' between participants was short (they all knew each other);
- the incentive was a sustainable economy with commercially sound agreements;
- cooperation was voluntary but conducted in close collaboration with regulatory authorities.

Environmental savings of Kalundborg are indicated by:

- Reduced resource consumption

  + Oil : 19,000 tons/year
  + Coal : 30,000 tons/year
  + Water : 600,000 m^3/year

- Reduced emissions

  + CO_2 : 130,000 tons/year
  + SO_2 : 3,700 tons/year

- Reusing of waste products

  + Fly ash : 135 tons/year
  + Sulfur : 2,800 tons/year
  + Gypsum : 80,000 tons/year
  + Nitrogen in sludge : 800,000 tons/year

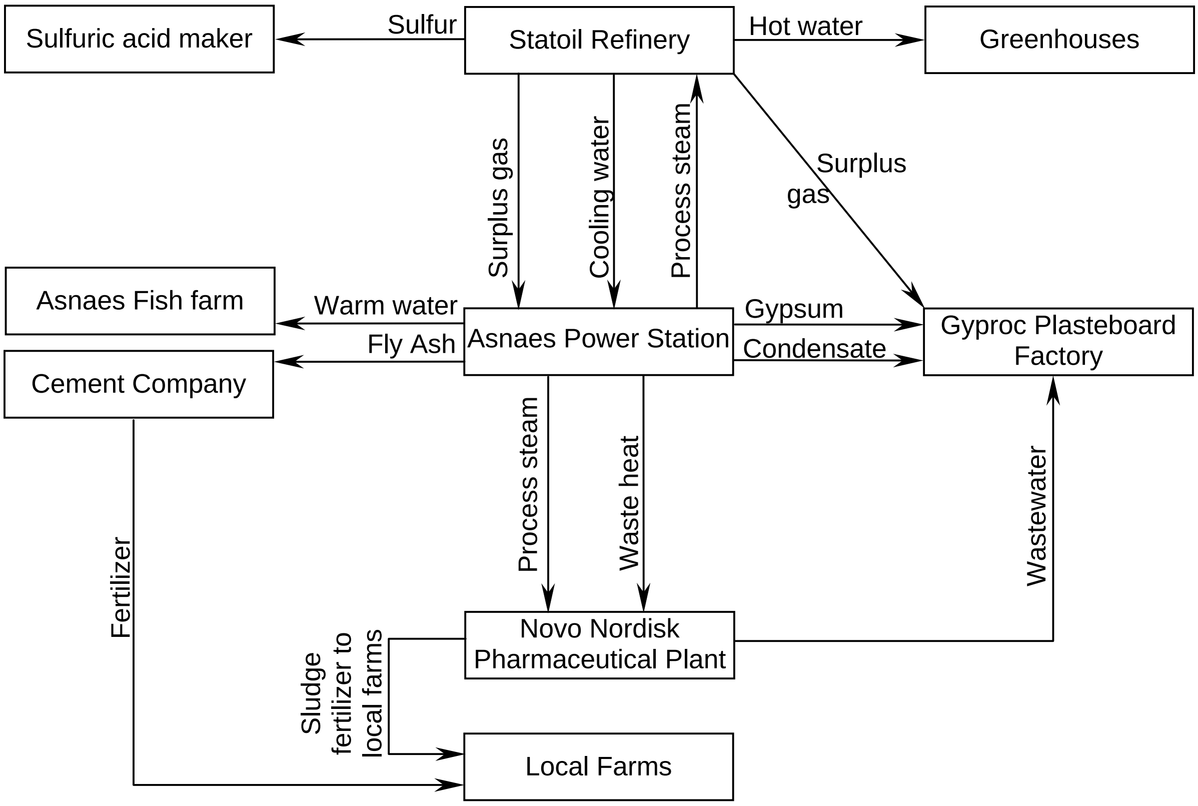


Fig. A1.1 Kalundborg Industrial Symbiosis (Cohen-Rosenthal and McGalliard, 2003).

2 BURNSIDE INDUSTRIAL PARK, Nova Scotia, Canada (Côté, 2001)

Burnside Indsutrial Park. Burnside Industrial Park locates in Dartmouth, Nova Scotia (Côté and Hall, 1995) on an area of about 760 ha (Lambert and Boons, 2002). This initiative, called "the industrial park as an ecosystem" started in 1992. There are approximately 1,300 companies and 17,00 employees in those businesses (Côté, 2001). The Park is one of the five largest in Canada.

Brunside is designated primarily to light manufacturing, distribution and commercial activities. One section of the Park is designated as a business park and attracts computer, health and technology companies. Although not specifically designated as such, another section has attracted many large trucking companies and their maintenance facilities. There is no "worker housing" at this time but there are two hotels in the park and constructing a third is being considered. Table A1.1 lists some of the sectors represented in Burnside. Companies encompass the range of types from local to multinational. The scale of the business extends from a few employees to 250 people.

Development Standards. Since the inception of the "Burnside as an Industrial Ecosystem" project, the municipality has strengthened the standards which apply to the Park. The objectives and convenants are:

- to protect property values and enhance the investment of business located in the Park by providing a well-planned and maintained development;
- to create an attractive and efficient business environment through sound land use, planning and environmental management standards;
- to ensure harmonious relationships among uses.

Two of the standards are worth noting here: "*… incorporating conservationist principles, preservation and upgrading of existing topography, vegetation and cover in conjunction with supplementary planting and treatment of consistent and compatible nature. Interesting, distinctive and unique site features and relationships in the existing environment should be maintained". And "… the supplementary planting of native species".*

The convenants are intended "*to ensure that the Park continues to be developed in a manner consistent with superior aesthetic and environmental protection standards and with the declared intention of creating a pleasant and harmonious environment for the Park's residents*". The requirements apply to architecture, landscaping, signage, protection of natural areas particularly streams, lakes and wetlands, and require buffer zones of undisturbed habitat or suitable green spaces around all watercourses.

Table A1.1 Sectors represented in Burnside Industrial Park

Sector	Sector
Accommodations	Distribution
Adhesives	Door & window manufacturing
Air conditioning	Electrical equipment
Automotive repair	Environmental services
Beverage products	Furniture manufacturing
Building materials	Food equipment
Business centers	Industrial equipment
Business firms	Steel fabrication
Carpeting and flooring	Machine shops
Chemical processing	Medical equipment
Commercial cleaners	Paint recycling
Clothing manufacturers	Paper/cardboard products
Communications equipment	Printings
Computer assembly and repair	Metal plating
Construction	Refrigeration
Containers and packaging	Transportation
Dairy products	Warehousing

Source: Côté, 2001.

Burnside as an Industrial Ecosystem. Largely because of its diversity, the park was selected a working laboratory for assessing strategies which would create inter-relationships between companies and between companies and their environment. In an initial study, a research team identified a number of strategies, guidelines, potential symbiotic relationships and support systems, which would facilitate the transformation of Burnside. Table A1.2 lists these support systems while Table A1.3 lists the strategies, which have been the focus of the continuing work.

Table A1.2 Support systems for designing, operating and transforming parks, estates into eco-industrial systems

No.	Support system
1	Information clearinghouse
2	Material exchange
3	Environmental audit capability
4	Educational and training program
5	Applied research programs
6	Enforcement of standards and regulations

Source: Côté et al., 1994.

Table A1.3 Strategies for designing, operating and transforming industrial parks into eco-industrial systems

No.	Support system	No.	Support system
1	Site selection	10	Inventory control
2	Site design	11	Co-location of businesses
3	Building design and construction	12	Material cycling and exchanges
4	Conservation of energy resources	13	Information collection and management
5	Substitution of materials	14	Encouraging “scavengers and decomposers
6	Using environmentally friendly products	15	Cascading materials
7	Environmental reviews or audits	16	Feedback and communication
8	New product development	17	Packaging waste reuse and reduction
9	Standardization		

Source: Côté et al., 1994.

Eco-Industrial Development. Burnside Industrial Park has sevred as an eco-industrial laboratory over the past 9 years. However, while investigating the application of eco-industrial development strategies, it collaborated with the municipality attempting to transform the existing infrastructure and companies while influencing the nature of the new infrastructure and industrial operations. Collaboration and networking has occurred at different levels: (1) the university and the municipality in studying the application of industrial ecology in the development towards an industrial park; (2) the university, the private electric utility company and governments in the creations of the Eco-Efficiency Centre; (3) material exchanges between two or more companies; (4) establishment of new companies taking advantage of opportunities in reuse, rental, repair, re-manufacturing and recycling. Two aspects, which are emphasized in the future are supply chain management of materials within the park and partnerships or joint ventures in the recovery of wasted materials. Collaboration with industry groups and governmental organizations in environmental management training, which will result in increasing awareness and testing of eco-efficiency analysis tools, should result in an increased understanding of benefits.

While an interest in eco-industrial development and a willingness to participate are important for launching projects, the main success factor is a continuing commitment by a group of partners from government, industry, academia, and community organizations. Eco-industrial developments are not short-term initiatives. Without this commitment, projects cannot be sustained.

3 FAIRFIELD ECO-INDUSTRIAL PARK PROJECT, Baltimore, Maryland, USA (Cohen-Rosenthal et al., 2003)

Fairfield industrial park is located in the Southeastern portion of the City of Baltimore. Industry in the 2,200 acre of Fairfield primarily consists of producers with processes based on petroleum and organic chemicals (e.g., asphalt manufacturing and distribution, oil and chemical companies) and smaller companies which aid the larger producers (e.g., truckling, tire retreading and box manufacturing). Fairfield has been described as a "carbon" based economy (Cornell University Work and Environment Initiative, 1995). This creates a great opportunity for further recycling of organic compounds and is one of the reasons that park advocates remain confident about Baltimore being a model for future industrial development.

The Fairfield EIP will retrofit industrial ecology principles to help existing companies further develop and expand, and recruit companies with excellent environmental records that fit into the carbon-based economy. The strategy is to recruit the following types of enterprises:

- manufacturing that fits with the current ecology (e.g., chemical companies, film/photo companies);
- environmental technologies;
- recyclers and waste exchange.

This will help Fairfield to achieve its goal of no new environmental impact accompanied by substantial economic growth with job creation as a top priority. The plan called for active strategies to assure high quality jobs, which have good wages and benefits.

4 PORT OF CAPE CHARLES SUSTAINABLE TECHNOLOGY INDUSTRIAL PARK PROJECT, Eastville, Northampton County, Virginia (van Koppen and Mol, 2002; Cohen-Rosenthal et al., 2003)

Situated in Northampton County, one of Virginia's poorest counties, the Port of Cape Charles Sustainable Technology Industrial Park is an area plagued by poverty and unemployment. The need to revitalize this area prompted citizens to develop Northampton County's Sustainable Development Action Strategy, which has been adopted by the County Board of Supervisors. Part of the comprehensive strategy is to develop the Sustainable Technology Industrial Park. According to its principles, established in 1995, this EIP not only aims at supporting, attracting and creating ecologically compatible enterprises, but also at stimulating sustainable development of community (van Koppen and Mol, 2002). The 570 acre park has been custom-zoned as a Sustainable Technologies Industrial Zone treatment. The park's development mission is to:

- provide a national development model that promotes business, people, economy, and natural and cultural resources;
- create family-wage jobs and training opportunities;
- protect and enhance natural and cultural resources, demonstrate conservation and efficient resource use, develop and use industrial ecology principles;
- support private businesses and industrial development, and revitalize the local economy;
- develop the next generation of industrial facilities which combine profit, resource, efficiency, industrial ecology, and pollution prevention.

The first company to occupy the park will be Solar Building System, a Swiss company that produces photovoltaic panels that convert sunlight into electricity. The recruitment aim is to attract industries that, like Solar Building Systems, have minimal emissions. Northampton County hopes to maximize and sustain its assets, which include productive land, clean water, and natural and cultural resources, by targeting six key industries: agriculture, seafood and aquaculture; heritage tourism; arts, crafts and local products; research and education; and new industry.

5 BROWNSVILLE ECO-INDUSTRIAL PARK PROJECT, Brownsville, Texas (Brownsville Economic Development Council, 2003a, 2003b, Cohen-Rosenthal et al., 2003*)*

The Brownsville Eco-Industrial Park project is a community effort to promote industrial development in a manner that minimizes industry's impact on the environment. The goal is to develop a workable community of manufacturing and service businesses in the Brownsville/Matamoros region that promotes economic efficiency by facilitating interchanges of byproducts and waste which one company discards but another can use as production input (Brownsville Economic Development Council, 2003b).

Brownsville Industrial Park (Brownsville, Texas) is a 60-acre park with enough capacity for one million square feet of warehousing and light manufacturing. The anchor tenant is VF Knitwear, the world's largest apparel manufacturer, which has a 300,000 square foot state-of-the-art warehouse facility there to service its Mexico and Central America operations (Brownsville Economic Development Council, 2003a).

6 RIVERSIDE ECO-PARK PROJECT, Burlington, Vermont (Warner, 2003)

The Riverside Eco-Park, to be located on Burlington's Intervale, has been conceived as a partnership of the public, private and non-profit sectors after four years of planning. A bedrock principle for the facility is the use of bio-energy for the betterment of Burlingtons's economy and quality of life. The vision of the Eco-Park, a 10-acre parcel plus the McNeil Generating Plant in the Intervale section of Burlinton, Vermont, is to be a model of environmentally sound and equitable economic development. It will consist of a complex of greenhouses and building utilizing "waste" heat, a byproduct from the MCNeil Plant. The Eco-Park is envisioned to include a range of sustainable and restorative uses related to organic agriculture, biotechnology, aquaculture, and "living machine" technology.

7 FCN's ECO-INDUSTRIAL PARK CHENEY PROJECT (FCN Eco-park, 2003)

FCN Industrial Park Cheney is designed as an Eco-Industrial Park (EIP). In North America, there is a growing excitement about the possibilities reflected in EIPs. In the United States, the President's Council on Sustainable Development formed an active task force on EIPs as one element of building a sustainable economy. The Environmental Protection Agency and the Department of Energy have been exploring the possibilities for EIPs.

FCN Industrial Park is located in Cheney, Spokane County, Washington State, approximately 15 miles Southwest of the City of Spokane. Cheney is situated on one of the highest points of the Big Ben Plateau, at an elevation of 2,340 feet above sea level, surrounded by gentle rolling hills. FCN plans to develop medium size manufacturing and warehouse building with office space on the industrial park, which will be for lease. FCN's use of sustainable design is supported by Government Agencies and private organization with expertise and advice, and all buildings will be built with environmentally sound material and using energy saving technologies with which energy costs will be reduced up to 70%. No pollution will occur in any form. Even the tenants will manufacture or distribute environmentally sound products.

FCN has already 2 building on Parcel "1" and Parcel "2" for leasing. The City of Cheney has issued a building permit for parcel "1" which consist of 3.3 acres with a 15,000 sq.ft manufacturing building where the foundation is in place and the steel framing is at the site. The building is highly insulated which includes insulated foundation and is designed to use passive solar energy and geo-exchange heating and cooling systems. The building is leased to Conservation Investment Cheney Limited Partnership for manufacturing of house packages for sustainable housing. Parcel "2" is 2 acres and will be leased to TUW Technological University of Washington as Research Institute having a work and testshop consisting of 8,000 sq.ft and 2,000 sq.ft of office space for the Foundation for the Conservation of Nature. Further, there is very high interest for parcel 16 from a lightweight steel truss company, Ultra Span Steel Trusses, which has a very good selling computer design truss system.

8 CIVANO ECO-INDUSTRIAL PARK PROJECT, Tucson, Arizona (Spitzer, 1996).

Civano Business Park is an integrated development park that emphasizes on human interaction and environmental responsibility. The business that are being conducted enable the Civano Business Park to become a center of sustainable technologies and practices. The Cinavo will become more like an EIP as it starts to assemble more like a "virtual corporation", where business with certain core capabilities (e.g. making of PVs, electric vehicles, circuit board, steel fabricator, design firms, renewable construction, etc.) coordinate their activities, share resources, and participate in joint operation, such as water treatment and reduce dependence on transportation and increase competitiveness. The current aim is to attract companies that fit into the general concepts of a sustainable community. At present, the chief measure of success, besides simply being a viable business district, is to succeed in attracting critical "flagship" companies, that both set the philosophical tone for the business development, the use and production of renewable resource technologies and also promote the idea of a business park that is the center for sustainable technologies.

9 EAST BAY ECO-INDUSTRIAL PARK PROJECT, San Francisco Bay, California (Lowe, 2003)

Key features of East Bay Eco-Industrial Park include:

- The anchor for this EIP will be a resource recovery facility encompassing reuse, recycling, re-manufacturing, and composting;
- Our recruitment strategy will build from this base to include other companies including the plants in the park's vicinity, who participants and energy inputs or outputs will help build a web of byproduct exchange. Other potential recruits will be areas of new renewable materials and energy economy;
- Site selection and planning will emphasize on keeping the ecological value in balance with economic issues. The site will be "landscaped" to reflect native ecosystem characteristics;
- Design of park infrastructure and building will emphasize energy efficiency, use of renewable energy and material, and pollution prevention.

The byproduct exchange network strategy will be implemented through a survey of potential recruits, survey of neighboring business, study of county waste stream reports and workshops with potential recruits.

APPENDIX 2: INVENTORY SHEET

CENTEMA
CENTER FOR ENVIRONMENTAL TECHNOLOGY & MANAGEMENT
C4/5-6 Dinh Bo Linh, F.26, Binh Thanh, Hochiminh
Tel: 84.8.8981504 Fax: 84.8.8981505

SONADEZI BIEN HOA
BIEN HOA INDUSTRIAL ZONE DEVELOPMENT COMPANY
No. 1, Street No. 1. Bien Hoa 1 IZ, Dong Nai Povince
Tel: 61.836138 Fax: 61.836250

DATA COLLECTION ON
PRODUCTION TECHNOLOGY AND ENVIRONMENT
Of Industrial Production Units In Bien Hoa 1 IZ

I GENERAL INFORMATION OF FIRM

1. Name:..Year of establishment..............
2. Address:..
3. Tel:...Fax:..
4. Firm's owner

100% foreign investment
Joint-venture (ratio of capital investment from Vietnam party:......................%)
100% domestic investment

State owned Co-operative Co. Ltd. Private

5. Type of industry

- Textile, garment
- Rubber and rubber products
- Plastic and plastic products
- Construction materials
- Food processing
- Electric and electronic equipment
- Mechanic
- Metallurgy
- Chemical and chemical products
- Animal food processing

6. Total investment (VND/USD):..

- Floating capital:......................................% of total property
- Fixed capital:..% of total property
- Annual turnover:..(VND/USD)

7. Products

Name	% Capacity		Capacity (unit/year)				
	Domestic	Export	1996	1997	1998	1999	2000

8. Total area of the firm:..(m^2)

- Attach a photocopy of layout of the firm
- Area of used land is

Provided by the Government
Rent from the Government
Rented from other owners
Family own land

II PRODUCTION TECHNOLOGY

1. Manpower

Total staff and workers	Higher education level	Engineers	Intermediate level	Workers level > 4/7	Administrative staff

2. Production technology

2.1 Production processes

(Draw a diagram of the production process(es) in separate sheets, in which you clearly describe each operation unit with inputs, products, byproducts and wastes).

2.2 Production facilities (machine and equipment)

Machine	Quantity	Electric power	Made in	By year	Capacity	Operation regime				
						Continuous	intermittent	A	B	C

A: the system is operated automatically
B: the system is operated semi-automatically
C: the system is operated manually.

2.3 Machines and equipment improvement or modification

- Old machines and equipment, before 1975 ☐
- Some (part of) machines and equipment was re-installed ☐
- New system ☐

3. Raw materials and chemicals

Name	Demand (unit/year)	Sources		Consumed (unit/year)				
		Domestic (%)	Imported (%)	1996	1997	1998	1999	2000

4. Fuel demand (average from 1990 to now)

Fuel	Purposes	Quantity (unit/year)
Diesel oil		
Fossil fuel oil		
Gasoline		
Lubricant		
Coal		
Other		

5. Electricity

- Supplied by…………………………………………………………………………………………
- Demand:…………………………..(KWh/year)
- Electricity utilization ratio in accordance with supply sources:

  + National electricity network : ………………… (%)
  + Industrial Zone Power Station : ………………… (%)
  + Own Generator : ………………… (%)

6. Water

- Supplied by…………………………………………………………………………………………
- Demand:…………………………..(m^3/year), of which:

+ Supply for production processes: ………………… (m^3/year)
+ Domestic use : ………………… (m^3/year)

7. Land use (from 1990 to now)

- Total area : ………………… (m^2)
- Production area : ………………… (m^2)
- Green area : ………………… (m^2)
- Local transportation area : ………………… (m^2)

III ENVIRONMENTAL PROTECTION

1. Wastes

Wastes	Types	Unit	Average quantity
Wastewater	- Domestic wastewater	m^3/day	
	- Industrial wastewater	m^3/day	
Solid wastes			
Air pollutants			

2. Current waste management and treatment methods

2.1 Wastewater

- Sewer system

+ Have separate sewer network : ☐ yes ☐ no
+ Have a combine sewer network : ☐ yes ☐ no

- Wastewater treatment

+ Have a domestic wastewater treatment system: ☐
+ Domestic wastewater treatment process (briefly describe the treatment process and indicate the year, at which the system was put into operation)

+ Do not have domestic wastewater treatment system: ☐
+ Planning for treating of domestic wastewater treatment (briefly describe the treatment process, treatment units, construction plan and expected date to put into operation)

+ Have industrial wastewater treatment system: ☐
+ Industrial wastewater treatment process (briefly describing treatment process and indicate the year, at which the system was put into operation)

+ Do not have industrial wastewater treatment system: ☐
+ Planning for treating of industrial wastewater treatment (briefly describe the treatment process, treatment units, construction plan and expected date to put into operation)

+ Receiving body of effluents of the firm:

Industrial zone combined sewer ☐
Percolating through soil ☐
Rivers, lakes, canals ☐

+ Reuse wastewater: …………(m^3/year) to……………………………….. …………………

+ Other wastewater handling methods:………………………………………………………..
……………………………………………………………………………………………………
………………………………………………………………………………………

2.2 Solid wastes

- Reuse and recycling of solid wastes

Type of solid wastes	Reuse and recycling methods	Quantity (unit/year)

- Treatment of non-hazardous solid wastes

+ Disposing together with domestic solid waste ☐
+ Collecting and disposing by other companies ☐
(Name of those companies:……………………………………………………………………...
……………………………………………………………………………………………..
……………………………………………………………………………………………..)
+ Onsite treatment of solid wastes ☐ following the process as described below

- Treatment of hazardous solid wastes

2.3 Air pollutants

- Reuse waste heat ☐ Yes ☐ No
If yes, describe reuse method, for what purposes/processes

- Treatment of air pollutants Yes ☐ No ☐
If yes, describe treatment process and indicate the year, at which the system was put into operation)

If no, specifying the plan for treating air pollutants (briefly describe treatment process, treatment units, construction plan and expected date to put into operation)

3. Implementation of environmental pollution and safety monitoring program

- Not conducting monitoring program yet ☐
- Monitoring frequency

Every one month ☐ Every three months ☐ Every six months ☐ Once a year ☐

- Name of organization, which carried out environmental quality measurements:……………….
……
……
………………………………………………………………………………

4. Total investment for environmental protection

Activities	Investment (VND/year)							
	1993	1994	1995	1996	1997	1998	1999	2000

IV COMMENTS OF THE FIRM'S MANAGERS ON THE IMPLEMENTATION OF THE ENVIRONMENTAL MANAGEMENT & MONITORING IN THE IZ

Dong Nai, ……………………
Director of the Firm
(Signature and Stamp)

APPENDIX 3: LIST OF INTERVIEWEES

Within the framework of this study on greening food processing industry in Vietnam, semi-structured, open-ended interviews were conducted from 1999 to mid-2002. Interviews about the existing industrial environmental management in Vietnam were held with:

- **At national level**, Md. Chu Thi Sang (Head of Environmental Appraisal Divisions, National Environmental Agency, MOSTE), Mr. Phan Van Hoa (Environmental Expert, Vietnam Industrial Zone Authority);

- **At provincial level**, Md. Doan Thi Toi (Head of Environmental Management Division, DOSTE of HCMC), Mr. Le Van Khoa (Deputy of Environmental Management Division, DOSTE of HCMC), Mr. Phan Van Het (Vice Director, DOSTE of Dong Nai Province), Mr. Duc (Head of Monitoring Section, DOSTE of Dong Nai Province), Mr. Truong Ngoc Quang (Expert of Environmental Management Section, DOSTE of Dong Nai Province), Mrs. Thuy (Expert of Environmental Management Section, DOSTE of Dong Nai Province), Mr. Hoang (Vice Director, DOSTE of Tay Ninh Province), Mr. Phan Van Yen (Manager of Planning and Environmental Department, Dong Nai Industrial Zones Authority), Ms. Phung (Manager of Planning and Environmental Department, Dong Nai Industrial Zones Authority).

- **At industrial zone level**, Md. Chu Thi Thu (Director of SONADEZI, Infrastructure Investment and Development Company, Dong Nai), Mr. Nguyen Quang Thoa (Vice Director of Environmental Service Enterprise, SONADEZI), Ms. Vu Thuy Linh (Expert of Environmental Service Enterprise, SONADEZI), Mr. Tran Thanh Hong (First Vice-President, SEPZONE Linh Trung), Mrs. Le Xuan Hong (Manager, Utilities and Operations Department, Vietnam-Singapore Industrial Park, Co. Ltd.), Mr. Nguyen Van Leo (Expert, Management Board of Vietnam-Singapore Industrial Park), Mrs. Nguyen Ngoc Quynh (Specialist, Marketing Department of Tan Thuan Industrial Promotion Company, Hiep Phuoc Industrial Park), Mr. Dao Duc Tho (Specialist, Marketing Department of Tan Thuan Industrial Promotion Company, Hiep Phuoc Industrial Park).

- **At enterprise level** (within Bien Hoa 1 and Bien Hoa 2 IZ), Mrs. Pham Thi Lan (Director, Bien Hoa Sugar Company, Bien Hoa 1 IZ); Ms. Pham Thi Bich Ha (Expert, Quality Assessment Section, Bien Hoa Coffee Factory, Bien Hoa 1 IZ); Mr. Tam (Engineer, Technical Section, DIELAC Milk Company, Bien Hoa 1 IZ); Mr. Lam (Engineer, Technical Section, DIELAC Milk Company, Bien Hoa 1 IZ); Mrs. Thu (Manager, Dong Nai Ice Enterprise Bien Hoa 1 IZ); Mr. Hung (Manager, DONANEWTOWER Company, Bien Hoa 1 IZ), Mr. Vu Bao Toan (Administrator, PROCONCO Animal Food Company, Bien Hoa 1 IZ), Mr. Khuong (Head of Technical Section, PROCONCO Animal Food Company, Bien Hoa 1 IZ), Mr. Nguyen Viet Minh (Manager of Water & Wastewater Treatment Plant, Dong Nai Paper Company, Bien Hoa 1 IZ), Mr. Minh (Manager of Administration, Dong Nai Paper Company, Bien Hoa 1 IZ), Mr. Hung (Manager of Technical and Product Quality Section, Dong Nai Paper Company, Bien Hoa 1 IZ), Mr. Vu (Head of Technical Section, Thanh Thanh Company, Bien Hoa 1 IZ), Mr. Doang Huu Huan (Vice Director, Dong Nai Rubber Enterprise, Bien Hoa 1 IZ), Mr. Nguyen Hoang Thai (Vice Director, Tam Hiep Sport Shoe Enterprise, Bien Hoa 1 IZ), Mr. Phong (Expert, Mechanical-Electrical Section, VIKO MOONSAL Company, Bien Hoa 1 IZ), Mr. Nhu (Organization Manager, VIETRONIC Company, Bien Hoa 1 IZ), Mr. Phong (Expert, Mechanical-Electrical Section, THIBIDI Company, Bien Hoa 1 IZ), Mr. Dien (Head of Technical Section, Dong Nai Battery Enterprise, Bien Hoa 1 IZ), Mr. Dieu (Manager, VINAPRO Company, Bien Hoa 1 IZ), Mr. Dinh (Manager, Bien Hoa Chemical Factory, Bien Hoa 1 IZ), Mr. Le Minh Hung (Administrator, Dong Nai Garment Company, Bien Hoa 1 IZ), Mr. Thai (Expert of Technical Section, Dong Nai Cotton-Wood Company, Bien Hoa 1 IZ), Mrs. Ly (Manager, Dong Nai Cotton-Wood Company, Bien Hoa 1 IZ), Mr. Trung (Expert of Business Section, Commodities Export Company, Bien Hoa 1 IZ), Mr. Tam (Head of mechanical-Electrical Section, Dong Nai Industrial Garment Company, Bien Hoa 1 IZ), Mr. Phan Tat Dat (Vice Director, Dong Nai Chemical Factory, Bien Hoa 1 IZ), Mr. Hoa (Administrator, Bien Hoa Concrete Company, Bien Hoa 1 IZ), Mr. Hai (Expert of Technical Section, Long Bien Copper Wire Company, Bien Hoa 1 IZ), Mr. Chinh (Manager, Roofing and Construction Material Company, Bien Hoa 1 IZ), Mr. Tran Minh Tuan (Head of Technical Section and Environmental Officer, NESTLE VIETNAM Company, Bien Hoa 2 IZ), Mr. Thai Tien Dung (Technical Manager, VINGAL Steel Pipe-Hot Dip Galvanizing Co. Ltd., Bien Hoa 2 IZ), Mrs. Le Xuan Trang (Quality Assessment Manager, NOVARTIS (Vietnam) Ltd. Crop Protection, Bien Hoa 2 IZ), Mr. Tran Hoang Hai (Manager, HAPPY VINA Cookware Co. Ltd., Bien Hoa 2 IZ), Nakao Teruto (Director, Hisamitsu Vietnam Pharmaceutical Co. Ltd., Bien Hoa 2 IZ), Mr. Hai (Expert of Technical Section, SUN NETUREN Company, Bien Hoa 2 IZ).

- **At enterprise level**, outside industrial zones and industrial waste treatment companies, Mr. Trang Khanh (Director, Tinh Cong Electroplating Company, Ho Chi Minh City), Mr. Tang A Pau (Director, Thanh Lap Trading and Environmental Protection Co. Ltd. (Industrial Waste and Hazardous Waste Treatment, HCMC), Mr. Nguyen Huu Cau (Owner, Tan Phu Thinh Cardboard Wrapping Processing Enterprise, HCMC), Mr. Nguyen Huu Ben (General Director, Vietnam Australia Environment J. S. Co. (VINAUSEN), HCMC), Mrs. Nguyen Thi Hien (Director, Green Environmental Company, HCMC), Mr. Nguyen Dang Khue (Vice Director, Green Environmental Company, HCMC), Mr. Le Van Phuoc (Manager, Blue River Company, Ba Ria-Vung Tau Province), Mr. Diep (Manager, Tan Phat Rai Hazardous Waste Treatment Company, Dong Nai Province), Mr. Vu Van Thang (Manager, Tan Phat Rai Hazardous Waste Treatment Company, Dong Nai Province).

Regarding tapioca processing sector, the following interviews were held:

- Tapioca producing households in Tra Co Village, Nguyen Van Thinh (12, Tra Co Hamlet, Binh Minh Commune, Thong Nhat District, Dong Nai Province)[143]; Vu Thi Hoa (69, Tra Co Hamlet); Vu Ngoc Ly (67, Tra Co Hamlet); Nguyen Hoang Long (5, Tra Co Hamlet); Nguyen Van Huong (4, Tra Co Hamlet); Nguyen Cong Trinh (44, Tra Co Hamlet); Nguyen Van Dat (25, Tra Co Hamlet); Nguyen Ngoc Trai (63, Tra Co Hamlet); Nguyen Thi Phuong (557, Tra Co Hamlet); Nguyen Van Cong (130, Tra Co Hamlet); Tran Cong Giao (174, Tra Co Hamlet); Nguyen Cong Hau (200, Tra Co Hamlet); Nguyen Duc Hanh (235, Tra Co Hamlet); Vu Sinh Thien (258, Tra Co Hamlet); Nguyen Hung Vuong (645, Tra Co Hamlet); Nguyen Thi Hong (958, Tra Co Hamlet); Bui Thi Can (526, Tra Co Hamlet); Pham Thai Phi (225, Tra Co Hamlet); Vu Kim Trang (965, Tra Co Hamlet); Tran Thi Hang (221, Tra Co Hamlet), Nguyen Van Dan (271, Tra Co Hamlet); Bui Van Han (20, Tra Co Hamlet); Nguyen Thi Huong (68, Tra Co Hamlet); Vu Ngoc Hung (114, Tra Co Hamlet); Nguyen Ngoc Cuong (124, Tra Co Hamlet); Nguyen Phi Tuyen (226, Tra Co Hamlet); Nguyen Huu Thanh (186, Tra Co Hamlet), Nguyen Ba Khang (282a, Tra Co Hamlet).

- At Tra Co Village, fish cultural households, Mr. Nguyen Van Hien (Villager, tapioca wastewater fishpond owner); Nguyen Thi Thao (Villager, tapioca wastewater fishpond owner), Nguyen Van Hung (Villager, tapioca wastewater fishpond owner), Thao Son (Villager, tapioca wastewater fishpond owner), Mr. Tho (Villager, non-tapioca wastewater fishpond owner),

[143] Addresses of these households only differ in household numbers. Therefore, addresses of the other households are only indicated by their household numbers.

- Tan Chau-Singapore Company, Mr. Huynh Duy Hau (General Director, Tan Chau-Singapore Company, Tay Ninh Province), Mr. Tu (Head of Technical Section, Tan Chau-Singapore Company, Tay Ninh Province).
- Other tapioca processing companies, Mr. Le Ngoc Thach (Deputy General Director, Tay Ninh Tapioca Co. Ltd, Tan Binh, Thanh Hoa, Tay Ninh Province), Mr. Hoang (Deputy Director, VEDAN Company, Binh Phuoc Province).

Other related informants including Mr. Nguyen Danh Hung (Vice Director of Nha Be Petroleum Storage, PETROLIMEX), Mr. Nguyen Phi Hoa (Chief of Technical Section of Nha Be Petroleum Storage, PETROLIMEX).

APPENDIX 4: VIETNAMESE INDUSTRIAL WASTEWATER DISCHARGE STANDARDS

INDUSTRIAL WASTEWATER DISCHARGE STANDARDS (TCVN 5945-1995)

1 Scope

1.1 This standard specifies limited values of parameters and concentration of substances in industrial wastewater.

In this standard “industrial wastewater” means: liquid water or wastewater produced by reason of working of production processes taking place at any industrial, serving and trading premises, etc.

1.2 This standard is applied to control the quality of industrial wastewater before being discharged into a water body.

“Water body” means” inland water, including any reservoir, pond, lake, river, stream, canal, drain, spring or well, any part of the sea abutting on the foreshore, and any other body of natural or artificial surface or subsurface water.

2 Limitation values

2.1 Limited values of parameters and maximum allowable concentrations of substances in industrial wastewater before being discharging into water bodies are stipulated in Table A4.1.

2.2 Discharge standards applying for wastewater produced by specific industries such as paper, textile or oil industries are specified in separate standard.

2.3 Industrial wastewater of which the values of parameters and concentrations of substances are equal to or lower than the values specified in the column A are allowed to discharge into water bodies used as domestic water supply sources.

2.4 Industrial wastewater which the values of parameters and concentrations of substances are equal to or lower than the values specified in column B are allowed to discharge only into the water bodies used for navigation, irrigation purposes or for bathing, aquatic breeding and cultivation, etc.

2.5 Industrial wastewater of which the values of parameters and concentrations of substances are higher than the values specified in column B but not exceeding those specified in column C are allowed to discharge only into specific water bodies as permitted by authorized agencies.

2.6 Industrial wastewater of which the values of parameters and concentrations of substances are greater than those specified in column C are not allowed to discharge into the surroundings.

2.7 Standard methods for analyzing parameters and concentrations of substances in industrial wastewater are specified in other current TCVNs.

Table A4.1 Limited values of parameters and allowable concentrations of pollutants

No.	Parameter and substance	Unit	Limitation values		
			A	B	C
1	Temperature	^{O}C	40	40	45
2	pH value	-	6 - 9	5.5 – 9	5 – 9
3	BOD_5 (20^0C)	mg/L	20	50	100
4	COD	mg/L	50	100	400
5	Suspended solids	mg/L	50	100	200
6	Arsenic	mg/L	0.05	0.1	0.5
7	Cadmium	mg/L	0.01	0.02	0.5
8	Lead	mg/L	0.1	0.5	1
9	Residual chlorine	mg/L	1	2	2
10	Chromium (VI)	mg/L	0.5	0.1	0.5
11	Chromium (III)	mg/L	0.1	1	2
12	Mineral oil and fat	mg/L	Not detectable	1	5
13	Animal vegetable fat and oil	mg/L	5	10	30
14	Copper	mg/L	0.2	1	5
15	Zinc	mg/L	1	2	5
16	Manganese	mg/L	0.2	1	5
17	Nickel	mg/L	0.2	1	2
18	Organic phosphorous	mg/L	0.2	0.5	1
19	Total phosphorous	mg/L	4	6	8
20	Iron	mg/L	1	5	10
21	Tetrachloethylene	mg/L	0.02	0.1	0.1
22	Tin	mg/L	0.2	1	5
23	Mercury	mg/L	0.005	0.005	0.01
24	Total nitrogen	mg/L	30	60	60
25	Trichloethylene	mg/L	0.05	0.3	0.3
26	Ammonia (as N)	mg/L	0.1	1	10
27	Fluoride	mg/L	1	2	5
28	Phenol	mg/L	0.001	0.05	1
29	Sulfide	mg/L	0.2	0.5	1
30	Cyanide	mg/L	0.05	0.1	0.2
31	Coliform	MPN/100 ml	5000	10000	-
32	Gross alpha activity	Bg/L	0.1	0.1	-
33	Gross beta activity	Bg/L	1.0	1.0	-

WATER QUALITY - STANDARDS FOR INDUSTRIAL EFFLUENTS DISCHARGED INTO RIVERS USED FOR DOMESTIC WATER SUPPLY (TCVN 6980-2001)

1 Scope

1.1 This standard specifies limit values of parameters and concentration of substances in industrial wastewater based on loading of contaminants in the wastewater and flow rate of the receiving rivers.

In this standard “industrial wastewater” means: liquid water or wastewater generated from production, manufacture processes, business taking place at any industrial sectors. Distance between discharge points and receiving follows the existing regulations.

1.2 This standard is applied simultaneously with TCVN 5945-1995 and is used to control the quality of industrial wastewater before discharging into certain rivers or springs (simplified as rivers), which are domestic water supply resources.

2 Limitation values

2.1 Limited values of parameters and concentrations of contaminants in wastewater, corresponding to discharge loading to rivers having different water flow rates, should not be higher than the corresponding values indicated in Table A4.2.

Parameters, which are not mentioned in Table A4.2, have to follow the TCVN 5945-1995.

2.2 Methods of sampling, analysis, calculation and determination of each parameter and concentration are specified in other TCVNs or indicated by environmental authorities if using other methods.

Table A4.2 Limited values of parameters and allowable concentrations of contaminants in industrial wastewater before discharging into rivers using for domestic water supply

Parameter	Q > 200 m^3/s			Q = 50-200 m^3/s			Q < 50 m^3/s		
	F1	F2	F3	F1	F2	F3	F1	F2	F3
Color, Co-Pt, pH = 7	20	20	20	20	20	20	20	20	20
Odor	No	no	no	no	no	no	no	no	no
BOD_5 (20^0C), mg/L	40	35	35	30	25	25	20	20	20
COD	70	60	60	60	50	50	50	40	40
Total suspended solid, mg/L	50	45	45	45	40	40	40	30	30
Arsen, As, mg/L	0.2	0.2	0.2	0.15	0.15	0.15	0.1	0.05	0.05
Lead, Pb, mg/L	0.1	0.1	0.1	0.08	0.08	0.08	0.06	0.06	0.06
Mineral oil and fat	5	5	5	5	5	5	5	5	5
Animal vegetable fat and oil	20	20	20	10	10	10	5	5	5
Copper, Cu, mg/L	0.4	0.4	0.4	0.3	0.3	0.3	0.2	0.2	0.2
Zinc, Zn, mg/L	1	1	1	0.7	0.7	0.7	0.5	0.5	0.5
Total phosphorous, P, mg/L	10	10	10	6	6	6	4	4	4
Chloride, Cl^-, mg/L	600	600	600	600	600	600	600	600	600
Coliform, MPN/100 mL	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000

Q: water flow rate of river (m^3/s)
F: wastewater flow rate in 24 h (m^3/day);
F1: wastewater flow rate in the range of 50 m^3/day to less than 500 m^3/day
F2: wastewater flow rate in the range of 500 m^3/day to less than 5,000 m^3/day
F3: wastewater flow rate in the range of 5,000 m^3/day and higher than 5,000 m^3/day

APPENDIX 5: VIETNAMESE AIR QUALITY STANDARDS

AMBIENT AIR QUALITY STANDARDS (TCVN 5937-1995)

1 Scope

1.1 This standard specifies concentration limits of main constituents in ambient air (carbon monoxide, nitrogen dioxide, ozone, sulfur dioxide, lead particlate, suspended particles).

1.2 This standard is applied to evaluate ambient air quality and to monitoring of air pollution status.

2 Limitation values

The limits of main parameters in ambient air are shown in the Table A5.1.

Table A5.1 Ambient air quality standards

(mg/m^3)

Parameter	1 hr averaging time	8 hr averaging time	24 hr averaging time
CO	40	10	5
NO_2	0.4	-	0.1
SO_2	0.5	-	0.3
Lead (particulate)	-	-	0.005
O_3	0.2	-	0.06
Suspended particulate matter	0.3	-	0.2

Note: Standard methods of analysis of ambient air quality parameters are specified in available current TCVNs.

MAXIMUM ALLOWABLE CONCENTRATION OF HAZARDOUS SUBSTANCES IN AMBIENT (TCVN 5938-1995)

1 Scope

1.1 This standard specifies the maximum allowable concentration of some organic and inorganic hazardous substances in ambient air.

1.2 This standard is applied to evaluation of ambient air quality and to monitoring of ambient air pollution status.

1.3 This standard is not applicable to the workplace air quality.

2 Limitation values

Maximum allowable concentrations of the hazardous substances in ambient air are shown in Table A5.2.

Table A5.2 Maximum allowable concentrations of some hazardous substances in ambient air

(mg/m^3)

No.	Substances	Chemical formula	Average over 24 hrs	Maximum on once occasion
1	Acrylonitrile	$CH_2 = CHCN$	0.2	-
2	Ammonia	NH_3	0.2	0.2
3	Aniline	$C_6H_5NH_2$	0.03	0.05
4	Anhydrous vanadium	V_2O_5	0.002	0.05
5	Arsenic (inorganic compound as As)	As	0.003	-
6	Hydrogen arsenic	AsH_3	0.002	-
7	Acetic acid	CH_3COOH	0.06	0.2
8	Hydrochloric acid	HCl	0.06	-
9	Nitric acid	HNO_3	0.15	0.4
10	Sulfuric acid	H_2SO_4	0.1	0.3
11	Benzene	C_6H_6	0.1	1.5
12	Particles containing SO_2			
	- Dianas 85 – 90% SiO_2		0.05	0.15
	- Diatomic brick 50% SiO_2		0.1	0.3
	- Cement 10% SiO_2		0.1	0.3
	- Dolomite 8% SiO_2		0.15	0.5
13	Particles containing asbestos		None	None
14	Cadmium (metal and oxide) as Cd	Cd	0.001	0.003
15	Carbon sulfide	CS_2	0.005	0.03
16	Carbon tetrachloride	CCl_4	2	4
17	Chlorofom	$CHCl_3$	0.02	-
18	Tetraethyl lead	$Pb(C_2H_5)_4$	None	0.005
19	Chlorine	Cl_2	0.03	0.1
20	Benzidine	$NH_2C_6H_4C_6H_4NH_2$	None	None
21	Chromium- metal and compound	Cr	0.0015	0.0015
22	1, 2 – Dichlorethane	$C_2H_4Cl_2$	1	3
23	DDT	$C_8H_{11}Cl_4$	0.5	-
24	Hydrogen fluoride	HF	0.005	0.02
25	Formaldehyde	HCHO	0.012	0.012
26	Hydrogen sulfide	H_2S	0.008	0.008
27	Hydrogen cyanide	HCN	0.01	0.01
28	Manganese and compound (as MnO_2)	Mn/MnO_2	0.01	-
29	Nickel (metal and compound)	Ni	0.001	-
30	Naphthalene		4	-
31	Phenol	C_6H_5OH	0.01	0.01
32	Styrene	$C_6H_5CH=CH_2$	0.003	0.003
33	Toluene	$C_6H_5CH_3$	0.6	0.6
34	Trichloroethylene	$ClCH=CCl_2$	1	4
35	Mercury (metal and compound)	Hg	0.0003	-
36	Vinylchloride	$ClCH=CH_2$	-	13
37	Gasoline		1.5	5.0
38	Tetrachloroethylene	C_2Cl_4	0.1	-

Note: Standard methods of concentration of the substances are specified in available current TCVNs.

INDUSTRIAL EMISSION STANDARDS FOR INORGANIC SUBSTANCES AND DUSTS (TCVN 5939-1995)

1 Scope

1.1 This standard specifies the maximum allowable concentration of inorganic substances and dusts in industrial emission gases emitted into the ambient air.

This standard, "industrial emission gas" means: smoke, gas, or gases or smokes containing dusts, particulate or inorganic substances produced by sources of any industrial process, or by sources of any serving and trading activity, or by other activities.

1.2 This standard is applied to check concentrations of industrial emission gases before being emitted into atmosphere.

2 Limitation values

Maximum concentration of the inorganic substances and dusts in industrial gaseous emissions emitted by any source into atmosphere should be compliant with the values shown in Table A5.3.

The limited values of concentration of inorganic substances, particulate and dusts specified in column A are applied to the emission gases of existing sources, in column B are applied to all sources, from the date which are stated by environmental authority.

The limited values of concentrations of substances and dusts in emission gases or smokes created by particular sources (e.g. cement production, oil refinery, vehicle exhaust, etc.) are specified in separate standards.

Table A5.3 Maximum allowable concentration (MAC) of smokes, dusts and inorganic substances in the industrial emission gases

(mg/m^3)

No.	Parameter	MAC	
		A	B
01	Particulate in smoke of		
	- Heating of metals	400	200
	- Asphalt	500	200
	- Cement pant	400	100
	- Other sources	600	400
02	Dust		
	- Containing silica	100	50
	- Containing asbestos	None	None
03	Antimony	40	25
04	Arsenic	30	10
05	Cadmium	20	1
06	Lead	30	10
07	Copper	150	20
08	Zinc	150	30
09	Chloride	250	20
10	HCl	500	200
11	Flouride, HF (any source)	100	10
12	H_2S	6	2
13	CO	1500	500
14	SO_2	1500	500
15	NO_x (any sourc)	2500	1000
16	NO_x (acid manufacturing)	4000	1000
17	H_2SO_4 (any source)	300	35
18	HNO_3	2000	70
19	Ammonia	300	100

Note: Standard analysis methods of concentration of the parameters in the industrial emission gases are specified in current TCVNs.

AIR QUALITY – STANDARDS FOR INORGANIC SUBSTANCES IN INDUSTRIAL EMISSION DISCHARGED IN RURAL AND MOUNTAINOUS REGIONS (TCVN 6993-2001)

1 Scope

This standard is applied to control concentrations of emission from stationary emission sources and to estimate and appraise emission from a new established or (an) upgraded industrial production enterprise.

This standard concretizes TCVN 5939-1995 taking into account emission loading of industrial gases containing inorganic pollutants, which are emitted into the environment in rural and mountainous regions, as well as the technological level and operation area of the enterprise.

2 This standard was developed based on the following standards:

- TCVN 5939-1995 - Air Quality - Industrial Emission Standards of Inorganic Substances and Dusts;
- TCVN 5940-1995 - Air Quality - Industrial Emission Standards of Organic Substances;
- TCVN 6994-2001 - Air Quality - Standards for Organic Substances in Industrial Emission in Industrial Zones.

3 Limited values

3.1 Maximum concentrations of the inorganic substances and dusts in industrial emission gases, corresponding to the emitting flow rate, technological level, releasing into rural and mountainous regions, should not be higher than the values indicated in Table A5.4 with $K_v = 1.2$.

3.2 If environmental authorities request more detailed division of rural and mountain areas ($K_v \neq 1.2$), it is possible to use the values of K_v indicated in Annex A of TCVN 5994-2001 with corresponding K_Q and K_{CN} of emission sources to calculate allowable concentrations of air pollutants to be emitted.

Table A5.4 Maximum allowable concentration of inorganic substances in industrial emission at different emission flow rates and technological levels, released into rural and mountainous regions

(mg/Nm^3)

Parameters	Technological Level A K_{CN} = 0.5			Technological Level B K_{CN} = 0.75			Technological Level C K_{CN} = 1		
	Q_1 K_Q = 1	Q_2 K_Q = 0.75	Q_3 K_Q = 0.5	Q_1 K_Q = 1	Q_2 K_Q = 0.75	Q_3 K_Q = 0.5	Q_1 K_Q = 1	Q_2 K_Q = 0.75	Q_3 K_Q = 0.5
Antimony	16	13.5	9	22.5	16.875	11.25	30	22.5	15
Arsenic	7.2	5.4	3.6	9	6.75	4.5	12	9	6
Cadmium	0.72	0.54	0.36	0.9	0.675	0.45	1.2	0.9	0.6
Lead	7.2	5.4	3.6	9	6.75	4.5	12	9	6
Copper	14.4	10.8	7.2	18	13.5	9	24	18	12
Zinc	21.6	16.2	10.6	27	20.25	13.5	36	27	18
Chlorine	14.4	10.8	7.2	18	13.5	9	24	18	12
HCl	144	108	72	180	135	90	240	180	120
F or HF acid (all sources)	7.2	5.4	3.6	9	6.75	4.5	12	9	6
H_2S	1.44	1.08	0.72	1.6	1.35	0.9	2.4	1.5	1.2
CO	360	270	100	450	337.5	225	600	450	300
SO_2	360	270	180	450	337.5	225	600	450	300
NO_x (all sources)	720	540	360	900	675	450	1,200	900	600
NO_x (acid producing enterprises)	720	540	360	900	675	450	1,200	900	600
H_2SO_4	25.2	18.9	12.6	31.5	23.625	15.75	42	31.5	21
HNO_3	50.4	37.8	25.2	63	47.25	31.5	84	63	42
Ammonia	72	54	36	90	67.5	45	120	90	60

- Q_1 specifies emission sources, which emission flow rates (Q) are lower than 5,000 m^3/h;
- Q_2 specifies emission sources, which emission flow rates are in the range of 5000 $m^3/h \leq Q < 20{,}000\ m^3/h$;
- Q_3 specifies emission sources, which emission flow rates equals or are higher than 20,000 m^3/h;
- Technological level A is applied to industrial production units, which equipment is as modern as other developed countries in the world;
- Technological level B is applied to industrial production units (level C), after upgrading equipment and production processes following requirements of environmental authorities in order to meet Vietnamese standards on air emissions, or after improving equipment and production processes to suit their production demand. This is also the case of industrial production units, which have equipment of category A, but the equipment was put in operation before this standard is promulgated;
- Technological level C is applied to industrial production units, which were put into operation before 1994;
- K_{CN} : Coefficient representing technological level of equipment;
- K_Q : Coefficient representing scale of emission sources;
- K_v : Coefficient represents the division of regions;
- Kv = 1,2 (in rural and mountainous regions);
- K_{CN} = 0,6 (technological level A);
- K_{CN} = 0,75 (technological level B);
- K_{CN} = 1 (technological level C);
- K_Q = 1 (Q1);
- K_Q = 0,75 (Q2);
- K_Q = 0,5 (Q3).

APPENDIX 6: REUSE OF FIBROUS RESIDUES FROM TAPIOCA PROCESSING FOR ALCOHOL PRODUCTION

Reuse of fibrous residues and pulp from tapioca processing for alcohol production was investigated by Bi and Gouzhen (1996), Agu et al. (1997), and Sriroth et al. (2000). Among these reports, an excellent evidence for utilization of such wastes for alcohol production is a processing facility capable of producing annually 3,000 tons of industrial grade ethanol from cassava fibrous residues and pulp, which is located in Mingyang Starch and Chemical Products Factory, Gaungxi province, China anh has been operated since 1993. The success of this factory led to the establishment of a number of similar enterprises with total capacity of more than 50,000 tons per annum in Gaungxi province (Bi and Guozhen, 1996). A typical composition of dried fibrous residues and pulp, and solids of tapioca wastewater generated from this factory is presented in Table A6.1. Starch contained in the fibrous residues and pulp and in wastewater is converted to glucose by enzymes excreted from microorganisms. The glucose is subsequently metabolized to ethanol by fermentation. Both processes can be explained by the following reactions (Bi and Guozhen, 1996):

$$\underset{\text{Starch}}{nC_6H_{10}O_5} + \underset{\text{Water}}{nH_2O} \xrightarrow{\text{Saccharification}} \underset{\text{Glucose}}{n\,C_6H_{12}O_6}$$

$$\underset{\text{Starch}}{nC_6H_{12}O_6} \xrightarrow{\text{Fermentation}} \underset{\text{Ethanol}}{2nC_2H_5OH} + 2nCO_2 + \text{Heat}$$

Table A6.1 Composition of dried fibrous residues and pulp, and solids in wastewater as used for ethanol production in Guangxi

Composition	Unit	Fibrous residues and pulp	Wastewater solids
Water	%	14	14
Starch	%	38 - 42	65
Cellulose/hemi-cellulose	%	40 - 42	6
Protein	%	2 - 3	6 - 7
Lipids	%	1	3 - 4
Others	%	5	5

Source: Bi and Guozhen, 1996.

The complete process of ethanol production is described in Fig. A6.1 and the following description is based on the paper of Bi and Guozhen (1996). In the production process, wet fibrous residues and pulp are mixed with tapioca wastewater in the ratio of 2:1 to maintain the final starch concentration of about 8-10% of the total weight. Bi and Guozhen (1996) stated that achieving a starch concentration in this range is important to ensure that fermentation progresses efficiently and that process inputs are kept to a minimum. Too low concentration of starch leads to un-optimal substrate levels, while a too high concentration of starch causes difficulties in pumping. Starch gelatinization is a process of cooking the fibrous residues and pulp with wastewater (called slurry mixture) under pressure. This process can be conducted either in batch or continuously. However, utilizing fibrous residues, pulp and tapioca wastewater as raw materials, batch processing is preferable, as this process can be easily adapted to the variable characteristics of these substrates. The slurry mixture is cooled in a reaction vessel. The pressure within the vessel is maintained at 0.2-0.3 Mpa by steam, thus providing a cooling temperature between 120-130^{0}C, for 1-2 hours. After cooking, the liquor remains superheated at a temperature higher than 100^{0}C. Therefore it must be cooled by passing through a flash evaporator. At the flash evaporator, a great amount of water quickly vaporizes causing the liquor temperature to drop. Cooled liquor (at about 90^{0}C) is allowed to flow automatically into the saccharification tank and its temperature will be reduced to about 60^{0}C. Saccharification is initiated by the introduction of an amylase enzyme. After saccharification, hydrolyzed liquor is pumped to a fermentation tank to convert glucose into ethanol and carbon dioxide in less than 30 hours. Finally, ethanol is extracted from a mixture of ethanol, volatile and non-volatile substances by distillation. This phase results in the production of sludge containing about 3-7% of solids and less than 0.2% alcohol.

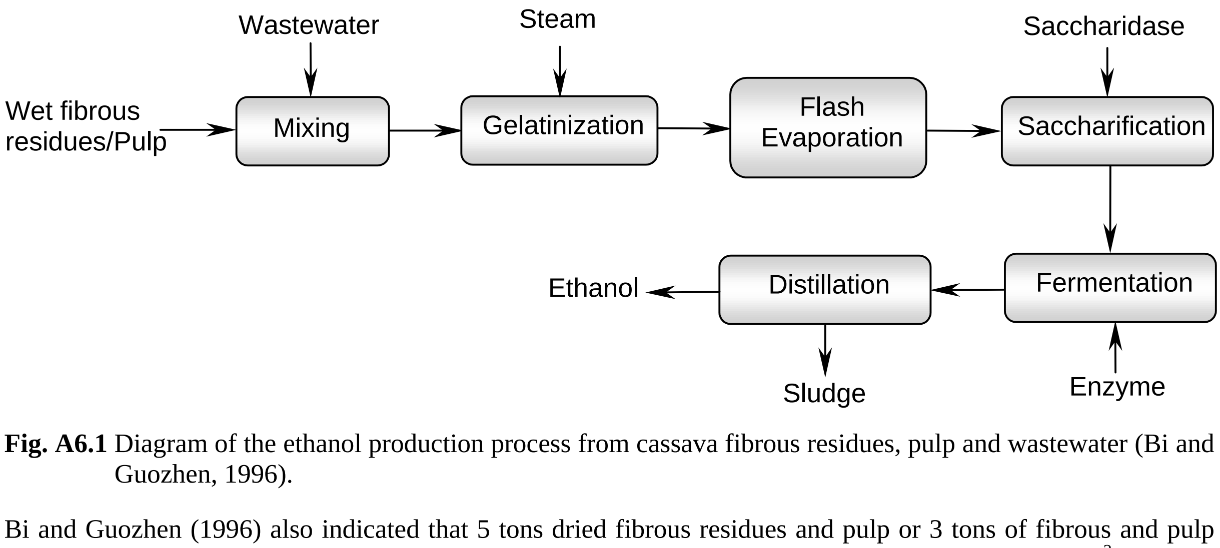


Fig. A6.1 Diagram of the ethanol production process from cassava fibrous residues, pulp and wastewater (Bi and Guozhen, 1996).

Bi and Guozhen (1996) also indicated that 5 tons dried fibrous residues and pulp or 3 tons of fibrous and pulp together with 1.5 tons of wastewater are required to produce 1 ton of ethanol. In addition, about 200 m^3 of water, 125 kWh of electricity and 1.5 tons of coal are consumed. Thus, if all solid non-products from tapioca processing of Tra Co village are reused for ethanol manufacturing, it will be sufficient to support a facility capable of producing 1,350 tons of industrial grade ethanol annually. In addition to the direct revenue generated from ethanol sales, the process contributes to the overall economic success of a starch processing operation by improving utilization of non-product materials. Beside benefiting from the consumption of starch in fibrous residues, pulp and wastewater for alcohol generation, energy is not required to dry the waste. With the current price of 8,000 VND/liter of industrial grade ethanol in Vietnam (equivalent to 0.533 USD/L at exchange ratio of the year 2001), income from reusing fibrous residues, pulp and tapioca wastewater to produce 1,365 tons ethanol per year is about 727,545 USD/year. When subtracting the money earned from selling ethanol (727,545 USD/year) of the production costs, which are about 30% of the total income, spent on electricity, energy, equipment, and labor, the net income will be about 509,282 USD/year or net profit is about 0.124 USD/kg of sun-dried materials. If sun-dried fibrous residues and pulp produced are sold as raw material for livestock food production, with a price of 0.0453 USD/kg of sun-dried materials, total net income is 183,600 USD/year. Thus, the profit from alcohol production is about 2.7 times higher than that of livestock food production. However, at present, the option to reuse fibrous residues and pulp for alcohol production is less attractive because of (1) more complicate production process, (2) less profit gained, and (3) creating other non-products that need to be treated. Bi and Guozhen (1996) indicated that for each ton ethanol produced, about 40 m^3 of sludge are created. In Gaungxi province, the sludge is treated by separating solids from the liquor and further fermented to produce feed-stuff. The liquid waste is treated biochemically to reduce BOD and COD in line with regulations of China (Bi and Guozhen, 1996). However, the alternative of reusing fibrous residues and pulp for alcohol production might be a possibility in the future, when the demand of alcohol as industrial raw material and as a fuel source increases.

APPENDIX 7: REUSE OF MOLASSES FROM SUGAR PRODUCTION IN FERMENTATION PROCESSES

Fermentation of molasses. Molasses from cane sugar manufacture has been an established substrate for rum manufacture and for limited production of industrial alcohol. In addition, molasses is used as an animal feed supplement and to a limited extent as a substrate for production of citric acid, glutamic acid, aconitic, glycerin, acetone, butanol, yeast and other fermentation byproducts (McNeil, 1984; Dat and Thanh, 1977).

Molasses of cane sugar obtained from raw sugar production is a complex mixture of fermented sugar, organic matters, nitrogen matters and other inorganic compounds. Composition of molasses from raw sugar production contains in average 25-40% of saccharoza, 12-13% sugar, 0.3 - 0.5% of nitrogen. Statistic data of molasses composition from different companies are summarized in Table A7.1. Composition of elements in ash of cane sugar molasses is presented in Table A7.2.

Table A7.1 Composition of molasses generated from raw sugar production

Unit: percentage

Molasses sample	Dry matters	Saccharoza	Sugar	Rafinoza	Ash	Organic matter	Total Nitrogen	P_2O_5	Quality index
Ivancovxki Distillery	81.45	52.23	8.07	1.97	3.5		0.19	0.036	74.36
Petrovxki Sugar Factory	81.00	-	1.80	-	-	-	-	-	61.90
Sugar Factories in USA	78.20	29.65	20.13	-	9.04	28.4	-	-	63.70
According to Andecoflera documents	83-85	30-40	12-18	-	7.0-10	20-25	-	-	-
Distilleries in England	-	39.65	25.51	-	11.74	23.4	-	-	63.6

Source: Dat and Thanh (1977).

Table A7.2 Composition of elements in ash of cane sugar molasses

Unit: percentage

Document	K_2O	CaO	MgO	P_2O_5	Fe_2O_3	SiO_2	SO_4^{2-}	Cl^-	Total
Mac-Djinnisa	3.5	1.5	0.1	0.2	0.2	0.5	1.6	0.4	8.0
Ndecoflera and Khiki	3.6	0.5	0.07	0.9	-	-	3.93	-	9.0

Source: Dat and Thanh (1977).

The molasses is pasteurized and diluted to different levels of sugar ratios 9-11% sugar for rum manufacturing or to 15-20% for industrial alcohol manufacturing. Molasses contains about 30-40% sucrose and 12-18% invert sugar. Following acidification with sulphuric acid and addition of nutrients, it is fermented by yeast for 24-48 hours at a temperature between 25^o and 35^{o}C. The fermentation generates heat and cooling water is required. The final yield of ethanol is approximately half the initial fermentable sugar concentration. Most yeast become sensitive to alcohol levels above 9-10% and this limits the initial sugar concentration and the fermentation rate. Yeast recycling is extensively practiced (McNeil, 1984).

In the following fermentation the alcohol passes a stripping column and continues to rectifying columns to reach levels up to 95% ethanol. The main waste is the stillage emanating from the first stripping column, otherwise known as vinasse, vinhoto, slops or dunder. Other wastewater is generated by washing the fermenters. Thus about 8-12 m^3 of stillage are discharged for each kiloliter of alcohol produced. Composition of molasses stillage can be referred from Table A7.3.

Distilleries located in rural areas can opt for irrigation under suitable conditions of climate, soil type and rainfall. The concept of disposing the nutrient substance in stillage back to the land is attractive. However, central distilleries can find it possible to irrigate only a fraction of the original growing area if massive transportation and pipeline costs are avoided. Careful monitoring of the soil and plant yields is required to avoid excessive salinity, deterioration in cane quality and rising levels of ash in juice. In addition, nitrogen and phosphorus supplements are required to avoid fertilizer imbalance (McNeil, 1984).

Table A7.3 Composition of molasses stillage (Australian sample)

Parameter	Unit	Concentration
pH	-	4.8
COD, total	mg/L	110,000
COD, soluble	mg/L	102,000
BOD, total	mg/L	73,000
BOD, soluble	mg/L	70,000
Total solid	%	11.9
Organic matter	%	8.8
Ash	%	3.0
Sulphate	mg/L	3,000
Total nitrogen	mg/L	2,300
Phosphate	mg/L	40
Potassium	mg/L	12,000
Sodium	mg/L	330
Calcium	mg/L	2,800
Magnesium	mg/L	1,700
Iron	mg/L	40
Manganese	mg/L	13

Source: McNeil (1984).

Studies in Brazil have shown that irrigation of stillage can improve soil and cane quality. Early reports quoted application rates of 419 m^3/ha (Guimares et al., 1968) and even up to 1000 m^3/ha (Monteiro, 1975). However, other studies in Brazil used dosage levels of only 35 m^3/ha (Brieger, 1977; 1979; Magro and da Gloria, 1977).

Cooper (1975) reports the application of stillage in Trinidad at rates of 61 to 185 m^3/ha, and notes that although cane sugar yields improved, the results were less favorable at the upper level. In Australia, Bieske (1979) has determined that the maximum application rate to sugar cane appears to be about 12 m^3/ha. This is due to the higher level of inorganic substances in Australian molasses. Bieske observed that this rate stillage was an effective source of potassium as muriate of potash in supplying the cane plants' requirements. Usher and Willington (1979) have reported the commencement of a trial in Australia with application rates of 100 m^3/ha.

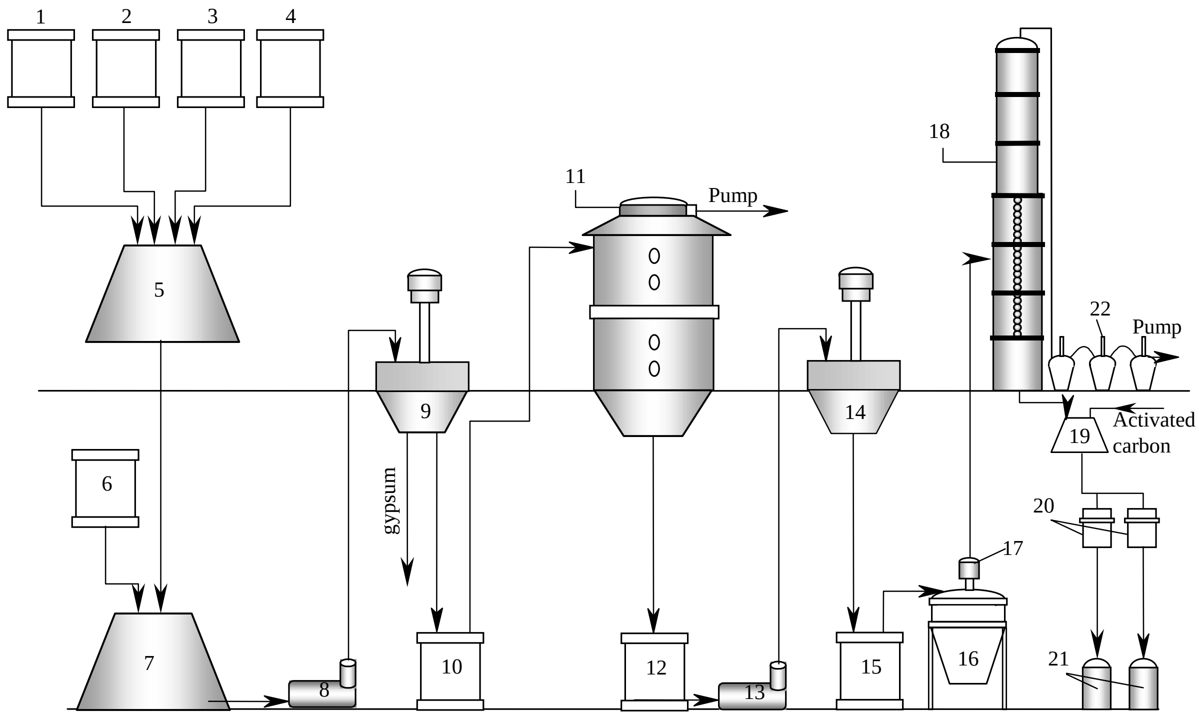
Some distilleries concentrate stillage to apply as a fertilizer or as an animal feed supplement. The degree of concentration only needs to be 30^o-35^o Brix but for purposes of transportation it should be concentrated to 60-65^0 Brix. Spray-dried material is hygroscopic and is therefore difficult to handle. In France, Lewicki (1978) reports applications of 60% stillage at rates of 2.5 to 3 ton/ha. Dubey et al. (1977) concentrate stillage to 75-80^o Brix mixed with cane factory filter mud to sell as a fertilizer.

The application of stillage as a fodder additive appears to have limitations due to vagaries of market conditions for animal sales and the prices of other fodders. The value of stillage as a food supplement is limited by the laxative effects of the inorganic constituents (Jackman, 1977). In addition, the cost of evaporation is high and distilleries will find it preferable to concentrate stillage to 60-65^0 Brix for incineration. The combustion at these concentrations is autothermal and the released energy is said to be sufficient to maintain the evaporating station (Jackman, 1977). Further, the ash is rich in potassium, which may have market value as fertilizer.

A limited amount of stillage is used for the production of biomass. Certain yeasts and fungi are able to grow in stillage by utilizing some of the residual sugar, organic acids and glycerol. The potential yield of biomass will depend on the organic content of the stillage. Kujaha et al., (1976) consider an average yield from molasses stillage would be 1 ton of yeast from 100 tons of stillage. However, large-scale production of biomass from stillage seems very doubtful. Firstly, protein prices greatly affect the economics of the process. Secondly, the production costs are relatively high. Nutrient additions of nitrogen and phosphorus are required, contributing up to 50% of the cost (Jackman, 1977). Heat is generated at the rate of about 3870 kcal/kg of yeast (Kujala et al., 1976) and expensive cooling equipment if required in hot climates. Aeration costs are also high. Finally, the reduction in organic matter is usually only 50-80%. Thus, there would still be highly polluting effluent from the biomass production.

Bread yeast production from molasses. Cane sugar molasses have been used as raw material for yeast production by many countries in the world (Dat and Thanh, 1977), for instance, a yeast production factory from cane sugar molasses with a capacity of 4000 ton/year was constructed in Jamaica. However, as cane sugar molasses has a dark color and a low nitrogen content, therefore, it has to be used in a mixture with beet sugar molasses for bread yeast production. Biotin in cane sugar molasses is very high, while pantotenic acid is relatively low. The use of mixture of these molasses creates suitable concentrations of growth stimulants and therefore, fermentation performance is high. Application of beet and cane sugar molasses mixture is efficient in Dovenkurta Yeast Factory (England) for producing bread yeast by Olsen and Tsima continuous method (Dat and Thanh, 1977).

Lactic acid production from molasses. Molasses is used as a carbon source to produce lactic acid. The lactic acid production process has been developed by academician Saposmikove, V.N. as presented in Fig. A9.1.



1-Water container, 2-Lime container, 3-Molasses container, 4-Nutrient container, 5-Fermentation reactor, 6-Sulphuric acid container, 7-Temporary container, 8-Pump, 9-Centrifuge, 10-Container of raw and low concentration lactic acid, 11-Vacuum pump, 12-Lactic acid container, 13-Pump, 14-Centrifuge, 15-Concentrated lactic acid container, 16- Distiller, 17-Filter, 18-Distill column, 19-Served container, 20-Porcelain filtration system, 21-Clean lactic acid powder, 22-Porcelain filtration system.

Fig. A9.1 Lactic acid production process from sugar molasses by distillation method.

One ton of produced lactic acid requires 2.5 - 3.5 ton of cane sugar molasses and other additives as follows:

- H_2SO_4 (d = 1.84)	0.8 ton/ton;	- Lime	0.2 ton/ton;
- Carbonate calcium	1.5 ton/ton;	- Activated carbon	0.01 ton/ton;
- Ferocyanua potassium	0.01 ton/ton.		

Lactic acid is used popularly in cake-candy, canned food, none alcohol beverage industry as well as pharmaceutical industry.

APPENDIX 8: ESTIMATION OF DOMESTIC WASTEWATER FLOW RATE AT BINH MINH COMMUNE

Households

- Population of Binh Minh Commune N = 15,160 persons
- Wastewater generation standard: q_0 = 150 L/person.day

$$Q_{ng}^{TB} = \frac{N \times q_o}{1000} = \frac{15160 \times 150}{1000} = 2274 \text{ m}^3/\text{day}$$

Schools

- 3486 pupils from 1 primary school, 2 secondary schools, and 3 kindergartens
- Wastewater generation standards q_0 = 20 L/person.day
- Working hours: 7h – 17h
- K_h = 1,8

$$Q_{ng}^{TB} = \frac{3486 \times 20}{1000} = 69.72 \text{ m}^3\text{/day}$$

Table A8.1 Changes in domestic wastewater flow rate of residential areas

Hours	Households		Schools		Total Q (m^3)
	K_h = 1,8		K_h = 1,8		
	%	Q(m^3)	%	Q(m^3)	
0 - 1	1.25	28.42			28.42
1 - 2	1.25	28.42			28.42
2 - 3	1.25	28.42			28.42
3 - 4	1.25	28.42			28.42
4 - 5	1.25	28.42			28.42
5 - 6	3.30	75.04			75.04
6 - 7	5.00	113.7	8.42	5.87	119.57
7 - 8	7.20	163.73	7.55	5.26	168.99
8 - 9	7.50	170.55	7.55	5.26	175.81
9 - 10	7.50	170.55	7.55	5.26	175.81
10 - 11	7.50	170.55	7.55	5.26	175.81
11 - 12	6.40	145.53	7.55	5.26	150.79
12 - 13	3.70	84.14	15.20	10.60	94.74
13 - 14	3.70	84.14	7.55	5.26	89.40
14 - 15	4.00	90.96	7.55	5.26	96.22
15 - 16	5.70	129.61	7.55	5.26	134.87
16 - 17	6.30	143.26	7.55	5.26	148.52
17 - 18	6.30	143.26	8.43	5.88	149.14
18 - 19	6.30	143.26			143.26
19 - 20	5.25	119.38			119.38
20 - 21	3.40	77.31			77.31
21 - 22	2.20	50.02			50.02
22 - 23	1.25	28.42			28.42
23 - 24	1.25	28.42			28.42
Total	100	**2273.93**	100	**69.69**	**2343.62**

SUMMARY

The significant contribution to Vietnam's gross domestic product over the years give evidence of the important role of food processing industry in the economic and industrial development of the country. This is even more relevant from now onwards, as it is Vietnam's development strategy to become one of the top agricultural countries in the world by the year 2010. However, it is not difficult to recognize that the rapid growth of food processing industry in Vietnam goes together with environmental deterioration and puts stress on natural resources. So far, most efforts in environmental management of (food processing) industry in Vietnam have mainly been focussing on dealing with wastes and emissions after they have been generated. While to some extent, this end-of-pipe approach helps to reduce or eliminate adverse environmental impacts from the generated wastes and emissions, in most cases, the isolated implementation of this approach shows several disadvantages, shortcomings and inefficiencies. Thus, it should not surprise us that environmental quality in Vietnam is still poor, although the end-of-pipe approach has been implemented from the early 1990s onwards.

In order to reduce present and future threats to human health and the environment, industrialized countries have developed and introduced alternative approaches, which can overcome some of the weaknesses of end-of-pipe treatment solutions and are more (economic and environmentally) effective and efficient in reducing the generation of wastes. From existing literature and the experiences of industrialized countries we can clearly envision various advantages of environmental protection strategies that are based on cleaner production, waste exchange (offsite reuse and recycling) or industrial ecology approach instead of end-of-pipe treatment solely. Certainly, each of these approaches can only be applied successfully in some circumstances and is limited in others. Therefore the combination and integration of some or all these approaches is often seen as the best or only strategy to overcome the continuing environmental deterioration. This potential is investigated in this study. The core objective of this research is to analyze and assess the possibilities and the potency for greening food processing industries in Vietnam, based on the combination and integration of existing pollution treatment and prevention approaches. More specifically, this study seeks to fulfil the questions on: how to apply and adapt the existing experiences of industrial ecosystem from highly industrialized Western countries to develop an (agro)-food processing industrial ecosystem with the existing institutions, technological and socio-economic conditions of Vietnam? Whether it is possible to apply these ideas for large stand-alone firms as well as small (household) and medium sized (agro)- food processing companies? What would be core features of a zero waste industrial ecosystem model of food processing industry in Vietnam? Which actors, institutions and relations are crucial or potentially crucial to introduce the proposed model in practice?

Dealing with these questions, a methodology to analyze and design pollution prevention models for (agro-food processing) industries, integrating the physical-technological and socio-institutional models is developed. Using various theoretical ideas of cleaner production/waste minimization, waste exchange and industrial ecology, a methodology towards physical-technological models of a zero waste industrial ecosystem is established having four basic steps. The methodology starts with analyzing the material and energy flows that run through the industrial systems and partly end up in wastes, followed by analyzing various possibilities to prevent the generation of wastes in the second step. The third step concentrates on identifying, analyzing and designing potential offsite recovery and reuse options. The last step entails the identification of remaining wastes that need to be treated properly before discharging into the environment. Together, these four steps form a systematic methodology that leads us towards (close to) a physical-technological model for a

zero waste industrial ecosystems. In addition, taking into account complex political, economic and social relations between the industrial system and actors outside, the triad-network model developed by Mol (1995) is applied to complement the physical-technological model with an actor and institutional analysis. The roles of actors and the interrelations between them and industrial systems are investigated in three networks: economic, policy and societal network.

The applicability of the developed methodology is assessed by applying it on different cases of the Vietnamese food industrial sector. Three case studies (at tapioca producing households in Tra Co Village, a large-scale tapioca processing plant of Tan Chau-Singapore Company, and food processing companies in Bien Hoa 1 IZ) represent differences between: (1) small/household-scale enterprises and large-scale companies; (2) one enterprise and a group of enterprises; (3) a group of enterprises from one industrial sector and a group of enterprises from different industrial sectors (but still within the broad category of agro-food industries); (4) enterprises located within and outside industrial zones, as industrial zones have specific advantages in industrial ecology design.

In general, these case studies illustrate that excessive generation of non-products (including reusable/valuable materials, wastes and air pollutant emission) arises due to: inefficient technology, inadequate processing, inadequate onsite and offsite reuse and recycling, cheap natural resources, financial limitations, no strict enforcement and lack of incentives on pollution prevention.

Experiences from the three case studies have made clear that failures in current environmental management due to improper performance of the existing actors and institutions can be indicated in the following five points. First, state environmental management authorities, especially provincial DOSTEs, face difficulties of high workload, lack of expertise, and scare resources for monitoring and enforcement. Second, specific regulations and incentives for producers to make their production processes more ecologically sound and to reuse and recycle wastes are completely lacking at the moment. Third, influences from economic agencies do not seem to encourage producers to improve their production efficiencies and environmental performances. Fourth, there is hardly any enduring relation between research institutes and the producers in neither production nor environmental protection. Finally, civil society is not actively involved in environmental issues.

Seeking possibilities to overcome the causes of excessive generation of non-products, these case studies have revealed that cleaner production, waste exchanges and ideas of industrial ecology are valuable in greening food processing industry, though the feasible technical options and organizational schemes are different in the different cases. The diversity of industrial system situations in Vietnam in terms of scale, size, industrial sector and location causes a number of dissimilarities in the proposed options and implementations to approach a zero waste (food processing) industrial ecosystems. Therefore, this study concludes that any general or national approach to green food processing industry is doomed to fail in practice if in its operationalization these differences are not taken into account. Though several constraints (in terms of technical dimensions, environmental policy, economic aspects and public participation) hampering the implementation of the proposed physical technological models of zero waste industrial ecosystems were found from the case studies, there also appear several opportunities to overcome these constraints.

The possibilities and approaches for greening food processing industry in Vietnam learned by experiences from these case studies can be generalized in a physical-technological model, in which (food processing) industry and agriculture cooperate. This model consists of food processing enterprises and all or some of the following components: other enterprises, which use products from food processing enterprises as raw materials, livestock feed production enterprise, fish culture households, livestock breeding households, composting plant, biogas production plant, agricultural fields and wastewater treatment plant. Though operationalization of this physical-technological model will vary due to the diversity of (food processing) industrial systems, this generalized model is the foundation for governmental authorities, planers, policy makers and environmentalists in reforming existing industrial systems and establishing new industrial systems as well.

Though several similarities and dissimilarities arose from the three case studies, it is possible to draw two general conclusions on the proposed methodology. First, the methodology to design a physical-technological model of a zero waste industrial ecosystem following four basic steps proved feasible to apply to any industrial system. Second, the case studies show that without an analysis of actor and institutions, any physical-technological model remains a theoretical possibility at best. An analysis of actors and institutions following a triad-network model proved useful in all studied industrial systems.

At last, this study specifies five crucial points, which reflect the very Western ideas of Industrial Ecology Concept when applied in Vietnam. First, the industrial ecology concept has been applied especially in Europe and USA market economics with advanced technological systems, while Vietnam is a less technological development country. Therefore, with the same kind of industrial sector, the application of industrial ecology in Vietnam will differ from European and American ones. Second, in Vietnam, the organizational and institutional structures around industry and industrial systems are in general simpler than what we see in Western countries. This means that an operationalisation of industrial ecology can rely less on all kinds of advanced organizational models. Third, a number of socio-institutional conditions that are crucial for advancing and implementing industrial ecology models in practice as present in advanced industrialized societies are absent or less developed in Vietnam. Thus, developing feasible options that have a high chance to be implemented and succeed in Vietnam will be different from those developed in advanced industrialized countries. Fourth, Vietnam still has a large number of reuse and recycling practices that are not so much motivated by environmental considerations but rather by economic ones. With further development of the economy in Vietnam, these existing recycling and reuse practice might come under pressures and need to be ‘protected’: that is an active industrial ecology policy needs to be developed to continue these practices. Finally, the large agricultural sector together with the large proportion of the land used for agricultural production opens favorable conditions for agro-industrial ecology models and practices in Vietnam.

SAMENVATTING

De voedingsmiddelenindustrie in Vietnam speelt een belangrijke rol in de industriële en economische ontwikkeling van het land. Dit blijkt uit de significante bijdrage van deze industriële sector aan het bruto nationaal product in de afgelopen jaren. Deze rol wordt alleen maar groter, omdat de Vietnamese regering het plan heeft om in 2010 bij de top van de agrarisch producerende landen in de wereld te horen. Voor de hand ligt dat deze snelle groei samen gaat met milieubelasting en druk op natuurlijke hulpbronnen. Tot op heden heeft milieumanagement in Vietnam zich hoofdzakelijk geconcentreerd op het achter of bestrijden van emissies. In sommige gevallen maken deze end-of-pipe benaderingen het mogelijk milieuvervuiling en emissies te voorkomen. Toch heeft in de meeste gevallen de geïsoleerde implementatie van deze benadering nadelen, tekortkomingen en is het inefficiënt. Daarom moet het niet verbazen dat het milieu in Vietnam in slechte staat verkeerd, terwijl de end-of-pipe technologieën reeds worden toegepast vanaf 1990.

Om de huidige en toekomstige bedreigingen voor de volksgezondheid en het milieu in de hand te houden, hebben geïndustrialiseerde landen alternatieve benaderingen geïntroduceerd, die de tekortkomingen van end-of-pipe oplossingen kunnen overwinnen. Bovendien zijn deze benaderingen (op economisch en milieugebied) effectiever en efficiënter in het reduceren van emissies. Uit literatuur en praktijkervaringen van geïndustrialiseerde landen kunnen we een helder beeld krijgen van de verschillende voordelen van milieubeschermingstrategieën, die gebaseerd zijn op afvalstoffenuitwisseling (extern hergebruik en recycling) en de industriële ecologie benadering, in vergelijking met het uitsluitend toepassen van end-of-pipe technologieën. Natuurlijk kunnen elk van deze benaderingen alleen succesvol worden toegepast onder bepaalde omstandigheden en is de toepassing in andere situaties beperkt. Daarom wordt vaak de combinatie en integratie van sommige van deze benaderingen beschouwd als de beste of zelfs de enige strategie om de voortdurende aantasting van het milieu te voorkomen. Deze integrale strategie is onderzocht in deze studie. Doelstelling van dit onderzoek is het analyseren en vaststellen van de mogelijkheden en de potentie tot “greening” van de voedingsmiddelenindustrie in Vietnam, gebaseerd op het combineren en integreren van de bestaande emissiebehandelmethoden en preventie. In het bijzonder probeert dit onderzoek antwoord te geven op de volgende vragen: Hoe moeten de bestaande ervaringen van industriële ecosystemen ontworpen voor sterk geïndustrialiseerde westerse landen worden toegepast en aangepast zodat een industrieel ecosysteem kan worden ontwikkeld voor de (agro-) voedingsmiddelenindustrie in Vietnam met de bestaande instituties, technologieën en sociaal economische condities? Is het mogelijk deze ideeën toe te passen op grootschalige zelfstandige voedingsmiddelen producerende bedrijven, als mede op het klein en midden bedrijf. Wat zouden de kernkenmerken van een ‘zero emission’ industrieel ecosysteem model voor de voedingsmiddelenindustrie in Vietnam zijn? Welke actoren, instituties en relaties zijn (in potentie) cruciaal bij het introduceren van het voorgestelde model in de praktijk?

Voor het beantwoorden van deze vragen is een methodologie ontwikkeld om een preventie model voor de (agro-voedingsmiddelen) industrie te analyseren en te ontwerpen, welke fysisch-technologische en sociaal-institutionele modellen integreert. Met de verschillende theoretische achtergronden over Cleaner Production en emissie minimalisatie, afvalstoffen uitwisseling en industriële ecologie is een methodologie voor het ontwerpen van een ‘zero emission’ industrieel ecosysteem ontwikkeld, bestaande uit vier basisstappen. De methode begint met het analyseren van de materiaal- en energiestromen die door het industriële systeem gaan en ten dele eindigen als emissie of afval, gevolgd door een analyse van de verschillende mogelijkheden om de productie van emissies te voorkomen. De derde stap concentreert zich op het identificeren, analyseren en ontwerpen van de potentiële externe herwin of hergebruik opties. De laatste stap bestaat uit het identificeren van de overgebleven emissies die op de juiste manier behandeld moeten worden alvorens ze geloosd kunnen worden in het milieu. Tezamen vormen deze vier stappen een systematische methodologie die ons leidt naar een fysisch-technologisch model voor een (nagenoeg) 'zero emission' industrieel ecosysteem. Om de complexe politieke economische en sociale relaties tussen het industriële systeem en de externe actoren mee te kunnen nemen, is het door Mol (1995) ontworpen Triad-netwerk model toegepast om het fysisch-technische model aan te vullen met actoren en instituties. De rollen van de actoren en de relaties tussen hen en het industriële systeem zijn onderzocht voor het economisch netwerk, maatschappelijk netwerk en beleidsnetwerk.

De toepassing van de ontwikkelde methodologie is getoetst op verschillende cases in de voedingsmiddelenindustrie in Vietnam. Drie case studies (bij tapioca producerende huishoudens in het dorp Tra Co, bij de grootschalige tapioca fabriek van Tan Chau-Singapore Company en bij voedingsmiddelenbedrijven gevestigd in het industrie terrein Bien Hoa 1) zijn representatief voor de verschillen tussen: (1) kleine / huishoudelijke vergeleken met grootschalige bedrijven, (2) één bedrijf ten opzichte van een groep bedrijven, (3) een groep bedrijven van dezelfde industriële sector en een groep bedrijven uit verschillende sectoren (nog steeds horende binnen de brede kaders van agro-voedingsmiddelen industrie), (4) bedrijven gevestigd binnen en buiten industrieterreinen, omdat voor de eerst genoemde speciale voordelen gelden voor het industriële ecologie ontwerp.

Over het algemeen illustreren alle drie de cases dat overmatige generatie van non-producten (bestaande uit herbruikbare waardevolle materialen, afval en emissie) optreden door inefficiënte technologieën, inadequaat produceren, inadequaat intern en extern hergebruik en recycling, goedkope natuurlijke hulpbronnen, financiële beperkingen, slappe handhaving en het ontbreken van aansporingen op het gebied van preventie.

Ervaringen uit de drie cases hebben aan het licht gebracht dat de tekortkomingen in het huidige milieumanagement als gevolg van slechte uitvoering door de bestaande actoren en instituties kunnen worden samengevat in de volgende vijf punten. Allereerst staan regeringsautoriteiten op het gebied van milieumanagement, in het bijzonder de provinciale DOSTEs, voor verschillende problemen: een hoge werkdruk, gebrek aan expertise en schaarse middelen voor monitoren en handhaving. Ten tweede ontbreken specifieke regelingen en aansporingen voor producenten om hun productieproces meer op een ecologisch systeem te laten lijken; hergebruik en recycling mogelijkheden ontbreken op dit moment volledig. Daarnaast hebben de aanmoedigingen van economische actoren niet genoeg invloed op de producenten om hun productie efficiëntie en milieuprestaties te verbeteren. In de vierde plaats bestaat er nauwelijks een duurzame relatie tussen onderzoeksinstituten en de producenten, voor productie noch voor milieu bescherming. Tenslotte zijn de omwonenden en lokale gemeenschappen niet actief betrokken bij milieuproblemen.

In de zoektocht naar mogelijkheden om de oorzaken van overmatige productie van zogenoemde non-producten te verhelpen, hebben de cases laten zien dat Cleaner Production, afvalstoffen uitwisseling en de ideeën van industriële ecologie waardevol zijn in "greening" van de voedingsmiddelenindustrie. De realiseerbare technische mogelijkheden en de organisatorische schema's verschillen echter tussen de drie cases. De diversiteit van de situaties waarin de industriële systemen in Vietnam verkeren met de betrekking tot schaal, omvang, industriële sector en locatie veroorzaakt een aantal verschillen in de voorgestelde opties en implementaties om een 'zero emission' (voedingsmiddelen) industrieel ecosysteem te benaderen. Daarom wordt uit deze studie geconcludeerd dat een algemene en nationale benadering om voedingsmiddelenindustrie milieuvriendelijker te maken, gedoemd is te mislukken als bij de operationalisering deze verschillen niet in acht worden genomen. Hoewel in de case studie verschillende belemmeringen gevonden zijn (op het gebied van technische omvang, milieubeleid, economische aspecten en publieke deelname) die de implementatie van de voorgestelde fysisch-technologische modellen van een 'zero emission' industrieel ecosysteem vertragen, zijn er ook duidelijke mogelijkheden zichtbaar om deze belemmeringen te overwinnen.

De mogelijkheden en benaderingen om de Vietnamese voedingsmiddelenindustrie te "vergroenen" kunnen worden samengevat in een fysisch-technologisch model, waarin (voedingsmiddelen) industrie en landbouw samenwerken. Dit model bestaat uit voedingsmiddelen producerende bedrijven en alle of sommige van de volgende componenten: andere bedrijven, (welke producten gebruiken van voedingsmiddelen produceren bedrijven, zoals grondstoffen), veevoeder productie bedrijven, visteelt huishoudens, landbouw arealen en waterzuiveringsinstallaties. Hoewel operationalisering van het fysisch-technologisch model zal variëren door de diversiteit aan (voedingsmiddelen) industriële systemen, is dit algemene model het fundament voor regeringsautoriteiten, ontwerpers, beleidsmakers en milieukundigen in zowel het hervormen van de bestaande industriële systemen als bij het tot stand brengen van nieuwe.

Hoewel zowel overeenkomsten als verschillen op tafel kwamen uit de drie case studies is het toch mogelijk om twee algemene conclusies te trekken over de voorgestelde methodologie. Ten eerste blijkt de vier stappen methodologie om een fysisch-technologisch model voor een 'zero emission' industrieel ecosysteem te ontwerpen toepasbaar op elk type industrieel systeem. Daarnaast laten de studies zien dat zonder een analyse van de actoren en instituties een fysisch-technologisch model een theoretische oplossing blijft. Het analyseren van de actoren en instituties aan de hand van een Triad-netwerk model bleek handig en bruikbaar in alle bestudeerde industriële systemen.

Concluderend, noemt deze studie vijf cruciale punten voor de Vietnamese toepassing van het westerse gedachtegoed van het Industriële Ecologie Concept. Allereerst is tot nu toe het concept van industriële ecologie voornamelijk toegepast in Europa en de Verenigde Staten, landen met economische markten en gekenmerkt door geavanceerde technologische systemen, Vietnam is een minder technologisch ontwikkeld land. Daarom zal de toepassing van industriële ecologie in Vietnam, als het om dezelfde industriële sector gaat, verschillen met toepassingen in Europa en de Verenigde Staten. Bovendien zijn in Vietnam de organisatorische en institutionele structuren rondom industrie en industriële systemen over het algemeen minder ontwikkeld en eenvoudiger vergeleken met westerse landen. Dit betekent dat operationalisering van industriële ecologie minder kan steunen op verschillende ver ontwikkelde organisatiemodellen. Tevens ontbreekt in Vietnam een aantal sociaal-institutionele condities die cruciaal zijn voor het verbeteren en implementeren van industriële ecologie modellen in de praktijk, welke in geïndustrialiseerde samenlevingen wel aanwezig zijn. Daarom verschillen de voor Vietnam ontwikkelde mogelijkheden die een hoge kans op slagen hebben bij de implementatie met naar verwachting succesvolle resultaten, van uitvoeringen voor geïndustrialiseerde landen. Ten vierde zijn er in Vietnam een groot aantal hergebruik en recycling toepassingen die niet zozeer worden gestimuleerd door milieu gerelateerde motieven, maar meer door economische. Met de toekomstige economische ontwikkeling van Vietnam in gedachten, komen deze bestaande hergebruik en recycling toepassingen onder druk te staan en dienen "beschermd" te worden: dat wil zeggen dat een actief beleid gericht op het industriële ecologie concept ontwikkeld moet worden om deze toepassingen te continueren in de praktijk. Tenslotte creëert de omvang van de landbouw sector en daarbij horende landgebruik gunstige omstandigheden voor agro-industriële ecologie modellen en toepassingen in Vietnam.

TÓM TẮT

Góp phần đáng kể vào tổng thu nhập quốc gia (GDP) hàng năm là bằng chứng thiết thực thể hiện vai trò quan trọng của ngành công nghiệp thực phẩm trong tiến trình phát triển kinh tế và công nghiệp của Việt Nam. Điều này đặc biệt có ý nghĩa khi chiến lược phát triển của Việt Nam là trở thành một trong những nước nông nghiệp đứng đầu thế giới vào năm 2010. Đồng thời, cũng có thể nhận thấy rằng sự phát triển nhanh chóng của ngành công nghiệp thực phẩm này đang đi cùng với các vấn đề nan giải về tài nguyên và môi trường. Cho đến nay, những cố gắng trong quản lý môi trường công nghiệp nói chung và công nghiệp thực phẩm nói riêng ở Việt Nam chủ yếu tập trung vào việc giải quyết chất thải đã phát sinh. Mặc dù trong một chừng mực nào đó, phương pháp xử lý cuối đường ống này đã hạn chế hoặc loại trừ những tác động có hại đến môi trường do chất thải gây ra. Tuy nhiên, trong hầu hết các trường hợp, việc áp dụng một cách đơn điệu các phương pháp này đều thể hiện những điểm bất lợi, hạn chế và không hiệu quả. Đó là lý do tại sao chất lượng môi trường ở Việt Nam vẫn không thể tốt hơn mặc dù các biện pháp xử lý cuối đường ống đã được áp dụng từ những năm 1990 đến nay.

Để hạn chế các tác động tiêu cực đối với sức khỏe cộng đồng và môi trường hiện tại và trong tương lai, các nước công nghiệp đã xây dựng và áp dụng những biện pháp hiệu quả hơn (về mặt kinh tế và môi trường) nhằm khắc phục những nhược điểm của các giải pháp xử lý cuối đường ống. Các tài liệu hiện có cũng như kinh nghiệm của các nước công nghiệp cho thấy chiến lược bảo vệ môi trường dựa trên sản xuất sạch hơn (cleaner production), trao đổi chất thải (tái sinh và tái sử dụng) (waste exchange) hoặc sinh thái công nghiệp có hiệu quả hơn biện pháp xử lý cuối đường ống. Hiển nhiên, mỗi giải pháp chỉ ứng dụng một cách thành công trong một số điều kiện nhất định và có thể bị hạn chế trong những điều kiện khác. Do đó, thông thường, việc phối hợp có định hướng đối với một số hoặc tất cả các giải pháp được xem là phương án tốt nhất hay là chiến lược khả thi nhất để khắc phục quá trình hủy hoại môi trường đang diễn ra liên tục. Đây là vấn đề cần nghiên cứu. Mục đích chính của đề tài nhằm phân tích và đánh giá khả năng và tiềm năng cải thiện môi trường ngành công nghiệp thực phẩm ở Việt Nam dựa trên sự phối hợp những biện pháp ngăn ngừa và xử lý ô nhiễm hiện có. Một cách cụ thể hơn, nghiên cứu được đặt ra nhằm tìm kiếm giải đáp cho các vấn đề: làm thế nào để áp dụng một cách phù hợp dựa trên kinh nghiệm về hệ sinh thái công nghiệp của các nước phương Tây để phát triển hệ sinh thái công nghiệp đối với ngành công nghiệp thực phẩm trong điều kiện kỹ thuật, kinh tế và xã hội hiện tại của Việt Nam? Có thể áp dụng những giải pháp này cho trường hợp các nhà máy công nghiệp thực phẩm quy mô lớn nằm riêng lẻ và các nhà máy quy mô vừa và nhỏ không? Mô hình hệ sinh thái công nghiệp không chất thải đối với ngành công nghiệp thực phẩm của Việt Nam sẽ mang những đặc tính cơ bản gì? Những cơ quan và tổ chức nào, thể chế và chính sách nào, và mối quan hệ nào giữa các tổ chức này đóng vai trò cốt yếu trong việc đưa mô hình đề xuất vào thực tế ứng dụng?

Để giải đáp những vấn đề đặt ra, phương pháp luận phân tích và thiết kế mô hình ngăn ngừa ô nhiễm đối với công nghiệp nói chung và ngành công nghiệp thực phẩm nói riêng đã được xây dựng - mô hình kết hợp giữa công nghệ với thể chế-chính sách-xã hội. Trên cơ sở lý thuyết về sản xuất sạch hơn/giảm thiểu chất thải (cleaner production/waste minimization), trao đổi chất thải (waste exchange) và sinh thái công nghiệp (industrial ecology), phương pháp luận xây dựng mô hình công nghệ (physical-technological model) đối với hệ sinh thái công nghiệp không chất thải (a zero waste industrial ecosystem) được phát triển qua bốn bước cơ bản. Bắt đầu bằng việc phân tích dòng vật chất và năng lượng liên quan đến hệ công nghiệp cần nghiên cứu từ nguyên liệu đưa vào hệ thống đến thành phẩm tạo thành và chất thải phát sinh. Trên cơ sở dữ liệu thu thập từ bước một, các giải pháp ngăn ngừa sự phát sinh chất thải được phân tích trong bước hai. Bước ba tập trung vào việc xác định, phân tích và thiết kế/đề xuất các giải pháp tái sinh và tái sử dụng chất

thải bên ngoài phạm vi của nhà máy phát sinh chất thải. Cuối cùng, phần chất thải phát sinh không thể tái sinh, tái sử dụng cần được xử lý hợp lý trước khi thải ra môi trường xung quanh. Sự kết hợp bốn bước nói trên tạo thành một phương pháp luận thống nhất để xây dựng mô hình công nghệ đối với các hệ sinh thái (gần như) không có chất thải. Bên cạnh đó, để đánh giá những mối quan hệ phức tạp về kinh tế và xã hội giữa hệ công nghiệp và các cơ quan, tổ chức và thành phần xã hội khác, mô hình triad-network của Mol (1995) được áp dụng nhằm phân tích vai trò của các tổ chức và mối tương quan giữa chúng với hệ công nghiệp. Các mối liên hệ được nghiên cứu ở ba phạm trù: kinh tế, các luật lệ và chính sách liên quan và xã hội.

Khả năng ứng dụng của phương pháp luận đã xây dựng được đánh giá bằng cách áp dụng vào các nghiên cứu điển hình đối với ngành công nghiệp thực phẩm ở Việt Nam. Ba nghiên cứu điển hình áp dụng cho các hộ gia đình sản xuất tinh bột khoai mì ở làng mì Trà Cổ, Biên Hòa, Đồng Nai; Công Ty Tinh Bột Mì Tân Châu-Singapore, Tây Ninh và các công ty thực phẩm thuộc khu công nghiệp Biên Hòa 1, Đồng Nai đặc trưng cho những điểm khác biệt giữa: (1) các cơ sở sản xuất quy mô nhỏ/hộ gia đình và các cơ sở sản xuất quy mô lớn; (2) một cơ sở sản xuất và một nhóm gồm nhiều cơ sở sản xuất; (3) một nhóm các cơ sở sản xuất của cùng một loại hình công nghiệp và nhóm của nhiều cơ sở sản xuất thuộc nhiều loại hình công nghiệp khác nhau (nhưng vẫn thuộc ngành công nghiệp thực phẩm); (4) các cơ sở nằm bên trong và bên ngoài khu công nghiệp, vì khu công nghiệp có những điểm thuận lợi trong việc thiết kế hệ sinh thái công nghiệp.

Một cách tổng quát, các nghiên cứu điển hình đều cho thấy rằng việc phát sinh nhiều thành phần không phải là sản phẩm, gọi chung là chất thải, (bao gồm cả các thành phần có thể tái sinh/tái sử dụng, chất thải và khí thải) chủ yếu do: công nghệ lạc hậu và hiệu quả không cao, vận hành quy trình không hợp lý, các phương pháp tái sinh và tái sử dụng tại cở sở hay bên ngoài cơ sở sản xuất không phù hợp, tài nguyên thiên nhiên rẻ tiền, hạn chế về tài chánh, việc bắt buộc thi hành luật môi trường không nghiêm khắc và thiếu các hình thức khuyến khích các nhà sản xuất thực hiện ngăn ngừa ô nhiễm.

Ba nghiên cứu điển hình cho thấy rằng những hạn chế trong quản lý môi trường hiện tại do việc thực thi không hiệu quả của các tổ chức và thể chế chính sách có thể đúc kết qua 5 điểm chính sau đây. Thứ nhất, các cơ quan quản lý môi trường, đặc biệt là các Sở Khoa Học Công Nghệ và Môi Trường (DOSTEs) đều phải đương đầu với khối lượng công việc quá lớn, thiếu chuyên môn, không đủ cơ sở vật chất và nhân lực để thực hiện công tác giảm sát cũng như bắt buộc cơ sở sản xuất thực thi các biện pháp bảo vệ môi trường. Thứ hai, hiện tại, những quy định và điều khoản khuyến khích các nhà sản xuất thực hiện sản xuất theo định hướng bảo vệ môi trường và tái sinh, tái sử dụng chất thải hầu như chưa được ban hành hoặc chỉ được đề cập đến một cách sơ lược. Thứ ba, các tổ chức liên quan đến kinh tế hầu như không có tác dụng thúc đẩy các nhà sản xuất cải tiến và nâng cao hiệu quả sản xuất cũng như môi trường. Thứ tư, hiện tại hầu như không có mối quan hệ lâu dài nào giữa các viện nghiên cứu và nhà sản xuất về công nghệ sản xuất cũng như bảo vệ môi trường được thiết lập. Cuối cùng, ở một số khu vực, vai trò của công dân đối với vấn đề môi trường công nghiệp vẫn còn hạn chế.

Các nghiên cứu điển hình cho thấy sản xuất sạch hơn, trao đổi chất thải và ý tưởng về sinh thái công nghiệp có giá trị trong việc hạn chế sự phát sinh chất thải và cải tiến môi trường ngành công nghiệp thực phẩm, mặc dù tính khả thi của các giải pháp công nghệ này sẽ khác nhau trong những điều kiện ứng dụng khác nhau. Tính đa dạng của hệ công nghiệp ở Việt Nam về mặt quy mô, loại hình và ví trị đã tạo nên sự khác biệt trong các giải pháp lựa chọn và việc thực thi chúng nhằm tiến đến hệ sinh thái công nghiệp (thực phẩm) không chất thải. Do đó, nghiên cứu này kết luận rằng bất kỳ giải pháp tổng quát hoặc khái quát hóa ở quy mô quốc gia nào áp dụng để cải tiến môi trường cho ngành công nghiệp thực phẩm đều sẽ bị thất bại trong thực tế nếu những điểm khác biệt này không được xem xét đến trong quá trình thực thi. Mặc dù các nghiên cứu điển hình cho thấy có nhiều yếu tố bất lợi (về mặt công nghệ, chính sách môi trường, kinh tế và sự tham gia của cộng đồng) gây ảnh hưởng đến việc đưa mô hình công nghệ đề xuất vào áp dụng trong thực tế, song bên cạnh đó cũng có nhiều cơ hội/khả năng khắc phục những hạn chế này.

Những khả năng và khuynh hướng cải tiến môi trường ngành công nghiệp thực phẩm Việt Nam rút ra từ những nghiên cứu điển hình có thể được khái quát hóa bằng mô hình công nghệ, trong đó công nghiệp (thực phẩm) và nông nghiệp phối hợp với nhau. Mô hình này bao gồm các cơ sở sản xuất thực phẩm và tất cả hoặc một số các thành phần sau đây: những nhà máy khác sử dụng sản phẩm của các cơ sở sản xuất thực phẩm làm nguyên liệu, nhà máy sản xuất thức ăn gia súc, các hộ gia đình nuôi cá, các hộ gia đình chăn nuôi gia súc (hoặc trại chăn nuôi), cơ sở sản xuất phân compost, cơ sở sản xuất biogas, khu vực trồng cây nông nghiệp và trạm xử lý nước thải. Mặc dù việc vận hành mô hình công nghệ này trong thực tế sẽ rất khác nhau do tính đa dạng của hệ công nghiệp, mô hình khái quát này sẽ là cơ sở để các nhà quản lý, quy hoạch, xây dựng luật và môi trường xem xét trong quá trình cải tiến các hệ công nghiệp hiện tại cũng như xây dựng những hệ công nghiệp mới theo khuynh hướng phát triển bền vững trong tương lai.

Mặc dù ba nghiên cứu điển hình thể hiện nhiều điểm giống và khác nhau, nhưng các nghiên cứu này cho phép kết luận chung đối với phương pháp luận đã xây dựng ở hai điểm chính. Thứ nhất, phương pháp luận để thiết kết mô hình công nghệ đối với hệ sinh thái công nghiệp không chất thải theo bốn bước cơ bản cho thấy khả thi để áp dụng đối với bất kỳ hệ công nghiệp nào. Thứ hai, các nghiên cứu điển hình cho thấy rằng nếu không phân tích mối liên quan giữa hệ công nghiệp với các tổ chức, thể chế, chính sách, kinh tế và xã hội, bất cứ mô hình công nghệ đề xuất nào cũng chỉ là mô hình mang tính khả thi lý thuyết mà thôi. Mô hình triad-network thể hiện tính hiệu quả trong việc phân tích các mối liên hệ này đối với tất cả các hệ công nghiệp nghiên cứu.

Cuối cùng, nghiên cứu chỉ rõ năm điểm cốt yếu thể hiện mức độ ứng dụng ý tưởng về Sinh Thái Công Nghiệp của các nước phương Tây khi áp dụng trong điều kiện Việt Nam. Thứ nhất, khái niệm sinh thái công nghiệp đã được áp dụng, đặc biệt ở nền kinh tế thị trường của các nước Châu Âu và Mỹ với công nghệ hiện đại, trong khi Việt Nam hiện là nước có công nghệ ít phát triển. Do đó, với cùng một loại hình công nghiệp, việc áp dụng sinh thái công nghiệp ở Việt Nam sẽ khác với các nước Châu Âu và Mỹ. Thứ hai, với cấu trúc tổ chức và hệ thống luật lệ chính sách đơn giản, việc đưa khái niệm sinh thái công nghiệp áp dụng ở Việt Nam ít phải dựa vào những dạng mô hình tổ chức tiên tiến của các nước phương Tây. Thứ ba, nhiều điều kiện chính sách-xã hội mang tính cốt yếu để đề xuất và thực hiện các mô hình sinh thái công nghiệp trong thực tế ở các nước công nghiệp thường không có hoặc ít phát triển ở Việt Nam. Như vậy, các phương án khả thi để thực hiện ở Việt Nam sẽ khác với các nước công nghiệp. Thứ tư, mặc dù Việt Nam hiện có nhiều ứng dụng thực tế về tái sinh và tái sử dụng chất thải, nhưng động cơ thúc đẩy thực hiện chủ yếu là do yếu tố kinh tế hơn là môi trường. Với khuynh hướng phát triển kinh tế của Việt Nam, thực tế tái sinh và tái sử dụng chất thải hiện tại có thể trở nên ít có ảnh hưởng và cần phải được "bảo vệ": chính sách về sinh thái công nghiệp tích cực cần phải được phát triển để duy trì thực tế ứng dụng này. Cuối cùng, sự phát triển và chiếm ưu thế của ngành công nghiệp-nông nghiệp (thực phẩm) và phần lớn đất đai được dùng cho sản xuất nông nghiệp là điều kiện thuận lợi cho việc áp dụng mô hình sinh thái công nghiệp-nông nghiệp trong thực tế ở Việt Nam.

ABOUT THE AUTHOR

Tran Thi My Dieu was born on May 4th 1971 in Nha Trang City, Khanh Hoa Province, Vietnam. Since September 1995, after obtaining a BE. Degree in Chemical Engineering from the Polytechnic University of Ho Chi Minh City, she has worked at the Center for Environmental Technology and Management (CENTEMA) as researcher as she still does. In August 1998, she obtained a Master Degree in Environmental Engineering, from the Asian Institute of Technology, Bangkok, Thailand. She has also worked as a lecturer at the Department of Environmental Technology of Van Lang University from 1998 up till now. She came to Wageningen University at the end of 1998 to start her PhD thesis.