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PLANNING OF AN INTEGRATED SOLID WASTE MANAGEMENT SYSTEM IN SURINAME: A CASE STUDY IN GREATER PARAMARIBO WITH FOCUS ON HOUSEHOLDS

Thesis submitted in fulfillment of the requirements

For the degree of Doctor (PhD) in Applied Biological Sciences

Dutch translation of the title:

PLANNING VAN EEN GEINTEGREERD AFVALBEHEER SYSTEEM IN SURINAME: EEN GEVALSTUDIE IN GROOT PARAMARIBO GECONCENTREERD OP HUISHOUDENS

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TABLE OF CONTENT

ABBREVIATIONS

ABS	Algemeen Bureau voor de Statistiek – Suriname
BOG	Office of Public Health of the Ministry of Public Health
BTC	Belgian Technical Cooperation
BTU	British thermal unit
C:N ratio	Carbon : Nutrient ratio
CBO	Community Based Organizations
CH_4	Methane
CO_2	Carbon dioxide
Cu	Copper
CV	Caloric value
EBS	Energy Company Suriname
EC	Electrical Conductivity
GHGs	Greenhouse gases
GNI	Gross National Income
GWh	Giga Watt-hour
HDPE	High-density polyethylene (plastics)
HSW	Household Solid Waste
IMSWM	Integrated Municipal Solid Waste Management
IPCC	Intergovernmental Panel on Climate Change
ISWM	Integrated Solid Waste Management
LCA	Life cycle assessment
LDPE	Low density polyethylene (plastics)
LFG	Landfill gases
Ministry of OW	Ministry of Public Works (Ministerie van Openbare Werken)
Mn	Manganese
MSW	Municipal Solid Waste
MSWM	Municipal Solid Waste Management
MW	Megawatt
NGO’s	Non-Governmental Organization

NH_3	Ammonia
NIMBY	Not-In-My-Backyard
NIMOS	National Institute for Environment and Development in Suriname
NO_x	Nitrogen dioxide
NV SAVEB	Surinam Waste Treatment Company (Surinaams Afvalverwerkings Bedrijf)
OECD	Organization for Economic Co-operation and Development
PAHO	Pan American Health Organization
PAYT	Pay-as-you-throw
PB	Pay -by-the-bag
PET	Polyethylene terephthalate (plastics)
PM_{10}	Particulate Matter
ppm	Parts per million
PPP	Public-Private Partnerships
SO_2	Sulphur dioxide
SW	Solid Waste
SWM	Solid Waste Management
TSP	Total Suspended Particles
TPY	Tons per year
UNEP	United Nation Environmental Program
VOC	Volatile organic carbon
VOV	Department of waste Collection and Disposal (Department Vuilophaal en Verwerking)
WASPAR	Foundation for Laundry for Private Hospitals
WIS	Waste information system
WM	Waste Management
WTE	Waste-To-Energy
Zn	Zinc

Chapter 1

General introduction

Chapter 1

General introduction

1.1 Introduction

Since the early 1970s, Solid Waste Management (SWM) in developing countries has received increasing attention from researchers and policy makers concerned to establish a sustainable management system (Gerlagh et al., 1999). The increasing scale of economic activity, i.e. industrialization, urbanization, rising standards of living and population growth, has led to an increase in the quantity of waste generated. We have to deal in one way or another with this large mass of organic and inorganic wastes. The environment has a limited capacity for waste assimilation therefore this assimilative capacity of the environment may be exceeded or put under too much stress to handle the large quantity of waste. This may result in pollution and resource degradation and consequently economic damage. Agenda 21 (1992), the action programme of the United Nations Conference on Environment and Sustainable Development in Rio in 1992 reaffirmed that environmentally sound practices for the management of waste is one of the major issues that needs to be addressed for maintaining the quality of Earth's environment and for achieving sustainable development. Environmentally sound waste management must go beyond the mere safe disposal or recovery of wastes that are generated, and must seek to address the root cause of the problem by attempting to change unsustainable patterns of production and consumption. This implies the application of the integrated life cycle management concept, which presents a unique opportunity to reconcile development with environmental protection.

1.2 Background

1.2.1 Waste problems

The state of SWM in Suriname is a serious concern. Currently, Suriname has required little or no waste management. Waste management is one of the major challenges confronting the government of Suriname. The economy of Suriname has rapidly moved towards the consumption of western products with an increase in per-capita waste generation through the years. Another aspect is the continuous expanding of the residential areas in Greater Paramaribo, which goes along with increasing waste collection areas. Together with these changes, solid waste has also undergone rapid changes in recent years (more plastics, chemicals, etc.). Our waste management system never could keep pace with these changes, which lead to enormous waste problems in the country. These waste problems are considered to have several dimensions. The waste management system has problems that have to do with finance, equipment, lack of data, attitude and behaviour of citizens, waste management staff and private enterprises. Other problems are caused more by factors that are not technical or financial but relate to managerial (in)capacities, the institutional framework, the environment, or the social or cultural context (tradition and knowledge of waste research). In these cases, it is not money or equipment that provides solutions, but rather changing social, institutional, legal or political conditions.

The problems associated with our current SWM system can be summarized as follows:

The department (VOV, Waste Collection and Disposal Services) which is in charge of waste disposal in Greater Paramaribo is only able to collect about 70% of solid waste generated within the city. This institute charged with responsibility of providing municipal solid waste management services has found it increasingly difficult to play this role. The difficulty has been aggravated by lack of effective legislation, inadequate funds and services, and inability of this institute to provide the services cost-efficiently.

In Suriname, the most common practice of disposing waste is mainly through legalized open dumping, other used methods are open burning and illegal dumping. The most common method of waste disposal is dumping in pits, designated as landfills but actually little more than open dumps, without any weighing facility. These improper solid waste management practices lead to substantial negative environmental impacts (for example water pollution and emission of greenhouse gases from open dumps), and health and safety problems (such as diseases spread by insects and rodents attracted by garbage heaps).

When solid waste streams increase, new methods need to be devised, such as composting and recycling, etc. The government does not have any solid waste management program or plan to handle current waste streams, so it is obvious that there are also no plans to improve solid waste management practices.

As Paramaribo grows economically, business activity and consumption patterns drive up solid waste quantities. The problem is becoming very acute due to lack of reliable waste generation and disposal patterns (data). Despite these developments, the government never conducted a waste characterization study. Therefore, there are no exact data about waste generation meaning that the government cannot adequately manage the produced waste stream. This has resulted in more waste left uncollected (low collection rate) and illegally dumped. Other problems related to the lack of waste generation data are the inadequate vehicle fleet and performance and to define the capacity of waste disposal facilities. In each case, health, aesthetic and planning issues are worsened and costs rise.

The waste disposal problems also stem from the fact that attitudes and perceptions towards wastes in people's minds and government officials have not been adequately considered. People do not feel responsible for the waste generation and disposal because they feel that it is the government's responsibility. There has been a tendency among government officials to concentrate more on waste collection rather than looking at the problem from a governance perspective.

Despite solid waste collection in Greater Paramaribo has improved through the years which has resulted in some benefits (greater collection coverage) still there have been major set backs in terms of deteriorating environmental conditions, poor working conditions, and inadequate operational funds to support waste management.

In spite of the presence of a waste collection service, still many people illegally dump or burn their garbage. Accumulation of waste within neighborhoods is the most visible problem in Greater Paramaribo. Waste collection points and illegal dumps become environmental hazards, especially given the very intermittent collection (in some areas) and the tendency for faecal or hazardous material to become intermixed with household refuse. In addition to being unsightly and generally unpleasant, such sites are a risk for children and exacerbating fly and rodent problems. Further, wastes can be washed away blocking drains and streams.

A combination of poverty, population pressure, and economic hardships is placing a considerable strain on households and the environment in Greater Paramaribo, which leads to deteriorating of the environment. Many people (59.2%) in Greater Paramaribo live below the internationally recognized poverty line of one US dollar a day (ABS, 2005). In view of this, one can imagine the pressure that is put on the city's infrastructure in the course of day-to-day activities. Besides, some urban residents are still living in sub-standard housing within settlements with little or no basic services.

The deterioration is also reflected in decaying infrastructure manifested in excessively pot-holed roads, poor storm drainage, mounting garbage heaps and unreliable electricity and water supplies.

The root cause of these waste problems can be traced to the system of performance and structural weaknesses of waste management departments.

1.2.2 Options for improvement

The municipal solid waste problem is serious and the government is trying to cope with it in the best way as possible. There is a tendency to move directly from problems to solution without an analysis of what is actually occurring. The most obvious is the extension of the collection services by hiring contractors to collect waste, contracting foreign consultants to develop a study to construct and manage a sanitary landfill and to formulate a waste act and a business plan. This is a good approach of the government but it shows clearly that the answer of the government is more money and more equipment, even when these are not (always) the essence of the problem. As a result, large expenses and money and equipment are used incorrectly (leading to corruption) for the waste problem that is still not yet solved.
To achieve environmentally sound solid waste management, it is essential to put forward a new paradigm for SWM that involves the consideration of institutional (laws and processes), social (customs and public education), financial (funding), economic (costs and job creation), technical (location and equipment), and environmental (natural resources and human health) factors. Such an integrated approach to SWM seems to be the best option and could well hold the key to effective and sustainable waste management system in Suriname.

There is an abundance of literature on solid waste and its appropriate management but there exists a lacuna with respect to a comprehensive study on integrated waste management for Suriname. It is clear that improvement of our SWM is one of the challenges faced by the government of Suriname. This doctoral thesis will explore the potential of integrated solid waste management and provide information how it can be applied in Suriname.

1.3 Research objectives

The purpose of this thesis is to suggest mechanisms to strengthen the current waste management practices in Greater Paramaribo.

The main objectives are to explore some of the facets of the waste problem, namely:

- to carry out a comprehensive waste characterization study for Greater Paramaribo and lay the foundation for extending this work to other areas and sectors in the country
- to build local capacities to deal with waste management
- to explore possibilities of resource recovery (recycling and composting) of waste with adapted technologies
- to add value to waste with a view to convert it to a more useful raw material as energy recovery
- to disseminate information about an integrated solid waste management system.

In order to address the solid waste problem I introduce in this study an integrated research focusing on four topics:

I. Household solid waste (HSW) characterization and data collection involving the development of a comprehensive survey on the generation and composition of HSW

II. Assessment of the recycling rate of recyclable materials in HSW which are useful to the society. Three clusters are studied:
   - Quantifying how much plastics (PET and HDPE) can be recovered
   - Quantifying how much organic waste can be composted
   - Quantifying the energy generated from waste

III. Composting experiment. To study the technical applicability of composting the organic part of HSW as a waste management option

IV. Developing a framework for integrated solid waste management (based on findings of the study).

The study does not pretend to produce a scientific document on new waste technologies or models or debate existing technologies or models but rather a document with a strong social relevance. The study is designed to support initiatives, bring useful information to all involved stakeholders (policymakers, communities, industries and academic/training bodies), and contribute to the setting-up of a vision for integrated management of waste in Suriname.

1.4 Problem Statement

Through the years, little attention has been paid to the management of municipal solid wastes. The situation with respect to waste management can be titled as particularly severe. While the government has improved dramatically our collection service in the last several years, there are still fundamental questions about solid waste management that need to be answered to come to the formulation and implementation of an integrated sustainable solid waste management system. Through the formulation of the following research questions, this study will fill this information gap by providing an assessment of the waste management system in operation:

- what are the actual problems and causes in our current waste management system?
- how much waste is generated on-site;
- how much illegal dumping or burning really occurs;
- what is the true potential of our solid wastes: recycling, composting, energy recovery?
- how can waste problems be solved?

1.5 Relevance of the research

There is a need for information to be shared, projects to be evaluated, and difficulties to be discussed on waste management practices in Suriname. This is necessary to develop practical alternatives to strengthen our current waste management practices and to increase awareness about more sustainable approaches to solid waste management. It is expected that the research will provide a systematic plan for solid waste management in the study area. This study can also provide useful information for solid waste managers and decision-makers when they are conducting long term planning of solid waste management activities. Lessons learned and experiences will be of use to others to increase understanding of solid waste management and inspire the development of ideas and actions. Finally, maximized environmental and economic benefits may be achieved through application.

1.6 Limitations of the study

The study is limited to the research of residential (household) solid waste in Greater Paramaribo. This is the garbage produced by households (and small businesses) that is picked up by the Department of Waste Collection and Disposal (VOV) and the private waste contractors (hired by VOV); other types of waste such as liquid, industrial and hazardous waste will not be investigated in this study. The limitation is a deliberate effort to make the project manageable given the time and resources available to complete the project.

1.7 Research strategy

The research is a combination of a literature review, interviews, and field research. The research is founded on qualitative and quantitative methods of data collection.

However, before gathering data, I made literature studies and identified theories and concepts most relevant to the study. Interviews were conducted with officials, these interviews were conducted to bring to light the present state of SWM in Suriname (development situation, problems and plans), especially in Greater Paramaribo. This approach ensures that all the local issues affecting waste management in Greater Paramaribo are taken into consideration. The results of the field research conducted, provided a good estimate of the generation of residential waste in Greater Paramaribo, insight of the technical possibilities of composting on pilot scale and the demand / willingness of households to participate in future SWM programs. The researches were conducted in 2002, 2003, 2004 and 2005.

1.8 Structure of the document

This study is organized into eight chapters:

1. To gain insight into how to develop the most efficient municipal solid waste management system, this thesis has been organized into eight chapters, starting with this introduction (refers to chapter 1).

2. To conduct a background study on solid waste management (refers to chapter 2). A literature study of solid waste management, its components, practices, processes and the various technologies was conducted to develop the background information.

3. To conduct a study on existing solid waste management practices in Suriname and related issues (refers to chapter 3). It offers a detailed description of current waste activities, problems and waste management policies in Suriname.

4. Case study research (refers to chapter 4 and 6). Two case studies were conducted under the following headings:

- generation and composition of household waste (chapter 4)
- composting experiment (chapter 6)

5. To conduct a study to the possibilities of recycling, composting and energy resource recovery (refers to chapter 5). Based on data described in chapter 4 an analysis is made to the potential capacity of a recycling - and compost plant and to calculate how much energy can be produced from household waste.

6. To formulate the best operational framework for solid waste management in Suriname and recommendations for future research (refers to chapter 7). A range of viable strategies are outlined with background information of the SWM features.

7. To formulate the main conclusions of this thesis (refers to chapter 8).

Chapter 2

Municipal solid waste management: literature review

Chapter 2

Municipal solid waste management: literature review

This chapter highlights the aspects and procedures of municipal solid waste (MSW) planning and management with an emphasis on developing countries.

2.1 Introduction

The United Nations Conference on Environment and Development, held in Rio de Janeiro in June 1992, focused world attention next to other problems also on the undesirable effects of economic – and population growth: climate change caused by the accumulation of green house gases, depletion of the ozone layer and the increased levels of municipal solid waste (Beede and Bloom, 1995). The conference reaffirmed that environmentally sound practice for the management of waste is one of the major issues that needs to be addressed for maintaining the quality of Earth's environment and for achieving sustainable development (Jaya Dhindaw, 2004). Among the many problems addressed, it was concluded that increased levels of municipal solid waste (MSW) are the undesirable by-product of population growth, the changes in consumption habits and economic development (Ojeda-Benitez and Beraud-Lozano, 2003).

Although MSW does not have the catastrophic potential of either global warming or stratospheric ozone depletion, it has long posed threats to environmental quality and human health and is typically of great local and immediate concern. Methane (CH_4) produced by the anaerobic decomposition of waste buried in landfills and open dumps is a significant contributor to global CH_4 emissions, with estimates ranging from 10 to 70 Tgrams per year (10^{12} g/yr). Global anthropogenic sources emit 360 Tg/yr, which suggests that landfills may account for 3 to 19% of the total (Doorn and Barlaz, 1995). Accelerating urbanization has led to rapid increase in MSW generation that has dramatically expanded the burden on local governments in many developing countries to collect, process, and dispose of MSW in socially efficient ways (Beede and Bloom, 1995) and the amounts of refuse destined for final disposal rapidly consume landfill capacity.

Nowadays, solid waste management is a problem of major relevance for all societies. In developing countries, this problem is neglected for decades, and a number of factors can be implicated in this neglect (Yhdego, 1995):

- politicians and government suffer to the out-of-sight, out-of-mind syndrome whereby urban solid waste is dumped away from sight of people,
- stagnating economy of the country means little investment into waste management leading to inappropriate technology,
- low living standard of communities which hinder the implementation of waste management due to struggle for survival and low awareness, and
- absence of planning for waste services (in housing developments).

Solid waste poses several major problems for the developing world (Pearce and Turner, 1994):

a) health hazards and environmental degradation from uncollected waste,
b) health hazards and environmental degradation from collected but poorly disposed of waste,
c) the economic burden of waste disposal on towns and cities.

Moreover, finding acceptable strategies to cope with such a problem is becoming a quite hard task, owing to the increasing awareness of environmental issues by population and authorities. This awareness led to new perspective holding that waste should be recovered or disposed of without jeopardizing human health and without using processes or methods, which could harm the environment. Linked with these ecological issues are concerns arising from the depletion of natural resources and the need for resource conservation (Koufodimos and Samaras, 2002). In general, such a consciousness has also led to the development of pollution control technologies and to more rigorous legislation on waste handling and disposal, to minimize the environmental impact associated with solid waste (Fiorucci et al., 2003).

The production and management of MSW can be thought to be a cycle with many very closely related stages. The cycle begins with the production of goods and continues with generation, storage, sweeping, collection and final disposal of waste. Studies concerning SWM are centred in the complete cycle or in some of the stages. Generally, the purpose of these studies is to achieve benefits such as implementing sustainable MSW management, promoting participation and welfare of individuals, contributing to environmental conservation practices (Ojeda-Benitez and Beraud-Lozano, 2003).

2.2 Definition of (municipal) solid waste

The concept of waste (reduce, reuse, recycle, called 3R's) seems obvious. In an effort to demonstrate just how much it is *not obvious*, some current definitions of waste are summarized. One method of defining waste is by a listing of activities or substances, which come within the range of definition. An alternative technique would be to define by reference to the purpose of the regulation. Consequently, if we associate waste with humans, we shall not ever be able to define waste objectively. The notion of waste is relative in two main respects. First, something becomes waste when it loses its primary function for the user; hence, someone's waste output is often someone else's raw material input. Secondly, the notion of waste is also relative to the technological state of the art and to the location of its generation. Waste is therefore a very dynamic concept (Pongrácz, 2002).

Waste is related to needless and excessive consumption; deterioration or decay by use; misuse or lack of use; useless or damaged material produced during or left over from manufacturing processes; and superfluous matter. Waste is distinguished from garbage. In this regard, waste is meant as "any residual materials which arise from human activities and which are not considered to be of immediate use", while garbage is defined as "any object which has no possible further use" (Gatot Yudoko, 2000).

According to Pongrácz (2002), waste is described as an unwanted, but not avoided output, whence its creation was not avoided either because it was not possible, or because one failed to avoid it. According to the author, there are four waste classes:

Class 1: non-wanted things, created not intended, or not avoided, with no purpose,

Class 2: things that were given a finite purpose, thus destined to become useless after fulfilling it,

Class 3: things with well-defined purpose, but their performance ceased being acceptable,

Class 4: things with well-defined purpose, and acceptable performance, but their users failed to use them for their intended purpose.

Read (1999) defines waste as any substance, which constitutes scrap material or an effluent, or other unwanted surplus substances arising from the application of a process, or any substance or article, which requires to be disposed of as being broken, worn out, contaminated or otherwise spoiled. MSW comprises primarily household collected waste, but also includes light commercial and industrial waste collected by local authorities. Additionally, household waste is an element of MSW which is by nature one of the hardest sources of waste to manage effectively, and because of the diverse nature of its material.

Municipal solid waste includes all solid wastes generated in the community except for industrial and agricultural wastes. It generally includes discarded durable and non-durable goods, containers and packaging, food scraps, yard trimmings, miscellaneous inorganic debris, including household hazardous wastes (for instance pesticides, batteries, left over paints etc.) and often construction and demolition debris and sludge and ashes generated by sewage treatment and municipal solid waste incinerators. There are eight major classifications of solid waste generators: residential, industrial, commercial, institutional, construction and demolition, municipal services, processes and agricultural. There is no consistent definition of MSW across countries. In some cases, it encompasses industrial and commercial waste and even construction and demolition debris, which make its estimation incorrect, and leads to erroneous policy formulation (Snigdha Chakrabarti & Prasenjit Sarkhel, 2003).

Hoornweg and Thomas (1999) defined waste as any unwanted material intentionally thrown away for disposal. They also classified eight major sources of MSW: residential, industrial, commercial, institutional, construction and demolition, municipal services, processes, and agriculture. MSW includes wastes generated from residential, commercial, industrial, construction and demolition, and municipal services. Often only residential waste is referred to as MSW, and in high-income countries, only 25 to 35 percent of the overall waste stream is from residential sources.

Waste refers to materials that are not prime products (i.e. products produced for the market) for which the generator has no further use for own purpose of production, transformation or consumption, and which he discards, or intends or is required to discard. Wastes may be generated during the extraction of raw materials during the processing of raw materials to intermediate and final products, during the consumption of final products, and during any other human activity (European Commission, 1975).

According to USEPA, solid waste is defined as any garbage, refuse, sludge from a wastewater treatment plant, water supply treatment plant, or air pollution control facility, and other discarded material, including solid, liquid, semisolid, or contained gaseous material, resulting from industrial, commercial, mining, and agricultural operations and from community activities (USEPA, 2001).

Solid wastes include all solid or semisolid materials that the processor no longer considers of sufficient value to retain. MSW is normally assumed to include all community wastes with the exception of industrial process wastes and agriculture wastes (Tchobanoglous et al., 1993).

MSW can be divided into recycled and non-recycled materials. The division of MSW between recycled and non-recycled materials depends on the nature and cost of available production, consumption, recycling and disposal technologies, as well as on government regulations, all of which can vary widely across economic settings.

Recycled materials consist of by-products of production or consumption activities that are gathered, refined, and used as inputs for production activities. Examples are discarded aluminum soft drink and beer cans that are melted down to create new cans, food and yard wastes that are composted and used to enhance soil fertility or are used to produce energy (bio-gas), and old newspapers and cardboard that are re-pulped to produce recycled paper or cardboard and plastic bottles that are melted down to produce energy or plastic pellets to make products such as garbage bins. The non-recycled portion of MSW consists of by-products that must generally be removed from their site because they attract vermin and flies, inhibiting mobility, clogging drains, and emitting unpleasant odours (Beede and Bloom, 1995).

According to Cointreau (1982), waste is a material, which is thrown away or aside as worthless. The entire concept of waste is subject to the value judgment of the primary owner or potential consumer. A waste is viewed as a discarded material, which has no consumer value to the person abandoning it.

Buenrostro et al. (2001) made a hierarchical classification of SW, proposed on the basis of the following assumptions:

- the SW generated within territorial jurisdiction of a municipality, irrespective of its physical and chemical characteristics and source of generation; it is classified as MSW,
- all economic activities generate a given pattern of SW,
- since economic and consuming activities generate SW, each of these activities constitutes a source.

The source classification of MSW considers three divisions: industrial, urban, and rural; each one is represented as a discrete entity. From these divisions, seven classes are derived in a hierarchical manner (table 2.1). In order to determine the type and source of SW generated, an alphanumeric code was assigned to every source considered. With the classification, a connection between the source (on basis of economic activity) and the type of waste is established and an overview is provided of the types of wastes expected to be generated in a municipality or state.

Table 2.1: Proposed classification of municipal solid waste sources (Buenrostro et al., 2001)

Division	Subdivision	Code	Class (source)	Type of waste	characteristics
Industrial		A	Industry	Industrial	Non-hazardous; potentially hazardous; hazardous
Urban	Non-residential	B	Commerce: department stores; supermarkets, restaurants, markets	commercial	Non-hazardous
		C	Special: needs special techniques for control	Pollutant; from hospitals	Potentially hazardous; biological-infectious
		D	Institutions and services: offices; education centres; libraries and recreations centres (stadium; theatres)	institutional	Non-hazardous
		E	Construction/demolition	Construction	Non-hazardous
	Residential	G	Household: houses; apartments	Domestic	Non-hazardous; potentially hazardous
Rural		F	Agriculture and animal husbandry	Agricultural and animal husbandry	Non-hazardous; potentially hazardous

It is obvious that there are numerous definitions for what constitutes waste. What appears to be common in the definitions is that waste is something that its holder has to be disposed of, or discarded. Whatever its origins, households, industrial or commercial, waste represents the imperfect utilization of raw materials, fuel and water, and hence financial loss for somebody (Read, 1999).

2.3 Solid waste management

‘Management’ can be defined as the carefully planned, judicious use of means to achieve a purpose or an end. In the case of solid waste management, the ‘end’ is the removal and disposal of unwanted material. To achieve this end, technical, environmental, administrative, economic and political issues must be addressed.

Solid waste management (SWM) may therefore be defined as that discipline associated with the control of generation, storage, collection, transfer and transport, processing and recovery, and final disposal of solid wastes in a manner that is in accordance with the best principles of public health, economics, engineering, urban and regional planning, conservation, aesthetics, and other environmental considerations which are also responsive to public attitudes (Jaya Dhindaw, 2004).

In its scope, WM is a complex task, which depends as much upon organization and cooperation between numerous public and private sector actors and as it does upon appropriate technical solutions. It includes all administrative, financial, legal, planning and engineering functions involved in the whole spectrum of solutions to the problem of solid waste. The solutions often involve complex interdisciplinary relationships among various fields such as planning, geography, economics, health science, engineering and politics (Schübeler et al., 1996).

According to Zender (1999), solid waste management (SWM) is the planned channeling and executing control of society’s wastes from generating source to ultimate end-use or “non-use”. Controlling wastes includes collection, hauling, and disposal, as well as recycling, reuse, and reduction.

Municipal Solid Waste Management (MSWM**)** refers to the collection, transfer, treatment, recycling, resource recovery, and disposal of solid waste generated in urban areas. MSWM is a major responsibility of local government and a complex service involving appropriate organizational, technical, and managerial capacity and cooperation between numerous stakeholders in both the private and public sectors (Bernstein, 2004).

Waste management is generally a practical discipline, searching out solutions to individual waste problems: reactionary solutions to control waste-related activities with the aim of protecting the environment and resource conservation.

Given that the everyday problems of waste management are so important to solve, it may even appear so that theorizing, instead of acting, is a loss of time and/or effort (Pongrácz, 2002).

To be able to design the most appropriate waste management system, SWM must have the following goals (Schübeler et al., 1996):

- to protect environmental health
- to promote the quality of the urban environment
- to support the efficiency and productivity of the economy
- to generate employment and income

To achieve the above goals, it is necessary to establish sustainable systems of solid waste management. Solid waste management goals cannot be achieved through isolated, sectoral approaches. Waste management is one of the priority issues concerning protection of the environment and conservation of natural resources. It has become an indispensable part of our modern life and has become increasingly complicated. Actually, there is an increasing attention by managers and planners to follow a sustainable approach to waste management and to integrate strategies that will produce the best practicable option. That is a quite hard task, as it is necessary to properly take into account economic, technical, and normative aspects, paying particular attention to environmental issues (Costi et al., 2004).

Waste management practices have become increasingly sophisticated and environmentally oriented. Sanitary landfills, for example, have replaced open dumps as the primary means of waste disposal. Enforcement and education programs on sound waste prevention and disposal have also expanded with increased knowledge of health and environmental effects of poorly disposed modern-waste streams. The improvement in solid waste management is not distributed among communities equally, due primarily to low income, poor education, and diseconomies of scale (increasing cost per unit as output increases). In general, rural communities in developing countries generally fall behind urban populations in developed countries in their waste programs (Zender, 1999). MSW management is a complex, multidisciplinary problem involving economic and technical aspects, normative constraints about the minimum requirements for recycling and sustainable development issues (Fiorucci et al., 2003). In this context, we can say that SWM can be divided into two groups: the conventional (informal) SWM and the integrated SWM.

Conventional waste management

The conventional system deals with the storage, collection, transportation and disposal of wastes designated as the responsibility of the municipal authorities (or firms under contract to them) which could be land disposal or incineration (figure 2.1). Recycling, re-use and waste minimization do not receive much attention. In many cities, the municipal and contracted system only handles a minor fraction of the potential wastes generated by industries, shops, institutions, hospitals, parks, construction works, and households, etc. In many cities, more wastes are "taken care of" outside of the municipal garbage system, "informally," than by the local authorities (Furedy, 1994) leading to illegal dumping and open burning.

This approach shows some disabilities which can be traced back to a few factors:
inability of the local authorities to pick up all the waste, lack of proper data, lack of financial resources, lack of skill, increasing throw-away mentality, improper disposal facilities, lack of proper legislation, improper organizational structure of the waste management authority, the lack of public participation and lastly the NIMBY (Not In My Backyard) syndrome (Furedy, 1994).

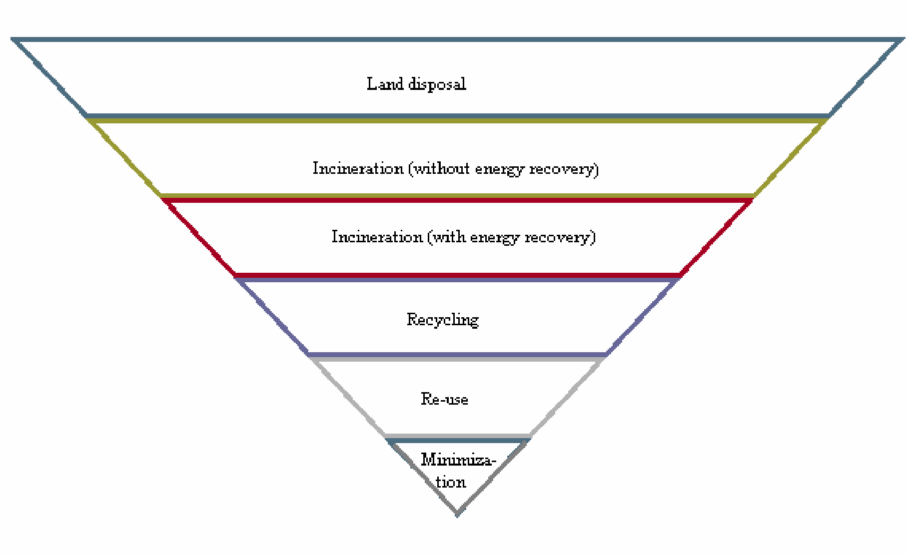


Figure 2.1: Elements of the conventional SWM

As is demonstrated by the narrow approach above, conventional waste management is often considered mainly a technical issue. The approach of the conventional waste management appears to be unsustainable in the nowadays given society, economy and environment, because the approach taken is too much focused only on the technical aspects (Janeen Tang, 2004).

The Brundtland report clearly explained that sustainable development could only be achieved if society in general learns to produce 'more (goods and services) from less (resources)' while generating less pollution and waste (Jaya Dhindaw, 2004). General awareness of our environmental problems has led to the development of cleaner technologies and more stringent legislation on waste handling and disposal to minimize the environmental impact associated with solid wastes. However, until recently the dominant practice of solid waste management has been an "end-of-pipe" approach (conventional SWM). More recently, the desire to conserve our finite resources has shifted the central concern of waste management to waste prevention and minimization (Wang et al., 1996). Focusing on the technical part only is not enough for proper technology choices or the design of waste management systems; other aspects (e.g. social, political, and financial) should be integrated in the analysis or decision-making process to arrive at an integrated and sustainable system (van de Klundert, 1999).

2.4 Integrated solid waste management (ISWM)

The integrated approach to SWM was a response to failures of the conventional approach. The "integrated solid waste management" (ISWM) concept was established by the U.S. Environmental Protection Agency (EPA) in the early 1990's to expand existing solid waste management initiatives. Instead of focusing only on the disposal of solid waste, ISWM includes preventing waste, minimizing the initial generation of materials through source reduction, reusing and recycling, and composting to reduce the volume of materials being sent to landfills or incineration (USEPA, 1995).

The anticipated benefits of an integrated approach to waste management include (Bartone, 2000):

- lower costs
- better cost management and cost recovery
- fewer health hazards
- less environmental pollution
- conservation of natural resources
- better coordination and performance
- improved public participation.

ISWM can be defined as the selection and application of suitable techniques, technologies and management programs to achieve waste management objectives and goals (Tanskanen, 2000).

ISWM refers to a waste management system that best suits the society, economy and environment in a given location, a city in most cases. The concept of ISWM not only considers technical or financial-economic sustainability as is conventionally done, but it also includes socio-cultural, environmental, institutional and political aspects that influence overall sustainability of waste management. ISWM also stands for a strategic and long-term approach. Waste management is seen in the ISWM approach as an equity and public health issue, which means that everybody has a right to a regular waste collection and proper sanitation (Anschiitz and van de Klundert, 2000).

Fabbricino (2001) defined an IMSW system as to be any system capable of using diverse collection methods for different components of waste, and directing the resulting flow of materials to chosen centralized treatment facilities dispersed sensibly throughout the area. IMSW systems consider also aspects related to policies, finances, economics, etc.

According to SWANA (1994, 2003), ISWM involves a series of complementary actions to reduce and recover value from wastes, and to dispose in an environmentally sound manner of those wastes that for technical and economic reasons cannot be eliminated or recovered. A broad definition of IMSWM encompasses source reduction/generation, collection, transfer, re-use, materials recycling, organic materials management (composting), conversion technologies (combustion), pollution prevention, waste to energy, landfilling (disposal) and landfill gas recovery. ISWM also involves the promotion of product stewardship and the purchase of recycled content products, fuels and energy derived from solid waste. The overarching goal of ISWM is to contribute to the health and safety of society, and to protect the natural environment. MSW management falls to local government to plan and assure the necessary operations or actions to remove and manage these solid wastes from their point of generation. Local government must then assure that there is a system to move these wastes through the management cycle. Finally, local government must assure that there is capacity to process and utilize, where possible, these wastes (SWANA, 1994).

2.4.1 Waste management hierarchy

ISWM generally is the same from country to country but the way and the degree that it is applied or the way that it is included in each country's environmental policies depends on each country's strategic views and targets. If waste management is to be a part of sustainable environmental management, it is important to recognize and understand the full range of ways in which wastes are recovered and used (Furedy, 1994).

According to European Union's action on Community Waste Strategy, the different treatment and disposal methods can be presented by the Waste Management Hierarchy (figure 2.2) which is:

- prevention/minimization (reducing the quantity and toxicity of waste in products and materials),
- materials recovery (reusing materials and products, recycling, composting),
- incineration (incineration with/without energy recovery) and
- landfilling (Koufodimos and Samara, 2002; Fiorucci et al., 2003).

This generally accepted waste hierarchy lists activities in terms of preference starting with activities that have the least social, economic and environmental cost and ending with those which have the highest costs (Bartelings, 2003). This philosophy has been adopted by most industrialized nations as the menu for developing solid waste management strategies and promotes environmentally sound handling of wastes, while, at the same time pursuing maximization of energy recovery (Bai and Sutanto, 2002). It provides a general framework, which promotes the environmentally sound handling of waste without providing a strictly determined route of waste management options that has to be followed (Koufodimos and Samara, 2002).

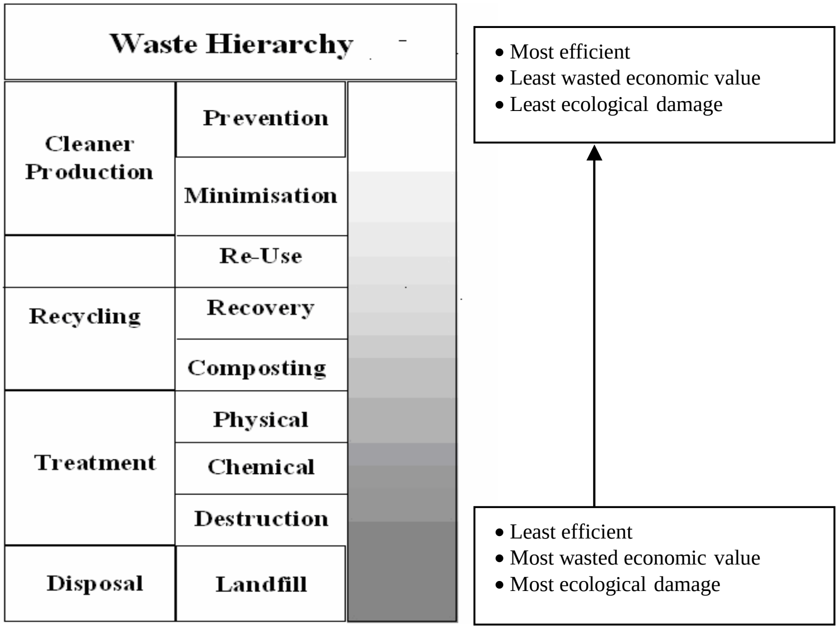


Figure 2.2: Steps in Waste Hierarchy (Waste Planning AP Prep. Planning Team/PU, 1999)

An integrated approach to SWM can deliver both environmental and economic sustainability. However, one must have in mind that no one single method can deal with all materials in waste in an environmentally sustainable way as any waste management system is built up of several closely related processes integrated together. There should not be any contradiction between the different methods instead; they should be regarded as complementing each other (Jaya Dhindaw, 2004). According to USEPA (1997), no single solid waste management approach is perfect. Some waste cannot be successfully recycled, composted, or converted to energy. In addition, some waste will always need to be landfilled, along with any residues from recycling, composting, and waste-to-energy (WTE). It is important that a waste management option is chosen for the waste and not vice-versa. Some of the prevailing environmental legislation creates such a situation, in which we are forced to assign waste that shall be treated by the prescribed way, even if it is not the best-preferred option to treat the waste (Pongrácz, 2002).

The implementation of a promising waste management plan considering the above-mentioned options requires information related to waste composition and physical and chemical characteristics. Considering each of the above mentioned waste management options it is obvious that some of them are not affected by waste composition, while some others are heavily depending on it. The extent to which any one option is used within a given country however varies largely depending on a number of factors such as topography, population density, transportation, infrastructure, socio-economic and environmental regulations (Koufodimos and Samara, 2002; Bai and Sutanto, 2002). The success of the first three options of the waste hierarchy in developing countries is almost entirely dependent on the behaviour of the citizens and the flourishing of the informal waste sector. Only the last two options are the ones that often require expensive technical equipment and are mostly under the jurisdiction of waste authorities. If waste authorities are to be involved in the top, better half of the waste hierarchy they must extend themselves to involve and educate citizens and support the informal waste economy (Gray-Donald, 2001).

The waste hierarchy is often suggested and used in waste policymaking, but in practice, the traditional method is still applied in many countries, even in industrialized countries (LCSWMPD, 2004). According to Martin (2003), waste programs based on the hierarchy enjoyed unparalleled successes in the 1990s and quickly formed the cornerstone of current waste management systems. In recent years, however, the once-steady progress of landfill diversion efforts has stalled. Recycling rates are leveling off, while waste generation continues to rise. While the hierarchy has received widespread support from environmentalists, industry groups and elected officials, over the past two years critics, have attacked its extensive reliance on source reduction and recycling as misguided and expensive (Schall, 1992).

Reasons for hierarchy's limitations (Martin, 2003):

- a severe disruption of existing scrap markets: saturated secondary-materials markets and marginal or negative returns,
- the rapid conversion of the solid-waste stream into a commodity stream: large service corporations, with greater access to capital, markets, and political influence, enjoyed a decided competitive advantage,
- the creation of relatively abundant and inexpensive state-of-the-art disposal capacity: as the volume of wastes flowing to local landfills and incinerators began to ebb through recycling, operators will face with the crisis of *excess* capacity, declining revenue streams, and unmet debt service thereby decreasing the disposal fee below the recycling cost,
- in general principle, socioeconomic changes, as well as significant advances in science and technology, have not been incorporated,
- implementing the waste management hierarchy system can be very expensive (Bartelings, 2003),
- the first priority, to reduce the amount of waste, is in general accepted. However, the other options for taking care of the remaining waste are still the topic of discussions (Finnveden et al., 2005).

The existing waste management hierarchy is essentially a two-dimensional paradigm that places waste-handling technology categories on the X-axis and then ranks them along the Y-axis according to their presumed level of environmental benefit (figure 2.2). It places little emphasis on science, relying instead on generalized notions of environmental performance more on the economic cost of waste management, which forms the major controlling factor in the decision-making process (Martin, 2003). This hypothesis can be supported by the results of the research of Williams and Taylor (2004) which approved that the majority of waste is landfilled (in England 77% of the waste ends up in landfill sites) and 13-14% is managed by recycling/composting.

In contrast, a new model is initiated based on a *three*-dimensional paradigm with the following axes (figure 2.3) (Martin, 2003): Environment (X-axis), Economy (Y-axis), and Society (Z-axis).

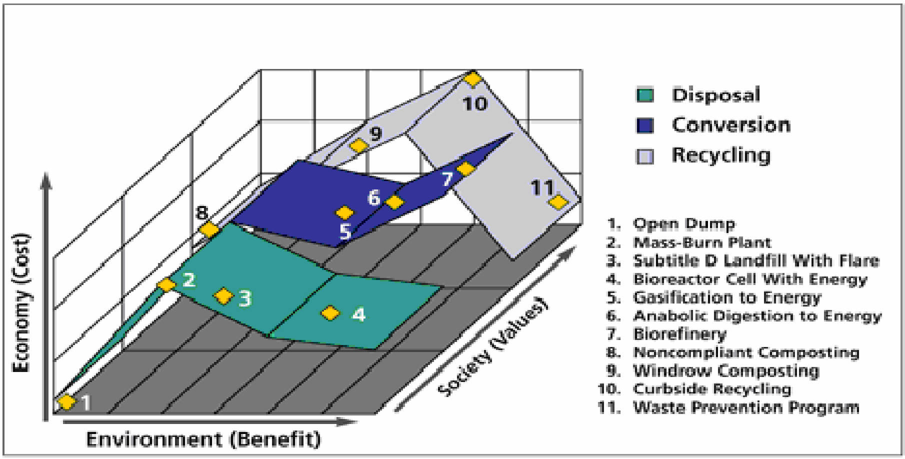


Figure 2.3: New integrated waste management hierarchy: representation of a performance-based environmental platform (Martin, 2003)

2.4.2 Conceptual framework for ISWM

Present day environmental concerns demand more: along with being safe, waste management must also follow the principles of sustainable development. More recently, however, the environmental considerations and social aspects have come to play a more important role. Therefore, for ISWM practices to be sustainable they must be (Anschiitz and van de Klundert, 2000):

1. *Socially acceptable*: the SWM systems must operate in a way that is acceptable to the majority of the people in a community. They should involve the community to inform and educate, develop trust and gain support.

2. *Environmentally effective*: the SWM systems must reduce the environmental burdens of waste management such as various emissions and effluent discharges.
3. *Economically affordable*: the SWM systems must operate at a cost acceptable to the community, which includes citizens, businesses and government.

The balance that would need to be achieved would be to reduce the overall environmental burdens and the waste management systems as far as possible within acceptable levels of cost (Jaya Dhindaw, 2004). Conceptual frameworks for ISWM comprising of stakeholders, waste management elements (activities/options) and strategies aspects (objectives/issues) have been developed by Schübeler et al. (1996) and Anschiitz and van de Klundert (2000). Based on these models, a conceptual framework for ISWM is presented in figure 2.4. As is shown in figure 2.4 sustainability is only possible if the three dimensions of the ISWM model - stakeholders, waste system elements and aspects - get adequate attention. In practice, they must be integrated with each other and not described as if they were separate. It is advisable to consider these dimensions, whenever a waste management system is being planned, analyzed, monitored, etc (Anschiitz et al., 2004).

The factor 'time' is included as a separate aspect in figure 2.4, because it is important for the sustainability of waste management. It is an aspect that should not be forgotten, as development and planning are long-term issues, which need time. Foreign donor agencies and local decision-makers do not always realize that and take adhoc decisions or propose short-term, visible projects. In countries with local and national elections a change of decision-maker every four, five years may turn previous policies upside down and may thwart attempts to arrive at sustainable, long-term solutions (Anschiitz and van de Klundert, 2000).

Waste management runs across different levels: household, neighborhood, city, region, and country (habitat scale). Any ISWM system should therefore distinguish different habitat scales and integrate them as much as possible by equity of service to all levels.

Integrating waste management with other urban systems such as drainage, agriculture, etc. can also enhance sustainability. For instance, compost made from organic waste can be applied in agriculture, public parks etc. and if solid waste is properly collected, residents will not so easily throw it in drains anymore, thus improving the drainage system in a city.

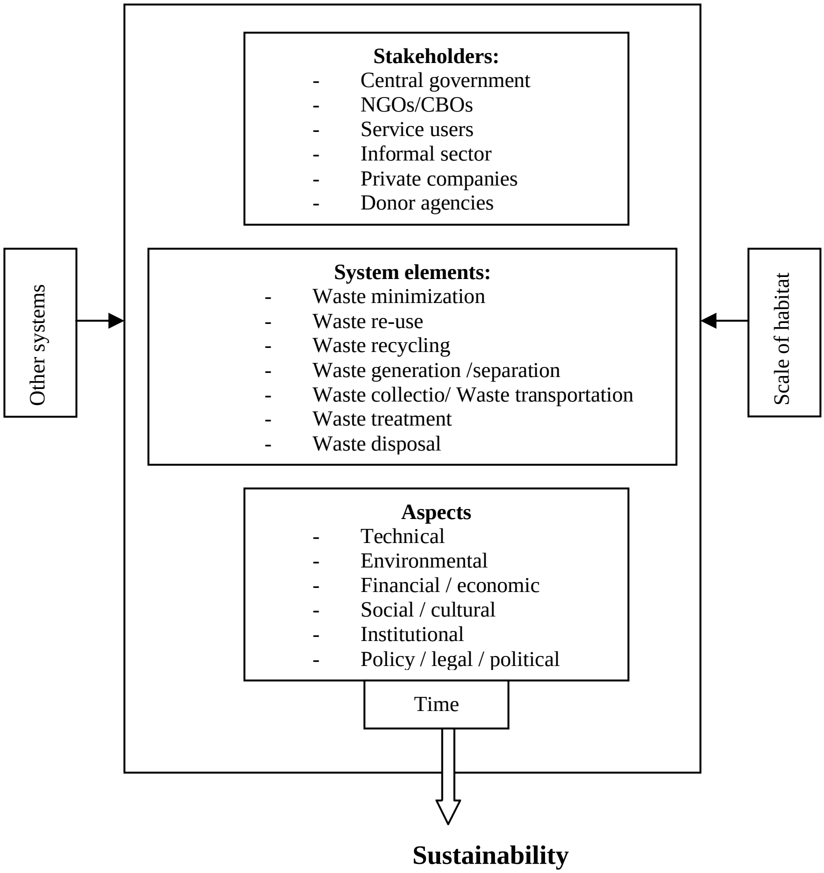


Figure 2.4: Three dimensions of ISWM (Anschiitz and van de Klundert, 2000)

The different types of integration will be explained further hereafter.

2.4.2.1 Integration of different stakeholder groups

To achieve sustainability in waste management it is important to look at the roles, interests and power structures prevalent in waste management. Experience in several countries has shown that co-operation and co-ordination between the different stakeholder groups like a government institute, service users, NGOs, CBOs, the private sector (formal and informal), and donor agencies, will ultimately lead to increased sustainability of a waste management system, such as changes in behavior and sharing of financial responsibilities (Bernstein, 2004). On the other hand, ignoring certain activities or groups (for example the informal sector that recovers and recycles a substantial amount of waste in most countries in the South) will result in decreased sustainability of the system, for example in the form of negative public health effects or increased unemployment.

The roles and responsibilities of the stakeholders are briefly described (Janeen Tang, 2004):

- Residents/households: are mainly interested in receiving effective and dependable waste collection service at a reasonably low price. They must cooperate and support waste management programs.
- NGOs: may help increase the capacity of people or community groups in understanding waste issues and provide important support to informal sector waste workers and enterprises, assisting them to organize themselves, to improve their working conditions and facilities, increase their earnings and extend their access to essential social services such as health care and schooling for children.
- Local governments: are generally responsible for the provision of solid waste collection and disposal services, for the provision of the entire range of infrastructure and social services, for establishing the institutional and legal framework for SWM and ensuring that local

officials have the necessary authority, powers and capacities. Responsibility for waste management is usually specified by laws and regulations.

- Private sector enterprises: may act as potential service suppliers. Operating in various forms of partnership with the public sector, they may provide capital, management and organizational capacity, labor and/or technical skills.
- External support agencies: acquire considerable expertise in the area of waste management. Besides, they can financially support waste management projects.

2.4.2.2 Waste management elements

The functional elements of the SWM system typically include: waste generation (sources, quantity, composition, storage); collection; transfer and transportation; processing or treatment; and final disposal.

Waste quantity

In order to plan the development of waste management facilities, the waste manager needs information about the quantities and types of wastes that are generated within and around the municipality (Rushbrook and Pugh, 1999; Hoornweg and Thomas, 1999; Rand et al., 2000; Mattsson and Ber, 2004). Solid waste generation is a function of private consumption expenditure, and thus it is correlated to gross domestic production, population growth, and increase in income (Inter-American Development Bank, 2003; Prawiradinata, 2004). The volume of MSW produced annually is increasing rapidly because of global urbanization, rapid industrialization and economic development (Dong Suocheng et al., 2001). World Resources Institute indicates that an increase of one percent in per capita income is associated with a 0.34 percent increase in total MSW generation, and that an increase of one percent in population is associated with a

1.04 percent increase in MSW (Beede and Bloom, 1995). Ashworth (1996) supposed that in the urban areas of most developed countries more than 50% of the MSW generated comes from households, 20–40% from commercial operations, and the remainder from industry. There have been only a few studies undertaken in major developing country metropolitan areas to characterize the sources of wastes. In general, it can be said that 50 to 70 % of the MSW consists of household waste (Ashworth, 1996). The following table 2.2 provides a perspective on municipal waste generation as it relates to income levels and urbanization.

Table 2.2: Global perspective global on solid waste quantities (kg/capita/day) (Inter-American Development Bank, 2003)

	Low Income Country	**Middle Income Country**	**High Income Country**
Mixed urban waste – large city	0.50 to 0.75	0.55 to 1.1	0.75 to 2.2
Mixed urban waste – medium-sized city	0.35 to 0.65	0.45 to 0.75	0.65 to 1.5
Residential waste only	0.25 to 0.45	0.35 to 0.65	0.55 to 1.0

- For purposes of this table, a medium-sized city has 100,000 to 500,000 residents, and a large city has above 500,000 residents.
- Urban waste includes residential, commercial, industrial and institutional waste, as well as street sweepings and yard waste.

The prediction of municipal solid waste generation plays an important role in a solid waste management. Per capita generation rates are generally more difficult to predict than population projections (Otten et al., 2002). Traditional forecasting methods (static models) for solid waste generation frequently count on the demographic and socio-economic factors on a per-capita basis. The per-capita coefficient may be taken as fixed over time or they may be projected to change with time. A new approach is to cover all or part of the above-mentioned dynamic features in forecasting analysis. To implement this method requires collecting thorough socio-economic and environmental information before the forecasting analysis can be performed. In many cases, municipalities might not have sufficient budget and management capacity to maintain a complete database of solid waste quantity and quality in support of such needs on a long-term basis (Dyson and Ni-Bin Chang, 2005). Above barriers are some of the reasons for the lack of waste generation data in developing countries.

Waste composition

The composition of MSW has two important consequences for planning and management. First the high organic content, accompanied by the hot and humid climate, results in the need for frequent collection and the appropriate design for storage containers or bins to overcome the unpleasant smell, rodents and insects which are attracted to the wastes. The second is the increasing inorganic constituents provide an attractive opportunity for recycling activities which in turn offer some special benefits, such as reducing the dependency on foreign imports, creating small-scale enterprises or home craft, creating employment, conserving resources, reducing pollution, and reducing the amount of solid wastes requiring disposal (Gatot Yudoko, 2000; Ojeda-Benitez and Beraud-Lozano, 2003). Waste composition depends on a number of factors such as food habits, cultural traditions, socio-economic and climatic conditions (Amponsah. and Salhi, 2004). In developing countries, municipal solid waste contains more than 50% organic matter and 30% recyclable materials, meaning a potential for recycling (table 2.3) (Rushbrook and Pugh, 1999).

Table 2.3: Patterns of municipal refuse quantities and characteristics for lower-, middle-, and higher-income countries (Rushbrook and Pugh, 1999)

	Lower-income countries (a)	Middle-income countries (b)	Higher-income countries (c)
Waste generation (kg/capita/day)	0.4–0.6	0.5–0.9	0.7–1.8
Waste densities (wet weight basis – kg/m^3)	250-500	170-330	100-70
Moisture content (% wet weight at point of generation)	40-80	40–60	20-30
Ranges of composition (% by wet weight)			
Paper	1-10	15-40	15-40
Glass, ceramics	1-10	1-10	4-10
Metals	1-5	1-5	3-13
Plastics	1-5	2-6	2-10
Leather, rubber	1-5	-	-
Wood, bones, straw	1-5	-	-
Textiles	1-5	2-10	2-10
Vegetable/putrescible	40-85	20-65	20-50
Miscellaneous	1-40	1-30	1-20

(a) Includes countries having a per capita income of less than US$360 in 1978

(b) Includes countries having a per capita income of more than US$360 and less than US$ 3500 in 1978

Waste collection

Collection not only includes gathering of solid waste and emptying containers into a suitable vehicle for storage, but also hauling the waste after collection to the location where the collection vehicle is emptied. This location maybe a transfer station, a processing station or a landfill disposal site (Jaya Dhindaw, 2004). Collection is by far the largest cost element in most MSWM systems, accounting for 60-70% of costs in industrialized countries, and 70-90% of costs in developing and transition countries (UNEP/IETC, 1996). Table 2.4 shows the relationships between income levels of countries and percentages of labor, capital, organization and management costs of solid waste collection. In response to this high level of expenditure and low level of service, the main argument raised for the private sector participation is that the private sector might be more efficient than the public sector in providing services. Private sector efficiency is said to be derived from management flexibility, freedom of action, greater financial discipline, and accountability to market forces (Karadag Dogan and Sakar Suleyman, 2003).

Table 2.4: Income levels vs. solid waste collection costs (Cointreau – Levine, 1994)

	Low income	Middle income	High income
Average income ($/capita/year)	350	1,950	17,500
Unit collection cost ($/ton)	15-30	30-70	70-120
As a % of labor, capital, Operation & Maintenance costs of total expenditure	40%	30%	10%
Total cost per capita ($/capita/year)	3-6	9-21	42-72
As a percentage of per capita solid waste collection cost	0.9-1.7	0.5 -1.1	0.2-0.4

It is important to note that different factors have pronounced impact on the waste collection and the cost of collection and transportation of solid waste to landfills which is presented in figure 2.5.

Once waste has been collected, there are three basic alternatives for MSW disposal (Daskalopoulos et al., 1998):

- direct dumping of unprocessed waste in a sanitary landfill or open dump,
- processing of the waste before final disposal (reduce waste volumes),
- processing of the waste to recover resources (materials and or energy) with subsequent disposal of residue.

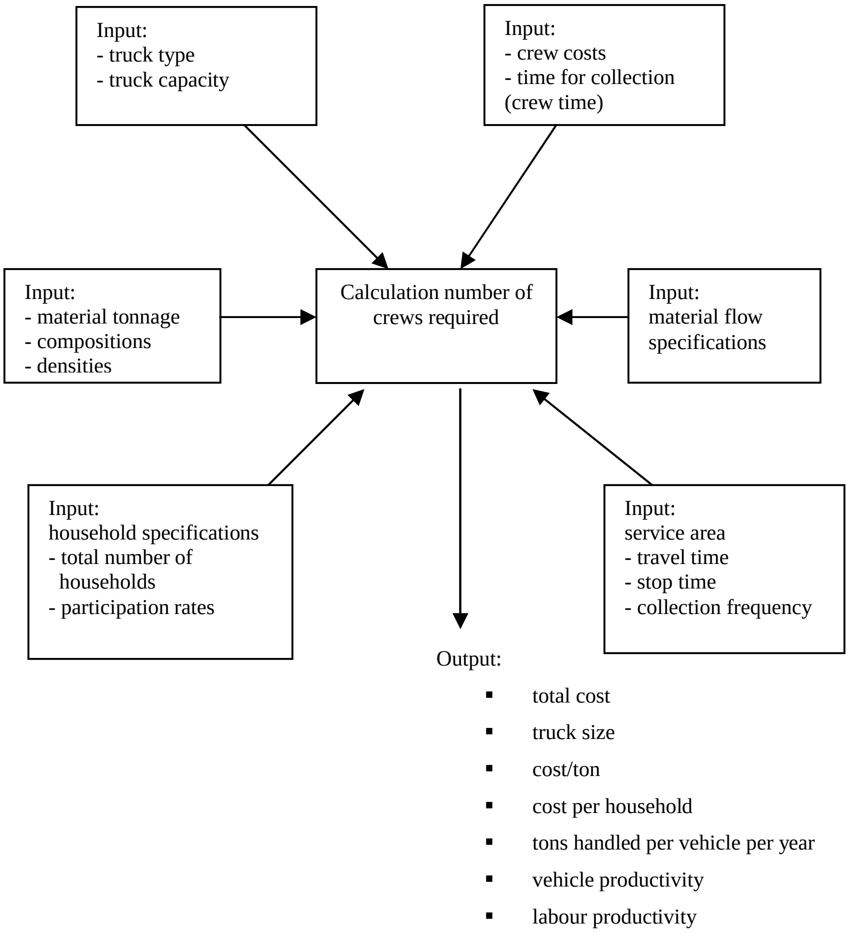


Figure 2.5: Collection cost model to estimate the cost of collecting materials (Ansems, 1998; Bartone and Oliviera, 1990)

Reclamation

Reclamation of material (reuse, recycling, and recovery) from solid wastes helps the community:

- economically (recovered materials use less energy in the process plant compared to virgin material; reduces importation costs (GAO-United States General Accounting Office, 1994).
- environmentally (reduce the amount of waste to be disposed of; limits soil erosion / pollution),
- socially (if organized properly can generate a livelihood for unskilled workers),
- ecologically (recycling conserves natural resources) (Kaseva and Gupta, 1996; Read, 1999).

Recycling

All recycling systems must have four major components in order to function, namely (Daskalopoulos et al., 1998):

- there must be a consistent and reliable source of the recycled materials,
- methods for processing the recovered materials must be in place,
- markets must exist for the reprocessed material,
- consumer’s willingness to participate (Heinz et al., 2004).

It is only when all these components function in an economically viable manner that a successful recycling system can exist. The costs and benefits of reclamation must be studied through a life cycle approach (Metin et al., 2003). A successful refuse collection and recycling scheme needs to be both user- and operator-friendly. There are a number of guiding principles which need to be considered when planning and carrying out service promotion (role of local authority), which include: (1) enhancing motivation/awareness, (2) incentives to participate, (3) enhancing convenience, (4) appealing norms, (5) use of neighborhoods (opportunity structures for participation), and (6) providing effective information, whereby promotions should be timely, specific and provided as close as possible to the point where the desired activity will take place (Read, 1999). To introduce a comprehensive formal waste management system (recycling program), these programs can legitimize and support informal waste workers and sweeper system in order to help create sustainable SWM solutions. Educational and community action programs have the potential to reduce the social stigma of working with waste, and raise awareness of citizens and planners of the integral role of waste workers in the city's daily functioning (Gray- Donald, 2001).

Composting

Currently, 50-70% of the weight of the entire MSW comprises of organic waste and can be readily composted. Composting is an attractive prospective in a policy of waste recycling to produce humus-like compounds to be used for soil improvement and plant growth. The separate collection and composting of organic household waste and yard waste has been in operation for many years in several countries, e.g. composting has a long tradition in India (Zurbrugg et al., 2004). Composting has several advantages: (1) it reduces volume of waste to the landfill or incinerator (2) it reduces emission of methane, a potential greenhouse gas, from landfilling and (3) the production of soil amendment material. By composting, a significant contribution could be made towards the closing of a valuable nutrient material cycle. In most developing countries, lack of economic and environmental motivation means that it will be very difficult, if not impossible, to explicitly promote source separation of compostable materials. Nevertheless, since the success of composting systems and the quality of the compost depend also on the materials that are composted, a separate collection system for compostables would facilitate the production of high-quality compost. Citizens can deliver organic waste to small/decentralized composting plants. The term “decentralized composting” is used here for schemes receiving the main organic waste bulk from neighborhoods where the composting site is located. These facilities will generally be in the range of 2 to 50 tons per day, depending on the size of the community and the proportion of compostable materials in the waste stream. Centralized composting refers to composting of wastes from multiple sources, where the wastes are transported from several points to a facility that can receive 10 to 200 tons per day. (Zurbrugg et al., 2004; UNEP/IETC, 1996; Plahl et al., 2002). Despite the aforementioned advantages, composting has the distinction of being the waste management system with the largest number of failed facilities worldwide. The problems most often cited for the failures of composting include: high operation and management costs, high transportation costs, poor quality product as a result of poor pre-sorting (especially of plastic and glass fragments), poor understanding of the composting process, technical failure (over-design of machines; failure of equipment), marketing failure, lack of community support (household co-operation) and competition from chemical fertilizers (which are often subsidized) (UNEP/IETC, 1996; Zurbrugg et al., 2004; Gatot Yudoko, 2000).

Waste minimization

The most effective way of dealing with waste is to ensure that it does not arise in the first place. Waste minimization and reuse must become an important focus of the waste management strategy. Up till now, waste minimization has taken place within industry and commerce. Still, one of the biggest criticisms leveled at industrial and commercial decision-makers is that not enough is done to prevent waste in the first place (Read, 2000). The present rates of householder participation and recognition in waste minimization is too small. An approach to influence households' attitude to waste minimization is focused on two factors:

- waste minimization at point of purchase; named buying to reduce waste (buy long-life products, buy goods with minimum of packaging),
- repair or re-use of household products; repair/re-use to reduce waste (re-use plastic/glass containers, repair objects).

Therefore, waste minimization campaigns should focus on how minimizing waste which can help to preserve the environment and maintain a good place to live (Tonglet et al., 2004).

Waste disposal

Simple open dumping has been the most common option because it is a cheap, fast, and a convenient mode of disposing of wastes in many developing countries (Rotich et al., 2005). The open dumps are responsible for the different environmental, aesthetic and health hazards (Shekdar, 1997). Illegal dumping and open burning are frequently associated with open dumping. Illegal dumping (also known as "fly dumping," or "midnight dumping") is the littering of waste that occurs at abandoned industrial, commercial, or residential buildings; vacant lots; and poorly lit areas such as roads and open waters (USEPA, 1998). From this perspective, when enough time has passed, and enough damage is noted and experienced, unsound disposal comes to be reviewed as unsustainable, contradictory of the holistic lifestyle, and thus “wrong” (Rotich et al., 2005). Using sanitary landfills as a mean becomes significant while public reluctance concerning open dumping and building of (more) incinerators turn out to be apparent (Weng and Ni-Bin Chang, 2001). Sanitary landfills incorporate a full set of measures which include gas control, collection and treatment of leachate, and the application of base liners. It also includes daily soil cover on waste, networks of monitoring systems; and implementation plans for closure and aftercare of the site (Kgathi and Bolaane, 2001). A number of general characteristics distinguish a sanitary landfill from an open dump, but these characteristics vary from region to region as well as from site to site. The general inputs and outputs/impacts related to landfilling are identical and are shown in figure 2.6.

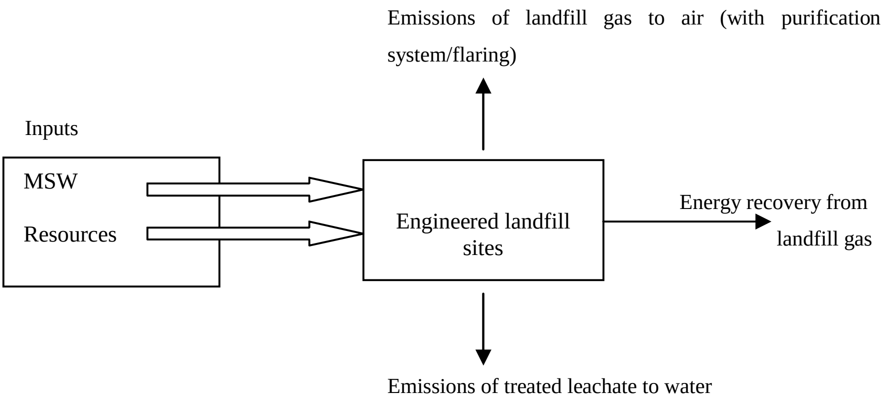


Figure 2.6: Representations of inputs and outputs to a landfill site that cause environmental impacts (European Commission, DG Environment, 2000)

Incineration

An alternative disposal option is incineration. The term incineration refers to the aerobic thermal treatment of MSW with or without the recovery of energy, with the disposal of residual by-products resulting from incineration. Although the specific sequence of unit processes differs between incineration plants, the overall inputs and outputs are similar (see figure 2.7).

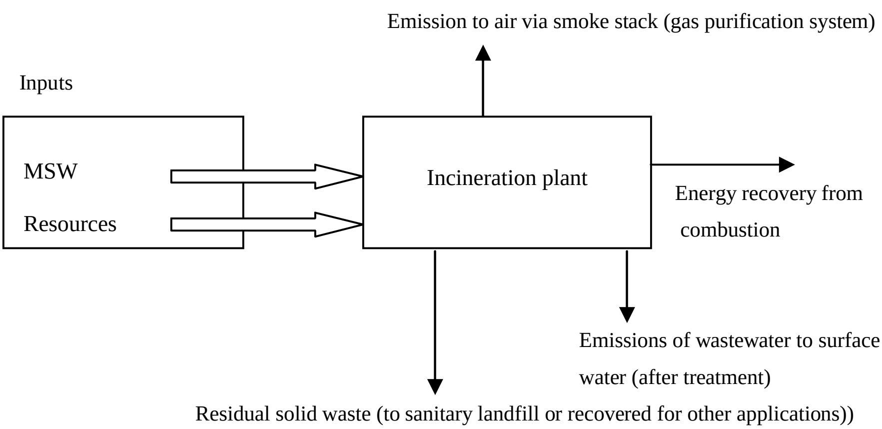


Figure 2.7: Representation of inputs and outputs to an incineration plant (European Commission, DG Environment, 2000)

2.4.2.3 Strategic aspects

There is an interrelationship between urban planning and management of solid wastes. One dominant planning model that has marked urban planning is strategic planning. Strategic planning is a cyclic process (Darius, 2003) and the main components are explained below.

To be politically sustainable, ISWM must be based on clearly formulated goals and priorities, which enjoy broad popular support. Examples of some goals are expanding of the collection services in the city and to introduce an environmentally sound disposal of solid waste (Otten et al., 2002).

Effective waste management and environmental protection programmes call for a clear definition of roles, jurisdictions, legal responsibilities and rights of the concerned governmental bodies and other organizations. The absence of clear jurisdiction may lead to controversies, ineffectiveness and/or inaction, undermining the political sustainability of ISWM systems (Bartone, 2001).

As a basis for performance-oriented management, a comprehensive "strategic plan" for the waste sector is required. This plan should provide relevant quantitative information on waste generation; specify targets for waste reduction, reuse, recycling, and service coverage (Fiorucci et al., 2003). It should describe the organization of waste collection, transfer and disposal in the medium and long-term. Such plans would outline the major system components and the projected relationships between various bodies and organizations involved in the system. They would provide guidelines regarding the degree of decentralization of specific waste management functions and responsibilities, the forms of private enterprise involvement in waste management processes and the role of people's participation. Objectives concerning cost-effective and locally sustainable ISWM would be specified, along with the associated financial policies (Fabbricino, 2001).

The instrumental basis for implementing the strategic plan comprises a legal and regulatory framework, which is elaborated in the form of laws, ordinances and regulations concerning solid waste management and includes corresponding inspection and enforcement responsibilities and procedures at national and local levels. Regulations should be few in number, transparent, unambiguous, easily understood and equitable. Furthermore, they should be conceived with regard to their contribution to urban physical and economic development (European Commission, DG Environment, 2000).

Authorities should consider the full range of available instruments within the policy framework. Regulation and controls must not be the only type of instrument available for achieving waste management goals. Options such as economic incentives must form part of the policy framework (Inter-American Development Bank, 2003).

Improved ISWM capacity normally requires innovations in the organizational structures, staffing plans and job descriptions of responsible local government bodies. The organizational status of the technical agency responsible for solid waste - as a municipal department or authority - needs to be determined.

Based on the defined role of the local government in ISWM, improvement efforts would give primary attention to appropriate financial planning and management methods, including cost-oriented accounting systems, budget planning and control, unit cost calculations and financial and economic analysis. With regard to operational planning, appropriate management methods and skills include data collection techniques, analysis of waste composition, waste generation projection and scenario techniques, formulation of equipment specifications, procurement procedures and management information systems for effective monitoring, evaluation and planning revision (USEPA, 1997).

As an initial step towards improvement, awareness-building measures regarding environmental and sanitation issues may be required among responsible staff and public. On the basis of community’s needs and organizational development plans an appropriate training programme is recommended (Thomas, 2001; Otten et al., 2002).

The main options available to local governments for financing capital investment in the solid waste sector are local budget resources and loans from financial agencies. A further option, is the private sector financing. It is usually preferable to finance operations through user charges rather than general tax revenues (EPAT, 1999). User charges should be based on the actual costs of solid waste management, and related, as far as possible, to the volume of collection service actually provided. Among larger waste generators (such as companies), variable fees may be used to manage the demand for waste services by providing added incentives for waste minimization. To achieve equity of waste service access, some cross-subsidization and/or financing out of general revenues will be required for low-income groups. Large-scale waste generators should pay the full cost of disposal services based on the "polluter pays" principle (Snigdha Chakrabarti and Prasenjit Sarkhel, 2003).

2.5 Private sector and solid waste management

Historically, MSW management services have primarily been provided by municipalities (local governments) as the sole agencies responsible for service delivery (operational and institutional). The demand for better services caused local government budgets to become more strained and political pressure to reduce the size and cost of government becomes more popular (Jacobsohn, 2001; Leavitt, 1994). Other constraints that have reportedly faced the public sector include excessive staff, obsolescent equipment, cumbersome procurement procedures, and inflexible work schedules, limitations on management changes, inadequate supervision, and strong worker unions (Dong Suocheng et al., 2001).

Given the high rates of urban growth and development and the limited local authorities' resources, the participation of other stakeholders is necessary in waste service delivery (Halla and Majani, 1999). Many government's leaders turned to the private sector to provide cost-effective and efficient municipal service (Jacobsohn, 2001, Cointreau, 2005). Two key alternatives to the present impasse are currently favoured: privatization and public-private partnerships (PPP) (Muller and Hoffman, 2001; Cointreau, 2005).

Privatization is a reduction in government activity by divesting government enterprises to private ownership and/or to commercialize government agencies (Cointreau-Levine, 1994; UNCHS (Habitat), 1998). The private sector is generally perceived to be better at design, construction, and in operations. The private sector's strength includes the ability to make decisions fast, manage and control costs, and be creative in strategy, design and the use of technologies and create access to financial resources.

PPP are considered as alternatives to full privatization in which government and private companies assume co-responsibility and co-ownership for the delivery of city services (joint venture). Through these partnerships, the advantages of the private sector – dynamics, access to finance, knowledge of technologies, managerial efficiency, and entrepreneurial spirit – are combined with the social responsibility, environmental awareness, local knowledge and job generation concerns of the public sector (Shafiul and Mansoor, 2004; Cointreau, 2005).

Government officials, who consider privatization, should be aware of the potential pitfalls of privatization and of the objections that opponents of privatization will raise. Some of the most-common objections and pitfalls have been identified (Segal and Moore, 2000):

- private sector is more interested in the more profitable parts of the waste management service, e.g. waste collection

- privatization will result in employee layoffs
- government is responsible for the health and safety of local residents and should not delegate that responsibility to firms motivated by profit
- as contracts become more lucrative, the contract-bidding process will become corrupt
- the dependence on only one contractor (creation of competitiveness in the solid waste industry is recommended).

For these reasons, a mix of public and private service can be an ideal arrangement (PPP) above full privatization. The government and private sector share stocks in the e.g. waste collection company. With a mix public and private service, the material tendency is to make both types of providers more accountable. As a result, the government is motivated to become more efficient, and the contractors recognize that the city cannot be held hostage to monopolies or collusions. At the other hand, urban waste is now defined as an economic good that helps in employment creation and income generation. Therefore, many governments involve the private sector through privatization of some of the services (Bartone, 1991).

However, the introduction of the private sector can produce the desired result only if proper monitoring and evaluation of public versus private service delivery and regulating practices are carried out. Therefore, it is desirable to create a monitoring and auditing agency to inspect the work of the private sector as well as maintain records and periodic reports (Massoud et al., 2003; Nunan, 2000). The focus must be on competition, transparency, and accountability (van de Klundert and Lardinois, 1995).

2.6 Financing solid waste management

2.6.1 Waste management costs

Governments have long provided pick-up and disposal services for households solid wastes; typically, these activities are free of charge or governments charged a fixed amount for the services. This type of service provision represents a simple solid waste policy: clean up the garbage (Skumatz, 1993; Seonghoon Hong, 1999). According to Myles (2004), experience shows that officials usually only know what is budgeted for solid-waste management. However, what is budgeted and what is actually spent differ. As a result, only vague or general identification of costs is made because there is no accounting of solid-waste expenditures (Myles, 2004). Knowing the full costs of municipal solid waste (MSW) management can help government officials to make better decisions about the solid waste program, improve the efficiency of services, and better plan for the future (USEPA, 1997). The identification of actual expenditures is important in order to make plans and decisions. For example, assume that a county government is considering changing from a "containerized" system of garbage collection to a "house-to-house" system or the opposite. The decision is easier if there are accurate records on current costs of providing this service (Myles, 2004).

The cost of municipal waste management is very complex due to the multiplicity of factors that affect it. Table 2.5 lists the types of costs that can be included in MSW management. The first three categories of costs together cover the “life cycle” of MSW activities from “cradle” (up-front costs) to “grave” (back-end costs). These costs give an accurate and useful accounting for management and reporting. The other categories of costs are not strictly costs of current MSW management and could give a misleading impression of current MSW costs. These costs are seen as externalities, which are not paid for under normal market conditions (European Commission, DG Environment, 2000). The decision to include these costs depends on the intended use of the cost information (USEPA, 1997). Table 2.6 provides perspective on how the costs are allocated in countries of various income levels. From this table it can be seen that developed countries invest more in their SWM system.

Table 2.5: Types and examples of MSW management costs (USEPA, 1997)

Types of costs	Examples
Up front costs	Public education and outreach
	Land acquisition
	Permitting
	Building construction/modification
Operating costs	Normal costs such as:
	Operation and maintenance (O&M)
	Capital costs
	Debt services
	Unexpected costs
Back-End costs	Site closure
	Building/equipment decommissioning
	Post-closure care
	Retirement/health benefits for current employees
Remediation costs at inactive sites	Investigation, containment, and cleanup of known releases of pollutants
	Closure and post-closure care at inactive site
Contingent cost	Remediation costs (future releases of pollutants from closed sites.)
	Liability costs (e.g. compensation for yet undiscovered and future damage to property and persons)
Environmental costs	Upstream environmental costs
	Downstream environmental costs
Social costs	Effects on property values, community image, aesthetic value
	Opportunity costs of alternative and future land uses
	Quality of life: noise, odor and traffic

Table 2.6: Global perspective on cost of proper solid waste management cost versus income (Pearce and Turner, 1994)

	Low Income Country	Middle Income Country	High Income Country
Average waste generation	0.2 t/capita/y	0.3 t/capita/y	0.6 t/capita/y
Average income from GNP (Gross National Product)	370 $/capita/y	2,400 $/capita/y	22,000 $/capita/y
Collection cost	10–30 $/t	30–70 $/t	70–120 $/t
Transfer cost	3–8 $/t	5–15 $/t	15–20 $/t
Disposal Cost	3–10 $/t	8–15 $/t	15–50 $/t
Total cost without transfer	13–40 $/t	38–85 $/t	90–170 $/t
Total cost with transfer	16–48 $/t	43–100 $/t	105–190 $/t
Total cost per capita	3–10 $/capita/y	12–30 $/capita/y	60–114 $/capita/y
Cost as % of income	0.7–2.6%	0.5–1.3%	0.2–0.5%

2.6.2 Economic instruments in SWM

The preferred environmental policy instrument to manage solid wastes was in the past the command and control (CAC) regulatory- or administrative instrument (fines, penalties, closure, imprisonment, environmental education, etc.). Because of information deficiencies and the lack of a proper 'system' perspective and success, these instruments are well-meaning but may not always represent a feasible policy objective (Lukyanenko et al., 2002). Regulatory instruments give the regulated few incentives to improve their performance on their own initiative. Failures of regulatory policies made policy-makers search for new and more effective policy-instruments. Economic instruments were the key to the integration of environmental considerations into other policy-areas, and this integration was the key to a sustainable development of waste management. Economic instruments (EIs) have been generally accepted at least in principle in most developed countries. The advantage of economic instruments is that they force producers and consumers to consider environmental concerns and to minimize their use - and waste - of energy and other resources as much as possible (Andersen, 1989). In solid waste management, EIs promise to improve the delivery of services and thus lessen the solid waste problem. For EIs to work effectively, the regulatory standards need to be clear and the compliance enforcement capacity adequate (Inter-American Development Bank, 2003). Economic instruments could be a chance for waste management. This kind of instrument is according to the criteria of the OECD economic efficient, environmentally efficient, administrative cost- effective and acceptable. The economic instrument has also an influence on the individual behavior (Lukyanenko et al., 2002).

Economic instruments as a tool for solid waste management are categorized as follows (Inter-American Development Bank, 2003; UNEP, 2005):

- *revenue raising (generating) instruments*: these include the various kinds of user charges for the provision of collection, transportation and final disposal services
- *revenue providing instruments*: seeks to change behavior by stimulating the private sector to improve its environmental performance, e.g. subsidies or reduction in taxes
- *non-revenue instruments*: include deposit-refund programmes, combine the incentive effects of charges (when a good is purchased and the deposit is made) and subsidies (when the good is returned or otherwise handled properly and the deposit is refunded) for the management of solid waste.

Selection of which instrument to implement depends on the country's solid waste problems and its baseline conditions affecting implementation. Some instruments require more skills to implement than others do; some require stronger judicial systems; some require competitive private sector involvement by companies able to obtain financing and legal advice, as well as to operate on a level playing field;

and some require cost recovery and penalty payment systems that are free of leakage and political interference (Inter-American Development Bank, 2003).

The main economic instruments used are:

- the involvement of private operators in the collection, transportation and final disposal of wastes (see 2.5)
- the deposit and refund system for recyclable wastes, especially paper, cardboard, glass, aluminum cans and plastic and
- the self-financing schemes by user charges or - fees

User charges

As local governments plan and implement SWM systems they will realize that these systems require increasing funds and greater involvement of the users. In this approach each user is charged a price for SWM service. Such charges are useful for generating the necessary revenues to cover costs for solid waste collection. In many developing countries, a user-fee is increasingly being incorporated in property taxes or electricity or water bills, or other means as cost recovery mechanism. The issue of fair charge for the level of service provided becomes a point of importance and political will. However, if the charges are set at very low levels the revenues generated are not earmarked to support the solid waste sector. However, most developing countries have difficulties in implementing user charges that adequately keep pace with inflation to cover costs. Another problem in developing countries is that the full cost of solid waste management is not readily apparent (Seguino et al., 1995; Cointreau-Levine, 1994).

There are two primary sources of user charges: a fixed fee (flat fee) and variable rate fee system.

Fix fee system

This is the traditional or conventional pricing system of charging a fix annual fee (flat fee) to each household for waste disposal services which is usually incorporated into the local property tax assessments or other pay system. The fee per household is the same regardless of how much or what they disposed of (Menell, 2004). This method provides little incentive for households to reduce solid waste generation for two reasons. First, the tax is not visible and instead is implicit in the property tax or other utility bill. Thus, there is often little association between the magnitude of the tax and quantity of household waste requiring disposal. Second, regardless of the quantity of solid waste an individual household disposes, the cost is the same (Seguino et al., 1995). However, in most developing and developed countries households receive fixed price collection services, regardless of the amount they dispose of (Snigdha Chakrabarti and Prasenjit Sarkhel, 2003). The main advantage of the flat fee pricing system is the low collection cost, since the government does not have to keep track of quantity of waste generated by an individual household. Another advantage is no incentive to illegal dumping (Bartelings, 2003).

Variable rate or Unit pricing system

Under a variable-rate system, customers are provided an economic signal to reduce the waste they throw away because garbage bills increase with the volume or weight of waste (Skumatz, 2002; USEPA, 1990). Alternatively, this system is referred to as “unit pricing”, “volume-based fees”, and “pay-by-the-bag” (PB) or pay-as-you-throw (PAYT). Under this system, waste collection fees are based on each unit disposed. The unit may be measured by the number of bags/cans or by the volume of solid waste disposal. A household’s solid waste disposal costs change with the number of bags of waste disposed since each bag is assessed a fee (Seguino et al., 1995a). From an economic perspective, charging households based on the volume or weight of their mixed refuse while providing free curbside collection of recyclable and compostable materials offered a promising approach (Menell, 2004). By introducing the unit pricing system, the government can stimulate recycling and waste separation (Bartelings, 2003).

2.7 Conclusions

In conclusion, in developing countries there is a growing recognition by governments and public about the magnitude of problems associated with waste (costs and amount) and its adverse impacts on the environment. Attempts to deal with planning and management of MSW in developing countries need to consider this complexity. In general, there are three approaches, the conventional -, the integrated – and the sustainable approach. While the conventional approach has its primary focus on technical aspects or operational efficiency of service delivery, the integrated approach focuses on ecological aspects and the last one is an interrelation of technical, economic, social and ecological aspects. ISWM systems need to work towards minimizing the waste generated, maximizing reuse and recycling and disposing of remaining waste in a controlled manner. The brief review of ISWM proved that the formulation of clear objectives (goals), hierarchy options and policy instruments are important to provide insights for the formulation and implementation of ISWM for developing countries. Even with strong political will, improving the SWM system is far from easy in developing countries. Governments face a host of factors that hinder their ability to respond to waste problems. Some examples are the use of policy measures is still focused on weak legislative measures, the generator of waste does not feel responsible for its waste, lack of partnership of stakeholders, and economic instruments are rare. These constraints form obstacles for the governments in developing countries to allocate funds or subsidize the implementation of ISWM. Because the conventional approach will not contribute to sustainable development, the governments in developing countries are more and more forced to follow an integrated approach to MSW planning and management. It is important that developing countries do not copy SWM system from developed countries because selection of inappropriate technology, equipment, etc. can lead to substantial losses to potential return on investment, frustration and incredibility in the government. Attention must be given to cost-effective technologies, greater economic efficiency, environmental health criteria and cost recovery.

Efficient municipal solid waste management systems require professional management, supported by an informed population and appropriate legislation and policies. The key drivers that help waste managers to plan and implement more integrated waste management systems are (Wilson et al., 2001):

- vision and stability
- waste quantity and composition
- adequate funding
- legislation
- combination of policy instruments
- public support

It can be said that effective SWM should begin with a consultative participatory process involving all stakeholders and each of them have a vital role to play.

Chapter 3

Current waste management activities in Greater Paramaribo

Chapter 3
Current waste management activities in Greater Paramaribo

This chapter evaluates the current operational practices in municipal solid waste (MSW) management in Suriname to provide knowledge in the problems of solid waste management. In seeking to address the waste management problems, it is important to review the history of the waste management system in the country. An assessment of the past is always critical in understanding the present and preparing for the future.

3.1 Country's characteristics and trends

3.1.1 Geographical setting

The Republic of Suriname is located on the North-eastern coast of the South American continent between 2°-6° North latitude and 54°-58° West longitude. It borders in the north to the Atlantic Ocean, in the south to Brazil, in the east to French Guyana and in the west to Guyana (figure 3.1). The land area of Suriname is about 164,000 sq. km. with a total population of about 487,024, the largest concentration (50%) being in Paramaribo, the capital of the Republic Suriname (figure 3.2).

3.1.2 Climate

The climate of Suriname is tropical with abundant rainfall, uniform temperature, and high humidity.

The average yearly rainfall 2,000 – 2,250 mm in Paramaribo is generally taken as representative of the country. Two wet and two dry seasons are to be observed here, with about 50% of the annual rainfall occurring in the four months long wet season and about 20% in the two months short wet season. The remaining of the annual rainfall occurs in the dry periods.

The average daily temperature in the coastal region is 27.8º Celsius (º C). January is the coldest month (average 26 º C) and October is the warmest (average 31º C). Annual variation of the average temperature lies within a range of 2°-3°C, in relation to variation of daily temperature, which is 7°-8°C.

The mean wind speed is 1.3 Beaufort. Maximum mean wind speeds occur during the dry seasons attaining 1.6 Beaufort in February with a second peak in September and October. Minimum mean wind speeds of 1.0 Beaufort occur in January. At the coast, the wind speed is 3-4 Beaufort during the day, becoming gradually weak to calm during the nocturnal hours in the interior.

For the coastal regions, daily air humidity is on average as high as 80-90 percent. In central and southern regions of the country, daily air humidity decreases and averages about 75 percent. In the forest tracts, air humidity depends, among others, on the penetration of sun radiation. Variation of relative air humidity in forest tracts lies within the limits of 70-100 percent and between 50-100 percent in open areas.

Figure 3.1: Location of Suriname (in red) (NIMOS-UNEP Chemicals, 2004)

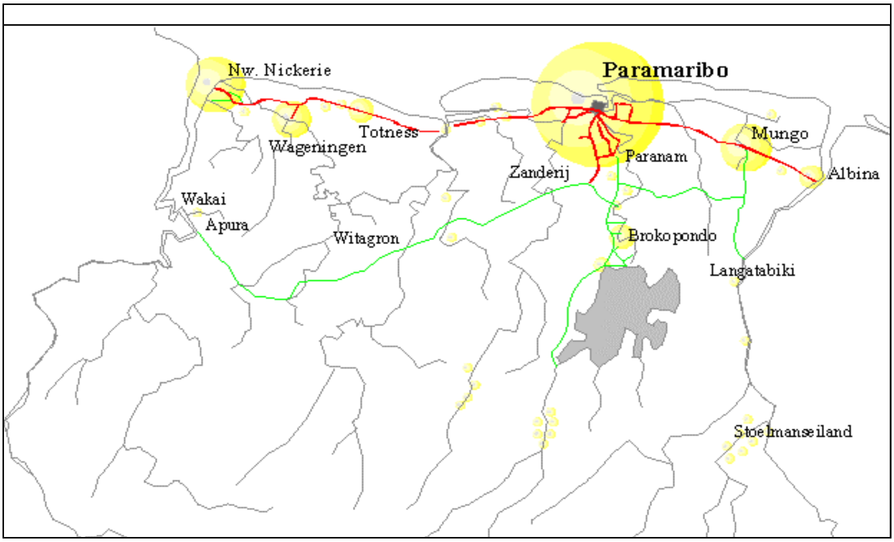


Figure 3.2: Distribution of population of Suriname (in yellow) (NIMOS-UNEP Chemicals, 2004)

3.1.3 Economy

According to the World Bank (2004), Suriname is categorized in the low-income group (GNI per capita: less than US$ 766-3,035).

Suriname's economy can be defined according to the characteristics below:

- narrow economic base
- economic dependence on larger countries for markets and investment and, most significantly, for sea and air transport
- geographic isolation within and between countries which can significantly limit economies of scale (also which, can effectively be reduced by proximity to an established sea or air route)
- inability to exploit land resources fully
- small populations, and hence a limited pool of skills
- production systems are often highly vulnerable
- densely populated coastline to land area, leaving the country vulnerable to marine and climate influences, such as storm waves, salt-related corrosion and marine pollution

- presence of traditional and/or community-based ‘subsistence’ systems of production, which may be sustainable in the face of country’s constraints.

3.1.4 Environmental management

Suriname has, since the establishment of the National Institute for Environment and Development in Suriname (NIMOS), adopted approaches that reflect its geography, the unique structure of its social, cultural and environmental priorities. Accordingly, Suriname shapes its strategic interests on the precautionary principle that environmental protection and environmental improvement are complementary to successful economical development. Today the success of its environmental protection measures receives worldwide recognition, such as the establishment of Central Suriname Nature Reserve. Suriname’s belief is that environmental protection requirements must be integrated into the definition and implementation of national and international policies to ensure maximum benefit. Over the next decade, Suriname will make sure that its population has a right to an environment worth living in by five basic prerequisites (NIMOS-UNEP Chemicals, 2004):

- management of climate change risks while preserving economic growth and international competitiveness
- implementation of “Environmental Friendliness”. This implies, inter-alia, prevention of environmental degradation by careful land-use planning
- adoption of economic instruments based on the “polluter-pays principle”
- practice of environmental pollution control. This includes treatment and recycling of waste water, safe management of hazardous waste and toxic chemicals
- monitoring of climate change and practice of biodiversity conservation. This includes concerns about climate change, biodiversity conservation and control of desertification.

3.2 Previous studies on waste management

The government of Suriname is aware of the waste problem in the country; therefore several consultants were hired to study this problem and its solutions. However, until present none of these plans/projects are activated. Below the most important studies/projects are summarized:

1. Construction of a sanitary landfill

By order of the government of Suriname, a Dutch consultant made a study to the construction and operation of a sanitary landfill. The planned location of the landfill is situated 13 km from the capital city Paramaribo (the current site of the present disposal area). The active surface of the disposal area will be 20 ha and the lifetime of this landfill will be 20 – 25 years. The construction of the landfill will be according to international standards. The landfill will operate in an environmental and hygienic way as part of the waste disposal management plan (leachate treatment). According to the consultant, environmental monitoring will be part of the waste disposal management and will consist of supervision of the continuous analyzing of the percolate, surface and groundwater, and complaints from the neighbors. The main obstacles in implementing this project were a question of political matter and finance.

2. Improving the solid waste management system

Roteb, the waste processing company of the city Rotterdam (The Netherlands) was interested to improve and develop together with the government of Suriname (Ministry of Public Works) our solid waste management system, especially waste collection. The main obstacle in the continuation of this cooperation was a political matter and finance. Suriname was not able to finance the activities to improve our waste system with financial aid from the Netherlands.

3. Waste to energy

This project involves the realization and guidance of the purchase of a technical installation (gasifier), with a capacity of 350 ton/day and a lifetime of 10 years, for waste gasification combined with energy generation. According to the consultant, every kind of waste can be gasified in this installation, from paper to tires to used engine oils, to hazardous process waste etc. Other advantages of this project are no emission of hazardous gases (furans and dioxins) such as in an incinerator, that the residue produced during the gasification process can be used as input material (source) for the process and that an enormous amount of energy will be produced (660 MW/day) which can be used for local consumption. The surplus of energy can be sold to neighbouring countries of which the yield will contribute to our foreign exchange. With the production of this form of energy, the current shortage of capacity for energy generation will be a thing of the past. Disadvantages of this system are that the investment (40-45 million Euro) is very high and there is no potential for recycling. The high investment can be the main obstacle in implementing this plan.

4. Improving the solid waste management system

For the moment, the government hired a consultant from The Nederlandse Antillen to assist the government in upgrading the current waste management system. This consultant already formulated a waste act (which already passed the Parliament) and developed a business plan for the future solid waste authority.

The general remark of these studies is that never a waste characterization study has been done. The figures used, were available from the waste department of the Ministry of Public Works and are according to the author not reliable.

3.3 Introduction: solid waste disposal – a historical perspective

3.3.1 Organization of solid waste management

Paramaribo is the capital city of Suriname and has a population of about 243,640 inhabitants with a square area of 182 km^2 (ABS, 2005a). Paramaribo is the commercial centre for the country. Historically, MSW management services have been provided by the local government. Residential refuse collection is performed by the Ministry of Public Works (Ministry of OW) and covers the municipality, Greater Paramaribo (urban area). Greater Paramaribo is formed by the districts of Paramaribo and a part of Wanica, with a population of about 272,331 inhabitants. Within this Ministry, the Department of Waste Collection and Disposal (VOV) is responsible for waste collection and disposal. Refuse collection consists of collection of waste placed at the curb by residents (door to door collection), from designated places (street or communal containers), the cleaning of illegal dumps and emptying waste containers of companies. All the collected waste is brought to the uncontrolled landfill, better say open dump.

The mission statement of VOV is to improve adequate waste collection and disposal in Greater Paramaribo (Chote, 2005).

The responsibilities of VOV are:

- to collect and dispose of the waste
- to analyze waste data for formulation of a waste disposal policy
- to advice the ministry with regard to waste disposal
- to participate in government workgroups and commissions concerning waste disposal
- to exploit all equipment in the matter of waste collection and disposal in an economically responsible way
- to organize on a regular basis meetings with workers and contractors.

Due to different reasons (explained further in this chapter) VOV is not able to reach all the responsibilities formulated, therefore, a commission was composed: Commission Independence Waste Collection and Disposal.
The main purpose of this commission is to turn VOV into an independent entity with the name Suriname's Waste Collection and Disposal Company (NV SAVEB). With the independence, the total system within the VOV will change, transforming VOV into a private business and not a government office. To perform on a business base, in the future, each customer that will make use of the services of NV SAVEB has to pay a fee.

To reach its purpose the commission is presently working on 4 projects:

- the introduction of a Waste Act; this act already passed the Board of Ministers and is momentary at the Council of the State. This act was formulated by the National Institute for Environment and Development and upgraded by a foreign consultant hired by the Ministry
- the set-up of a business plan; consists of measures how the new waste company must be exploited in an economically responsible way formulated by the foreign consultant
- the set-up of a waste collection plan including zone definition and route description within the collection zones
- adaptation of the existing open dump for the construction and operation of a sanitary landfill according to international environmental standards.

Financing of these projects will be possible from Development Aid from the Netherlands, State's budget and partly from private means.

For the moment, VOV is guided by a chief official and consists of the following offices:

- Waste disposal -   uncontrolled landfill
- Business office -   responsible for the wash place
- Administration -   responsible for warehouse and office care

- Exploitation - responsible for control, small maintenance, zone division, containers and maintenance of the ground-plot.

The following organogram (figure 3.3) represents the existing organization structure of VOV. At present VOV employs 179 employees.

Since VOV is only responsible for waste collection and disposal in Greater Paramaribo, this Department has a cooperative joint with other government organizations to collect and dispose of waste in other parts of the country.

The government organizations with VOV are cooperating with:

- The Ministry of Regional Development, especially the District-commissioners: are responsible for waste collection in their own districts (mainly crowded inhabited rural areas)
- The Directorate Milieubeheer: is responsible for the collection of crude waste such as car wrecks, discarded washing machines and garden waste (trunks of trees and branches); the cleaning of illegal dumps; the cleaning of plots after festivities; maintenance of public gardens; the cleaning of fire-beak areas; the cleaning of dead animal bodies along public roads and at the request of private people (on payment) the cleaning of demolition – and construction waste, etc.

A problem is that each of these waste collection institutes are subjected to political interference and complex bureaucratic rules. Limited observation leads us to conclude that funding and the political support behind management may be more important than formal organizational structures.

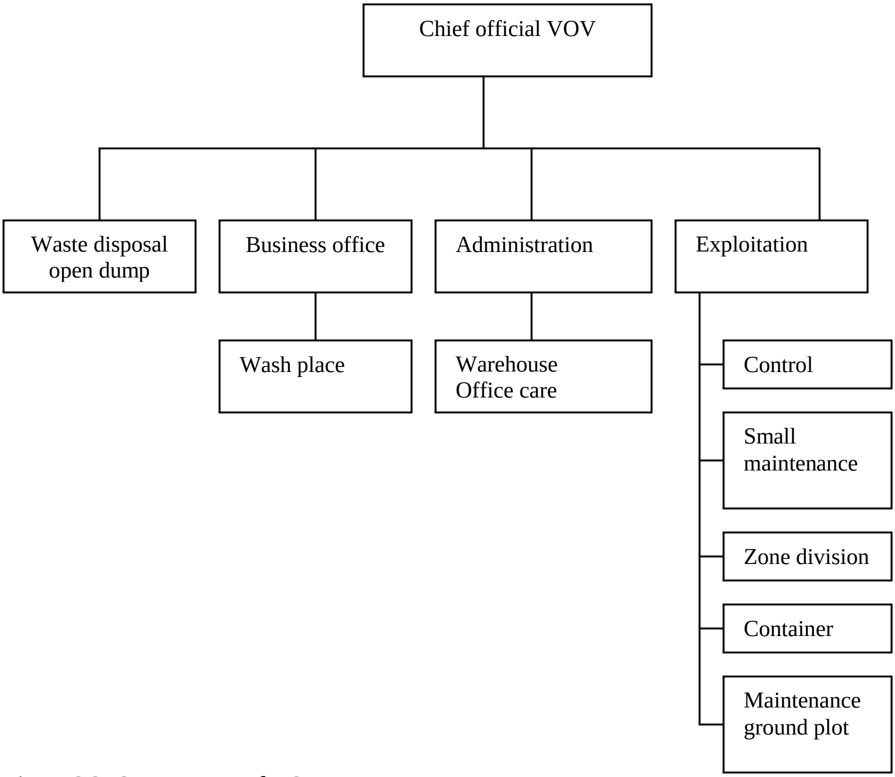


Figure 3.3: Organogram of VOV

Other institutions that are involved in residential waste in Suriname are:

- Office of Public Health of the Ministry of Public Health (BOG): control of hygiene in hospitals, restaurants, schools, polyclinics, etc. and education and information regarding environmental hygiene matters and sickness caused by waste, responsible for environmental and health standards
- National Institute for Environment and Development (NIMOS): legislation, environmental problems, education and information
- Non-Governmental Organizations (NGO's) - Foundation for Clean Suriname: environmental education project; cleanup-projects
- University of Suriname – Environmental Department: research and higher environmental education

- Pan American Health Organization (PAHO): support and advice related to waste collection and disposal; waste education and information to primary schools and support of activities to increase environmental awareness among the general public
- Private companies: supply financial support to information and education projects.

3.3.2 Constraints and limitations of solid waste management

The approaches, methods and techniques employed in solid waste management in Suriname are often inadequate and are limited to collection, transportation and disposal (in open dumps). The waste management system that is applied in Suriname is presented in figure 3.4.

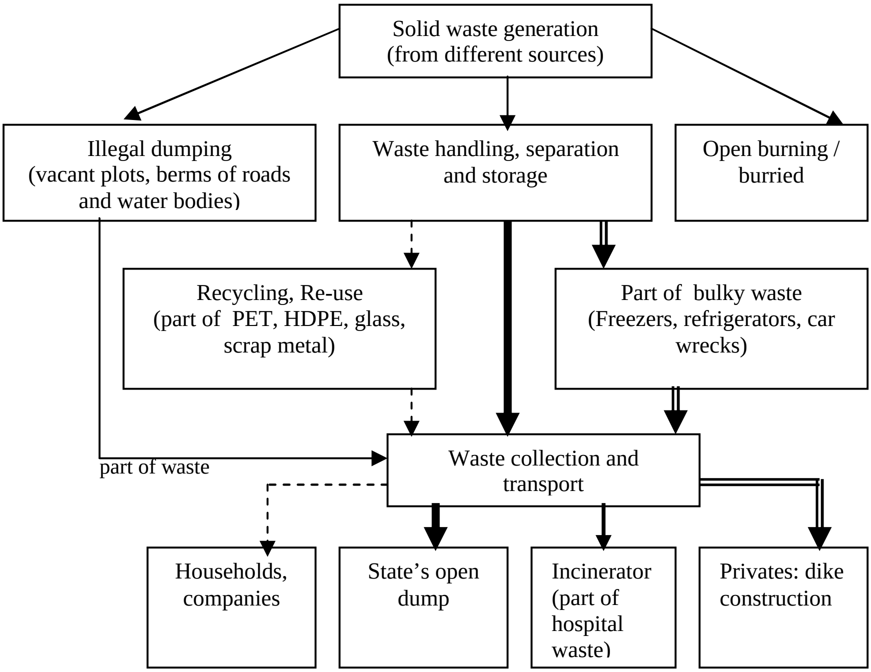


Figure 3.4: Basic components of SWM in Greater Paramaribo

The solid waste management system in Suriname displays an array of problems. These problems can be categorized into technical, financial, institutional, economic, and social constraints. Hereafter follows an explanation of these constraints.

(a) Technical Constraints

In Suriname, the coverage of solid waste collection service is inefficient. More specifically, in Greater Paramaribo, the transport distances for waste collection are constantly increasing due to the expansion of the city. Hence, it becomes more time-consuming, expensive and less efficient.

Another technical constraint is the inadequate disposal of solid waste: most of the solid wastes are dumped in an uncontrolled manner in different space locations normally called open dumps. These dumps make very uneconomical use of the available space, give waste pickers and animals free access to the dumps and often produce contamination of the environment.

Lack of reliable waste statistics and waste characterization studies to define the quantity and quality of waste generated were never implemented. As a result, improving the disposal site would have little impact on the overall solid waste management effectiveness.

Research and development activities in solid waste management have often been of low priority to the government. This has resulted in the selection of inappropriate technology that does not suit local climatic and physical conditions, financial and human resource capabilities, and social or cultural acceptability of the country.

(b) Financial Constraints

In general, solid waste management is given a very low priority in Suriname. As a result, very limited funds are provided to the solid waste management sector by the government, and the levels of services required for protection of public health and the environment are not attained.

Financial problems are the main reasons for inadequate disposal of solid waste especially where the ministry is underfinanced and population growth continues. The financial problem is acute at the government level where the local taxation system is inadequately developed and, therefore, the financial basis for public services, including solid waste management, is weak. This weak financial basis of local governments can be supplemented by the collection of user service charges; however, the latter is not introduced yet in Suriname. Generally waste collection and disposal services are provided free of charge. An effective strategy for raising funds needs to be searched to ensure its sustainability.

In addition to the limited funds, the government in Suriname is lacking good financial management and planning. The lack of financial management and planning, particularly full cost accounting, depletes the limited resources available even more quickly, and causes several services to halt for some periods, thus losing the trust of service users.

(c) Institutional Constraints

Several institutions are usually involved (see above) at least partially in solid waste management. Although, there are some roles/functions of these various national agencies defined in relation to solid waste management, the lack of coordination among these agencies often results in limited support to other agencies projects. This leads to wasting of resources, and unsustainability of overall solid waste management.

The lack of effective legislation for solid waste management is partially responsible for the roles/functions of the relevant national agencies not being clearly defined and the lack of coordination among them. Legislation related to solid waste management in Suriname is usually fragmented, and several laws (e.g., Police Penalty Act, Hindrance Act, etc.) include some clauses on rules/regulations regarding environmental/solid waste management. The rules and regulations are enforced by the different agencies. However, there are often duplication of responsibilities of the agencies involved and gaps/missing elements in the regulatory provisions for the development of effective solid waste management systems.

Another constraint is the lack of overall plans for solid waste management. As a result, decisions are taken or projects are implemented without due consideration to their appropriateness in the overall solid waste management system.

Another problem is the lack of enforcement of existing legislation, particularly about the prevention of littering and indiscriminate dumping of waste. It should be also noted that legislation is only effective if it is enforced. Therefore, comprehensive legislation, which avoids the duplication of responsibilities, fills in the gaps of important regulatory functions, and is enforceable, is required for sustainable development of solid waste management systems. This is one of the planned projects that will be implemented (see above).

Because of a low priority given to the sector, the institutional capacity of government agencies involved in solid waste management is generally weak. These weak local government institutions are not always provided with clear mandates and sufficient resources to fulfill the mandates. Coordination among the government institutions is critical to achieve the most cost-effective alternatives for solid waste management in the area. For instance, the sitings of the disposal facility Ornamibo and the faecal dumpsite were disapproved by the Office of Public Health but the Ministry of Public Works forced its decision. However, as these facilities are usually considered unwanted installations and create not-in-my-backyard (NIMBY) syndromes among the residents, the government was not willing to relocate them. The lack of a coordinating body among the government institutions often leads to disintegrated and unsustainable programmes for solid waste management.

The local government normally employs a clumsy bureaucratic system. Since this sector feels that the sole responsibility is in its hand, it always manages the system by itself. The other stakeholders, like the residents, the commercials, the offices, etc. are mostly not asked to participate in making decisions and executing the waste related activities. The government does not feel accountable to the people at all. In most cases, the financial, personnel and other kinds of management are not transparent. Very few or none of the residents (general public) learn how money is spent and what results are achieved; this leads to financial scandals within this Ministry.

Other common problematic areas are the improper quantity and quality of staff dealing with waste management related issues. Without adequately trained personnel, the projects initiated with the help of external consultants (see above) will not be continued on the long term. The government is not well equipped with technical, managerial, autonomous capacities and due to strong political wills they can hardly issue proper policies, measures, bills and/or regulations suited for waste problem's prevention and solution. Consequently, the people, commercials and industries do not follow the rules and regulations since the state itself cannot enforce them.

The policy to go for costly and advanced technology in solid waste management (e.g. incineration) does not coincide with local professional believes and the country’s financial conditions but more often it only allows some of government officials to get side line commissions. This normally results in misplacement of priorities in terms of budgetary allocation for SWM projects.

(d) Economic Constraints

Suriname has weak economic bases and, hence, insufficient funds for sustainable development of solid waste management systems. Economic and industrial development plays key roles in solid waste management because they enable funds, which can be allocated for solid waste management, providing a more sustainable financial basis. Due to lack of liability in the government, private companies are not willing to support financing the waste sector.

The lack of industry manufacturing solid waste equipment and spare parts and a limited foreign exchange for importing such equipment/spare parts are the rule rather than exception in Suriname. Lack of which is often responsible for the irregular and insufficient solid waste collection and disposal services in our country.

(e) Social Constraints

The social status of solid waste management workers is generally low in Suriname: although they are treated well by some residents, people are still swearing at them. Such people's perception leads to the disrespect for the work and in turn produces low working ethics of labours.

The low public awareness and school education about the importance of proper solid waste management for health and well-being of people severely restricts the use of community-based approaches. People are still throwing waste out of windows from buses and cars; others are dumping their waste in canals, along the streets and vacant plots. NGO's present programs and spots on TV about the behavior of the population concerning waste but these activities do not increase there awareness. These programs will have no effect unless they are not combined with penalties for offenders. The Police Act meets the latter but is not maintained.

At dump sites waste picking or scavenging activities are common scenes and vagabonds and animals (dogs and rats) are frequently disturbing street refuse bins. The waste pickers involved have received low school education and they are affected by limited employment opportunities available. However, if organized properly, their activities can be effectively incorporated into a waste recycling system. Such an opportunistic approach is required for sustainable development of solid waste management programmes. The existence of vagabonds/animals creates sometimes an obstacle to the operation of solid waste collection because they are littering the content of the waste bins. Waste collectors do not receive vocational training to obtain knowledge and skills required for their jobs so they do not understand the importance of their work and behave also in that way.

Although VOV is encountered with these limitations, they have established a procedure for dealing with costumer's complaint. If a costumer has any complaint about the service or the fee (companies), then he or she can send his/her complaint by directly going to VOV office or calling by telephone. VOV contacts the waste collector crew or the contractor responsible for the operation in the relating collection zone e.g. to attend yet the zone or company.

3.3.3 Legislation

There are several laws that directly or indirectly address environmental issues. The existing laws are outdated and represent gaps, which in many cases led to system dysfunction. The inconsistent interpretation and lack of knowledge of legislation at different levels has consequently been the source of much confusion for e.g. a definition of waste, standards and requirements, economic tools (fees and penalties) and emission limits are missing in current legislation addressing environmental issues. Presently, Suriname does not have any law that regulates the collection, transport, disposal or treatment of waste. Some of the existing legislation concerning waste management is listed below.

- *the Hindrance act (G.B 1930 no 64)*

Applicable to facilities (firms) that produce waste, can cause nuisance, danger or damage. On the strength of this act, a permit can be refused or special conditions can be attended to the permit. Sanction at violation: a custody at the most of 14 days or a fine not exceeding US$36.00.

- *the Police Penal law (G.B 1942 no 152 / S.B 1980 no 121)*

Article 39a: Applicable to the illegal dumping of waste. Sanction at violation: a custody at the most of two months or a fine not exceeding US$ 182.00.
Article 51: Applicable to contamination of a draw-well
Article 73: Applicable to dumping of car wrecks along public roads
Sanction at violation: a fine equals the cost for collection, disposal and nullifying.

- *Decree 1980 no 68*

Applicable to the ecological condition of residential areas: cleanliness of plots.

Sanction at violation: a custody at the most of one month or a fine not exceeding US$91.00.

- *Decree 1981 no 125*

Applicable to abandoned plots (cleanliness of plots).

The President of Suriname is authorized to declare by resolution to suspect that if there is on the unique piece of plot neither proprietary right nor collateral right the plot will be State Demesne.

- *Decree 1985 no 40*

This decree puts regulation for licensed establishments and professions.

Several departments linked to several Ministries are responsible for these laws, which make enforcement impracticable. Another problem the institutions and public are encountering is the lack of coordination between these departments.

An essential primary step in municipal solid waste management is the requirement to make producers of waste responsible for the whole chain of waste collection, transportation and disposal and for preventing any offence in the disposing, treating or storing of their waste. From this point of view, NIMOS formulated a concept Environmental Law, which includes an integrated approach to environmental management, including waste management. In cooperation with an external consultant, the Ministry of Public Works formulated a Waste Act, which will change the face of solid waste management. The waste act includes 17 chapters which are dealing with the description of the different waste types; the establishment of waste collection company and its responsibilities; regulations concerning waste collection; guidelines for a waste plan; guidelines for waste disposal and treatment; facility management specifications; application of different economic tools; guidelines for enforcement and sanctions and environmental measures. This law that is in the process of approval will be considered the most relevant law concerning waste management.

3.4 Solid waste generation

Suriname has no reports on waste quantification and characterization. No reliable data exist about the generation and composition of the waste entering the uncontrolled landfill (Ornamibo). VOV made a very rough calculation about the waste generation in Greater Paramaribo (visual measurement): 70,000 ton of residential waste per year and 50,000 ton of crude waste (commercial, industrial, etc.) per year. According to officials of VOV, this estimation was done using the following two methods:

- a single counting of incoming trucks at the disposal site and estimating their capacity (there is no scale at the entrance of the dump and no written reports available)
- the use of World Bank generation rate for Developing Countries 0.4 kg/capita/day.

These data are used for years by VOV as the reference generation rate not taking into account that waste generation could increase with years. The latter is confirmed by waste collection crews who experience an increase in the total waste generation. The last can be attributed mainly to urbanization and increased consumption of products (enhanced product imports). The lack of essential equipment (weighbridges) at the disposal site makes the direct determination of disposed waste quantities impossible. Therefore, there is no information on waste composition and generation rates as a function of season or socio-economic status of an area.

Management of any solid waste requires the knowledge of the sources of waste generation, generation rates, quantities of waste generated, the physical and chemical characteristics of the waste. It is also pertinent to know the components and composition of waste. Therefore, a three-year research was done in waste characterization at the University of Suriname – Environmental Department. This research was done to contribute in the improvement of waste management policy and to determine the most efficient way to manage our wastes. Other reasons were to support waste management authorities/officials in order to estimate the resource recovery value and necessary collection equipment. This study was sponsored by the Belgian Technical Cooperation (BTC) and for detailed information see chapter IV.

Although waste characterization is a key component in any MSWM system, such data are not commonly compiled by VOV. This may change as VOV will upgrade the SWM system.

3.5 Solid waste collection and transport

3.5.1 Collection area Greater Paramaribo

Although most areas in Greater Paramaribo have waste collection services, this service is usually not available to all sectors of the population. Waste is usually collected from the high and middle-income areas of the city but in some lower-income areas, this service is less than the two other areas. In these lower-income areas the roads are in poor condition making it difficult for waste collection vehicles to assess the area.

The collection service area Greater Paramaribo has a square area of 250 km^2 and is divided in 3 areas, which are subdivided in 88 collection zones (Chote, 2005). This division is as follows:

- Area North: 34 collection zones
- Area Midst: 29 collection zones
- Area South: 25 collection zones

Due to urbanization and increasing parceling projects, VOV has plans to make a new division. Greater Paramaribo has a population size of 272,331 inhabitants and 63,333 households (ABS, 2005a) and is characterized by an intensive development; the development density differs from collection zone to collection zone. For a major part the accessibility to many collection areas is in a bad condition; with the implementation of the project of the government ”Asphalt of the primary roads” the condition of many roads is improved.

The boundaries of the collection area of Greater Paramaribo are defined as follows:

- in the North by the area Leonsberg
- in the East by the Suriname river
- in the West by the Derde Rijweg
- in the South by the Nieuw Weergevonden weg

Since 2002, VOV is also in charge of waste collection and disposal in the following areas (increase of the collection area):

- Indira Gandhiweg up to Lelydorp
- Kwatta up to 4^{e} Rijweg + Sophia’s lust
- Highway up to Km 10 (Suralco weg)
- Commissaris Weythingweg up to Leiding 9A
- Nieuw Weergevonden weg up to Magentabrug

Each collection zone is designated with a code; for example, collection zone N2 includes the following streets: Tourtonnelaan, David Simon straat, Wilhelmina straat, Jamaludin straat, and Arnold straat. The collection of solid waste from the households in the collection zones occurred by contractors. The zones are (not equally) divided among the contractors; to prevent problems in the future VOV aims at an equal division of collection zones among the contractors.

The Ministry of Public Works auctioned contracts to collect garbage in the zones to the lowest qualified bidders. Contractors are paid monthly lump sums for collecting and disposing of wastes generated in their respective zones. Collecting garbage in residential areas is very expensive. It must be recognized that companies sometimes try to break into bidding "strategically." That is, they offer a low price, knowing they will not make a normal profit; just to be sure, they get a contract. Private firms (or individuals who own a truck) also provide service on a fee basis to households and commercial establishments. The latter complains about the service of VOV (not reliable) and therefore they hire their own private collector. At random, the waste collection activities of the contractors are controlled by controllers. These controllers check if the contractors are doing their work in a proper way and trace illegal dumping places. Contractors receive orders to clean up these illegal dumps. Up to the present, the waste collection system is still deficient.

3.5.2 Collection frequency

In Greater Paramaribo waste collection is twice a week for each collection zone (not including the many areas of Greater Paramaribo, which are not serviced at all) from Monday until Saturday between 7.30 – 15.00 hr (also on rush hours, and on very busy days until 18.00 hr) through collection routes determined by the driver of a collection truck. Each area has its specific days for collecting waste. Frequency of collection (two times a week), in many cases, is determined by technical considerations such as putrefaction rates of the wastes, weather, vehicle availability, and routing necessities. On the other hand the efficiency of household waste collection depends on area size, length of route, number of residence, set out rate, traffic situation, and household behavior. In the town centre waste is collected every day; twice a day, in the morning and after closing of shops. There are plans to shrink the boundaries of the town centre with the intention to service the centre once a day.

The cleaning of small illegal dumps occurred 7 days a week by contractors; cleaning of large illegal dumps occurs by Milieubeheer. With these groups of contractors, VOV (cleaning small dumps) has special arrangements: they may transport a maximum of 4 loads per day to the dumpsite. If the collection crew reaches its maximum and there is still waste left, they have to stop working. The result is that some illegal dumps never disappear in case the crew did not finish the cleaning job.

3.5.3 Collection equipment

The collection of solid waste is made by VOV and by private firms (10 contractors hired by the VOV). The contractors make use of the following equipment for collection of all or part of the wastes (photo 3.1):

- back-loaded compactor truck (13) (capacities of 17 T, 12 T, 9 T)
- open trucks (4) (capacities of 4 T)
- open trucks with crane (1), for cleaning illegal dumps
- pick-ups (3) (capacity of 2 T)
- brooms and rake: manual cleaning (street sweeping)
- containers
- litter baskets

Photo 3.1: Equipment to collect household waste in Greater Paramaribo.
The trucks are very old, overloaded and wait in a cue for unloading

The most widely used vehicle for waste collection is the compactor truck, which has closed container storage for the waste, and a lift at the rear for automatic emptying of bins and waste containers into a scoop fitted to the container of the vehicle. When loading sacks/bags/buckets/boxes into the compactor trucks, the worker lifts the waste sack manually into the scoop. Waste collection is also carried out using other means, such as open trucks and pick-ups, depending on the availability of economic resources, road conditions, and socio-economic level of the collection area. VOV has the disposal of 4 compactor trucks; which are 7-8 years old. Trucks have an expected life of about 15,000 hours of service, whether they run four hours a day or 14 hours a day, they must be depreciated accordingly (UNEP/IETC, 1996; Corrales and Horton, 1995). For the moment (in 2005), two are in operation; of the other two one is for 3 years out of use and the other one since 1 year.

These 2 compactor trucks are used by VOV:

- to collect waste in the town centre, and
- for emptying street (communal) containers and containers which are hired out to different companies and institutions (such as the university, bakeries, hospitals, etc.).

Compactor trucks function well in paved urban areas. However, there is a common problem throughout the country with respect to the efficient use of government's equipment: both the equipment and maintenance are very expensive and not properly scheduled. Frequently, VOV indebts itself by purchasing these trucks without taking into account the infrastructure needed for their maintenance. Thus, a large portion of these trucks are put out of operation due to lack of parts or trained personnel. Just as VOV has not been setting aside depreciation charges, VOV (or some contractors) may find itself in an awkward position, when trucks need to be replaced but there is not enough money to do so. VOV can resolve this problem by privatizing the collection services; administration of funds will be more efficient, so the trucks can operate most of the time.

According to UNEP/IETC (1996), many solid waste professionals recommend open trucks over compactor trucks, because costs are much lower, maintenance is cheaper, and the wastes tend to be very dense, with little compactability. Still, local government officials are interested in purchasing compactor trucks, even if this implies large debts, due to the 'modern' image that this equipment brings. On the other hand the use of compacting vehicles has become the standard of sound practice for waste collection. A compactor truck:

- allows waste containers to be emptied into the vehicle from the rear, the front, or the side;
- compacts the waste to a high density using hydraulic or mechanical pressure and more waste can be collected per truck;
- removes the waste from view quickly; and
- inhibits vectors and insects from reaching the waste during collection and transport (UNEP/IETC, 1996).

According to Cointreau (1982), the use of compactor trucks is ineffective for waste consisting mostly of organic waste because there is no need for compacting. Further, these trucks are expensive and of inappropriate technology for developing countries. The waste generated in Suriname is mostly organic so there is no urgent need for these types of trucks; it would be better to use open trucks, which are covered with a net after finishing the waste collection activities. One would say that we are going backwards (in case we choose for open trucks) instead of forward because everywhere in the world open trucks are disappearing. On the other hand with a compactor truck one can serve more household per length of time, thus having a higher efficiency.

Next to waste collection VOV hires out containers to institutions, restaurants, shops, schools, companies, hospitals, etc. Many of these containers are in bad condition due to bad maintenance and ageing (over 6 years old). These

firms/institutions pay a fee as mentioned below, but it is not sufficient to cover the cost for collection service.
Containers are also placed in areas, which cannot be served by trucks due to narrow streets, or the streets are in bad condition (street containers, for which no fee is charged). These containers are placed on corners of streets, in which residents can dump their waste to prevent that they dump their waste illegally. All these containers are emptied by compactor trucks of VOV. Due to the small capacity and number of these containers, the plot around these street containers turned into illegal dumps, which lead to malodors, attraction of animals, vermin and insects, etc.
VOV has at its disposal two types of containers (for servicing companies):

- 557 galvanized (metal) containers; content 1100 L, the monthly fee amounts to US$ 1.82 for each container and for each emptying US$ 0.73
- 73 mini plastic containers; content 240 L, the monthly fee amounts to US$ 0.36 for each container and for each emptying US$ 0.18.

Despite such low fees some companies or institutions refuse to pay or have a backlog of payment. Some companies hire only the containers from VOV but for disposing of their waste, they hire private contractors (sometimes the same contractors as VOV) because they are not guaranteed of a regular service of VOV.

Some years ago, VOV started a project distributing mini plastic containers in several neighborhoods for waste collection, but the project failed. Many households did not use these containers for waste storage but for other purposes; the reason was the lack of adequate instruction to the public.

Since august 2004, the Ministry of Public Works placed litter baskets in the town centre used for collection of waste in public places/streets. With the placement of litter containers VOV hopes that littering of waste will be reduced in the town centre.

Both collection of market wastes and street sweeping in commercial areas are most often the responsibility of the Directorate Milieubeheer. Sweeping is generally performed manually with brooms and rakes. The streets are swept with the closing of the market place and commercial center by mainly female personnel who have demonstrated greater efficiency. These women are usually uneducated and are single mothers in great need of work and money, and sweeping is one of the few job sources. Carefully, we may say that these women are more conscious of the relationship between proper waste management and good health. Collections from market places and commercial centers are done in the afternoon to evening. In the case of markets with stalls assigned to individual vendors, the vendor is generally responsible for sweeping his/her stall and placing the debris at the curb. Municipal street sweepers clean these common areas and set out the waste for pick up by the collection vehicle. This waste is then removed later for disposal.

3.5.4 Collection method

The door-to-door (kerbside) collection is the main collection method for the collection of residential waste. The refuse collection vehicle tours for Greater Paramaribo can be described as follows: the refuse is placed in containers (special garbage bags, buckets, boxes, plastic shopping bags, communal containers, etc.) along the streets and it is collected by a fleet of vehicles (photo 3.2). The collector crew is responsible for driving the vehicle, unloading full containers in the truck, and emptying the contents of the truck at the disposal site. The vehicle leaves the depot (VOV) at the start of the day and must return there empty at the end of the day (in case of VOV trucks). The first trip begins where the vehicle collects the refuse along the streets. When the vehicle is full it goes directly to the dumpsite located at a distance of 13 km from the city-centre to unload the refuse. The vehicle then goes back to the same or another collection zone to begin its second trip. After completing its final trip, the vehicle proceeds to the dump site to unload for the last time, and finally returns to the garage of the vehicle owner (in case of a contractor). Each tour is a sequence of one or more trips.

Greater Paramaribo is divided into collection zones by VOV, the so-called "macro-routing". The problem we have in our waste collection system is the construction of feasible vehicle routes in a collection zone (micro-routing). For the moment, the truck driver defines his own route plan. This problem has obviously effect on the collection of waste: trucks drive backwards in streets, crowded streets, pass crossings or a street more than once, and longer collection times. In the near future, this routing problem will belong to the past because VOV will develop in cooperation with a consultant a routing plan for waste collection.

VOV is unable to provide service to all residents in Greater Paramaribo. It is estimated that waste collection coverage is 70%. In areas with no or inadequate collection, littering or illegal dumping of waste is a great problem. Some roads or corners turn into small open dumps. Extending service coverage will be a big challenge for the government. This extending service coverage will be vital in efforts to reduce pollution from waste burning and illegal dumping but three weaknesses of VOV can be pointed out:

- inability to self finance its operations and inappropriate investment
- lack of sustainable waste management practices
- inefficiency in operation and maintenance

Collection is a key link in the chain of MSWM from the point of generation to ultimate disposal. In any initiative to upgrade waste management service, sustainable, contextually appropriate collection should be a major focus of attention (Strasma et al., 1999). Increasing the collection service coverage includes the improvement of the quality of the existing waste management system by: improving human resource capacity; introducing a fee collection system; developing environmental awareness among the general public;

developing institutional arrangements; increasing financial capacity of the responsible authority and increasing partnerships among local authorities, communities and the private sector (Gatot Yudoko, 2000).

Photo 3.2: Containers in which waste is stored. Waste is offered in plastic garbage bags, empty rice bags, buckets, plastic sacks, and old freezers. To prevent animals opening garbage bags they are put on a platform made of wood or metal

3.6 Open dumps

In Suriname, we do not have (sanitary) landfills. In the absence of landfills, wastes have been disposed of in open dumps. The government adopts open dumping as the main treatment/disposal method as it is reasonably inexpensive and low in maintenance.

History of open dumps

In Suriname, solid waste is traditionally disposed of in open dumpsites. There were 3 open dumps situated all over Greater Paramaribo (table 3.1), just next or close to residential areas (distance < 500m). Suriname has not yet developed regulations specifying the minimally acceptable technical criteria for these dumps.

Table 3.1: Overview of legal open dumps in Suriname

Open dump - Location	Opened (year)	Closed (year)	Applied method
1. Dageraad weg	--	1970	Waste dumped in an abandoned sand pit
2. Charlesburg	1970	April 1997	idem
3. Jan Steen straat	1994	September 1999	idem
4. Ornamibo	1999	Still open	Waste dumped on marshland

Current open dump - Ornamibo

Ornamibo is since 1999 in operation as the only official legal open dump for the city (photo 3.3) and is situated along the Para creek at a distance of 13 km from the town centre. The Para creek is a branch of the Para river where many recreation activities (mainly swimming) are exploited. The site was privately owned, but the government made barter with the owner. Ornamibo was not the first choice of the ministry but confronted with the NIMBY (Not In My Back Yard) syndrome from the local communities at other locations, the government decided to locate the dump on this site despite counter-arguments of the Office of Public Health. Ornamibo dump covers a total area of 52 hectares and the area is characterized as marshland. The location of the dump and its functioning does not comply with international environmental standards. In fact, the government was going to construct a sanitary landfill at Ornamibo but due to lack of finance the site was changed into an open dump. A complete plan was already written by an external consultant how to construct, manage and close this sanitary landfill.

Photo 3.3: Open dump Ornamibo
Facilities at the dump: bulldozer to spread the waste, sand to cover the waste (sometimes), shelter for the workers

The Ornamibo dump, including the old ones, has no liners, no daily cover, no equipment to weigh the collected waste, no leachate collection and treatment system, no environmental monitoring, no sanitation facilities and no fence to keep out scavengers (waste pickers). All wastes generated and collected are dumped indiscriminately.

The open dump is operated by 7 regular workers. Trucks (VOV, its contractors and private) are entering the dumpsite without weighing or without paying a landfilling fee or gate fee; only some visual checks (of VOV trucks and its contractors) at the entrance occur (checkpoint), such as the time of arrival, contract number or plate number of the truck. VOV keeps a bulldozer (hired) at the site which is used to spread the waste over the dump area and sometimes to cover some of the older waste with a layer of soil (in case there is money available). In general, the waste is not covered by soil due to lack of finance. In the rainy season, the road to the dump changes into a slough but after many complaints of the truck drivers VOV asphalted part of the road. This road is quite narrow so garbage trucks cannot turn and once they arrived at the dump they turn at the checkpoint and drive backwards to the unloading site at the dump. This situation creates a cue of garbage trucks at the dumpsite.

Waste pickers (30 - 40) enter freely into the dumps and gather a wide range of materials, despite the presence of guards at the entrance of the dump. They sift through garbage as quickly as it arrives, looking for metal, plastic and glass bottles, and other valuable waste products (photo 3.4). These scavengers (men and women of different races) wade through the waste together with a few dogs and hundreds of large black birds (vultures). By contrast, past sporadic attempts to restrict access to Ornamibo's unfenced dump had no lasting impact, so VOV allows the waste pickers now to work on the dump as far as they create no problems (fighting, quarreling).

Ornamibo continues to be a threat to public health. Methane gas is present and can be the reason that at times the dump catches fire. Waste pickers also create fire outbreaks at the dumpsite; they burn the copper wires to get rid of any excess material. The fires create thick smoke fumes at the dump, which can be seen from kilometers distance. Burning creates thick smoke that contains carbon monoxide, soot, and nitrogen oxide, all of which are hazardous to human health and degrade urban air quality. Burning of waste, especially plastics, can release chlorinated hydrocarbons into the air.

Photo 3.4: Waste pickers at work on the dump
Metal, plastics, clothes, etc. are gathered. Scavengers stand close to the load of the truck to look for valuable materials

All the drainage ditches on the site are full with waste materials, especially plastic products (photo 3.5). Mosquitoes can breed in stagnant water collecting in pools as well as in the old tires that litter the area. People living near the dump complain about the flies’ and mosquito’s outbreak and of snakes entering their yard. They use a lot of pesticides to get rid of these insects: grammoxone for the snakes and insect killer for the flies; these pesticides can affect the health at excessive and wrong use. Other complaints from residents and schools are problems with malodors. The government and residents will be dealing with these problems for years to come.

Photo 3.5: Effects of inadequate operation at the dump: the drainage ditches are full of plastics; black birds (vultures) are attracted by organic waste, burning of waste

Surely enough, the neighboring communities would benefit greatly if the open dump, Ornamibo, is closed. The ministry of Public Works has plans to build a sanitary landfill at the same site of the existing open dump. Eventually, a new landfill site will be needed. In fact, the use of open dumps should be avoided because they pose a permanent threat to the environment and health. Open dumping represents the old attitude of “out of sight out of mind” (USEPA, 1998).

Alternatives to of open dumping comprise sanitary landfill and incineration.
Technical - (engineering measures, leachate and landfill gas management, operation measures), practical - and social considerations must be addressed when planning landfills. It is important to realize that the landfill must be located within a reasonable distance to waste collection areas along a good road system.

A sanitary landfill has both advantages and drawbacks. Some advantages of sanitary landfill include economic savings; less investment is needed compared to incineration, more practical than incineration, and no need to separate waste. Disadvantages of sanitary landfill include finding suitable land (site), compliance with (national) (environmental) standards, possible opposition from local communities, need for site maintenance after its closure, and risks of methane gas if not properly managed. After its closure, a landfill could not be used for settlement sites. Several aspects need to be regarded in selecting sites for final disposal. These aspects comprise legal, environmental regulations, impact assessment analysis, public order, city cleanliness, land use and spatial plans (Kurian, 2002).

An incineration can be planned to dispose of most of the hazardous waste (e.g. medical waste). Incineration can reduce waste to 80-95% in terms of volume (Rand et al., 2000). Smoke (gaseous emissions) and ash from incinerations should meet standards and wastewater should be treated. Incineration is per ton waste almost 7x more expensive than operating a sanitary landfill. According to Gatot Yudoko (2000), incineration can become a viable option in the future due to increasing difficulty in finding sites, increasing land prices, decreasing of state land and the changing nature of waste. In developing countries, the high financial start-up and operational capital required to implement incineration facilities will be among the major barriers to successful adoption of this technology (Rand et al., 2000).

3.7 Reuse

Glass bottles (beer and soft drinks) are the only components of the solid waste that are being reused by the respective beverage companies. The glass bottles are imported from Trinidad for use in the packaging of soft drinks and beer manufactured by respectively Fernandes Bottling Company and Parbo Breweries. On these returnable bottles for soft drink and beer, deposits are paid which is the main incentive for the citizens to return the bottles (deposit refund system). On the other hand returning the bottles to the manufacturers decrease their production cost. In the beginning of 2005, a food processing company started a program whereby the community, focused on schools, could return all its glass bottles and containers. They already reuse the glass products but the response from the community is very low; of the 450,000 – 500,000 glass products they used per year only 50,000 – 60,000 return back to the company by scavengers and others. With this project, they hope to reuse more glass products.

Research, done in the years 2002-2004, indicated that reuse is a common phenomenon especially for the low-income families. Without education, campaigns, or being told by others, these families had consciously practiced reuse as part of their life strategy. The reuse of glass containers and newspaper is common, particularly among the households. Some residents take plastic bags to the supermarket as a carrier bag and other use glass containers and plastic bags to store products. Often old newspapers is collected to clean their windows and to use in car repair-shops. Some residents collect glass and plastic bottles for people in the home craft industry (for the production of syrup and pickles). Tires are usually recapped at least once before being discarded. Nevertheless, this last activity suffered from the import of second hand tires. However, this suggestion does not necessarily imply that public education in reuse is not needed. Public education in reuse and waste reduction will be increasingly important when the standards of living start to improve or as environmental standards are developed. For instance, when the low-income families have their income increased, there is no guarantee that they will keep up their habits to reuse, also called the "new rich person" syndrome. The new rich people want to enjoy his or her new standard of living like everyone else (Gatot Yudoko, 2000). Waste pickers select on the disposal site glass- and plastic bottles, which they delivered to customers. Also during collection of household waste, members of the collection crew of open trucks separate plastic and glass bottles which are also delivered to customers. When the Office of Standards is developed or will officially operate in Suriname, this office will put regulations e.g. on the reuse of glass and plastic bottles that are now used in the home craft sector. It needs to be noticed that the Office of Public Health frequently control these home craft industries. These regulations may decrease the reuse of plastic and glass bottles in this sector due to strict hygienic rules because the home craft sector has to invest in proper washing machines (increase the price of the end product) or the opposite can happen that people have more confidence in reuse products which will enhance source separation.

3.8 Source separation

The importance of source separation has long been recognized, but its implementation will not be easy. People are not motivated to separate their waste because afterwards it will be mixed again in the collection vehicles by the waste crew. Fernandes Bottling Company started in 1999 with a PET soft drink bottles recycling project in which source separation at household level was promoted. At the beginning of the project, the support was low, but after focusing on schools, the project received good support. Source separation at commercial level (restaurants, canteen) was not a success, because the efforts to separate waste at that level did not receive necessary support, so the company decided to stop collecting bottles from these branches and continued its project with schools. The support of the national government to this project is nihil.

Source separation is also conducted extensively by waste pickers; in fact, the government and other stakeholders in this sector should recognize their role in the recycling and reuse industry. The government currently did not have policies regarding waste pickers. They did state that waste pickers activities at the open dump disturb the work of collection crews and the official workers. According to VOV, waste pickers are not officially allowed to scavenge at the disposal site, but there is an unofficial policy to allow them to work.

Learning from this experience, it can be concluded that source separation implied not only separating waste into different storage bins, but also required the use of appropriate collection vehicles as well as trained staff. According to Bai and Sutanto (2002), the use of compaction trucks in waste collection made it difficult to retrieve these valuable resources from domestic waste, which was the case in Singapore. The recyclables were contaminated resulting in loss of material and low selling price. Success of source separation will be influenced by several factors such as public education, public participation, good waste management service, monitoring and enforcement of regulations (Gatot Yudoko, 2000). It would take time to educate the public and gain their willingness to participate because people are not interested in issues about waste. The only important thing is that their waste had to be removed by the government and illegal dumps must be cleaned, that is all.

3.9 Recycling

In Suriname, we rely much more heavily on the informal sector for recycling while rarely having formal recycling programs in place. Only plastic material recycling seems to have been achieved (on small scale) in Suriname. For the moment, only 4 companies are involved in recycling.

- Fernandes Bottling Company: collection of PET (Polyethylene Terephthalate) soft drink bottles

The collection sources are the primary schools. 250 schools attend in this source separation and collection program and are dispersed over different districts: Paramaribo, Saramacca, Coronie, Nickerie, Para, Commewijne and Marowijne. This collection program has a competition character; the school with the highest collection rate receives a price. The other schools are stimulated in collection by receiving soft drinks at delivering the empty bottles. To facilitate their participation, Fernandes supplies the schools with special collection bins or with special pink 60 L bags and collects the bottles from the schools. Once these bottles are collected they are transported to the storehouse, the lids are removed (made from HDPE=high-density polyethylene material) and the bottles are chipped in a chipper machine. This machine has a capacity of 6500 bottles per hour (227.500 PET bottles in one week). The only consumer of the chipped PET plastic material was a concrete producing company (VABI); they used the chipped plastic (instead of sand) for making building bricks. Due to some technical constraints, such as the lower strength of the bricks and low acceptation of the market, VABI was not really enthusiast in continuation of the project. Although VABI discontinued the intake of chipped PET plastic, the collection of bottles is still increasing (table 3.2); therefore, Fernandes was obliged to prolong this project with the schools. Due to its effort, Fernandes is collecting and recycling 9 % of the PET bottles (in 2004). For the moment, this company is looking for possibilities to export the chipped PET bottles to a recycling firm in Barbados.

Table 3.2: collection efficiency of PET bottles

Year	# PET bottles
1999	20,000
2000	43,000
2001	500,000
2002	1,200,000
2003	1,900,000
2004	2,100,000

Although many companies in Suriname import and produce a huge amount of plastic bottles (PET and HDPE) especially from the Caribbean (e.g. Trinidad), none of these companies are interested to participate in this recycling project. According to these companies, this project is doomed to failure due to the low environmental awareness and the bad attitude of the public; so it will be waste of money and time.

- Waste plastic recycling company Lemmers

This company, established 13 years ago, uses waste plastic material (PET and HDPE) such as broken or rejected gallon bottles and crates from different companies such as Fernandes and CIC. CIC, a detergent manufacturer, that makes use of returnable deposit (HDPE) gallons, delivers rejected bottles to the recycling company Lemmers. This plastic material is chipped in a chipper machine; placed in feeder where it is homogenized or mixed with import PVC pellets; melted and under pressure it is pushed through an extruder with the production of pipes at the end of the line. These pipes are used as drainage pipes but are mainly used by the porknokkers in the gold mining industry. The company produces next to these pipes also electrical supplies. All its products are for the local market.

- NV COBO

This company, established in 1986, collects scrap metal for export purposes. Scrap is collected from the companies: Suralco, the biggest industrial firm (Alumina producer) in the country; Billiton, a bauxite mining company; State Oil Company; Traverco; VSH steel company; Energy company (EBS); Sail (shrimp and fish company) and Cambior, a gold mining company. COBO is in charge of collecting all the scrap metal of these companies and pays to these companies a fee of US$ 20 – 30 per ton. The scrap metal is shipped mainly to Europe and America. There are plans to build in the beginning of 2006 a steel factory based on scrap metal from the local market (companies, households, individuals). The factory will have a capacity of 30,000T per year and will produce reinforcing steel. According to COBO manager, the available scrap on the local market can guarantee a production for 3 years after that the company has to import scrap from other Caribbean countries.

- Firm National Plastics Suriname

This company produces plastic bags and started since 2003 with the recycling of industrial waste from its production process. The waste materials consist of solvents (industrial alcohol) and ink (90%). With very sophisticated equipment the ink is separated from the solvent, the regenerated solvent is used in the press process, and part is exported. This firm is the only one in Caribbean, which recycled waste material from the press process.

Recycling is at an early stage of development. Many stakeholders (NGO's, residents, companies) agreed that recycling could be done more effectively through source separation efforts. There are presently no incentive schemes designed to promote recycling or reuse (except from above companies). The pricing structures do not emphasize waste avoidance, materials recovery and reuse. Furthermore, citizens do not pay for solid waste management services at all.

3.10 Composting

Third world cities have traditionally a significantly higher percentage of organic matter in their waste streams, which is also the case for Suriname, which means that there is a high potential for composting. Overall, even though the organic content of the MSW in the Suriname may exceed 50% (wet basis); composting is not a significant component of solid waste management practice. Backyard composting is limited to some households and small pilot projects. Residents drop off their garden- and vegetable waste in a pit or heap and it is decomposed. Some NGOs and Community Based Organizations (CBO) promote the practice in rural areas but the practice does not have a significant impact on solid waste management at the city level. However, these projects primarily target rural, agricultural areas and focus on the use of garden and agriculture wastes rather than municipal solid waste. The compost produced is largely for self-consumption. According to UNEP/IECT (1996), compost may be a large forgone opportunity but waste stream high in organic material may have potentially high yields of compost.

A composting research was implemented at the Environmental Department, University of Suriname. It was meant to try out the applicability of composting as one of the strategies for minimizing waste and recovering resources from household waste. An experimental work was carried out along with laboratory analysis. Chapter VI deals in detail with this subject.

3.11 Incineration

Virtually no incinerators operate in Suriname. The costs of this technology are far too high to be considered by the local government as an appropriate waste management technology (UNEP/IETC, 1996). Two tiny incinerators operate in Suriname: the incinerator of the Academic Hospital and WASPAR (Foundation for Laundry for Private Hospitals). These incinerators process wastes originating from hospitals. In the past, medical waste of hospitals was transported to the incinerator of Suralco, but the last one stopped its service to the hospitals. Instead, Alcoa Foundation financed an incinerator for the hospitals. Because the hospitals could not find a proper location, they build this facility on the WASPAR complex. WASPAR was established in 1978 with the purpose to assist hospitals and social institution (e.g. old people’s home) with their laundry. The incinerator came into operation in June 2001. WASPAR incinerates medical waste from the following institutions: Sint Vincentius hospital, State hospital, Diakonessenhuis hospital, Pharmacies, Health Control Laboratory, Kidney foundation, Dental surgery, and Red Cross. The Office of Public Health (BOG) controls the operation of this incinerator because it is situated in a residential area. BOG monitors: the hygiene of the workplace; safety of the workers; and if there is no accumulation of waste. WASPAR incinerates the following medical waste:

- ampoule and syringe (these are delivered in special prick resistant containers)
- blood scrotum and tubes (in special package)
- outdated medicine from pharmacies

- gloves and bandage from the surgery rooms
- mattresses and bedclothes of AIDS patients.

All other medical waste is dumped at Ornamibo, except for placenta, intestines and amputated body parts, which are buried at designated sites. Waste pickers and workers at this dump are exposed to dangerous hospital wastes. The delivered waste to the incinerator must come up to the requirements:

- properly packed: no dripping package
- infectious material must be delivered in a red package or in a black bag with a red label
- the weight per bag must be less than 20 kg (therefore all incoming waste is weighed).

The incinerator has a capacity of 600 L, but due to the high demand for waste incineration, the incinerator operates twice a day. The incinerator is filled manually and opening and closing occurs automatically. The incinerator is an electrical furnace and it reaches a temperature of 1250^{0}C. All workers are equipped with gloves, heat resistant coats, safety goggles, boots and dust masks. The ash of the incinerator is collected in bags and dumped at Ornamibo, the open dump.

Hospital wastes have received more attention than industrial wastes in Suriname though much work is still needed to achieve proper management of these wastes. Hospitals are aware of the danger of their waste so a large part of the work done on hospital wastes is related to characterization and separation. Thus, there is a good understanding of the sources of pathogenic, chemically hazardous, and regular solid wastes within the health facility. Presently there are no regulations that require that all hospital wastes be collected and transported to an incinerator.

The State Wood Processing Company (Bruynzeel) has the disposal of a gasifier (outdated) in which waste wood is burnt to generate steam for drying wood. This gasifier is also used for other purposes, e.g. the burning of drugs. This gasifier is a source of serious air pollution for the surroundings; most of the time black smoke is coming out of the chimney.

3.12 Health impacts of deficient solid waste services

All activities in solid waste management involve risk, either to the worker directly involved, or to the nearby residents. Risks occur at every step in the process, from the point where residents handle wastes in the home for collection or recycling, to the point of ultimate disposal (Cointreau, 2004). An important factor in the Suriname context, however, is the lack of basic epidemiological data on the health impact of prevailing waste management practices that would motivate and drive the authorities to adopt safer management techniques. Indeed, little attention has been focused so far on the health impact of chronic exposure to MSW in Suriname.

The mixed (food wastes, dead animals, hospital waste, etc.) and uncontrolled dumping of wastes at Ornamibo, the toxic chemicals and pathogens that it contains may have a grave impact, whether directly on the staff in charge of collection and disposal, the waste pickers, or indirectly on the surrounding environment and the residents living near the disposal sites. Likewise, improper disposal of medical wastes may increase the public health threats posed by infectious disease organisms. Illness and even death can result if wastes from hospitals and clinics are collected, transported, and disposed of in the same manner as commercial and household trash (Strasma et al., 1999).

The landfill gases which escape into the atmosphere contribute to green house gas emissions and cause breathing problems to workers and waste pickers. Leachate from the open dump contains harmful organic compounds as well as heavy metals. When the leachate reaches streams or groundwater bodies used by households or farms, humans are exposed to contaminated water. According to

Manas Ranjan Ray et al. (2005), these practices are considered unsafe for human health and the environment.

Collection of household waste is hard work and can be dangerous. It involves working on a vehicle that moves through traffic during all seasons and rush hours and collectors have to cross the street to collect the waste. Collection of household waste is also a job, which requires repeated heavy physical activity such as lifting, carrying, and pushing. In addition, the collection crews are most at risk since they come into direct contact with bacteria and viruses present in the waste. The collectors can also be hurt injured by sharp objects. Further, some of these workers are treated unkind by residents. As compaction of the waste in the compactor truck and handling of waste may cause micro-organisms and dust to become aerolized, collectors are also at risk of being exposed to bioaerosols and leachate generated from the waste. Chun-Yuh Yang et al. (2001) found that waste collectors were more likely to report gastrointestinal symptoms (nausea and diarrhea) than in the general work force; certain dust from household waste may cause airway inflammation and that the effects were associated with higher (1-30-B-D-glucan levels (respiratory problems); acute irritative symptoms and musculoskeletal symptoms, and injuries. It needs to be noticed that to reduce injuries the collectors are provided with boots, gloves and dust masks; due to high temperature, most of the collectors do not wear the dust masks. Chun-Yuh Yang et al. (2001) noted that working as a waste collector is associated with a high risk of occupational injuries. In 2004, a crew member was killed after he was crushed in the compactor unit of a garbage truck. In 2005, a crew member came into shock when he saw blood coming out of a garbage truck, as a baby who was dumped in a garbage bag was compacted together with the waste.

The lack of reliable collection service undoubtedly takes a toll on the public health and aesthetics of Greater Paramaribo. As the urban share of the population grows this problem is likely to increase. Adequate solid waste collection and disposal may not be as important for human health as access to potable water.

However, trash accumulating in open waters and vacant lots in poorly served neighborhoods undermines property values and therefore discourages the investment needed to improve those neighborhoods. Moreover, deficient collection and disposal can lead to diseases. Furthermore, humans are exposed to toxic substances by leachate from illegal dumps and emissions from open burning (Heller and Catapetra, 2003). On the other hand, inadequate collection causes drains and sewers to be clogged, which cause flooding of residence plots exposing the people to water borne diseases. So public health will be seriously jeopardized as a result. Urban poverty and poor environmental conditions in most parts of the world are inextricably linked. People with low incomes or who live in poverty are divested of the capability to improve the environment where they live (Bernstein, 2004). This was obviously the case in the low-income areas of our study areas (the presence of illegal dumps, littering of waste).

Solid wastes with high organic and moisture contents can serve as a breeding place for insects, flies, a reservoir for bacteria, and a source of food for these animal vectors. The problem is further exacerbated by the high ambient temperature, which probably promotes rapid proliferation of these flies (Howard, 2001). The insects may spread malaria, dengue fever, yellow fever (mosquitoes), typhoid fever (houseflies), gastroenteritis (cockroaches), leptospirosis (rats and mice) and bacillary dysentery, among other illnesses. In addition to serving as disease vectors, flies and mosquitoes facilitate transmission by biting and stinging people. Scratching due to scabies or a mosquito bite, for example, abrades the skin, thereby providing an opening for the invasion of bacteria and viruses. Salmonella (the cause of typhoid and paratyphoid fevers), shigella (responsible for bacillary dysentery), and other fecally transmitted pathogens are abundant in many neighborhoods due to poor sanitation and lack of adequate water supplies (Strasma et al., 1999; Cointreau, 1982). The empty bottles, tires, plastic cups and other receptacles that litter in the residential areas contribute significantly to this mosquito problem and to the increased transmission of dengue fever. The spread of dengue fever is now a serious concern of the Public Health Office in

Paramaribo. In addition to causing illness and death in the population, dengue fever is also causing thousands of dollars to be spent annually for hospital care and mosquito control. These costs can be reduced significantly if there is proper disposal of wastes. The same can be said for the other animal vectors.

People who scavenge at open dump are most at risk since they come into direct contact with bacteria and viruses, abundance of flies and offensive odors coupled with the lack of proper protective devices. Scavengers were interviewed and asked to fill in a questionnaire giving information about age, literacy, family, socioeconomic conditions, habits, type and duration of work, and respiratory problems or other health problems. Since many scavengers were poorly educated, the investigators filled in the questionnaires. The scavengers reported that they do not experience health problems and they do not attend any doctor (mostly due to lack of money) if they feel sick, they use home-made medicine. They experience problems with offensive odors that create sometimes headache or dizziness.

3.13 Problems in waste management

Various problems in Greater Paramaribo have been identified in our waste management system. These problems are environmental pollution due to household waste, the gap between increasing service demand and VOV’s capabilities, inappropriate planning and management, lack of coordination, lack of participation, lack of awareness and education and weak law enforcement.

3.13.1 Waste burning and illegal dumping

Waste burning and illegal dumping by households are almost uncontrollable. Findings from surveys, done in 2002 – 2004, completed for several neighborhoods and households provide insights about waste burning. Sixty percent (60%) mentioned that they did waste burning in their area to reduce waste. The results from the survey indicated that open burning frequency is strongly associated with income level and is also strongly dependent upon the availability of the collection service in the area. In areas that did not have service from VOV, all residents practiced waste burning or burying routinely, because they have no other option. Frequently supermarket owners and other small shops render their self-guilty of open burning, although they can be serviced by VOV on payment.

Despite the collection service attends the areas twice a week still some people perform the bad habit of burning their waste. Sometimes, it can happen that the collection service experiences a problem with the collection vehicles or the collection crew, so the scheduled service can be absent or attends the area on a delayed schedule (sometimes the next day).

Open burning is inefficient and polluting because it creates low temperature fires, receives little oxygen and produces a lot of smoke, which is unhealthy to breathe. Additionally, these conditions may result in incomplete combustion, increased pollutant emissions and that a substantial amount of waste is left unburned. The heavy metal and dioxin emissions from open burning are many times greater (20) on a per unit garbage basis than the emissions from a controlled incinerator. Virtually all of the pollutants are released into the air close to ground level where they are easily inhaled (USEPA, 1997a).

In Greater Paramaribo, some residents used to have flooding problems during rainy seasons due to clogged canals in their area because households dump their waste (food wastes, plastics, tires, car wrecks, freezers, etc.) into the open waters. Flooding is not always related to clogged canals due to waste dumping; this problem is frequently caused by inadequate infrastructure (too small culverts, outdated and broken sluices) and the dumping of waste in these canals deteriorates the problem. Another problem with illegal dumping is that some residents complain about offensive odours and the increased number of flies and rats due to the illegal dumps around their homes or on vacant plots, etc. (photo 3.6).

Photo 3.6: Illegal dumping of waste

A specific problem that is encountered in the country is the excessive littering of plastic waste. In Paramaribo and indeed all other urban centres in Suriname, plastic waste (bags and bottles) of all sizes and colours are found dotting the landscape. Examples of practices that constitute littering include drivers and passengers throwing unwanted articles out of car windows; pedestrians dropping garbage at the road side; households placing unsecured garbage at the roadside and dumping of garbage onto empty lots. Besides this visual pollution that affects such sectors as tourism, plastic wastes contribute to the blockage of drains and gutters creating serious storm water problems, plastic wastes into water bodies can kill aquatic wildlife when they ingest the plastics mistaking them for food and plastics take many years to degrade. Furthermore, plastic waste litter can be linked to dengue. The magnitude of this health problem received the attention from the Public Health Office due to dengue outbreaks in several parts of the country from time to time.

To reduce littering in their neighborhood some households are cooperating in keeping their neighborhood clean by placing signs with the message “do not litter”. Some companies are doing the same, but these signs do not always have their effect.

3.13.2 The gap between the increasing service demand and the capability of VOV

The gap between the increasing service demand and VOV capability has left some areas unserved and caused unsatisfactory service delivery to some areas already receiving service. There are several reasons why this occurs. VOV has inadequate funding to provide sufficient collection, lack of transportation vehicles and crews, inability to self finance its operation, inefficiency in operation and maintenance, inappropriate investment and inefficiency in collection. In addition, VOV does not collect service fees to cover the operating and maintenance costs. The Ministry of Public Works has traditionally provided unlimited refuse removal service to all citizens and has funded that service from the National State budget. Tight municipal budgets and heightened concern about the environment have complicated the solid waste task. Another reason why some areas do not receive service is the urbanization and increasing development of residential areas widening the gap between service demand and the capacity of VOV. Frequently one can read advertisements about new housing development projects in the newspapers; it seems that controlling the growth of new residential areas by the government is almost impossible. The fact that some areas do not get services from VOV is not surprising.

Increasing disposal costs, tight local budgets, and growing environmental concerns have fundamentally changed the mission of the Ministry. With an external consultant, the ministry has developed several plans to improve solid waste practices (4.1.1). One of these plans is the introduction of a collection fee for waste services. Service fee has not been implemented yet (except for emptying the containers of institutions/companies against a very low price) for several reasons; such as social and political reasons. Politicians think that fees will be an unpopular act for the public and they are reluctant to make the decision. With the virtually small budget for several years, VOV has to manage with increasing operation costs. VOV does not have its own purse but is dependent of Public Treasury – Ministry of Finance. VOV admitted that in dealing with this situation, sometimes they had to reduce service quality by decreasing the collection and transportation frequency, especially in the suburb areas. Another major challenge in service provision facing the government or VOV is to increase service coverage and quality. This can be achieved by creating funds (e.g. fees) and developing solid waste management plans.

In order to know the public's opinions about a fee payment, surveys were conducted with households to ask about this issue. A majority of the households was willing to pay a fee but all respondents expressed that with their willingness to pay the government must improve the collection service for total Greater Paramaribo.

3.13.3 Inappropriate planning and management

Solid waste management problems in Paramaribo are largely a result of lack of a waste management policy and framework that would aim at improving the standards, efficiency and coverage of waste from "Cradle-to-Grave".

Some problems are related with the current planning and management culture in Surname: lack of long term planning. Planning and management of municipal solid waste in Greater Paramaribo lacked a long-term perspective. The existing planning mode is more reactive (ad hoc) than proactive. In this regard, the government or VOV has no comprehensive long-term plan, for instance, a five-year plan; but they are developing different projects by external consultants (Netherlands and Aruba). It would be better if these projects would be part of a long-term strategic plan of VOV, whereby each project has to be implemented according to a scheduled period. The existing working strategy looked more like a matter of prestige strengthened by party politics.

The government's and VOV's poor capability in planning capacity had been partly due to the limited number of qualified persons. The government is experiencing difficulties in recruiting qualified graduates from universities with good reputations because they might find elsewhere better paid jobs, the salary offered by the government is not high enough, or they think that working with waste is not prestigious.

The existing planning and management of municipal solid waste had not emphasized waste reduction and resource recovery. Thus, any interest to give value to waste or to process it is lacking. Actually, this is not surprising because VOV has long been handling waste as solely a technical problem. Institutional efforts regarding waste reduction and recovery through reuse, recycling, and composting will be relatively new, although such efforts and practices have been done by households, waste pickers, research institutions and some companies.

VOV views itself as the sole actor responsible for solid waste management, as a result that potential contributions from other actors such as private firms, the public and NGO's had not received recognition. If VOV changes its view by not only focusing on collection, transportation and disposal but see reduction and recovery also as a main part of the solid waste management system, then actors such as NGO's and the local community, have to be recognized and involved because it will be impossible to tackle this issue by VOV alone (Gatot Yudoko, 2000).

Field observations also revealed that VOV is unable to maintain the compactor truck fleet. Most of the contractors hired by VOV have compactor trucks, these private firms are able to pay for the purchase and maintenance of the trucks. When they offer their service to the government, the latter has to pay a fee corresponding the operation cost of the contractors. The government is able to pay although they are frequently behind in the payment, sometimes 3-6 months, which is more a matter of mismanagement and bureaucracy.

The question is: can VOV cope with the financial and technological aspects of waste management (e.g. compactor trucks) or does VOV use expensive and inappropriate technology, and therefore improper investment?
The answer is no, because if VOV is able to pay the contractors they must be able to manage the operation of compactor trucks, but as mentioned before VOV has a lot of limitations and problems which can make the practice of operation a problem.

3.13.4 Lack of participation and partnership

Lack of participation and partnership with the private sector can be considered a problem. The private sector, in particular contractors, has capacity to take part in service provision. Jacobsohn (2001) recognized that in many developing countries, privatization of services enables the provision of service more efficiently than when local authorities provided it. The only formal public-private partnership in waste management in Suriname is the service contracts awarded to private companies (contractors). The contract involves SW collection and transportation from different areas, and disposal of the waste to the dumpsite, Ornamibo, at an agreed monthly rate. The private companies are doing very well but payment problems can lead to poor performance or even to no collection of waste until the financial problems are solved.

Consultants advised VOV to become an independent state company (see 3.4.1), not a private company. Supported by consultants VOV seems unwilling to subcontract some of its tasks. In this regard, officials of VOV defended their position by stating that contracting out their activities will transfer some of their revenues to other parties and this would leave it with a strongly reduced budget. In addition, the decision to privatize VOV will become a political decision of the parliament.

Besides the private sector, NGO's and other institutions are not satisfied with their partnership with VOV. They are concerned with the government's unwillingness to recognize roles and participation from public and NGO's in solid waste management. This has been because of NGO's used to stand against the government's policies or acts and for the government this kind of operation is quite unknown or unacceptable. This does not mean that NGO's do not contribute in the solid waste management system (see paragraph 3.4.1) however; their contribution is limited mostly to information dissemination and education. NGO's and other institutions are involved in different education projects but they are confronted with two main problems: low community participation and low community awareness. Several causes are underlying these problems: people do not feel responsible for the cleanliness of their neighborhood because it is the responsibility of the government; households are willing to participate only in special events requiring their participation; lack of education; and the economical status can be also a factor. In several laws, these basic aspects are covered but due to the lack of enforcement and penalties (or too low penalties) people showed an irresponsible behavior.

The lack of public participation in the solid waste management has been noticed by several actors in the community. They indicated the importance of public participation in several basic aspects related to solid waste management, such as proper storage and disposal, avoiding illegal dumping and waste burning, ensuring the cleanliness of their areas, and paying service fees.

3.13.5 Lack of awareness and education

Many stakeholders raised concern about the lack of environmental awareness of many government institutions about issues related to solid waste planning and management.

The first issue is the lack of awareness regarding the value of waste. Officials and general public see waste as a nuisance that one has to get rid of as quickly as possible; they do not see the value of it and its benefits and that one has to treat waste accordingly like promoting recycling, source separation, composting and waste minimization, etc. Therefore, government institutions (except NIMOS) do not support initiatives of e.g. companies or NGO's and other institutions. The different limitations and problems VOV is encountering can be a lack of this awareness. Waste minimization is a relatively new topic in Suriname but it is time to start promoting the idea of waste minimization to all relevant stakeholders, in particular the industry and the public (households).

The second issue is the low / lack of community awareness about aspects of waste management, which is already mentioned above. For many people, to throw waste on any spaces is a normal behavior. Most of them have the attitude to pose the responsibility to VOV.

The third issue is the lack of adequate public education in solid waste management aspects. We always simply jump to solutions that the government should develop educational and campaign programs for different groups of people, schoolchildren, housewives, old aged group and general public. However, experiences show that this activity (to provide simple information, warning and reminding people not to do this and that) is not effective. What has been done is not wrong but it is not enough. Public education is necessary in order to improve solid waste management systems; however, efforts are limited and infrequent. NGO's, the Ministry of Education and the Ministry of Environment, supported financially by companies, carry out educational campaigns directed toward the public, producing posters, pamphlets, and other educational materials. These education programs, mostly TV spots, offered to the public are not presented on a regular basis or there is no continuation and they do not cover all aspects of solid waste management. The NGO's go also to the schools, where they give talks on good solid waste management practices at home and in the streets. However, these campaigns are not done continuously, and their impact on the children is not very large. Financial resources also limit these campaigns, and the messages rarely go through the mass media due to the high cost of placing advertisements and the missing of shock effects (people are dying or becoming seriously sick of waste). These shortcomings are ascribed to lack of support from the local government, lack of funding and lack of research.

In recent years, a new trend can be observed in the development of environmental awareness in children. The underlying concept here is that the most important target group in public education is children, and that schools need to be the avenue to teach them. Environmental awareness, including proper handling of solid waste, is increasingly incorporated as part of the elementary school curriculum. The programs include development of textbooks, teacher training, and hands-on activities. These programs are initiated by PAHO (Pan American Health Organization) in cooperation with the Ministry of Education.

To tackle this attitude aspect, one should start from analyzing more considerately why people throw garbage and litter on streets and other open spaces. Why they do not cooperate in different kinds of waste problem solving activities? The reasons behind such practices are: (a) ignorance, (b) habit, and (c) consequences from some beliefs (Mongkolnchaiarunya, 1999).

Ignorance and thoughtlessness also play a big role in this matter. In the past, residents could throw garbage in open spaces and the public still was not disturbed from odors, bad scenery, emissions, and vector diseases. Nowadays wastes have increased many times more, vacant spaces are rare, and the type of waste is changed to be more in-organics (plastics), which is difficult or not possible to be composted naturally. Nevertheless, many people do not realize this change and still keep on their traditional practices. They have no awareness on the consequences from what they have done which will affect their lives and the lives of the following generations.

Some people have developed the *habit* of making messes (i.e. by throwing wastes anywhere around them) from their socialization and surroundings. This habit or behavior develops further, when they grow up since no one teaches them seriously how to make a clean and tidy environment. In addition, some people have been brought up in the messy environment and get used to it. They do not have any value for nice and clean environment either.

The last reason deals with people's *beliefs*. Some people have the idea that they can do whatever they want to, without caring for the others' feelings or troublesome. For them, to throw litter or denying cooperating in any waste management programs is "peanut" in their views or is meant for others.

3.13.6 Weak law enforcement

In fact laws and regulations, generally termed as ‘command and control‘ instruments (CACs), are the most prevalent mode of solid waste management. They prescribe the standards to be complied with by economic agents and their decisions on what, how, when, where and how much to produce, consume, emit and clean up. However, vigilance and enforcement capacity must be adequate (UNDP-ETD-DTIE, 2000). Solid waste management in Suriname has largely relied on command and control strategies, an approach that has proved to be inefficient as evidenced by the mountains of uncollected or illegally dumped solid waste. The following problems with CAC approaches are encountered: the weak law enforcement and monitoring, inadequate detail in law, lack of inspection staff, lack of transport, inadequate empowerment of inspectors to ticket offenders, political intervention to quash tickets, disinterest by the courts for these minor offences, inadequate police coverage to enable arrests and follow them through the court system, and non-deterring fines and penalties. These issues are raised by many stakeholders.

As mentioned before, the government has laws containing penalties for those throwing waste in illegal places. A few signs publicizing this law were placed in several public places, such as main streets and parks (photo 3.7). Field observations at several places, such as bus terminal and main streets, revealed that often such a sign was accompanied by waste scattered nearby.

The weak law enforcement can be reduced by a more coordinated approach involving various stakeholders, presently the different institutions work too much independently from each other, not knowing what the other is doing and on ad hoc base. Their efforts are well-intentioned but a coordinated approach is preferred.

Photo 3.7: Legal signs for preventing littering of waste

3.14 Financing

Where there is such performance of monitoring and enforcement capacity weaknesses, economic instruments (EIs) offer a viable alternative (UNDP-ETD-DTIE, 2000). The use of economic instruments for solid waste management is not well established in Suriname although some instruments are used to a limited extent such as charges for the hire of containers, refuse removal for companies and deposit-refund system of private companies (brewery industry, soft drink company and detergent soap company). For the last case, consumers pay deposits for reusable glass bottles and plastic gallons, which are refunded upon return of the bottles.

Charges collected for solid waste services from companies flow to the coffers of the central government. These funds are then allocated across the different central government ministries. Solid waste management is then funded by allocations from the responsible ministry for waste collection, transport, disposal, administrative cost, operation and maintenance, taking into account that the ministry is also responsible for other infrastructural works (e.g. the drainage system). The funds do not accommodate the actual budget required for the solid waste management program, projects, and operations, etc. Inadequate performance is often the result.

As mentioned before the households in Suriname do not pay for the solid waste collection service. However, on the other hand the costs for solid waste management are continually rising (table 3.3). The annual budgeted expenditures of the Ministry of Public Works was in 2003, US$ 27,571,429 (ABS, 2004) of which US$ 1,364,726 was allocated for solid waste management. This means that 4.9 % of the Ministerial budget is allocated for waste management. Compared with state's budgeted expenditure (US$ 424,035,714 in 2003) solid waste management is about 0.32 percent. Within local governments of developing countries, expenditure for municipal solid waste services is usually 20 to 50 percent of total municipal expenditure (Cointreau-Levine, 1994). In response to this low level of expenditure, the level of service is quite high (collection coverage of 70%). This situation can change by the introduction of a cost recovery system based on fees, which seems to be more advantageous than the taxing system.

Without access to funding, creating an integrated waste management system that takes advantage of economies of scale is impossible. Access to capital (public or private) plays an important role both in program planning and system realization, to avoid above-mentioned financial restraint. While in many cases this is dictated by national legislation, often local politicians have considerable influence in this matter (Wilson et al., 2001).

Table 3.3: Working expenses VOV (Chote, 2005)

Aspects	**1995 (US$)**	**1997 (US$)**	**2003 (US$)***
Salaries and wages	13,942	17,372	251,431
Allowances	3,853	9,824	35,588
Exploitation vehicles	19,756	15,855	22,289
Rent of vehicles	114,545	154,545	917,637
Tires and spare parts	5,456	9,091	55,664
Fuel and lubricants	7,273	10,909	32,959
Service to third-party	364	7,428	18,182
Purchase of materials	12,444	72,727	30,976
Total	177,633	297,751	1,364,726

*the high inflation has led to a high increase in SWM costs

3.15 Summary of existing SWM situation

Table 3.4 gives an overview of the existing SWM situation in Suriname.

Table 3.4: Summary of existing solid waste management situation

Aspect/Activity	Weak	Strong
Waste management planning	- no formal waste management policy - lack of planning - poor management (deficiencies)	- concept business plan for waste entity
Waste management legislations, regulation	- lack of appropriate legislation - insufficient enforcement	- concept Waste Act
Responsible government agencies (institutional and managerial)	- lack of coordination among agencies and government - bureaucracy - narrow view of waste management - Inadequate institutional arrangements - untrained personnel or lack of experts - unclear goals and objectives of waste management	- Ministry of Public Works: VOV (waste department) - Ministry of Regional Development – waste issues in districts - Ministry of Public Health: Milieubeheer (after the election in May 2005 this Department is classed under the Ministry of Internal Affairs)
Waste storage	- waste is stored in different containers - no specified rules for containerization - street containers are in bad Condition	
Source separation	- lack in promoting source separation - no source separation protocol	
Reuse		- returnable glass drink bottles - deposit for glass bottles
Recycle	- most recycling is through the informal sector (schools, waste pickers, households) - lack of interest of municipal authorities in recycling efforts	- recycling of PET bottles, scrap metal by private companies
Waste collection	- no collection fee - accumulation of uncollected waste - lack of service provision in some areas - inadequate service coverage - environmental and public health risks from waste - narrow, bad maintained inaccessible, blind road - traffic congestion - routing problems (micro routing)	- waste collection is undertaken - use of open trucks and compactor trucks - macro routing - cleaning of illegal dumps

Continued Table 3.4: Summary of existing solid waste management situation

Aspect/Activity	Weak	Strong
Waste disposal activities	- waste disposal located in marshland - open dump - scavenging at open dump - illegal dumps - no landfilling fee - difficulty in finding sites for landfill - inappropriate disposal methods: illegal dumping and burning	- plans to build sanitary landfill - asphalt road to dump
Composting	- rarely undertaken despite the high percentage of organic material in the waste stream	- CBO and institutions organized training in composting
Incineration	- not common	- two tiny incinerators for selected hospital waste
Funding arrangement	- no collection fee and landfilling (gate) fee - fee from companies too low - insufficient funding from national government - low cost recovery	
Social aspect	- low/lack environmental awareness - negative public behavior to waste pickers - limited community participation - limited environmental Programs	- educational environmental TV spots - environmental education at primary schools

3.16 Conclusions

It may be concluded that the Ministry of Public Works (VOV) is unable to cope with growing solid waste problems. Our current waste management system is limited to collection, transportation and disposal (in open dumpsites) and is characterized by lack of strategic planning, lack of institutional arrangement, inadequate operation, lack of effective financial management and lack of adequate environmental protection and their relationships. This situation is similar to many cities in developing countries, where the authorities responsible for waste management rarely have appropriate strategies and methods for mobilisation resources or the necessary appropriate infrastructure for organised waste management. The classical approach to SWM, which considers the government as the only responsible, ignores several socio-economic aspects of the existing solid waste system, thereby contributing to the problems of inefficiency and ineffectiveness of the waste management system. In case the government does not take actions, a serious environmental disaster awaits our nation. Some first signals are already observed such as the outbreak of dengue and flooding during (short) rainstorms.

With its growing responsibilities and limited funds, the government must make strategic choices about which problems to tackle first. Setting priorities by assessing the scale of impact and the cost as well as the appropriateness of the solution are important components of good management. To set about these problems can become complex because of the wide variety of issues, which need to be addressed. Therefore, the government has to introduce an integrated approach to solve waste problems whereby attention should be given to the quality of the collection service, system of cost recovery from users, privatization of collection systems, and development of environmentally safer methods for disposal (composting, sanitary landfilling).

Chapter 4

Case study I: Characterization of household solid waste in Greater Paramaribo

Chapter 4
Case study I: Characterization of household solid waste in Greater Paramaribo

This chapter describes the results and experiences of sampling household waste at the source of generation (residents) in Greater Paramaribo undertaken in 2002 - 2004. Additional surveys have been undertaken in 2005 focusing on waste collectors, truck performance, waste pickers and truck counting at the disposal site because few people know about the activities of these people.

4.1 Introduction

In order to accomplish ‘integrated solid waste management’ which is the advanced concept of optimizing waste management in a country, reliable data on the quantity and quality of waste are required (Toshihiko Matsuto and Nobutoshi Tanaka, 1993). Successful operation and planning of solid waste management systems frequently depend on accurate data of solid waste quantities produced. Knowledge of quantity and composition of municipal solid waste (MSW) is essential for the planning of waste management systems, waste management policy formulation and evaluation and for designing appropriate pollution control measures. Other reasons include a need to estimate material recovery potential, to identify sources of waste generation, to facilitate design of processing and collection equipment, to estimate physical, chemical, and thermal properties of the wastes, and to maintain compliance with local, state, and national regulations.

Despite the central role of these aspects, there is a lack of solid waste data from the different sources especially in Suriname due to insufficient budget and unavailable management which results in a situation where records of solid waste generation and composition data are missing or are not up to date. Without a good insight in the quantities of solid waste that can be expected, decisions about equipment and landfill space and capacity and recycling or composting markets cannot be reliably made. The last identifies which waste categories can be targeted for recycling, reduction or composting programs. A clear estimation of the quantities and characteristics of waste being generated is thus a key component in the development of cost effective solid waste management strategies (Gerlagh et al., 1999).

In order to understand how much waste is generated it is crucial to undertake a waste characterization study according to internationally accepted methodologies. This means the description of the type (composition) and amounts (generated or produced waste) of waste present in a waste stream.

A waste characterization study has several objectives. Through developing a waste composition estimate the outcome of the study can be used for:

- establishing a baseline methodology for future monitoring and prediction of solid waste generation
- understanding factors affecting waste generation rates
- describing the physical, chemical, and biological properties associated with MSW
- using waste composition and properties in performing calculations for landfill capacity and behavior, garbage fee and waste collection costs
- providing a data base for improving the operation of existing waste management system
- providing a data base for the development of regulations
- providing a data base that can be used in long term planning
- assisting in creating local educational materials on solid waste management
- identifying material categories and their quantities in the waste stream for potential reduction, composting and recycling
- assisting the local authorities in setting future policy direction and waste management plan and priorities

These objectives are often combined together.

Estimating the waste generated is a big challenge because one has to deal with several issues. The composition of generated waste is extremely variable as a consequence of seasons, life style, locally legislation, demography and geography. These variations make defining and measuring the composition of waste more difficult and at the same time more essential. The issues that have to be taken into account for waste generation measurement are (Recycling Council of Alberta, 2004):

- where is measured: at the source (e.g. households), at a transfer station, at landfills
- wet and dry weight of the waste
- municipal waste, ICI (Institution, Commercial, Industrial), residential waste only
- sample size and sampling method (random or systematic)
- time of year / seasonality

In the case of residential waste, the major factors affecting the amount and type of waste generated are (Rushbrook and Pugh, 1999):

- household size
- household age structure
- household income
- type of dwelling
- geographical location
- time of year

Waste composition studies can be expensive, however it is important that these studies are conducted and in a cost-effective manner, that will provide information that is consistent with the study objectives. The composition of waste varies from house to house, business to business, by day, by season, by socio-economic conditions, by geographic areas and by country. So there is no clearly defined methodology, one has to adopt it to its local or country's situation.

4.1.1 Nature of the problem

MSW is becoming an acute problem in Paramaribo, the capital city of Suriname, due to the increase in urban population, lack of sanitary landfills, lack of an efficient collection service, lack of national waste management plans, lack of budget, old dated laws and the high import rate. Such developments have impacts on the environment and human health. With its restricted budget the government committed some efforts based on ad hoc decisions to control the MSW but still the waste problem cannot be governed. One of the profound causes of the waste problem is the lack of reliable data about the quantity and composition of waste generated by the different sources (e.g. households, institutional, commercial and industrial establishments).

Waste data of sufficient quality have hardly ever been obtained in Suriname. Waste characterization studies have never been done according to statistically defensible ways in Suriname and even when it did, the methodology used was not stringent. The reasons are:

- methodological problems
- financial problems/lack of funding
- lack of awareness among local waste management officials of its importance
- time-consuming effect of composition analysis studies
- lack of access to weighbridges at disposal sites.

The Ministry of Public Works made a very rough estimate of the amount of waste generated by adding up the estimated capacity of all trucks arriving at the open dump (Ornamibo). Problems accompanying with this method were:

- the heterogeneity of the waste which is not included in the data
- compaction of the waste

- no information available on the composition of the waste
- this analysis should be performed a number of times during the year or every year to improve the reliability and to observe trends, and not once as occurred.
- there were no published results, so these data will be of limited relevance.

Previously a group of students of the Environmental Department, supervised by the author, did a research on import data of specified products to define how much waste would be generated after the lifetime of these products. It regarded the products: glass-, paper-, plastic-, and metal products. The problem they faced was the inconsequent record keeping of data by the Office of Statistics. In some periods the units were in kg, some times in pieces, which made summation very difficult.

It is important that a clear delineation of data requirements and protocols to be used for the collection of data is required. The need for standardized waste characterization protocols is required, as the quantities of waste collected has increased significantly, the waste management systems are far more complex, and the economic resources available for the collection of waste characterization data are limited. Worldwide there are several ways to implement waste composition studies, but the core is to develop a waste composition methodology that will be practically and economically appropriate for Suriname, so it can be used for future solid waste management planning activities and prediction.

4.1.2 Aim and scope of this work

To solve the waste problems in Suriname an integrated solid waste management model must be developed. The first start to reach this model is the implementation of a waste characterization study.

In the period May – October in 2002, 2003 and 2004 a residential (household) solid waste composition study was conducted in Paramaribo.
The study investigated the quantity (how much) and quality (type) of waste generated at residential level and the determinants that can have influence on waste generation rates: ethnic and socio-economic factors, and a possible trend in the household waste.

The primary objectives of the study were to develop a representative and statistically estimate of the quantity and composition of the solid waste stream in Paramaribo and a methodology that can be used for the future.

The methodology for this survey was as follows:

- collection of literature, existing studies and reports on waste generation at household level
- formation and instruction of a project team (consisting of a coordinator, L. Zuilen, and 6 students)
- designing and conducting questionnaire survey, selecting material categories and developing waste sort working sheets
- dividing of Greater Paramaribo in three economic classes (low, medium and high income groups)
- choosing of 4 research areas within the three economic classes based on logistic and ethnic distribution, were chosen.
- collection of information on the numbers of households in the counties
- selection of households and collection of information on the size of households
- estimation of the solid waste generation rate for each research area. This field survey was based on the *direct waste sampling* method (4.2.1). This technique is quite accurate in defining waste categories and quantity, but is costly and labor intensive
- compilation of the collected data
- laboratory analysis of waste samples

The participating facilities in accomplishing the objectives described above were the Anton de Kom University (Faculty of Technology), in Paramaribo which facilitates the project team with transport, the Environmental Department which accommodates the survey with students who conduct part of the survey as a curricula item and the Chemistry- and Soil Laboratory where analyzing of the waste samples occurred.

4.2 Residential solid waste characterization – literature review

Waste characterization means finding out how much paper, glass, food waste, etc. is discarded in a waste stream (CIWMB, 1990). Tchobanoglous et al. (1993) described the goal of waste characterization as the identification of the sources, characteristics, and quantities of the wastes generated. Waste characterization information helps in planning how to reduce waste, set up recycling programs, and conserve money and resources. This information can also be used for solid waste planning. Waste characterization data are collected by taking samples of waste, and sorting it into material types. Therefore, samples will be taken from the generator (e.g. households).

The following will give a brief analysis of published survey on residential solid waste characterization methods or techniques.

4.2.1 Data collection method

Several researchers and institutions conducted a number of residential solid waste generation studies. Most of these studies used basically the same methodologies or techniques, modified to their situation.

Once a government or institution decides that a waste composition study is required it needs to develop a study methodology. There are in general three methods for determining the composition of urban solid waste streams (Shanklin et al., 2002):

- waste product analysis
- market product analysis
- direct sampling and analysis

Waste product analysis: Waste stream analysis is another term used characterizing the waste stream of a specific operation for a designated time period. It is "a method for collecting, sorting, and measuring the amount and type of wastes generated by an operation". It is necessary to have a waste processing facility available, and to know the details of materials balances through it in order to apply this technique. Data should be collected for a minimum of one week; the length of time depends on how the data are to be used and the accuracy required. The results are averaged to estimate the amount of wastes that the facility generates for a period of time.

Market product analysis: This method, also known as the material flow method (material flows approach), applies the concept of conservation of mass to track quantities of materials as they move through a defined system or region in order to estimate the composition of the solid waste stream. In this approach, a material balance is undertaken for a material in a region to derive the quantity of that material that would be expected to report to the waste stream. The material flow methodology in this instance is based on the production weight data for materials and products. Generation data are the result of making specific adjustments for imports, exports, and diversions to the production data by each material and product category. The method also considers the useful life of products. One of the problems with the material flow approach is that it is difficult to quantify product residues, such as food left in the container and detergent remaining in the package (Shan-Shan Chung and Chi-Sun Poon, 2001). Further, criticisms of this method include the fact that the focus is on product categories and not waste stream categories. Another problem with the method is that it can exclude some significant waste components because they do not originate in the product sector, such as yard waste. An advantage of this method is that it is more applicable to large geographical areas, i.e. the entire country, rather than local studies (Reinhart and McCauley-Bell, 1996).

Direct waste sampling method (output method): Direct sampling, a conventional approach, involves sampling, manually sorting the waste into several categories or components, and weighing each component from the waste stream of a specific generator (households, disposal site). Subsequently, additional physical and chemical analysis such as moisture content, specific density, specific energy (calorific value) and elemental analysis may be undertaken. This is the most common method employed and may be the only method practically available for determining the material composition in some regions. When using the direct sampling method, the following questions must be addressed:

- how will representative samples of waste be obtained?
- how large should each sample be? and
- how many samples should be selected to achieve the desired level of accuracy in the results?

The responses to these questions will influence the cost of conducting the study as well as the usefulness of the data. The advantage of this method is that it provides information critical and unique to local planning for waste collection, recycling, treatment, and disposal. A disadvantage includes the cost associated with a waste composition study, which often limits the number of samples taken and therefore the accuracy of the data and the physical process of hand-sorting waste into categories is often an unpleasant task (Parfitt and Flowerdew, 1997). Another disadvantage of this method is the vulnerability of the data to bias due to poor planning with regard to demographic issues, seasonality, irregular events, etc. (Reinhart and McCauley-Bell, 1996).

USEPA (1995) identifies a variety of waste characterization techniques:

- **Modeling techniques**

  - *waste generator sampling*: that applies generic waste generation rates and other community features to predict the waste quantities and types at household level. A weighing program is necessary to determine waste weights obtained from a known population. The multiplier in this case is expressed as per capita generation rate (SENES, 1999; CIWMB, 1990).

  - *landfill sampling*: where the community is served by a landfill with a scale. Generic waste composition data can be applied by weighing collection vehicles as they arrived at the landfill sites (ASTM D 5231-92; SENES, 1999; CIWMB, 1990). For a community with a landfill that lacks a scale, a very rough estimate of the total volume of waste generated can be obtained by counting the number of trucks arriving at the landfill and multiplying the number by an estimate of the volume in each truck.

- **Physical techniques**

  Sampling techniques use statistical methods to predict the total waste stream quantity and composition by analyzing small volumes. The techniques used for sample selection:

  - *quartering technique*: involves quartering each truckload and select a quarter of the sample. The sample should be weighed and separated into components.

  - *block technique*: a sample from a truckload is chosen, without mixing and then a sample is chosen from the center of the pile of waste.

  - *grid technique*: the landfill area is divided in grids (equal size square). The truckloads are divided according to the grid; samples are selected from each of the different grids.

- **Direct measurement techniques**
  Bar-code monitoring is used to determine the weight and type of materials collected from each generator in the community for billing purposes. This method has been criticized for being costly.

USEPA recommended that waste characterization should be performed at least four times over a year, avoiding seasonal events to ensure that results are not skewed by seasonal events (ASTM D 5231-92; Ireland EPA, 1996; OWDO, 2002).

Reinhart and McCauley-Bell (1996) recommended the quartering technique (see USEPA, 1995) and stressed on mixing the waste with a front-end loader due to stratifying of the material; heavier material tends to sink and lighter waste moves to the top of the pile. They stated that background information on population demographics, seasonal and economic influences and vehicle routes are important to ensure accurate characterization of the waste stream and therefore recommend stratified, systematic sampling.

Oregon DEQ (1995) implemented solid waste characterization at landfill site by choosing truckloads of designated areas (residential route, commercial route, mixed route). Each sample is weighed and sorted. DEQ posed that waste taken from garbage trucks cannot be accurately separated in the field because of thoroughly mixing and compression. Wet wastes become smeared and absorbed into other wastes, causing contamination. To evaluate this contamination, sorted samples were taken to the laboratory and examined in detail.

OWDO (2002) and WHO (1996) use a different approach. A special collection crew collects the refuse from the curb from a pre-specified collection route and brings it to a sorting area, where the material is sorted and weighed. Contact with the residents must be avoided as much as possible prior to and during the waste study for preventing a change in the normal behavior of residents in the study area (OWDO, 2002; Ireland EPA, 1996).

According to Ireland EPA (1996), the sampling area is divided in social groups depending on the number of households in the area, type of housing, social background and type of collection system. The actual houses to be sampled are selected from the information of the sampling area. A separate vehicle collects the waste from the selected households on the same day as the normal collection scheme and brings it to the sorting area.

Franklin Associates (1997) used the material flows approach to quantify and characterize the municipal solid waste stream. This method is based on production data for the material and the product category in the waste stream with adjustment made for imports, exports and product life span. It assumes that every manufactured item has a limited life cycle and becomes waste afterwards. This methodology works great for national or international waste projections, but becomes less useful on a smaller scale. Another criticism is that product residue associated with other items in the MSW is not accounted for.

MFE (2002) proposed several sampling techniques: random sampling for smaller areas and stratified sampling for towns with distinctly different socio-economic areas. Sampling at the source is difficult, especially where refuse bags are not used. The survey team will need to be equipped with plastic bags to tip the refuse. This way of sampling is time consuming.

To quantify the wastes DOS (2000) used extrapolated data of previous waste composition studies, per capita sales information obtained from industry, trade association, retail outlets and other national data.

To implement MSW composition study, Beck (2000) divided the study areas in geographical zones. Sorting and weighing of the different waste categories occurred at different solid waste facilities (landfill sites, transfer stations) during one week. Beck posed that seasonal differences are not statistically substantial.

Main parameters affecting the annual quantity and composition of MSW generated are the population of a country (the more people living in a country, the more waste produced) and the mean living standard of the country, expressed in terms of the gross domestic product (GPD) describing the economic prosperity of the country. Therefore these two parameters have been widely used to predict the amount of MSW generation. Daskalopoulos et al., (1998) developed a model to predict the total amount of MSW arising annually (figure 4.0):

For Europe: $MSW = 0.1292*GPD^{0.4414}*Population^{0.4855}$

For USA: $MSW = 4.08413*10^{-3}*GPD^{0.458}*Population^{1.24075}$

where:
MSW = Municipal solid waste (million tones per year)
GPD = Gross domestic product expressed in US$

Beigli et al. (2004) estimated the final MSW generation model for European cities based on the following equations:

- for cities with very high prosperity:

$MSW^t = 359.5 + 0.014*GPD^t - 197.1*\log(INF_{urb})$

- for cities with high prosperity

$MSW^t = 276.5 + 0.016*GPD^t - 126.5*\log(INF_{urb})$

- for cities with low and medium prosperity

$MSW^t = -360.7 - 375.6*\log(INF_{nat}) + 8.93*POP_{15\text{-}59} - 123.9*HHSIZE^t + 11.7*LIFEEXP^t$

where:

MSW^t = municipal solid waste generated (kg / capita / year)

GPD^t = gross national domestic product per capita per year

INF = infant mortality rate per 1,000 births in the city (INF_{urb}) or in the country (INF_{nat})

POP_{15-59} = percentage of the population aged 15 to 59 years

HHSIZE = average household size

$LIFEEXP^t$ = life expectancy at birth

t = year

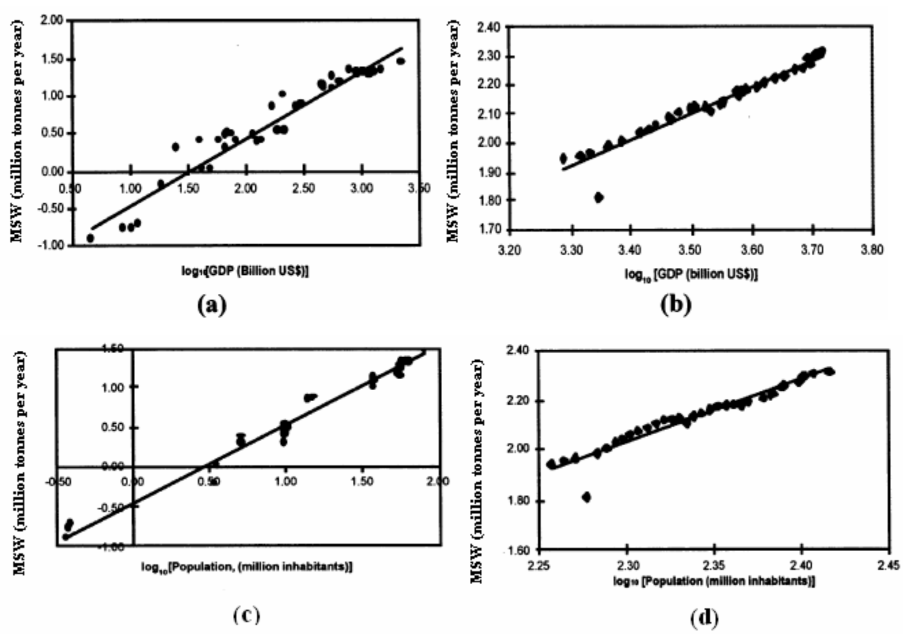


Figure 4.0: The relationship MSW arisings versus GDP for: (a) Europe and (b) the USA and MSW generation versus population (c) Europe and (d) the USA (Daskalopoulos et al., 1998)

According Daskalopoulos et al. (1998), the increasing figures for USA are attributed to the American lifestyle: the continual discarding of still functionally useful products in order to buy new ones.

Above mentioned methodologies are applied in developed countries: USA, Europe, Canada, New Zealand and Ireland.

Below some methodologies are described as conducted in developing countries.

For solid waste characterization studies, WHO (1996) defines that the residential areas involved in the study must represent different socio-economic population groups (e.g. according to ethnic groups and/or income levels: low, middle and high income groups, family size). The waste generated can be collected from the pre-specified collection route at a fixed time for 8 successive days to allow variation in waste generation over a week. The collected waste is transported to the dumpsite where all measurements have been taken.

In an early solid waste generation study Arnold (1995) carried out a pilot study in a residential area where each household was supplied with plastic bags for collecting their waste. The sampling program took place over 7 consecutive days whereby the sampling procedure occurred according to the Flintoff method as Arnold reported.

Van der Merwe and Steyl (1997) used the following formula to calculate the amount of waste generated per ward:

$$X_i = \sum^n (a \times d)$$

where:

X_i = total waste (kg)

a = people per household

d = group waste factor

n = ward number

Since the amount of waste produced varies according to the socio-economic class, van der Merwe and Steyl (1997) divided the sampling population in two socio-economic groups: low and high-income areas.

Guven (2001) used the stratified sampling method to define the household waste composition. The field study was supported with a questionnaire survey which includes the following items: number of persons living in each household in the respective week, education level, type of housing, heating system and type and amount of fuel used. Weekly solid wastes of each household were collected during 3 days of the week. The selected households were supplied with plastic bags to put their waste, which were collected and transported to the sorting location.

4.2.2 Justification of sample size

Determining the number of samples to conduct solid waste generation studies is still disputable. To depict the reliability of solid waste generation data, the selected sample should contain a sufficient number of households keeping in mind that the sample size must be kept within reasonable limits taking into account costs, quality of the study and the size of the sampling team.

Beck (2000) recommended that in general statistical principles dictate that roughly 15 to 20 representative samples can be obtained from the residential waste stream.
Typically, waste samples are collected from about 5% to 10% of on-base housing. This should result in a statistically significant sample. However, a larger number of residences should be sampled if additional information, such as waste generation by rank (income), is desired (Parks and Brockman, 2000).

CIWMB (1998) reported that the following formula can be used to determine the number of samples:

$$N = (zs / \delta)^2$$

A 90% confidence level shall be used in this formula.

where:
N = number of samples
z = normal standard deviation for the confidence level desired
s = estimated standard level
δ = level of precision or sensitivity

SENES (1999) used the following equation to calculate the number of samples:

$n_i = (t\ s_i / d)2$

where:
n_i = the number of samples to collect for its waste category
t = the t-statistics for the desired confidence level and the number of samples
s_i = the estimated standard deviation for the waste category
d = the precision requirement (i.e. one half the range of the confidence interval)
GPD

Deviation from above sources is permitted in case the provided data are statistically representative and in the event of financial- or other resource constraints (CIWMB, 1998).
In table 4.1 an overview is given of the recommended sample size from different sources.

Table 4.1: Sample numbers for residential waste characterization studies

Source	Minimum number of samples	Minimum sample weights
CIWMB (1998)	15 per season (30 per year)	91 kg
Beck (2000)	15-20 (max. 30) per season	91 kg
SENES (1999)	9 from each sampling area	100 kg
MFE (2002)	Depends on the waste categories in the waste stream. The more of a category (food waste) in a plastic bag than fewer bags are required to estimate food waste than in the in the case of glass which is less present in a plastic bag	
WHO (1996)	10-20 households per area	
Oregon DEQ (1995)	15	68-80 kg
OWDO (2002)	30 plus one extra as a contingency	
Parks and Brockman (2000)	5% to 10% of on-base housing	

4.2.3 Material categories

The lack of specific definition for waste categories has created a variety in the amount of waste categories. Break down of the waste stream in waste categories depends on the different purposes of the studies undertaken and of the designer of the study. Frequently the waste stream is categorized into groups of items that are relatively easy to recognize or based on their economic value. Some main used categories are food waste (organic waste), plastics, paper, glass, and metal..

4.2.4 Statistical measurements

Usually the entire quantity of solid waste being generated cannot be economically or practically sorted. Therefore a representative sampling method must be used to obtain study samples and these samples must be analyzed to estimate the composition of the entire waste stream.

The following terms used to characterize solid waste are (Reinhart and McCauley-Bell, 1996; SENES, 1999; Beck, 2000):

- mean (mathematical average)
- confidence interval (CI) (expression of statistical accuracy)
- standard deviation (measure of the amount of variation that might be expected between the actual indicator value and the forecasted value).

4.2.5 Generation rates and characteristics

According to Hoornweg and Thomas (1999), Sterner and Bartelings (1999), Jenkins et al. (1999), Seguino et al. (1995), generation rates for MSW vary from city to city and from season to season and have a strong correlation with demographic data, levels of economic development and activity. They concluded that:

- high income countries produce between 1.1 and 5.0 kg / capita / day,
- middle income countries generate between 0.52 and 1.0 kg / capita / day, whilst
- low income countries have generation rates between 0.45 and 0.89 kg / capita / day.

The composition of MSW varies significantly, with low and middle income countries generating waste containing over 70% organic content, with corresponding moisture content in excess of 50 %. Hoornweg and Thomas (1999), Pitzler (2000) and Beck (2000) addressed that in developed countries the MSW stream consists mainly of paper, plastic, glass and metal products.

According to UNEP/IETC (1996), waste characterization data, specific to African cities, are not generally available. In addition, here a correlation can be made between the income level of the generators with the generation rate and composition of the MSW stream. As delivered (wet basis) MSW from Accra, Ibadan, Dakar, Abidjan, and Lusaka shows a range of per-capita generation rates of 0.5-0.8 kg per day (compared to 1-2 kg per person per day in the OECD countries); putrescible organic content ranging from 35-80% (generally toward the higher end of this range); and plastic, glass, paper, and metals at less than 10%.

From the available data from South American and Caribbean countries UNEP/IETC (1996) reported, that quantity and quality of wastes are also related to the economic conditions of these countries. The richer ones generate more wastes per inhabitant, and their wastes tend to contain more paper, glass, and metal than in the poorer countries. Waste quantities generated range between 0.3-1.0 kg/inhabitant/day (this includes commercial, market, and street-cleaning wastes). On average, wastes are very humid (approximately, 45-50%) and have a high organic content (40-50%). Organic content (and, therefore, humidity) tends to be higher in poorer countries.

Waste is an extremely variable material therefore different surveys will always show different results (Open University-Scotland, 2004).

4.2.6 Physical Properties

According to Tchobanoglous et al. (1993), the important physical properties of MSW include density (sometimes referred to as specific weight), moisture content, particle size and porosity. Moisture content is the most commonly used parameter and is defined by the amount of moisture as a percentage of the wet weight of the waste material. Moisture content is important in regard to density, compaction, understanding the composting process, leachate development, leaching of in-organic components in landfills, and the use of incinerators.

Common contaminants of waste items include moisture, food, and dirt. Although these materials are normal components of the waste stream, they are of concern when they add significantly to the weight of paper, plastic film, yard waste, and containers. During placement in collection vehicles, the contamination increases when waste is squeezed causing materials to smear or stick together and forcing moisture from food and other wet wastes onto other absorbent items. In addition, contamination can occur during sampling and sorting as a result of mixing and/or inclement weather. Several methods have been used to account for contamination. The samples can be taken to a laboratory where they are weighed, cleaned, and air dried. Durable items, such as glass and plastic containers, can be washed prior to air drying. If the contaminant category can be identified (for example, food) each contaminant category should be properly adjusted for the weight of contamination (Reinhart and McCauley-Bell, 1996).

4.2.7 Concluding remarks

Review of above studies demonstrates that:

- In developed countries contact with the residents are avoided during the sampling period to prevent skew in the data.
- In developing countries contact with the residents is important because of the attitude of the people (dump their waste, not accustom with these studies, wrong perceptions) and of the lack of socio-economic-demographic data, the questionnaire survey must be conducted to get up to date information
- Due to financial constraints the sampling period in developing countries is much shorter than in developed countries, where sampling is recommended in each season
- In developing countries landfill based sampling is a problem because of the mix collection routes and the lack of mono landfills and weighing facilities
- The generation rate is much higher in developed countries. In developing countries the waste consists mainly of organic waste.
- Methodologies for determining waste composition in developing countries were rarely discussed
- The composition for MSW is assumed to be based on wet weight.

4.3 Methodology

4.3.1 Selection of study area

To get representative results, Greater Paramaribo was divided, based on socio-economic stratification, into three economic classes:

- low income class
- middle income class
- high income class

The socio-economic level of the communities was based on the housing type (Abu Qdais et al., 1997), its property value and construction characteristics (Ojeda-Benitez et al., 2003). This information was confirmed later after interviewing, which gave also information on the family size, education, profession and property status.

In order to identify representative study areas to be used for sampling and analysis of residential waste, a field observation was conducted. The study areas need to represent each of the following characteristics:

- density residence (high, medium, low)
- waste collection must exists in the area
- racial distribution
- family size
- type of house: villa, modern buildings, small detached houses
- logistics.

Based on above characteristics the following study areas were chosen (map 1):

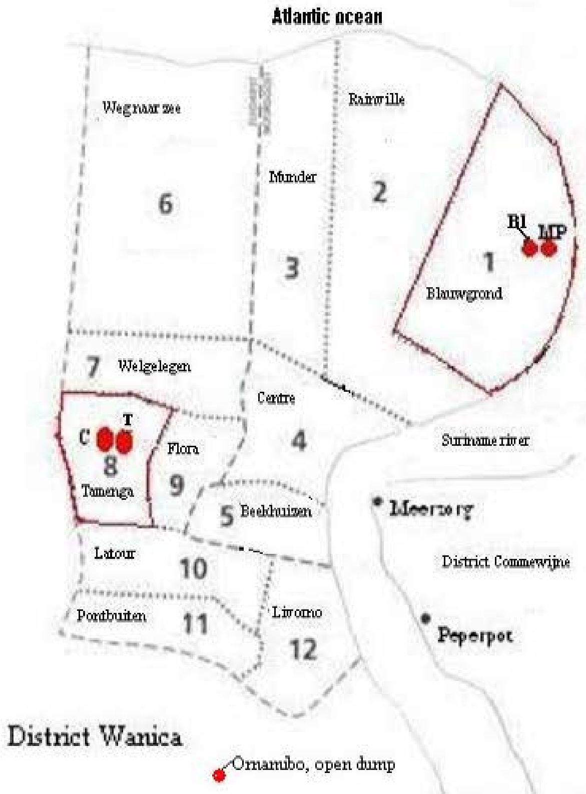
- MonPlasir (high income)
- Blauwgrond (low income)
- Cupido (medium income) and
- Tamenga (low income)

In table 4.2 the main characteristics of the study areas are given.

Table 4.2: Study area characteristics

Name of county or study area	**MonPlasir**	**Blauwgrond**	**Cupido**	**Tamenga**
Economic class	High (business men and highly educated)	Low (administrative, retired)	Medium (educated)	Low (retired, low educated)
Family size	Low	High	Low-high	High (many households have a 2-3 generation family)
Density residence	Low	High	Medium	High
Type of dwelling	Villa's (own investment)	Normal to small, detached houses (own investment)	Big to normal, modern buildings (own investment)	Normal, some badly maintained (build by the government)
Racial distribution	Mix of different ethnic groups	Dominantly Asian	Dominantly black	Dominantly black
Natural Environment	Asphalted streets, no litter of waste in the streets, no stray dogs, beautiful maintained gardens	Paved, unpaved and narrow streets, a lot of litter, in some streets illegal disposal sites, stray dogs	Asphalted streets, no litter of waste, few stray dogs, good maintained gardens	Asphalted streets, illegal dumps, stray dogs, a lot of litter
Social Environment	See no people walking on the street, every house has more than one car , almost every house is guarded, all households have servants and gardeners	Crowded streets, a lot of households have a car (second hand)	See no people walking on the street, every household has a car, some households have servants	Crowded streets, a lot of males of working age hanging on corners of the street (smoking), even during school time children are walking on the street, few households have a car
Waste collection	yes	Yes, not all streets	yes	yes
Waste container (mainly)	Garbage bags	Plastic grocery bags, buckets	Garbage bags, grocery bags	Plastic grocery bags and buckets

Map 1: General map of Greater Paramaribo (including research areas)



Ressort 1: Research areas - Bl (Blauwgrond) and MP (MonPlasir)
Ressort 8: Research areas - T (Tamenga) and C (Cupido)
(numbered areas represent (counties of) District Paramaribo)

Source: Talgrachics n.v., 1994

4.3.2 Selection of households

To get representative results in the survey it was decided to select 20 randomly households of each socio-economic category. A map of Paramaribo was available showing the location of the different selected counties. In each county a field observation was done by counting the number of streets and houses. The project team drove slowly in the streets counting the houses. Each house number in a county represents a household which will be sampled. The house numbers were written on a slip of paper, folded and placed in a box. The box was thoroughly shaken and with eyes closed a number was drawn out; one by one until the desired size of 20 was reached. The selected households who were willing to participate were interviewed by the project team to obtain information from the households and the purpose of the study was explained. The latter was very important because in Suriname people are not accustomed that others (except vagabonds) are turning garbage bags or bins. An information folder, explaining the purpose of the study and a structured questionnaire were developed consisting of the following indicators: number of persons living in the selected household, degree of environmental awareness, education level, income, link with the neighborhood and house, information on collection service, waste disposal practices, willingness to pay for better waste management. The questionnaires were filled (by the project team) before conducting the field survey (analyzing garbage bags or bins). In case a household refused to participate in the composition study, above selection method was repeated to select a new household. Sampling at source was dependent on the willingness of households to participate, so we worked with the households who were willing to participate. Due to operational limitations in the field (limited resources, time and field-assistants) and suspiciousness of households, the optimum number of samples (20) was not obtained.

4.3.3 Length of study

Sampling was conducted from June until October of each year (2002, 2003, and 2004), which included the dry and wet seasons and also school holidays. To develop a reliable and consistent information database, waste samples were collected for 6 consecutive days per sampling period in each area. The target was to implement 3 sampling periods per area. Not for all research areas this schedule could be reached due to limitation of the size of the project team. Sampling occurred in the morning except the days that the waste collection service attends the county. Households that participated less than three days were expelled from the study for further research for statistical reasons (Swinscow, 1997).

4.3.4 Material categories

The selection of the material (waste) category was a critical step. Overall, the categories selected needed to balance the objectives of the future waste management activities (recycling, composting potential) and the current practical efforts. A total of 18 waste material categories were defined into which samples were hand sorted in the field but in the results these components were adopted to the classification scheme of the Hoornweg and Thomas (1999) into 6 component categories: compostables (includes food, yard and wood wastes), paper, plastic, glass, metal and others (includes ceramic, textiles, leather, rubber, inert, etc). Table 4.3 summarizes the material categories that were used in the study.

Durable goods (white and brown goods) are not included because these items are not collected by the solid waste collection service. The data on waste composition of this study represents the percentage of the waste matters in the domestic waste stream on a wet weight basis.

Table 4.3: Material categories analyzed in the field

Main material group	Material category
Organic waste	Compostable: fresh fruit and vegetable
	Food preparation waste (cooked)
	Other: meat, pits of fruit
Paper	Newspaper, magazines, writing paper, packaging paper
Cardboard (1)	Folding boxes, corrugated carton
Carton container	Drink cartons
Plastic	PET
	HDPE
	Other plastics: PVC, LDPE, PP, PS, multi resin
Glass	Glass: bottles and jars (container)
	Other glass: non container
Metals	Al cans (container)
	Other metals: non containers
Yard waste	Leaves, grass, chopped trimmings (2)
Textile	
Batteries	
Wood (3)	Small pieces
Rest	Rubber, leather, medical waste, rock, dust, diapers, composite, ceramics, leftover of paints in cans, light bulbs

(1), (2), (3): big branches, brush, stumps, trimmings, unfolded boxes and big pieces of wood are not collected by the collection service.

4.3.5 Material and equipment

The following materials were used for conducting the household waste composition survey:

- a household scale (max. weight 2 kg ± 10gr): to weigh the waste (2002)
- digital scale (max. weight 6 and 10 kg ± 0.1gr): to weigh the waste
- plastic bags: small, medium, extra large grocery bags and garbage bags
- plastic sheets: used to spread waste on this sheets

- gloves: to handle waste
- dust masks
- disinfectant to clean sheet and equipment
- disinfectant soap to wash hands
- paper towel
- first aid kit
- field map and forms
- pencils
- map
- labels: for coding the measured plastic bags
- knife
- scissor
- bottle of water
- raincoat
- camera
- transport

To maximize the safety of the project team each member (crew) was dressed with a shirt with long sleeves, gloves, dust mask, cap, protective footwear and trousers (long legs). For the sampling areas cars of the university were available and also the crew members used their own cars.

4.3.6 Classifying the waste stream (data collection)

The following steps were involved in classifying the waste stream:

- the crew was instructed on how they should carry out the sampling
- preparing for collection: the selected households were informed beforehand of the selection (sampling) days. This information was printed on paper. Most of the people keep their waste inside to prevent that dog and rats tear the bags open so that all the waste litter on the street. This information was also necessary in case that nobody was at

home the waste could be put on a reachable place for the crew. Even though this information was spread still some people forget to put their waste, burnt or dumped it.

- the bags / buckets were collected on the sampling date. We tried to collect the sample materials at approximately the same time every day.
- the plastic sheet is spread on the ground
- the bags are opened and the contents is emptied on the plastic sheet (also the bucket)
- the waste is separated into different types on the plastic sheet (see waste categories). A lot of bags and buckets contained a lot of maggots, crawling over the waste and the sheet. The waste was also frequently contaminated with water, which made separation sometimes difficult. Where there was too much water this waste was put to the category rest even though it did not belong to that category. Another problem that was faced with was the foul smell coming from the waste, although we had dust mask it was sometimes hard to breathe.
- each type of waste was weighed (in grams) separately and the weight was recorded on the data sheet (see appendix I) (photo 4.1)
- after measuring the waste it is put back into labeled bag and sealed. This label was necessary so that the households and the crew knew that the particular waste was already measured. The household cannot use a labeled bag anymore. The measured content of a bucket is put into a bag so the household can use the bucket again.
- the sheet and scale are cleaned with disinfectant, the hands are cleaned with alcohol
- the crew moved to the next house on the list
- these steps were repeated everyday for the duration of the study
- feedback: after every measuring day a feedback was hold to discuss problems and find solutions, this was also necessary to upgrade the methodology.

Photo 4.1: Separation and weighing of individual waste components

In the high - and medium income areas measuring occurred on the street, in front of the houses. Measuring on the plot of the households was not possible because most people were absent or the fences are electronically alarm protected or have terrible looking blood dogs. For safety reasons for the crew members it was avoided to enter such places.

In low-income areas measuring occurs mainly on the plot of the houses (no alarm, no blood dogs, and most of the time there was always somebody at home).

The households need not to separate the waste (not a custom in Suriname), they just offer the bag/bucket of mixed waste and the crew members separate the waste into categories. The crew did not bring away any measured bags; it was left for the household to put it themselves for the collection service, which is attending the county

4.3.7 Laboratory analysis

The moisture content of waste samples was measured in the laboratory. This information is useful for planning the design and operation of composting. Two samples, of the categories food waste and paper/cardboard, were collected during the field sampling from the low-income area (Tamenga) and analyzed in the laboratory. For each sample the moisture content was done in duplicate. The moisture content, density and ash content were determined according to the procedure described as in Cornell Composting – Science and Engineering (Trautmann and Richard, 1995; Mohee, 2002). The physical characteristics of the materials studied are presented below:

Material	Moisture content	Ash content	Density (g/cm^3)
Food waste	75.49 %	19.61%	2.21
Paper/cardboard	21.46 %	9.45 %	0.45

4.4 Results and discussion

4.4.1 Waste generation and composition

A total quantity of 2.6 tonnes of solid wastes was analyzed in the three-year research period. This quantity was generated by the different households, which belong to various socio-economic classes (table 4.4). The resulting waste sample size was 293 households among the different socio-economic groups on the whole research period (table 4.4). In table 4.5 a representation is given of the number of houses (households) in each socio-economic group in comparison with the number of participating households; the target size of 20 households per area was not achieved.

Table 4.4: Measured waste generation per year (kg) for each county

Year	County			
	Blauwgrond	**Tamenga**	**Cupido**	**MonPlasir**
2002	84.17 [1] (18/91)	354.03 [3] (43/282)	569.02 [3] (54/212)	207.74 [2] (15/62)
2003	135.23 [1] (14/71)	108.72 [1] (14/55)	71.86 [1] (13/48)	160.57 [1] (10/38)
2004	168.95 [2] (29/112)	342.85 [2] (38/204)	213.82 [2] (30/101)	193.74 [2] (16/64)
Total	388.35	805.6	854.7	562.05

[1,2,3] Indicates frequency of sampling per year

(a/b) *a* indicates total number of participating households and *b* total members of households

These data show that the waste production fluctuates enormously per county and per year, this can be ascribed to the following:

- frequency of sampling was not distributed evenly per year per county due to a limit in field workers and time constraint
- most of the time the optimal number of participating households was not reached. It was sometimes very hard to convince people to participate in this research.

Table 4.5: Household income categories and housing units in each income category

Income group	**Residential sources**	**Research period**	**Number of housing units**	**% of total housing units**	**# of sampled households**
Low income	Tamenga	2002	423	24	15
	Blauwgrond	2002	873	30	18
Medium income	Cupido	2002	158	31	19
High income	MonPlasir	2002	281	15	9
Total			**1735**	**100**	**61**
Low income	Tamenga	2003	423	27	14
	Blauwgrond	2003	908	27	14
Medium income	Cupido	2003	160	26	13
High income	MonPlasir	2003	276	20	10
Total			**1767**	**100**	**51**
Low income	Tamenga	2004	423	32	19
	Blauwgrond	2004	915	26	15
Medium income	Cupido	2004	161	27	16
High income	MonPlasir	2004	283	15	9
Total			**1782**	**100**	**59**

The components of HSW for different socio-economic classes are given in the figures 4.1- 4.4. Based on the recycling approach, the results showed that the principal constituents of HSW are compostables, plastic and paper. It can be noted that organic waste (compostables) constitutes 60 % of the total waste quantities. This can be explained by the fact that in Suriname there is a minimum use of processed food in the eating habits; people still favor preparing fresh vegetables, fruit and meat. On the other hand, the absence of recycling and composting programs in Suriname results in large quantities of these wastes entering the waste stream. These figures reflect that the middle and high income levels produce more food waste (60 %); this might be expected because most people of low income group feed their domestic animals with food leftovers. The percentages of the other components do not differ so much among the different economic income groups. Also it might be noted that the percentage of paper/cardboard in the waste (7 %) is relatively low compared with plastic (11 %). This is due to the fact that plastics are widely used as packaging material. There has also been a shift from glass bottles to plastic bottles over the years, especially for soft drinks. Presently, a very small part of plastics is recycled (e.g. Fernandes Bottling Company) but it does not have influence on waste reduction. A lot of bottles are littering the environment; this is imputed to a low environmental awareness of the users (consumers and producers) of these bottles and the lack of adequate legislation. Due to the 'open door policy' regarding the import of products from the Caribbean (Jamaica, Trinidad), it needs to be noticed that the high import of plastics (products and packaging material) from the Caribbean aggravates this litter problem.

Figure 4.1: Average solid waste composition (%) Tamenga

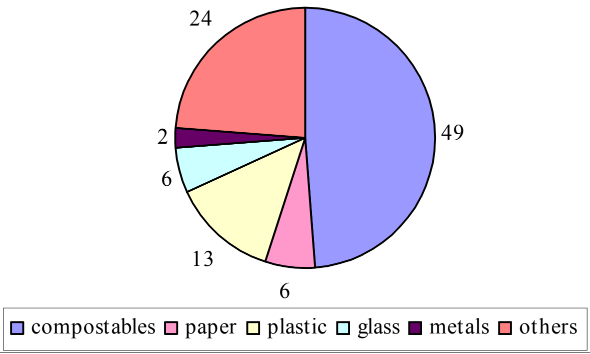


Figure 4.2: Average solid waste composition (%) Blauwgrond

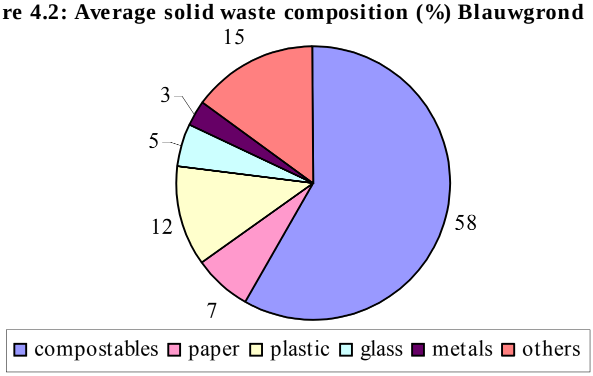
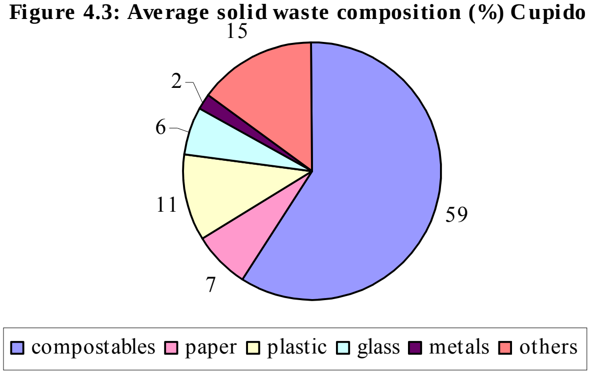
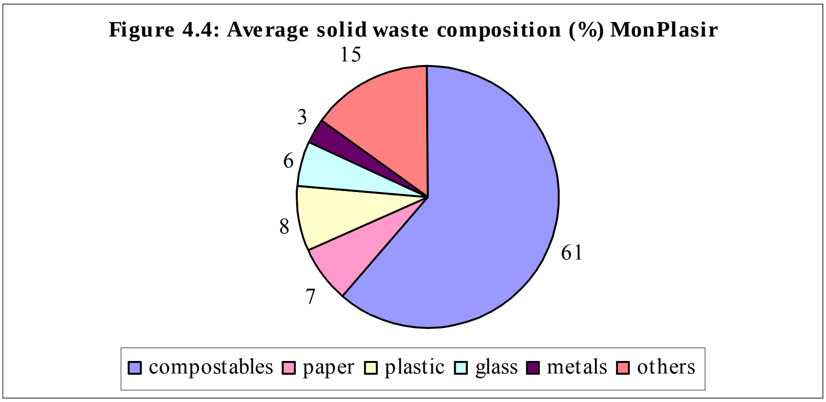


Figure 4.3: Average solid waste composition (%) Cupido





By comparing the waste composition, reported for developing countries, it can be concluded that the obtained results support the explanation of Fehr et al. (2000), Bernache-Perez et al. (2001) and Bolaane and Mansoor (2004) that the content of organic waste in developing countries is high, ranging from 50 to 80 %. High content of organic wastes is attended by high moisture levels which make the waste very dense ruling out incineration and cause very rapid deterioration of vehicles. The figures of Suriname resemble also the data of waste characterization in selected Caribbean countries, which are as follows (PAHO, 2002):

Category	St. Vincent and the Grenadines (%)	Jamaica (%)	Barbados (%)	Trinidad (%)	Suriname (%)
Organic	49.6	53.96	59	46	57
Plastics	8.4	11.77	9	12	11
Glass	5.6	4.27	18.1	6	6
Metals	3.8	5.25	8.6	7	3

Fehr et al. (2000) reported that HSW from developed countries has a high content of packaging made of paper, plastic, glass and metal, therefore, the waste has a low density. This indicates that in the developed countries, the content of biodegradable waste is low; it hardly reaches 50% of the total generated household waste which can also be ascribed to intensive composting programs.

4.4.2 Waste generation rate per capita

The average waste generated by the different household economic categories is given in table 4.6 and figure 4.5. The average waste generated by the different household economic classes was 0.77, 0.50 and 0.35 kg per capita per day for high, medium and low income, respectively. From the available data, it is clear that quantities of wastes are related to the economic conditions of the area.

Table 4.6: Trend in waste generation in the research areas (kg/capita /day ± standard deviation)

Residential area	**Trend in waste generation**						**Average Straight main**
	2002/1	**2002/2**	**2002/3**	**2003**	**2004/1**	**2004/2**	
MonPlasir (HI)	0.64 ± 0.17	**0.93** ± 0.64	NA	**0.90** ± 0.36	0.61 ± 0.21	**0.80** ± 0.51	0.774 ± 0.15
	0.78± 0.21			0.90 ± 0.36	0.70 ± 0.13		
Cupido (MI)	**0.62** ± 0.20	0.49 ± 0.18	0.52 ± 0.17	0.34 ± 0.12	0.49 ± 0.25	**0.53** ± 0.18	0.5 ± 0.1
	0.55 ± 0.07			0.33 ± 0.12	0,51± 0.03		
Tamenga (LI)	0.2 ± 0.06	0.3 ± 0.11	**0.39** ± 0.17	**0.51** ± 0.24	**0.44** ± 0.14	0.41 ±0.11	0. 37 ± 0.11
	0.29 ± 0.09			0,51± 0.24	0,42 ± 0.02		
Blauwgrond (LI)	**0.19** ± 0.07	NA	NA	**0.45** ± 0.26	**0.38** ± 0.22	0.24 ± 0.08	0.32 ± 0.15
	0.19 ± 0.07			0.45 ± 0.26	0.31 ± 0.10		

NA: not available;

The numbers in bold indicate the highest rate measured in that specific year.

Data were subjected to one-way ANOVA – (original and transformed data) and the Kruskal-Wallis test (non-parametric test of ANOVA) to determine if there were significant differences in the waste generation rates among the different economic classes. In the high and medium income classes there are no significant differences but in the low income classes there are significant differences which can be explained by people's behaviour (burn or dump their waste). In appendix II a review of the results of the tests is given.

It is noted that the highest generation rate (0.93 kg/capita/day) was found in the high income area and the lowest rate (0.19 kg/capita/day) in the low in come area. It is obvious that the socio-economic status of households affects the quantity and components of waste generated. Both generation rate and composition show a positive correlation with socio-economic class.

Figure 4.5: Average generation rate of HSW in the different socio-economic areas

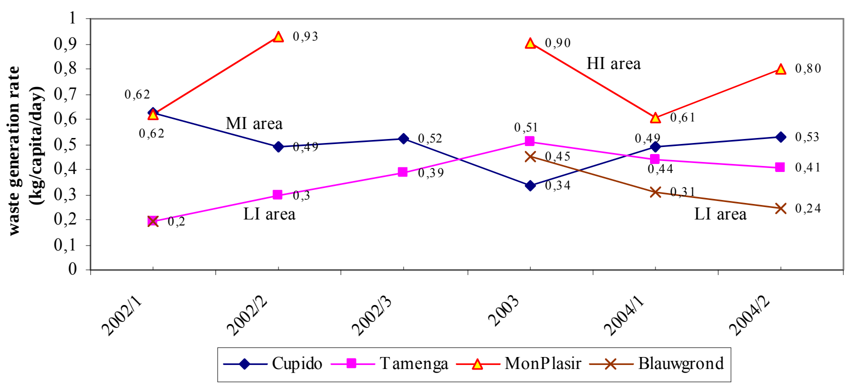


Table 4.7 represents the waste generation rate for the different research periods. From this table it can be concluded that in general the generation rate increased with respect to 2002, but based on these figures it is difficult to conclude that the waste generation rate is increasing throughout the years; more data must be available. On the other hand, factors as mentioned before had a quite big influence on the produced data.

Table 4.7: Waste generation rate (kg/person/day ± standard deviation) per year for Greater Paramaribo

	2002	2003	2004	Average	Geometric mean rate of increase[4]
Method I[1] Straight mean	0.47 ± 0.24	0.55 ± 0.25	0.49 ± 0.17	0.50 ± 0.04	0.09 %
Method II[2] Straight mean	0.53 ± 0.32	0.55 ± 0.25	0.54 ± 0.19	0.54 ± 0.08	0.25 %
Method III[3] Weighted mean	0.41 ± 0,27	0.53 ± 0,24	0.46 ± 0,13	0.47 ± 0.06	3.91 %

[1]All values are included in computing the mean which is thereby affected by unusually high and low data values. The problem encountered: mean value is influenced disproportionately by these values.

[2]Only the highest set out rate figures are used.

[3]A weight is attributed to the mean to signify its importance. In this case the weight is the % of total housing units. Since the participating households in the low-income areas are much higher than the population in the higher income areas they should be given more importance in the calculation giving a more realistic accounting of the overall waste generation rate.
The resultant weighted average of waste generation rate for all households in 'Greater Paramaribo' was calculated with the following formula (Bolaane and Mansoor, 2004 and Abu Qdais et al., 1997):

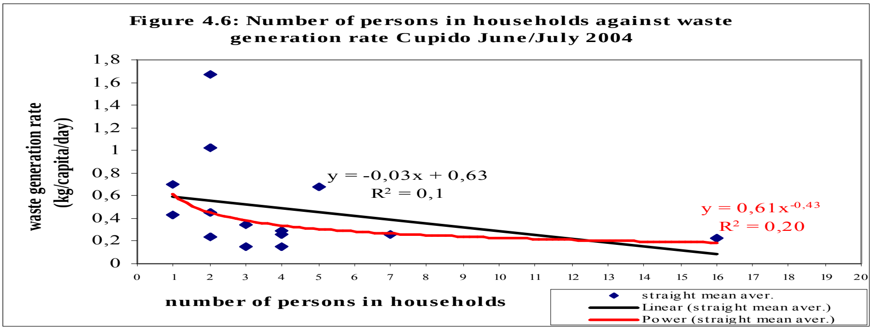
$\sum$ (Generation rate x percentage of total housing units)$_n$ / 100% = kg/capita/day

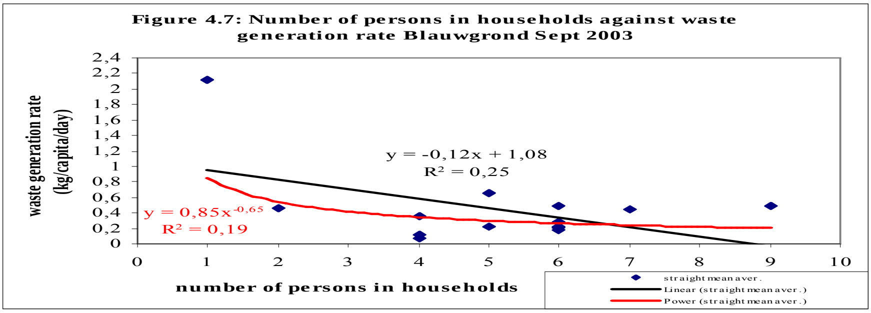
With data based on the tables 4.3 and 4.6 the waste generation rate for all households is:
2002: (0.78 x 15) + (0.55 x 31) + (0.29 x 24) + (0.19 x 30) / 100 = 0.41
2003: (0.90 x 20) + (0.34 x 26) + (0.51 x 27) + (0.45 x 27) / 100 = 0.53
2004: (0.70 x 15) + (0.51 x 27) + (0.42 x 32) + (0.31 x 27) / 100 = 0.46

[4]Geometric mean rate of increase: $\left(\sqrt[n]{\frac{\text{value at end of period}}{\text{value at beginning of period}}} - 1 \right) x100\%$

(n = number of years)

To establish the influence of some social characteristics obtained during the survey on household waste generation, the number of persons in a household was correlated with waste generation rate. The correlation depicted, showed that there was in general a weak relationship between number of persons in a household and the waste generation rate (figure 4.6 and 4.7); the increase in household size did not correspond with an increase in the waste generation rate. This means that the number of persons in a household has a minor influence on household waste generation. The correlation coefficient (r) was in most observation periods lower than 0.4 (Appendix II). According to Swinscow (1997), absolute values of r between 0-0.19 are regarded as very weak; 0.2-0.39 as weak; 0.40-0.59 as moderate; 0.6-0.79 as strong and 0.8-1 as very strong. In most observation periods the calculated p value exceeded the p value of 0.05, indicating also a weak correlation. If we look at the exponential trend line (in red) we observe that it closely follows the real values of the waste generation rate which indicates that this trend line presents a better relation between the size of households and waste generation than the linear trend line (black). The equation produced in this relation (red trend line) can play an important role in the future in developing a fee system whereby the size of households can influence the fee. The correlation data in Appendix II show that outliners in the household size (figure 4.6) does not influence the correlation, the result remains the same.





4.4.3 Gross household waste production

The results of the research are extrapolated to calculate the generation rate at national level. The overall weighted average generation rate for 'Greater Paramaribo' is: 0.47 ± 0.06 kg/capita/day (table 4.7). This figure is higher than the HSW generation rates reported for low income countries to which Suriname belongs. This difference arises because Suriname has a different degree of economic prosperity, culture and lifestyle. The Inter-American development Bank (2003) reported a HSW rate of 0.25 - 0.45 kg/capita/day for low income countries. MSW rate is reported to be for Nepal 0.5; India 0.46; Tanzania 0.34 kg/capita/day (Kaseva and Gupta, 1996; UMP Asia News, 1999). According to PAHO (2002), waste generation rate for MSW in selected Caribbean countries is as follows: St. Vincent and the Grenadines 0.73; Jamaica 1; Barbados 0.9 kg/cap/day. It needs to be noticed that the figures of Suriname concerned only HSW.

It is commonly accepted that waste generation grows approximately proportional to a country's population. In addition, countries with higher gross domestic product (GDP) per capita typically generate more waste per capita. The amount of waste generated per capita times the population determines the amount of MSW available for disposal (USEPA, 2005).

Based on the acquired data the yearly produced HSW can be estimated. The formula used to estimate the residential solid waste generation:

GR x P x 365 = TPY

GR = generation rate
P = population
365 = conversion of days into years
TPY = Tons per year

The yearly estimated residential solid waste generated amounts for 'Greater Paramaribo':

	2002	2003	2004
Population	271,603**	272,065*	272,331*
Waste generated (T)	40,645	52,631	45,724
Average/year (T)	46,364		

* Source ABS 2004

** Estimated: total population is based on population of district Paramaribo and 1/3 of district Wanica

Due to the fact the waste collection service is not attending all residential areas it is assumed that the collection frequency is 70%, which equals 46,364 ton. Thus 30% of the generated waste is illegally dumped and burned. This is expected to be: 19,870 ton. Total average waste produced: 66,234 ton per year (0.53 kg/cap/day).

In this figure we have to take open burning/illegal dumping into account. The estimate of open burning is obtained by the formula (Snigdha Chakrabarti and Prasenjit Sarkhel, 2003):

Open burning (tonnes / year) =
(100-collection frequency) x per capita generation x urban population x 365 x *e*/100.000.000

e denotes the percentage of combustible matter burnt and is assumed to be 75.

Open burning for Greater Paramaribo:

(100-70) x 0.467 x 272,331 x 365 x 75/100,000,000 = 1,044 ton/year

The waste that is illegally dumped: 19,870 – 1,044 = 18,826 T/year.

Of the waste that is illegally dumped part is cleaned by the government and finally ends up on the open dump Ornamibo.

This analysis resulted in low generation rates for a number of reasons.
The low number of residential samples in the study and the low level of participation especially in the beginning period of the research influenced the generation rate significantly. Sampling at the source was dependent on the willingness of households to participate. Another reason was the awareness of the people who still have dumping habits although the collection service attends all collection areas twice a week. The participating households and members in the low income areas were twice as much as in the high income area; still in the last areas the generation rate is much higher. Households in low income areas dumped their waste before measuring or did not put all the produced waste for measuring. This was obviously the case for the low income area Blauwgrond. The generation rate was during the whole research period very low. In Tamenga, the second low income area, the participation improved which can clearly be seen in the increase of the generation rate. Despite the explanation that the survey was for academic purposes, participants in the low income areas were suspicious that the results of the survey would be used for tax services or fees for waste management services. Some of them indicated that they were not comfortable with individuals having access to their waste content. Absence of the head of the household especially in the low income areas was a significant factor in determining the daily participation in the survey. In the medium and high income areas the waste was placed beforehand for measuring or was brought for sampling by the servant.

Another important aspect that must be taken into consideration is the legal aspects of solid waste management. In September 2004 the waste act passed the parliament, which means that hopefully by next year this act will be operational. With this act dumping and burning of waste will be reduced because these activities will be fined for the future. This act comprises also the improvement of the waste management system which include that waste collection services will be available for more residents. Instead of 1/3 of the population of Wanica, 2/3 of the population will have waste collection services.

Comparison of methods

Table 4.8 gives an overview of solid waste production based on several methods, which are described in the previous and following paragraphs.

Table 4.8: Solid waste production (Ton) for Greater Paramaribo based on several methods

	Direct sampling method (household waste) (T)	**Worldbank formula Domestic waste[2] (T)**	**Model for European cities with low and medium prosperity (MSW)[3] (T)**	**Truck routing[4] (household waste) (T)**	**Truck counting at dump[5] (household waste) (T)**
2002	40,645 / 58,046[1]				
2003	52,631 / 75,187[1]				
2004	45,724 / 65,320[1]	523,155 / 250,901	17,334		
2005				71,648	54,604
Generation rate: T/day	127	1,433 / 687		196	150
SWM Cost/ton[6]	US$ 29	US$ 2.63/ 5.43		US$ 19	US$ 25

[1]the first figure includes measured field data and the second includes 100% collection coverage

[2]Domestic waste = PP x $(1+GR_{pp})^n$ x w_c x (GR_{KF}) = 272,331 x (1+1.3) x 0.47 x (1+3.9). This figure is multiplied with 365 days (Rand et al., 2000).

PP = present population; GR_{PP} = growth rate; w_c = waste generation per capita; GR_{KF} = foreseen increase growth rate of waste generation; n = year

The second figure is based on the World Resources Institutes which assumes that a one percent increase in population is associated with a 1.04 percent increase in MSW (Beede and David, 1995).
Domestic waste = PP x $(1+GR_{pp})^n$ x w_c x (GR_{KF}) = 272,331 x (1+1.3) x 0.47 x (1+1.35). This figure is multiplied with 365 days.

[3]$MSW^t = -360.7 - 375.6*\log(INF_{nat}) + 8.93*POP_{15\text{-}59} - 123.9*HHSIZE^t + 11.7*LIFEEXP^t$

$MSW = -360.7 - 375.6*\log(13) + 8.93*61 - 123.9*4.3 + 11.7*71$

This figure is multiplied with the population data for 2004. The value obtained can be regarded as an outlier and will not be used in further calculations.

[4]During truck routing in the residential areas the collected bags were counted. The following formula was used to calculate the generation rate per household:
(# bags x weight/bag x pick ups/week) x 52 : # households

[5]At the dumpsite the weight of all trucks of the waste collection service was estimated in a certain time span and extrapolated for the yearly waste collection.

[6]Cost are based on data of 2003 from VOV (table 3.3)

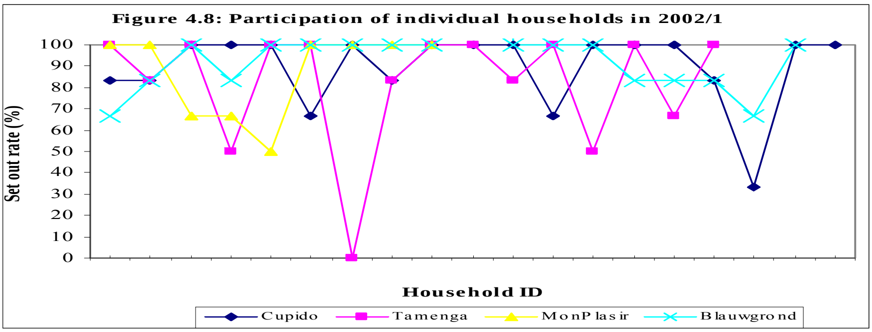
Between the models there is a discrepancy in the amount of waste calculated which can be assigned to:

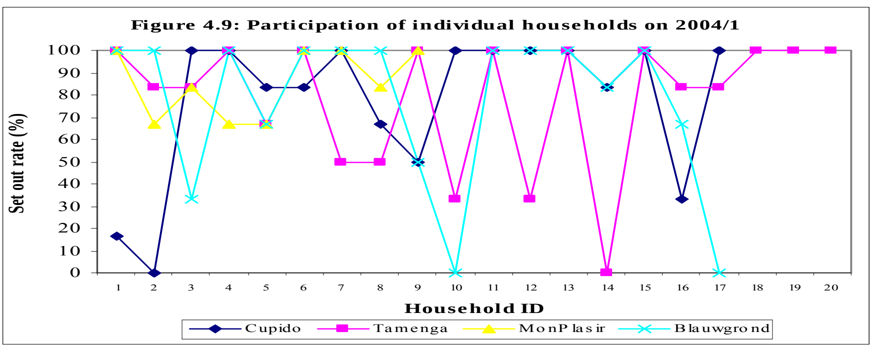
- models are based on theoretical values,
- visual measurements increase personal errors in estimating the weights; a lot of trucks arriving at the dump were overloaded,
- the capacity of the trucks was noted, not taken into account the overload factor,
- at the dump the yearly tonnage was calculated based on a dumping time of 5 hours per day and 313 days per year (not including sundays)
- waste quantities received by truck routing (bag counting) include also waste from shops, schools, etc. It needs to be noticed that a major part of the waste was from households.

4.4.4 Participation rate of households

During the study some households dropped out for several reasons: sickness, holidays, absence of the family or the head of the households, forgot to place the waste for sampling or were not interested anymore. Only households that did contribute for three days and more are included in the analysis. Although two days are enough, three days are better as a check (Swinscow, 1997). Comparing the set out rate (the fraction of residences on a given route at which materials are put out for collection (sampling) on a given collection (sampling) day (Everett et al., 1998)) at the start of the survey (2002) and the last implementing phase (2004) it can be noted that this was improved. In general, the drop-out rate was higher in the low income areas (figure 4.8 and 4.9). The increased set out rate could be ascribed to:

- better understanding of the reason of the project
- acquaintance of the survey and the team because for three years the survey was done in the same area
- increase of environmental awareness.





4.4.5 Recyclable contents

Figures 4.1 – 4.4 showed that the compostables constitute the largest portion of the HSW followed by plastic. These high percentages in the waste indicate that there is a potential for recycling but on the other hand that there are no formal recycling and composting projects, except for the companies mentioned before. Therefore, small scale compost plants and composting at household scale (backyard composting) should be stimulated. To study the technical applicability of composting, experiments were carried out as a pilot project, see chapter VI for detailed information.

A closer examination reveals that plastic bottles/containers are found in relatively small proportion (HDPE (2%) /PET (2%) plastics) and the majority in the waste stream is film plastic (other plastics: 7%) products.

During the characterization study it was found that the level of contamination of the compostables and recyclables was high. Three main causes were noted:

- cross-contamination resulting from mixing of waste,
- disposal habits of households : households tended to use the plastic bags as trash bags, waste has a high moisture content due to mixing with food waste and the input of rain.

All phenomena together confirmed that in addition to a source separation network at household level, waste officials have important roles to play in enhancing recyclability of materials.

4.5 Questionnaire survey of households

The questionnaire survey in the study areas covered only the households who were willing to participate in the project. Some households did not want to answer questions but were willing to participate in the waste research. Especially in the high income areas we were confronted with this phenomenon. The two main reasons were: the questionnaire is time-consuming and the personal aspect of some questions. The questionnaire was used to collect data and information on experiences and views of households on management of solid waste in their home or area as well as other socio-economic aspects. The questionnaire had six sections:

1) identification of the interviewee; 2) the relative importance of garbage in relationship to neighborhood problems; 3) analyzing of present collection services; 4) present practices of solid waste treatment at the household level; 5) opinions of the new garbage collection plan; 6) personal data of the interviewee.
It has been found that:

- the number of houses increases each year in the research areas (only houses where people are living in),
- surprisingly to notice is that most of the interviewees were men in all income groups (>55%),
- in the areas Tamenga (low-income) and Cupido (medium-income) 60% of the interviewed households were blacks, in Blauwgrond (low-income) 70% were asians and in Mon Plasir (high–income) 70% were of mixed race,
- most people live more than 16 years in the area and have a great affinity for their neighborhood. In the medium - and low income area this period is more than 50% and in the high income area this is 29%,
- 80 – 85 % put their waste for the garbage service,
- newspaper has a high re-use potential (60%): is used for cleaning glass windows and is collected for car-painting shops,
- all people have their own garden and 60 % of the households burnt their garden waste,
- 70 % of the households considered expire date, price and quality as a dominant factor in buying products above environmental aspects such as durability and amount of package material,
- 60% of the households in the high-income group are willing to pay a waste collection fee; 50% of the households in the middle-income group are willing to pay and from the lower income group 30-40% of the households are willing to pay. The willingness to pay is highest in the higher income group,
- all household want to participate in a curbside recycling program and are able to pay a fee,
- 30% has no idea how much they want to pay and 50% are able to pay a fee of € 3,00 per month,

- 50% of the households want to participate in a 'bring away' recycling program,
- 60% is not willing to pay a fee in a 'bring away' recycling program,
- 75% of the households are informed about existence of the private PET bottle recycling program (from media) but do not know the output of the project,
- in all research areas the collection service attends these areas twice a week,
- more than 50% of the households are satisfied with the collection service and gave a score of more than 8,
- in high income area households experience more problems with littering of waste. Due to the excess of open plots in this area which is less densely populated than the poorer areas, people from outside this area use these vacant plots as dumps. The low income areas are densely populated so it is more difficult for people coming from outside the area to dump their waste (social control),
- in the high income areas more households used the special waste bags for putting waste for the collection service. People in low income areas use next to waste plastic bags also other containers such as plastic package material and buckets,
- in the low income areas the size of the households is larger. More than 50% of the households is >5 members per family; in medium and high income areas the size of the household varies between 3-5 members (>59%); the education level and the awareness is much higher in the high income area,
- some people from the low income areas dumped or burnt much of their waste. That is also one of the reasons why the generation rate in these areas is much lower.

4.6 Time and Motion Survey

A waste collection vehicle survey (truck routing) was conducted in two collection zones (Cupido-Mattonshoop-Balona and Tamenga-Bams) in Greater Paramaribo in 2005. This visual survey was conducted to observe the collection efficiency and the practices. In each collection we spent two days in following waste haulers along a regular route. A digital camera was used to record the crew’s activity.
Every truck was met in the morning at VOV where the haulers have to sign administrative papers before leaving. We checked that the vehicle was empty and followed the vehicle on its route to see that the waste from all of the houses on the route was collected, to note any exceptions, and to obtain information of the situation at the disposal facility.

Objective of the survey

The objective of this study was to obtain the following information on the current collection and haulage system for solid waste management in Paramaribo:

- to understand the present situation of waste collection
- to verify collection efficiencies for the different vehicle types and collection systems
- to detail labor inputs required for each task.

Findings of the survey

The results of this survey are summarized in Table 4.9. The key findings from the Time and Motion Survey can be summarized as follows:

- in both collection zones compactor trucks were used; during driving the collectors hang on the back of the truck in the collection zone,
- one truck went for fuelling in Paramaribo North but its collection area is in the eastern part of the city thereby collection starts that day almost one and a half hour later,

- typical garbage trucks have an axle weight of more than 8 Ton per front axle and 20 Ton for the highest axle weight of vehicle, traveling city streets which is higher than axle pressure of roads (8 Ton),
- the route is scheduled by the truck driver, for one of the zones the driver used different routes each day (Cupido),
- for both zones the start time for collection was different. One day collection started 7.30 hour and the other day 9.15 hour,
- by observation, it was noted that the collectors are walking and running behind the truck. The distance appeared to play a role in walk and running speed. Collectors walked slower when the collection vehicle was close to the set-out(s); they walked faster when the vehicle was far from set-outs,
- the people use different types of waste bins according to their affordability and choice: special garbage bags, buckets, boxes, containers, plastic bags. Some of the bags/bins are difficult for waste collection workers to lift, carry, and empty them into the waste collection trucks. Some waste bins are too heavy to lift by one worker, two workers have to lift and carry it. When it is too heavy to lift they leave the waste behind,
- next to residential waste the collectors pick also waste from supermarkets, butcher shops, schools along the route,
- collectors receive tips and water or food from residents,
- some of the bags are damaged by dogs or rats or boxes are wet by the waste itself, when lifting, they break and the waste is scattered on the ground. The waste is manually shoveled by the collectors (photo 4.2),
- where waste is put on corners for collection (no containers present), it is common to find waste scattered on the ground desecrating the area (creates conditions similar to waste heaps). This situation represents poor work condition for the collectors who then have to shovel all the waste physically on to their trucks (photo 4.2),

- some people do not put their waste on time along the street; the collector waits for the garbage bag or people run behind the garbage truck and dump the waste themselves into the truck,
- waste was also placed along the curbside after the vehicle had already passed through the area. This was the case when they missed the garbage truck,
- during working the collectors have a break to drink or eat,
- several times the waste is compacted (frequently in front of houses), residents complain about the malodors and leachate,
- the trucks drove several times backwards in streets, especially in dead-ended, narrow streets,
- although the collection service attends the area, waste is commonly burned; we could observe rests of burned material,
- the discharge time (defined as the time required for a vehicle to enter the disposal site, discharge waste and depart from the site) is influenced by the condition on the dumpsite. The only road to the site is narrow and is used as entrance and exit, this causes long waiting times despite an improvement in on-site infrastructure (partly asphalted road),
- during waste collection the velocity of the trucks is 20 km/hour which can increase to 40 km/hour. The normal velocity varies between 40-60 km/hour; except in a traffic-jam where the velocity drops to 5-10 km/hour.

Photo 4.2: Problems during waste collection: burst of plastic bags, condition of roads, compaction of waste in front of residences (leachate from waste and malodors), cleaning of waste collection points

Table 4.9: Records of movement of garbage trucks

Collec-tion area	**Cap. packer (T)**	**# of house-holds**	**# of bags**	**# Comp.**	**T. Comp. (min)**	**# turns**	**S. in collection area (km)**	**T. in collection area (hr)**	**S. area - dumpsite (km)**	**T. area to site**	**T. wait site (min)**	**S./T. site-garage**
Cupido 2005 (1)	9	661	1559	25	14.8	5	28	3.33	9	1.07 hr	27	19 km
												22 min
Cupido 2005 (2)	9	859	1636	28	14	5	25	3.52	15	57 min	16	21 km
												22 min
Tamenga 2005 (1)	8.7	699	1444	38	17.6	10	19	3.30	17	30 min	17	18 km
												34 min
Tamenga 2005 (2)	8.7	703	1647	40	16.27	10	40	4.48	16	40 min	17	12 km
												34 min
Tamenga 2004	8.7	631		23	10.02		18	3	16	29 min	11	12 km
												17 min
Blauw-grond 2004		576		16	9.04		30	3.30	17	45 min		

S=distance; T=time; Comp.=compaction

From these field data an attempt is made to calculate the number of trucks to collect all household waste in Greater Paramaribo:

Number of vehicles required: N = SF / XW
(http://msw.cecs.ucf.edu/collection.ppt)

N = number of vehicles required
S = total number of customers serviced per week
F = collection-frequency
X = number of customers a truck can serve per day
W = number of work days per week

Collection area	Capacity truck	S	F	X	W	N
Tamenga	8.7 T	63,333	2	678	6	31
Cupido	9 T	63,333	2	760	6	28

The average number of compactor trucks required to collect all household waste in Greater Paramaribo is estimated on 30 (based on a truck capacity of 9 T and 1 trip per day). For efficiency it is advisable that trucks make two trips per day; the number of trucks required will be 15. Considering the accessibility of the different collection areas and the condition of the roads it is recommended that a truck fleet consisting of compactors and open trucks is purchased: 60 % of compactors (9) and 40% of dump (open) trucks (12). The costs associated with the purchase of these trucks are 540,000 Euro (9 x 38,000 Euro + 12 x 16,500 Euro). The current truck fleet available for HSW collection consists of 13 compactors (average capacity: 12 Ton) and 4 dump (open) trucks (capacity of 4 Ton) of which the latter makes mostly two trips a day. It is obvious that the current truck fleet is not adequate to collect all HSW in Greater Paramaribo.

Depending on the type of waste container the number of containers can be calculated as is represented below:

Contai-ner type	Waste generated (T)	# of times waste removed per year	Waste removed each time (T)	# HH	Waste removed each time/ HH (kg)	# of bags / year	Cost / year US$
Plastic bags (60 L)	45,724	104	440	63,333	6.9	126,666	19,000
Idem	71,648	104	689	63,333	11	253,332	31,667

In case wheeled bins (mini container) of 120 L are used at least 38,000 are required to supply 60% of the household with a bin which will be emptied once a week. The investment cost for these bins are valued at 1,634,000 Euro (38,000 x 43 Euro) with a depreciation period of 5 years. Based on above data the costs for waste collection calculated for Greater Paramaribo are: US$ 17 per ton for plastic bags and US$ 25 for mini containers combined with plastics bags or communal containers (1,014 containers of 1,100 L, each 325 Euro) with costs for households between US$ 12 – 18 per year (see Appendix III). The input of waste bins will increase the cost for waste collection. Because of the necessity of the availability of standby trucks (4 of each type) the collection cost will increase to US$ 18 – 26 / ton waste and for households to US$ 13 – 19 / year. It needs to be noticed that this value does not include costs for waste treatment and/or disposal in contrast with the current costs (US$ 29 per ton) which includes all SWM costs (see table 4.8). The calculated collection cost per ton corresponds to the collection cost in low income countries (10-30 US$/ton); the same passes for the total cost per capita per year which amounts for low income countries 3-10 US$/capita/year. (Pearce and Turner, 1994).

Comments

- The number of stops and starts may have a great impact on the trucks. Repeated starting and stopping (especially stopping) will increase the damage to streets depending on the weight of the load being carried. The higher axle load of the trucks will also damage the streets. This “repeated starting and stopping” will also damage the environment (air pollution in combination with fuel efficiency concerning the old trucks).
- Waste heaps (designated sites) are a common method for waste collection in some parts of the collection area (collection zone Tamenga). This type of waste collection allows waste to scatter by wind or animals. Scattered waste creates unsanitary and unhygienic conditions in the area around the heap. Flies and bad odor affect residents nearby. The manual loading of waste from heaps is labor intensive and inefficient, because it requires a lot of worker time. This habit slows down the collection process. It is advised to place communal containers, but residents are afraid that the site will become an illegal garbage dump.
- To improve waste collection the government has to take into account the achievement of a cost effective and efficient municipal solid waste collection service. Some relevant factors are: route selection, pick-up schedule, public participation and awareness, conditions of physical infrastructure and equipment, and input of communal containers.
- To improve the collection service the government must upgrade the collection equipment and introduce a standardized container system such as special plastic bags with logo or color, mini containers or communal containers.
- Seeing the time and distance covered for waste collection a study to the construction and operation of a transfer station is recommended.

4.7 Social Environmental Survey at the disposal site

A two days survey was carried out in 2005 on the official open dump of Greater Paramaribo. The Social Environmental Survey (SES) is divided into two parts: (1) a record of the trucks entering the disposal site and (2) an interview with waste pickers working at the disposal site.

Objective of the survey

The main purpose of the survey is to obtain information on people's working conditions at the disposal site (social, environmental and health) and recording the truck arrivals.

Findings of the survey

A. Waste picker survey

The results of the survey are summarized below:

- 30-40 waste pickers operate at the dump, the majority is men and there are also a few women. There are no child waste pickers,
- the majority of waste pickers lives within 3 km (or half an hour) of the dump and are traveling by foot and bus,
- waste pickers collected various recyclables at the disposal site. The most common waste material collected by the waste pickers are metal, plastic – and glass bottles, and sometimes batteries. Plastic bottles are the main sources of income along with metal and glass bottles,
- the waste pickers come from poorer families, none of them finished their school, these workers often live with their families. On the whole it is found that 45% has their own household and that 73% of the interviewees have children,

- overall 27% were above the age group of 40, 27% in the age group of 30-40 years of age, 36% were in the age group of 20-30, and 9% below 20 years of age,
- waste picking is a mean to survive. Waste pickers make a living by collecting and selling recyclable materials out of municipal solid waste on the dumpsite. This waste comes from domestic, industrial and commercial sources,
- most waste pickers have additional work to survive (in the construction, collecting waste for companies, gardener, carpenter), 27 % said that the money is enough,
- the quantity and kind of material collected depends on the number of waste pickers on the dump, weather condition, content of the waste. Several kilograms of the wastes are collected daily: depending on a success day can 5-20 sacks of bottles (1 sack = 100 bottles) be collected. In the average 80 -100 kg of recycled material is collected per day,
- prices at which recyclable waste materials are sold to waste dealers vary: plastic for US$ 0.32 per kg, metal for US$ 0.36 per kg and glass bottles vary between US$ 0.18 - 0.54 per bottle. Normally each one is earning about a maximum of US$12.5 per day,
- the materials are generally sold to waste dealers or to small scale private business on a daily basis, as they have no place to store the waste,
- the vast majority worked alone rather than as part of a team and they have a well-coordinated method of working. Sometimes there is competition (55%) from other waste pickers over materials and territory,
- waste pickers stated no health hazards and problems, they do not suffer from diseases. A small number (30%) said that they have problems of dizziness and 50 % said that they have problems with the smoke, flies and malodors,
- the waste pickers use gloves to work and a stick to sort through the waste. Some waste pickers dress in long-sleeved shirts, pants, hats and

boots. Some covered their mouths with a piece of fabric while working on the dump. When it rained, raincoats are worn to work,

- sanitation facilities at the landfill site are obsolete and no source of clean water is available,
- when a garbage truck arrived the pickers rushed to the truck and began sorting through the fresh waste that has just been unloaded; some of them have almost been buried under garbage of these trucks. These conditions make it difficult to avoid illness and disease,
- almost all the waste pickers interviewed collect waste on a daily basis, only during daytime. Most of the waste pickers (64%) worked an average of more than five hours a day and five to seven days a week,
- there are no restrictions by VOV for waste pickers to work on the dump, only if they make trouble or hinder the official workers of VOV can forbid them to enter the dump,
- most waste pickers mentioned that they will not continue doing this work for the rest of their life. They are looking for jobs in the construction branch, as a guard, in a furniture factory, in the agriculture, or as a truck driver.

B. Disposal site

The results are summarized below:

	Day 1	Day 2
Checktime	3.35 hr (10.30 – 2.05)	4. 05 hr (10.00-14.05)
Open trucks (flat back)	14 (of which 5 covered with a net)	16 (of which 12 covered with a net)
Compactor	10	12
# trips	- open trucks: 8 made 2 trips and 6 made 1 trip - compactors: 1 made 2 trips, 9 made 1 trip	- open trucks: 1 made 3 trips, 6 made 2 trips and 9 made 1 trip - all compactors made 1 trip
Total waste	175.4 T	141.7 T
Waste collected/year	54,899 T	54,309 T
Unloading time (average)	7.24 min	7.8 min
Collection zone	Rayon middle	Rayon middle
Remarks	- trucks are overloaded	- trucks are overloaded - compactor stuck in the mud

Comments

- Most reasons for waste picking as a means to survive are unemployment and poverty. Moreover, the very nature of this activity requires no skill, no investment and no contacts or references.
- Waste pickers face various problems. Their working conditions are affected by the environmental degradation caused at the disposal site.
- Studies have indicated that a relationship exists between solid waste handling and increased health risk. Health surveys show that their health status is poor and their life expectancy falls far below national averages. The risk is greatest in developing countries, where the contact between the solid waste worker and waste is greatest and the level of protection is least (Papiya Sarkai, 2003; Hunt, 1996). The occupational health hazards of waste pickers arise from two aspects: poverty and the occupation itself. Since they belong to the poor section of the urban population, they are not able to pay a doctor. In the hope of discovering some saleable items the waste pickers rummage through putrefying waste heaps including toxic medical waste coming in direct contact with the waste material. This makes them highly susceptible to a number of health hazards. There are no records in Suriname to track the health risk of waste pickers about the injuries, infections and different types of illness.
- Government approaches to regulate the access to the dumpsite fails because VOV cannot control this situation and also due to personal feeling to these people (they also need to survive)
- Though the waste pickers play a significant role in the entire process of waste management (recycling) their services go unnoticed and issues concerning their livelihood go unaddressed. The status of waste pickers needs to be changed. This could involve the formalization of the sector (supported by government rules), giving the waste pickers official recognition and protection. These people can be involved in the implementation of recycling programs which would be easier than developing totally new separation/recycling options that exclude them. This would also help restore their self-esteem apart from assuring their livelihood.

- The situation of the Ornamibo disposal site is getting worse; it has become an urgent issue for VOV to improve the operation and management of the dumpsite. To prevent trucks stick in the mud the infrastructure needs to be improved. Because a lot of people are living near the disposal site, while some waste pickers are working at this site it is necessary for VOV to grasp the socio-environmental situation in and around the final disposal site. This open dump must be closed and a sanitary landfill must be constructed in order to avoid negative impacts on these people and environment.
- The introduction of a weighing system at the dump is necessary for waste records. With this weighing system waste characterization studies can be reduced to at least twice a year.

4.8 Conclusions

A detailed characterization of MSW is a mandatory first step to develop sound strategies of integrated solid waste management strategies.

This study is the first of its kind in Suriname and allowed to detect figures in the generation and composition of HSW. It can be used as a baseline for further characterization studies. It needs to be noted that this study excluded the analysis of the other sources of MSW.

Overall, the survey showed that applied household sampling technique is reliable in estimating the quantity of waste generated at the source. The results of the field study were able to provide enough information to successfully demonstrate the potential use of the method and make recommendations to strengthen the waste management practices. However, care must be taken in interpreting the results as they could be affected by other factors such as dumping and burning and participation rate of households.

Direct sampling (the research method) is a reliable method because it presents not only the amount and the different components of the waste stream but it includes also the socio-economic variables. The more people are acquainted with this kind of research the more their suspiciousness will disappear, thereby increasing the set-out rate resulting in more reliable results. Although residents appeared to support the research, it took several requests and explanations to receive their trust. Interactions with the other stakeholders were very positive and the respondents were able to provide constructive insight into current waste management practices.

Further studies on the waste characterization of HSW should be encouraged. Efforts should be devoted to obtain estimates of the generation rates and composition of other waste resources based on sampling protocols. Studies particularly focusing on these aspects might be worthwhile for a good solid waste management system.

It may be concluded that truck routing is a relatively reliable method, because the households freely dump all their waste for collection without having any reticence, but it does not describe the composition of the waste.

The community in which this study was carried out is classified as high-, middle- and low income. The results showed the following waste generation rate relation: lower income < middle income < high income.

This study has shown that an average of 0.47 kg per capita per day of HSW is generated within the urban residential area of Greater Paramaribo. Correction of this average is necessary due to illegal dumping of burning of wastes. With the upcoming waste act, these activities will be forbidden and punished. Taking this legal action into account the real average generation rate is 0.53 kg per capita per day. In that case the annual household solid waste is projected to be 66,234 Ton per year for Greater Paramaribo.

According to the extrapolation results, the composition of the wastes is largely organic in nature, with vegetable and green wastes occupying 60% and 11% of plastic material. Based on these results, it can be said that the first element to consider in the recovery of solid waste is composting the organic fraction, either through home composting or decentralized composting. Should most of the presently recyclable and compostable material be diverted, the overall waste stream to the landfill would decline. For composting and recycling initiatives to be successful attention must be given to extensive planning, management modifications, capital layout and environmental awareness education programs.

Household wastes are high in variation in terms of total weight of different components categories generated by households. The composition reflects week to week fluctuations in what individual households discard.

With regard to the socio-economic analysis the results show the following characteristics:

- the amount of waste generated is positively related to income
- environmental awareness and educational level increase with income
- the main factor determining the “Willingness to Pay” is income.

With rising incomes, urbanization and little or no waste diversion, it is being projected that the quantity of solid waste generated will continue to increase. A maximum yearly increase of 3.91 % would be expected. Increasing waste quantities will increase stress on landfill capacity leading up to the demand for new landfill sites which will become more difficult to find therefore, other waste disposal options must be explored.

Waste collection is inefficient and is influenced by different factors such as too heavy bags, they burst open and collectors need to clean the site, scattered illegal collection points, and nonfunctional routes leading to too much turns and backs in streets especially with the heavy compactors.

Given its importance improvement of the collection efficiency is desirable which implies investment in waste collection. An analysis has proved that the following facilities are required: 9 compactors, 12 dump trucks, at least 38,000 mini containers of 120 L and 1,014 communal containers of 1,100 L. The associated collection costs for this improvement are placed around US$ 18 per ton when plastic bags are used and US$ 26 per ton for mini containers. The costs for households are accounted for US$ 13 – 19 per year. At this high level of expenditure it will be normal that the government introduces a collection fee (the generator of waste has to pay for the waste to be collected and removed).

According to the travel time (30 min – 1 hr) and distance (15 – 17 km) from collection area to disposal area it may be concluded that the establishment of a transfer station is justified but an environmental impact study and a feasibility study must confirm this assumption.

Chapter 5

Quantification of the potential resource recovery value of household solid waste

Chapter 5

Quantification of the potential resource recovery value of household solid waste

Resource recovery can be an effective tool in managing waste streams. Resource recovery includes any process that can recover energy and/or recyclable materials from collected MSW. Questions that arise include: how much waste can be recovered?, are the quantities generated feasible to be recovered?, what are the environmental benefits or costs?. The first step in developing an effective recycling or energy recovery program is to determine the composition of the solid waste generated at the source (chapter IV). In this chapter it is calculated how much waste can be recycled in Suriname.

5.1 Recycling

5.1.1 Recycling rates

The potential recyclables in our residential waste is as follows: fresh vegetables and fruits (34.59%), plastics (PET/HDPE) (4.22%), glass bottles/containers (5.01%) and aluminum cans (1.94%). Based on these figures it can be calculated that 45.76% (≈ 46%) of the household waste can be recycled.
Inspection of the collection service area finds out that under current conditions 11% (inhabitants of District Para receiving waste collection service : inhabitants of Paramaribo = 28,692 : 272,331) of the population cannot be served with the kerbside collection system for logistic reasons in the first years of the program. The maximum recycling rate will be:

$$46 \text{ x} \left(\frac{100-11}{100} \right) = 40.94\%$$

The questionnaire survey, on public attitudes to recycling, showed that on the average 50 % of the people are willing to participate in a recycling program. Taking this factor into account, the recycling rate is now:

$$40.94 \text{ x } \left(\frac{100 - 50}{100} \right) = 20.47\%$$

Even those people who do take part will not recycle everything that they can in a proper way. Some will not bother to rinse out food cans and put them in the recycling box, others will not store food waste for the composting collection (even in an outside bin) and some will forget which materials are recyclable. Let's say that these difficulties mean that 15% of the recyclable material is 'lost' to the waste bins. In this case the final recycling rate is:

$$20.47 \text{ x } \left(\frac{100 - 15}{100} \right) = 17.40\%$$

This calculation is based on conservative figures and the result is quite low but compared with the recycling rate (10%) in developing countries (World Bank, 2003), resource recovery in Suriname has great potential. Recycling inorganic materials from MSW in developing countries is often well developed by activities of the informal sector although such activities are seldom recognized, supported, or promoted by local governments (World Bank, 2003). The situation in developed countries is very different, since resource recovery is undertaken by the formal sector, driven by law and a general public concern for the environment, and often at considerable expense (Zurbrugg et al., 2004). The recycling rate for most European countries is around 50%, for others it is much lower; some examples are given below (Friends of the Earth, 2004):

- 64% Austria (recycling 24 % / compost 40 %)
- 71.6 % Belgium (Indaver Info, 2005)

- 48% Germany
- 11 % recycling England & Wales
- 9% recycling Greece, and
- 4% recycling Portugal.

Based on the yearly estimated residential solid waste generation, the amount of materials that can be recycled is calculated below:

	fresh vegetables and fruits	**plastics (PET/HDPE)**	**glass bottles/containers**	**Aluminum cans**
potential recyclables	34.59%	4.22%	5.01%	1.94%
Recycling rate	17.40%			
Average HSW* generated per year (T)	**Recycling production /year (T)**			
46,364 (Direct sampling method)	2.790	340	404	157
71,648 (Truck routing)	4.312	525	625	242
54,604 (Truck counting)	3.286	401	476	184
Daily Production (Ton/day)	10.7	1.31	1.55	0.6

* see table 4.8

5.1.2 Composting

The amount of waste to be composted 11 T per day, seems to be too small to be economic feasible but according to USEPA (1999), composting is an economically attractive disposal method for almost every size scale.

Based on the input of 11 T food waste per day, with an output of 2.5 T compost per day it is strongly suggested to start first with a small scale project because this system is less costly compared to a centralized commercial one (Iftekhar Enayetullah and Maqsood Sinham, 1999). In the eighties, in many developing countries centralized composting plants were implemented but due to before mentioned problems most of them failed. These plants experienced many problems which had mainly to do with low skill (sophisticated plants), low managerial inputs and operating efficiencies resulting in high production costs (Cointreau-Levine, 1994). The last few years the practice of small scale composting has been stimulated and seems to be a successful mechanism.

However, the data about the food waste production in this study is only based on residential waste; commercial waste (from restaurants, market places) is not included. To implement a composting plant these waste sources have to be included in the production schemes. We have also to take into account that food waste composting generally requires the addition of a bulking; these extra inputs will result in a higher overall capacity of the compost facility agent (Koppel and Dolan, 2004).

The most common question arising when considering composting is: will composting be economiccally feasible. Unfortunately, there is no simple answer to this question - in part, because of the wide variety of local circumstances that influence the cost of waste management. An accurate estimate of the cost of a composting facility requires detailed knowledge of project specific criteria such as location, site conditions, waste composition, facility size and level of technology. The cost of collecting and composting organic wastes should be evaluated as a component of an integrated system of waste management (as part of the waste collection/disposal service). Except the cost factor we have to take into account that composting facilities may suffer from the competition of the currently used fertilizers and the Not-In–My-Back-Yard (NIMBY) syndrome. This means that the location choice can be a problem, unless the site is located in an area that is sparsely populated, which may in turn increase transport cost.

5.1.3 Plastic recycling

Although plastics comprise only around 11 % of our domestic waste by weight, around 340 T of plastics or 4.22% (PET - bottles used for carbonated and other drinks - and HDPE -bottles used for milk and detergent containers) have a recycling potential. In this figure is not included the 2.1 million PET bottles (± 70 Ton) recycled per year by Fernandes Bottling Company in Paramaribo. This figure (340 T) can significantly increase with the collection of bottles from public events as festivities, sports, etc. With the prospective that the use of PET and HDPE bottles as package material is increasing in Suriname, the implementation of a recycling plant in cooperation with Fernandes (or other private company) supported by established recycling programs can be a success in the future. The set-up of such a plant can be as follows: collection of bottles, sorted at the plastic recycling facility, then baled or chipped and exported to a reprocessing plant e.g. to Barbados. The establishment of this plant will contribute to the reduction of littering of plastic waste (reducing environmental degradation).

Key barriers to plastic bottle recycling are identified as: (i) lack of collection / sorting infrastructure, (ii) adverse collection scheme economics and the low efficiency of existing collection infrastructure and (iii) the lack of market stability for collected material (European Union, 2003).

Wrapping films, grocery bags (LDPE #4) form in our plastic stream the most important part but they are difficult to recycle because of their high contamination degree. Incineration, due to the high energy content, and landfilling present the only opportunities for this type of plastic (Saha and Ghoshal, 2005).
Worldwide plastic recycling has a good perspective: at present, plastic bottles are the most commonly recycled post-consumer plastic products made from either HDPE or PET. Furthermore, these plastics are the fastest growing but least dense component of MSW (Sharp, 2005). Also plastic bottle recycling creates the highest number of potential jobs per tonne compared with other recyclable materials and the dependence on landfill space, will specifically target this component for recycling. (European Union, 2003).

Unfortunately, not all recyclables can be recovered, mainly because of generator indifference to and ignorance of the recycling program. Contamination of potential recyclables also reduces recovery potential. Recyclability of these materials is also affected by other conditions such as frequency of pickups, moisture content of MSW and sorting technology, to list a few (Reid, 1996). Further, the economics of plastic bottle recycling requires that the efficiency of collection schemes must be improved, and the true price presently paid for the collection of bottles and the fee for disposal in landfill sites must be taken into account (European Union, 2003). Another aspect is that low landfill fee in contrast with high separate collection cost will not stimulate recycling.

5.1.4 Success of recycling / composting

The success of recycling / composting depends on many factors. To increase the recycling rate attention has to be paid to the following actions:

- Implementation of a best practice recycling program.

Collection of recyclables is seen as an integral part of a successful recycling strategy – because it makes recycling accessible and easy for the average householder. This does not mean that everyone will take part in recycling. Collection must be efficient i.e. with minimum energy input, to maximize the environmental benefit of recycling.

- The government must place national waste recycling target.

Guidelines must be developed of how much recyclables must be recycled e.g. per year. Therefore a database of how much waste is generated and recovered is very important to make future prognoses.

- Recycling must be legalized

Making recycling mandatory would increase participation. This is an unpopular step, but it may be necessary to meet future recycling goals. Mandatory recycling tends to produce a negative attitude towards recycling, and may cause some persons to resist the program whenever possible. Mandatory recycling combined with incentives (e.g. deposit) can be a mean to increase recycling. This option requires funds to pay to the participants.

- Continuous public education.

Normally, the best method to increase recycling is through education. Unless people see a benefit, there is little chance they will participate. One way to increase recycling is to increase individual participation by education programs. These programs must deal with different waste topics or insights and must occur on a regular basis.

- Finding markets for the material.

The only way to increase recycling to meet future recycling goals is to find markets for materials. A detailed market study is important to have insight in the economic feasibility, demand, and price fluctuations.

- Costs for recycling

Curbside collection of recyclable material can be expensive because the inherent costs of curbside collection are high, but also because amounts collected per residence (household) are small compared to the total waste stream. Also extra activity and time may be required, because the collection of commingled or segregated recyclables may involve sorting into different compartments of the collection truck or at the processing site. A major problem with collection is that plastics are lightweight and bulky, and therefore uneconomical to transport unless crushed down.

5.2 Energy recovery from landfilling

With growing emphasis on greenhouse gases (GHGs) and methods of meeting the Kyoto Protocol promises, a survey is done to present a clear picture of energy recovery through MSW management.

The Energy Company Suriname (EBS) is in charge of the electricity production and distribution for Suriname. The electrical energy is generated from hydropower and fossil fuel (diesel generators). The energy demand is growing each year, from 92 MW/ 577 GWh in 2000 to 130 MW / 850 GWh in 2005, a growth rate of 7.5% per year. EBS can not supply this demand which leads to electrical energy shortage in the country. To contribute to the elimination of this electrical energy shortage different projects are under construction:

- the increasing operation of the number of diesel generators of EBS,
- the construction of a 15 MW electrical power station by Staats Olie Suriname. This electrical power station shall consist of diesel generators running on heavy fuel oil, a product of the company itself.

Although Suriname has neither an electricity generation plan(t) from municipal solid waste nor any scientific disposal facility, in this paragraph the energy potential from household waste is studied. The estimation of methane emissions from the landfill is quite uncertain because the total amount of waste disposed of to the landfill is not reliably known. The calculation will therefore be based on the latest survey data for household waste providing an average annual methane emission estimate. The technical details of electricity generation are out of scope in this study.

Calculation of energy recovery

Control of methane emissions from the future planned landfill, will benefit both Suriname and the world, since it will generate electricity for the country and help stabilize global climate change by reducing the release of a potent greenhouse gas (GHG) (Park Jin-Won and Shin Ho-Chul, 2001). The energy content of MSW from Suriname, for the planned sanitary landfill, is estimated based on its physical composition (components: food, paper, plastic). The method used (simplified IPCC method) assumes that methane is released from SW in the year that the waste is disposed of. However, this is not true as methane generation from SW occurs after a certain period of time from its disposal to when anaerobic conditions are created (usually beginning 1 to 2 years after the waste is put in place), and continues over several years (over a 20 to 25 year cycle and tends to peak in 5 to 10 years) (USEPA, 2005; Tchobanoglous et al., 1993). The theoretical default values used in the formula on methane generation, oxidation and collection have been collected from literature (Tsai, 2005; IPCC, 1996). The CH_4 generation will be estimated from Suriname's solid waste generation taking into account that no recycling program for paper, kitchen and yard waste is executed.

According to the applied method, LFG recovery flow rates are converted to CH_4 emission rates. Methane (CH_4) from landfill gasses (LFG) is produced by the anaerobic decomposition of various matters (kitchen garbage, paper, wood and leaf). IPCC defines a theoretical composition of 50 % methane in generated landfill gas as the default value (the IPCC default value, F = 0.5).

MCF (Methane Correction factor) is the part of the waste left to degrade under anaerobic conditions and is dependent on the type of landfill. In unmanaged and shallow landfills, a larger part of the landfilled materials is degraded under aerobic conditions. MCF has been altered in the historic calculations. It was set at 0.4 from 1945 to 1969 and at 0.8 from 1970 to 1979 for all waste categories. From 1980 it has been 1.0 for household and business waste, and 0.8 for industrial waste. From 2003 MCF is set at 1 for all materials.

The model calculated the DOC (Degradable Organic Carbon of MSW) and DOC_f (fraction of DOC that really degrades or dissimilated), and recalculated the volume landfill gas to mass CH_4 emitted at the end. The factor transforming dissimilated DOC to methane gas produced, will then be F*16/12, where 16/12 is the mole weight ratio between methane and carbon (conversion rate from carbon into methane) (Ngnikam et al., 2001; TA-2079/2005).

Simplified IPCC model for methane emission (Tsai, 2005; Sudhakar and Parikh, 2002)**:**

CH_4 emissions (Gg/yr) = MSW_T x MSW_F x MCF x DOC x DOC_F x F x 16/12

where:

MSW_T: total MSW generated (Gg/yr = 10^3 T/yr)

MSW_F: fraction of MSW disposed of to landfills

MCF : methane correction factor (0.4 – 1.0; default value 0.6)

DOC : fraction of degradable organic carbon (0.08 – 0.21)

DOC_F : fraction of total DOC that actually degrades (default value 0.77)

F : fraction of methane in LFG (default value is 0.5)

DOC = 0.4 x P + 0.15 x K + 0.3 x W

where:

P: fraction of papers in MSW (6.75%)

K: fraction of kitchen garbage in MSW (56.75 %)

W: fraction of woods/leaves in MSW (3.86%)

DOC = 0.4 x 0.0675 + 0.15 x 0.5675 + 0.3 x 0.0386 = 0.12

CH_4 emission (T/yr) from HSW is calculated as follows:

HSW generated x 1 x 0.6 x 0.12 x 0.77 x 0.5 x 16/12

The estimated methane recovered and emission reductions are calculated below. To produce electricity the methane is burned in an internal combustion engine to power a generator (figure 5.1). Based on the yearly estimated residential solid waste generation, the electricity production is calculated below.

Average HSW generated (T)**	CH_4 emission landfill (10^3 T/yr) (1)	*Emis-sion in 10^6 m^3	Average hourly heat input rate 10^6 (kJ/hr) (4)	Electricity production in per year (GWh) (5)	Baseline CH_4 emission equivalent to CO_2 in 10^3 Ton (6)	Reduced CH_4 emission Equivalent to CO_2 in 10^3 Ton (7)
46,364	1.71	2.37	12.76	8.83 = (0.61 10^3 CH_4 T)	35.91	12.81
71,648	2.64	3.67	19.56	13.69 = (0.95 10^3 CH_4 T)	55.44	20
54,604	2.01	2.80	14.91	10.43= (0.72 10^3 CH_4 T)	42.21	15.12

- (3) x ($37.68x10^3$ kJ/m^3) / 7000 hours = (4)
- one year has 7000 productive hours
- efficiency of the boiler (how much of the energy input is converted to electricity) is 36%.
- (4) x 7000 hrs x (1 kWh / 3600 kJ) x 0.36 = (5)
- (5) represents the electricity production
- (1) x 21 (IPCC GWP value for CH_4) = (6)
- (5) x 21 (IPCC GWP value for CH_4) = (7)

*Source: Murphy and.Mckeogh, 2004; Onyx, 2004.

** see table 4.8

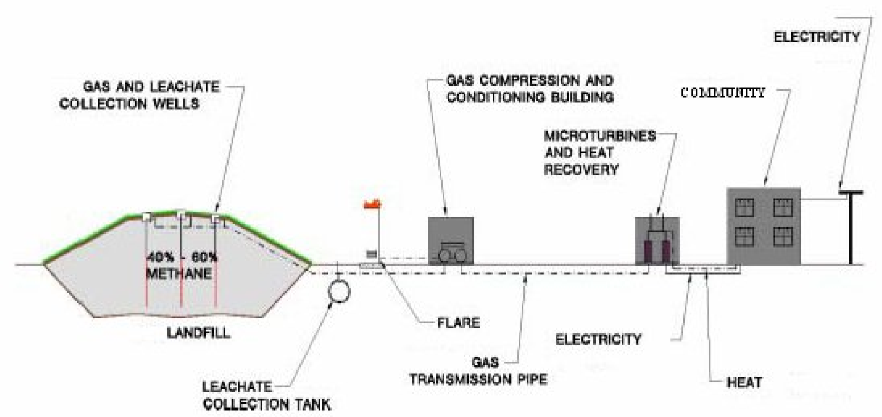


Figure 5.1: Lay-out of LFG to energy system (Torressani and Peotter, 2004)

It can be concluded that the energy recovered from the landfill (9 - 14 GWh) will not cover the national demand of energy (850 GWh). Therefore, it is necessary not to think to cover the national demand but to focus more on the delivery to local communities thereby using the existing transmission system. According to Rand et al. (2000), this kind of energy plant must be located near an existing grid to avoid costly transmission systems. A gas collection system must be present in landfills to gather LFG. Gas will be collected through vertical wells and a series of trenches that are typically installed following the closing of a landfill cell. The design, construction and operation of the energy system (electricity plant) pose a number of challenges such as local situation, meeting environmental standards, and operation costs, etc. (Torressani and Peotter, 2004). Because of economic consideration (against low recovery rate) the attempt to recover energy is not advised. But still a study must be done to search for the energy need in the neighboring areas of the landfill by making an inventory of the number of residents and economic activities. This study must be done simultaneously with a cost-benefit analysis. A positive impact of this project is the reduced CH_4 emission (13 – 20 x10^3 Ton per year).

Other options to manage the landfill gases collected from either system are to release them to the atmosphere for dilution or flaring them in which the methane in the gaseous emissions is burned (figure 5.2). When released to the atmosphere, methane is a potent greenhouse gas with a Global Warming Potential (GWP) 23 (21) times that of CO_2. Combustion of methane is recommended, however, it leads to the production of carbon dioxide and water. The release of carbon dioxide is beneficial because, as mentioned before, the global warming potential of methane is much greater than that of carbon dioxide (Lee and Jones-Lee, 1993).

The best way to reduce or eliminate any landfill gas is to prevent organic waste entering the landfill which can occur by composting this component of the waste stream.

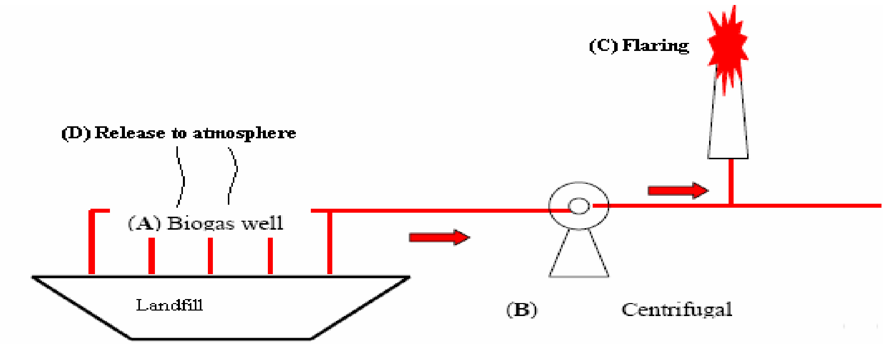


Figure 5.2: Schematic design of flaring LFG (Onyx, 2004)

5.3 Energy recovery by incineration

Another option of utilizing MSW is energy recovery through incineration (combustion or direct incineration). Heat from the combustion process is used to turn water into steam, which is then routed to a steam turbine-generator for power generation (figure 5.3). In order to evaluate the feasibility of energy recovery as an integral part of SWM system it is of great importance to determine the energy content or caloric value (CV) of the solid waste, which is defined as the number of heat units involved when unit mass of material is completely burned. The energy content of any material, such as solid waste, is a function of many parameters, namely, physical composition of the waste (methods 1 and 2 below), moisture content and ash content (Abu-Qdais and Abu-Qdais, 2000). There are several experimental and empirical approaches available for determining the CV of MSW. For this study two models (below) have been used, of which the parameters (composition of waste) were available.

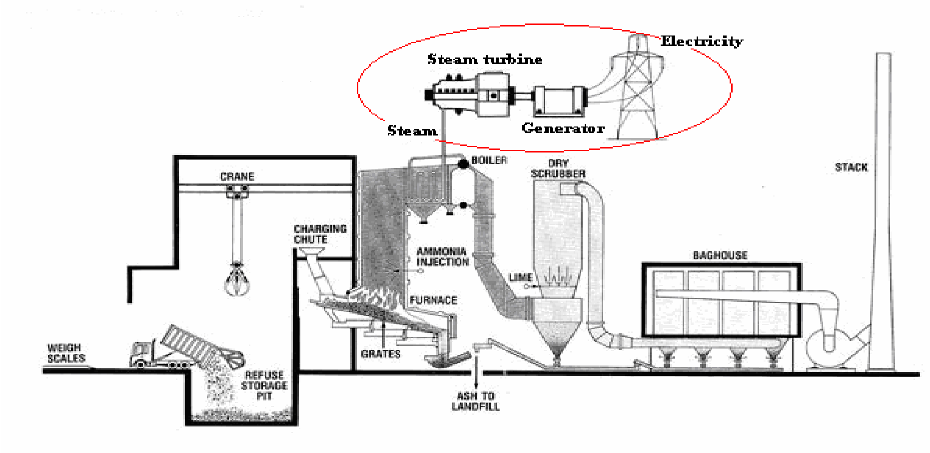


Figure 5.3: Schematic diagram of waste to energy incineration (Clarke, 2002)

1. E = 23{F + 3.6 (PA)} + 160 (PL) (Abu-Qdais and Abu-Qdais, 2000)

where:

E = energy content of MSW (Btu/lb = 0.002 MJ/kg)

PL = percentage of plastic by weight

F = percentage of food waste by weight

PA = percentage of paper waste by weight

The calculated energy content is:

E = 23 {0.5652 + 3.6(0.069)} + 160(0.1167) = 0.087 MJ/kg

With this formula the energy generated from HSW is calculated (presented below): average HSW generated yearly x 0.087 MJ/kg

HSW generated (T)*	Energy from waste 10^6 (MJ)	Energy from waste (GWh)
46,364	4.03	1.12
71,648	6.23	1.71
54,604	4.75	1.3

* see table 4.8

2. E = ∑(Amount of each waste component in 100 kg x Effective caloric value of each component) x total amount of generated waste (Andersson et al., 2001)

Energy generated from waste incineration for each 100 kg of HSW is presented below:

Waste categories	Effective caloric values (MJ/kg) (1)*	Amount of each waste component in 100 kg (kg) (2)	Energy produced from Suriname waste (MJ) (1x2)
Plastic	40.7	10.82	440.37
Paper	15.2	7.39	112.33
Food	6.6	60.19	397.25
Glass	0	5.97	0
Metal	0	2.57	0
Wood	16.7	0.53	8.85
Garden waste	6.1	4.54	27.69
Textiles	13.5	2.03	27.41
Rest	6	11.23	67.38
Total energy produced			1,081.28

* Source: Andersson et al., 2001

According to Rand et al. (2000), the average caloric of the waste must be at least 7 MJ/kg to justify incineration. Based on the caloric value of 11 MJ/kg (1,081.28 MJ/ 100kg) energy generation is justified for Suriname.

Based on the yearly residential solid waste generation, the total amount of energy that can be produced is calculated below:

Average waste generated (T)	Energy produced from Suriname waste (MJ/100 kg)	Total amount of energy 10^6 (MJ)	Total amount of energy / year (GWh)
46,364	1,081.28	501.32	140
71,648	1,081.28	774.72	217
54,604	1,081.28	590.42	165

Both methods show that different amounts of energy can be produced from our waste. In the first method only the main components are included in the calculations. The second method made use of the heating value of every component present in the waste making the amount of energy produced more reliable.

Based on the calculations it is obvious that also by incineration the energy produced (140 – 217 GWh) from household waste is not enough to cover our energy demand (850 GWh). The same solution as landfilling can be applied namely, to use the energy to supply communities who live near the landfill. A detailed study needs to be done to define the economic feasibility.

It is clear that plastic, paper and food generate the most energy per kg. The plastic fraction in the sorted waste generates the most energy with food coming in second. For that reason, more energy can be extracted from waste that contains a larger percentage of plastic fractions. A downside to the large energy production from plastic and paper is that they also have the largest amounts of emission to the environment. Both fractions emit the greatest amounts of CO_2 and N_2O which are well known green house gases (Andersson et al., 2001). Due to the high moisture content and low heat production, food produce a small amount of energy from incineration but due to the high percentage in our waste the net energy is still high. This low-caloric value and high-moisture content waste can be mixed with wastes such as sawdust from lumber mill (which are available in huge quantities); the resultant mixed waste might be suitable for energy generation (Ashworth, 1996).

For the moment there are no recycling programs operational, but in case any of these programs will start the waste to the incineration plant will be reduced thereby decreasing the amount of produced energy. On the other hand the increasing amount of plastic package material can change the prospective of energy production through incineration.

Energy recovery by gasification

Gasification is another method of thermal processing of waste. Gasification of MSW is a special type of incineration where thermal decomposition takes place in the presence of a small amount of oxygen or air, compared with incineration. The gas which is generated can then be burned in industrial boilers or cleaned up and used in combustion turbines for electricity generation as in incineration.

MahaRaj consultancy presented the government of Suriname a project proposal in which is described that energy can be produced from waste through gasification (DWT, 2005). This project concluded that with a waste generation of 350 T per day, a gasifier with a capacity of 600T per day will produce minimally 660 MW of energy (207 GWh per year) by gas and steam turbines. The investment cost in this plant is calculated to be 40-45 million Euros. The capacity of the gasifier is oversized but according to the consultant this is no problem because waste from the old closed dumps can be used as input material. The advantage of this gasification process is that all kinds of waste can be burned from household -, industrial -, chemical -, hospital waste, to metals, rubber, etc. (DWT, 2005). It needs to be noted that it is not clear how these figures are derived. The assumption that waste from old dumps can be used is not completely true, because a visit to old closed dumps showed only plastic waste, metals and other inert material mixed with a lot of sand. The last have a caloric value of zero to six decreasing the amount of energy to generate. All other material is degraded through the years. Also the amount of energy generated will decrease because a lot of energy will be needed to dry the liquid (slurry) waste stream.

In conclusion, there are some factors that will influence the result of the energy calculations. First, the percentages of the sorted waste components are a yearly representation of residential waste and not of the total MSW stream. Secondly, the energy from the sorted residential waste cannot represent the actual energy from incineration. The real electricity generation figures may increase hereby but on the other hand our waste has a high organic percentage, increasing the moisture content. According to Corrales and Horton (1995), waste from low-income countries is less suitable for incineration than waste from higher income countries because it has a higher percentage of moisture and non-burnable inert materials such as ash and sand. The waste will require therefore more energy for burning and burning will become more expensive. The third assumption is that methane recovery will start in the first year of dumping, however, LFG generation tends to peak early in the cycle (5 to 10 years) and then tapers until all decomposable material is converted and/or moisture is exhausted.

Incineration and landfilling are at the bottom of the waste hierarchy so both are viable components of an integrated system, but the choice between these options requires a systematic comparison of all costs and benefits involved (Dijkgraaf and Vollebergh, 2004). In many developing countries, incineration and landfilling are methods that are not generally used. Open dumping is still the prevalent method of waste disposal and this method is not feasible in generating energy. Only in a few countries (Indonesia, Barbados) sanitary landfills are in operation and a few practice energy recovery (Indonesia). Bermuda (Caribbean) invested in incineration as land space is very critical and the island's only landfill site was nearing its capacity. Heat generated from the incinerator will be used to generate electricity (Caricom/UNEP, 2003; World Bank, 2003). Most of these facilities are implemented with support of international organizations (World Bank, 2003). The combination of high moisture content, lack of regulation of waste incineration, and high investments limit the effective use of combustion technologies for existing MSW streams in Suriname.

5.4 Open burning

Poor collection or disposal practices stimulate to practice open burning. Open burning is a common phenomenon in Suriname. Open burning of MSW adversely affects the environment by emitting pollutants in the atmosphere with serious implications for the health of local people. Open burning of wastes at sites no closer than ½ kilometer from nearest dwellings will have no significant ill health effects due to air pollutants (Crawley, 1999) but in Suriname waste is burned a few meters from the houses so the risks for nuisance and health impacts will increase. The problem of open burning is strengthened by the fact that this activity is practiced in densely populated areas and all types of waste are burned, from food or meat rests to batteries, tires, etc. In an asthma-workshop held in 2004 in Suriname, doctors stated that chronic chest infection is the ninth dead cause in the country (Dagblad Suriname, 2004). One of the reasons could be the deteriorating air quality due to open burning. To increase people's awareness of the negative effects of open burning, a private organization (Romano Health Foundation) established a program targeting at the reduction of open burning and its health effects. This program had no effect; several reasons can be ascribed to this failure such as the lack of reliable data of what kind of pollutants and how much is emitted by open burning. Other shortcomings of this program were the lack of shock effects and its ad hoc character (not on continuous base).

It is increasingly felt that the first step towards sustainable waste management is to quantify factors affecting environmental quality pertaining to MSW. An attempt is made here to adopt a methodology which endeavors to quantify the emission load on account of open burning of HSW. In order to contribute to information dissemination an emissions load is made on account of open burning which equals 1.044 T (see paragraph 4.4.3).

Emission load due to open burning

The estimate of open burning (1.044 T) is multiplied by the emission factor of various pollutants (Chabi Sinha, 1997; Pechan and Associates, 2002) to arrive at the emission load and are compared with WHO guidelines (WHO, 2000). The calculated emission load for the major pollutants is presented in Table 5.1.

Table 5.1: Emission load of pollutants due to open burning of HSW

Pollutant	Emission factors (kg/tonne)	Emission load due to open burning in Suriname (T/year)	Guidelines ($\mu g/m^3$) / average exposure time
TSP	37	38.63	-
SO_2	0.5	0.52	50 (annual)
NO_x (as NO_2)	2.7	2.82	40 (annual)
PM_{10}	17.3	18.03	50 (24 hour)
$PM_{2.5}$	15.8	16.5	-
CO	38.6	40.34	10 mg/m^3 (8 hours)
VOC	3.9	4.07	-

Based on these data it can be concluded that the air quality has reached unhealthy levels and considering the negative impacts of open burning, this activity must be prevented. The contribution of companies in the deteriorating of the air quality is not included in this calculation. To stop open burning, it is important that appropriate waste management strategies (improvement of the waste collection services; increased waste collection coverage) and technologies (composting, recycling) together with education programs are implemented.

5.5 Life cycle assessment of waste management methodologies

When the above mentioned methods are compared with each other normally a life cycle assessment (LCA) is carried out. Therefore, a LCA will be employed to compare the environmental impact of recycling, incineration and the landfilling of municipal solid waste in Greater Paramaribo.
LCA is an environmental management tool that attempts to predict the overall environmental impact of a process over its entire life cycle and is applied to assess the environmental sustainability of waste management systems (Mendes et al., 2004). The general categories of environmental impacts needing consideration include resource use, human health, and ecological considerations (Finnveden

and Ekvall, 1998). One important choice when defining the scope of an LCA is the type of impacts included. According to the LCA definition, the study should include ‘the environmental aspects and potential impacts’ (Finnveden and Ekvall, 1998).

5.5.1 Environmental impacts

Table 5.2 summarizes the environmental impacts of the different waste management technologies.

Table 5.2: Environmental impacts of different waste management technologies

	Composting	**Plastic recycling**	**Landfilling**	**Incineration**
Energy conservation		+		
Reduction GHG	+	+		
Reduction in littering of waste		+		
Emission of CH_4			-	
Emission of CO_2			-	-
Emission of dioxins/furans				-
Emission of flue gas and ash (contains heavy metals)				-
Emission of ammonia (NH_3)	-			
Gas treatment			-	-
Loss of valuable materials			-	-
Loss of land			-	
Leachate production			-	
Energy production			+	+
Reduced use of fertilizer and pesticide	+			
NIMBY	-		-	-

- indicates presence negative of impact
+ indicates presence positive of impact
Composting and recycling have the least negative impacts.

Other environmental considerations:

Recycling

- Plastic bottles can take an estimated 500 years or more to degrade
- Plastic has a high energy value. Increased diversion rates are significant threats to the economic viability of incineration facilities. Without combustible waste materials to supply heating value, solid waste incineration requires consumption of substantial amounts of auxiliary fuel and generation of steam or electrical energy is impossible increasing the net operating costs (Morris, 1996).
- Market/demand: these activities strongly depend on the market. Only when there is a demand from recyclers or farmers, when there is no demand or low price, the facilities have to be closed.
- Dependence on public participation: success of recycling depends strongly on public participation, especially in the separation of waste.

Incineration/Gasification

- Incineration of food waste and sludge requires a lot of energy for evaporation of the water (William, 1998) reducing the net energy produced.
- Because of the high temperature in the gasifier and reducing conditions after the combustion zone, the compounds (dioxins and furans) are not formed in comparison with incineration where these products are formed.
- Dioxins are extremely toxic, with a wide range of possible effects. They are also very long-lived and can be deposited (including on food sources) over a very wide geographic area.
- Product gas requires attention; it contains particulate matter, heavy metals, ammonia, hydrogen chloride, hydrogen sulphide, and NO_x. These gases will require treatment (scrubbers, baghouse filters, electrostatic precipitators, and cyclone separators) to reduce contribution to global warming (Scottish Environment Protection Agency, 2000).

5.5.2 Economic impacts

Plastic recycling

- Reported costs for plastic bottle collection scheme vary between US$ 89 and US$ 625 per tonne of bottles recycled (European Union, 2003). Issues such as locality, household density, contractor availability, collection method and material market value will all influence the overall cost per tonne of plastic bottle recycling.
- Scrap prices for baled plastic: PET bottles US$ 561/ton and Mixed HDPE US$ 418/ton (Recycled Plastics Markets, 2005).
- No foreign investment necessary, only foreign currency for the purchase of a baler, chipper machines, and spare parts. Most of the equipment is locally available or can be constructed.
- More permanent jobs can be created (per million tonnes of waste processed) by recycling and composting compared to landfill and incineration (Green Peace, 1996):

  Landfill: 40-60 jobs

  Incineration: 100-290 jobs

  Composting: 200-300 jobs

  Recycling: 400-590 jobs

Incineration

- Because building an incinerator has such high capital costs, incinerator operators typically require contracts with local authorities to supply them with a minimum amount of waste to burn over a long time – 25 to 30 years.
- To be economically feasible the capacity of individual incineration lines should be at least 240 T per day. A plant should have at least two individual lines (Rand et al., 2000).
- The typical capital investment for a mass burn waste incinerator ranges from US$ 50 million to US$ 280 million depending on its capacity, making it the most costly solid waste management option available (Platt, 2004).

- Incinerators often require foreign financing to build and maintain.
- The net cost per ton to burn wastes is at least twice the cost of controlled landfilling, and many times of recycling and composting strategies (Platt, 2004).
- Gasification technology is in a developing stage with a limited number of units in operation.

Landfilling

- Production of energy is limited. A period longer than 20 years is not considered for gas recovery because gas production in landfill-gas-to-energy operations may fall to an uneconomic level within that time (Tchobanoglous et al., 1993).

5.6 Conclusions

- The waste generation data must be expanded to waste data concerning other sources such as institutional-, hospital-, industrial waste, etc.
- These data will present reliable calculations on the capacity of recycling plants and energy recovery data, which will also contribute to the improvement of the total waste management system.
- More research is needed to solidify the assumptions that energy recovery from landfilling and incineration for electricity generation is feasible (also technical and economical analysis). The energy figures are based only on residential waste data.
- The implementation of small scale facilities for composting and plastic recycling is recommended and can be used as model plants. Although they will be model-plants they must be business-oriented. Home composting by households can also be promoted.
- Landfilling without energy recovery but attended by composting and recycling seem a feasible option for improvement for our SWM.

- LFG need to be flared or burned, instead of emitting to the atmosphere, converting methane into carbon dioxide.
- In case the government is interested in an energy recovery plant they must take into consideration that the generated energy will not cover national electricity demand; this study needs further research and also co-operation with the existing energy providers is important.
- Incineration and gasification are options that are not feasible in the near future due to low energy output and high capital investment.
- Open burning has a tremendous impact on human health. Further detailed research is needed to determine the health level of the air but considering its negative impacts this activity must be eliminated.

Chapter 6

Case study II: Demonstration project on composting of organic household solid waste

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Case study II: Demonstration project on composting of organic household solid waste

Composting of organic material, often contributing to more than 50% of the total waste amount, is still fairly limited but often has great recovery potential. This chapter describes the results of a composting experiment based on HSW for the purpose to explore the technical applicability of composting in Suriname.

6.1 Introduction

Increasing quantities of urban solid waste and the immediate and serious environmental problems are a major challenge for municipal authorities. In low income countries, much in-organic waste such as metals and glass is recycled by the informal sector; however the organic portion of waste constitutes more than 50 % of the total solid waste generated by weight but this waste remains unutilized although it has a great recovery potential. An explanation for this phenomenon is that in most societies, waste is still considered as a nuisance rather than a valuable, high energetic input.

Organic waste is a threat for the health of residents as the indiscriminate waste dumps attract rodents and other disease carrying vectors. Organic waste contributes to pollution of soil and water bodies through leachate, and in the process of uncontrolled anaerobic degradation, it contributes to global warming by the produced methane (Ahmed and Zurbrugg, 2002).

A possible step in mitigating these detrimental effects is enhancing resource recovery for the organic waste fraction. Recycling of organic wastes by composting can widely be seen as an integral part of the municipal solid waste management. Composting is obviously not a panacea to today's waste management problems, but it should be an important component within the integrated municipal management strategies. For the future composting has an important part to play in the integrated waste management system (Shanklin et al., 2002).

Composting is considered an environmental friendly and a more appropriate alternative for solid-waste treatment than conventional methods like landfilling and incineration (Lau and Wong, 2000). Landfills have some use potential: completed landfills can be landscaped into parks, and, if a landfill is properly equipped, vented methane can be burned for energy. However the expensive, high tech solutions, such as incineration plants, are often neither affordable nor feasible. More important, disposing of materials in landfills makes separation and recycling nearly impossible. Furthermore, landfilling of materials is an immediate waste of potential resources and anaerobic decomposition in the landfill creates pollution and produces methane, a greenhouse gas. Combustion of wastes requires fossil fuels for energy generation and creates air and water pollution, increases human and ecosystem health hazards and contributes to global warming (Mitchell, 2001).

6.1.1 Nature of the problem

Background

In Suriname, all organic waste is disposed of mainly in an open dump and also by open burning and illegal dumping. The government has never struggled (often neglected) to place composting on the agenda as an effective treatment option for organic wastes. This has largely been due to the following reasons:

- landfill space has been always readily available
- waste disposal authority has always been chosen to send the wastes to landfill for final disposal

- there has been no encouragement for companies and individuals to investigate the viability of composting as a means of treating their waste
- a lack of understanding of the composting process, its management requirements and the value of the end product (compost).

The accumulation of garbage, shortcomings in transport and storage facilities due to budget constraints, led to an unbearable situation in certain areas, especially in Paramaribo. With the rapid urbanization and the limited suitable land available for public purposes near the capital city, the government uses ecological sensitive land (e.g. marshland) for waste disposal. These phenomena cause a lot of problems: threat of health of humans and environmental degradation. The government has been experiencing the challenges of managing its solid waste.

Organic waste is still considered as discarded and worthless in Suriname. This concept can be changed by revaluing and using organic waste as highly energetic raw materials for a series of productive processes. It is an urgent task for the government to develop alternative treatments for organic waste. Biological treatment using aerobic composting can provide a means to stabilize the organic waste and convert it into organic fertilizer which can be reused in agriculture and landscaping. Most of the organic waste from residents, markets and food processing facilities are biodegradable and should constitute an excellent raw material for composting. Composting of organic waste can thus play in the future an important part in the integrated waste management system.

For this reason it is important to identify the organic part of the waste stream in order to calculate the capacity of future compost plant. Based upon a resident (household) waste characterization study conducted in 2002, 2003 and 2004 in Paramaribo, it is proved that organic wastes are the most important component of the waste stream (49 - 61 %). Organic wastes are dominant in high income areas (61 %) while low income areas dispose less organic waste (49 – 58 %) because a part of the waste is given to domestic animals, is used as mulch (fresh waste is added to soil and plants) and is burned or illegally dumped.

The country has no composting plant, and a low awareness exists among the residents about composting and the use of compost. When interviewed, a few residents convert the organic waste (fruit and vegetable waste) into compost. Fresh waste is added directly to soil and plants, thinking that this will transform into a fertilizer. Others dump the waste in a hole to be composted and plant vegetables after some time on this spot. The major difference between compost-amended soil and using fresh waste material is that organic matter in compost is already "degraded". Fresh material requires the degradation to take place in the soil, which allows for both anaerobic and aerobic decomposition of organic matter. Compost acts as a shelter for the antagonists that compete with plant pathogens which prevent the germination of spores and infection of plants growing on the amended soil, implications for soil and nutrient management, as well as plant health and pest management. Chemicals left after anaerobic decomposition largely reduce compost quality (Sullivan, 2004).

In the period 1996 – 2001, there had been 5 small scale projects of aerobic composting of organic wastes. These projects were implemented under supervision of Ms. H. van de Lande (University of Suriname –Biology and Chemistry Department). The localities of these projects were the rural areas (the hinterland and suburbs of Paramaribo); women were taught in sustainable home gardening: to make compost from garden -, vegetable - and fruit waste and how it can be used to it improve soil condition. The produced compost was used on the household’s vegetable plots; the surplus of the cultivated vegetables could be used to sell (income generation). The projects were sponsored by Pan American Health Organization (PAHO), the Dutch Embassy and Canadian Funds. Except for the sponsors, the results of these projects were not published (personal communication H. van de Lande). Although the process was shown to be technically feasible, its cost-effectiveness was not demonstrated. As a result, it was never implemented on commercial scale.

The limited awareness concerning compost and its use, the wide availability of inexpensive inorganic fertilizers and the absence of past and current composting facilities can be considered a major hindrance in compost utilization. Availability of examples of products for demonstration purposes would be of great value in raising awareness.

Knowledge about the composting process based on municipal solid waste is limited, and therefore research efforts have to be put into composting. Compost bins built at the University have been used for this research to increase our knowledge on the process dynamics. Knowledge gained with this experiment can be used to implement commercial composting.

6.1.2 Aim and scope of this work

The research project on the potential use of organic waste in Paramaribo was undertaken as collaboration between the Ghent University – Department of Soil Management and Soil Care (Belgium) and the University of Suriname – Environmental Department. The research was implemented in the period June – October 2003 and May – August 2004.

There have been no attempts to implement composting programs to handle the large amount of organic waste that is produced in Greater Paramaribo. Therefore, a composting experiment was implemented at the University of Suriname and the composting procedure adapted in this project was the compost bin type. Field operations and experimental work were carried out along with pertinent laboratory analysis. It was meant to try out the applicability of composting as one of the strategies for minimizing waste and recovering resources from household waste. Among other things, the project is to provide a comprehensive and theoretical program which future studies can further investigate by following up on our recommendations to reduce costs and to expand the possibilities.

The overall aim of the project centers on improving the local waste situation in the country, which includes promoting the decision-making process on a municipal level to regard composting as a viable option for solid waste management.

The specific objectives of the project are the following:

- to convert organic kitchen waste into a safe compost product through a scientific method based on research findings (compost bin method)
- to try out the applicability of composting as one of the strategies of waste management
- to increase the knowledge on issues relevant to process problems through theoretical and experimental investigation
- to conduct a composting experiment that would determine the effectiveness of organic waste. All the facets of composting operation including collection and handling procedures, waste characterization, physical and chemical parameters, material blending, recipe formulation, active composting and curing procedures, odour control and quality of finished compost
- to assess the main constraints for initiating and operating composting projects.

To meet the aforementioned objectives, the following main issues were studied:

- development of a methodological concept: the necessary separation and collection of compostable waste by staff and student participation (first period)
- organic waste management: types of waste generated and how much; issues relevant to the process management (second period)

- quality of the end product (compost): laboratory analyses were implemented in order to determine the quality of the compost (third period).

6.1.3 Limitations

The present study had some limitations. First, it was necessary to limit the collection sources to a few institutions (homes) close to the university as waste segregation is not widely practiced and waste recycling is minimal. The second limitation of the study has to do with measuring equipment. Not all parameters could be measured or analyzed due to lack of equipment, such as a muffle oven with temperature higher than 800 ^{0}C, CO_2- and O_2 meter.

6.2 Composting - literature review

6.2.1 Introduction

Composting is a biological process in which microbes metabolize readily degradable organic matter into nutrient rich humus, which is a structural component of soil (Mitchell, 2001). The organisms that decompose the organic waste require oxygen, water, and nutrients to function. They produce compost, carbon dioxide, heat and water. In nature, composting is a spontaneous biological process and occurs with unsteady rate (Bertoldi de and Schnappinger, 2002). At commercial level, the process must be constantly under control, optimizing the main process parameters in order to obtain a highly stabilized product in a short time. Compost can be used as a source of nutrients and soil conditioner in agriculture and landscaping (Pace et al., 1995 and Spanos et al., 1998).

The treatment of organic wastes by composting offers a few technical advantages:

- for a municipal authority in charge of solid waste management recycling of organic waste by composting helps to decrease disposal costs, prolongs the life span of the sites and also reduces the detrimental impact of disposal sites caused by the organics largely responsible for the leachate and methane problems. This is one of the reasons why solid waste managers are now exploring ways to reduce the flow of biodegradable materials to landfills (EAWAG-SANDEC, 2000)

- enhancing recycling and incineration operations by removing organic matter from the waste stream (Bertoldi de and Schnappinger, 2002 and Hoornweg et al., 2000)
- provides an excellent opportunity to improve a city's overall waste collection program (Bertoldi de and Schnappinger, 2002 and Hoornweg et al., 2000)
- the possibility to treat a large range of quantities of wastes with a low level of technology (Vallini et al., 2002)
- can be started with small capital and operating cost (Bertoldi de and Schnappinger, 2002 and Hoornweg et al., 2000)
- composting leads to the production of compost which may be used as amendment or fertilizer in soils enhancing clumping and, therefore, improving texture and permeability of soil to air and water (Lau and Wong, 2000)
- promoting recycling and utilization of valuable resources in organic wastes contributes to a permanent improvement in the waste management situation (Lau and Wong, 2000)
- the improvement of urban health and sanitation conditions
- promoting composting as a business is seen as a means of enhancing income and improving health and the environment for the urban poor
- composting kills pathogens and weed seeds (Tiquia et al., 2002)
- composting can significantly reduce waste volume and weight
- solid waste treatment than conventional methods like landfilling and incineration
- integrating re-use behaviour is perceived as an environmental and social benefit
- development of additional revenue by composting (Mitchell, 2001).

When planning a waste composting project, the following areas need to be addressed (New Hampshire Department of Environmental Services, 1998):

- type of composting process and operation: can range from a low level of technology to a highly sophisticated system
- process control parameters: oxygen and aeration, C:N ratio, moisture content, particle size, temperature, time
- quantity of material: depends on the availability of material. Data can be obtained from waste generation studies
- material collection: choice of collection method which depends on the cost, convenience, household participation rate, amount of waste
- facility siting: land requirement which depends on the volume of waste and level of technology
- public education: is a vital component and should start as soon as possible as the process is initiated and must be a continuous process
- equipment: equipment for handling movement, turning, watering, screening and monitoring of the material
- staffing: a dedicated staff is necessary. Important responsibilities for monitoring, recordkeeping, quality control
- marketing and use: there are a number of uses for compost. Its use depends on the quality, acceptance and price.

During composting, the micro-organisms consume oxygen (O_2) while feeding on organic matter. Composting is the result of microbial activities which convert organic matter to more stable, humified forms and to inorganic products (e.g. carbon dioxide, water, ammonia, nitrate, methane) under controlled conditions, releasing heat as a metabolic waste product (Spanos et al., 1998). As this aerobic metabolism occurs, the structural integrity of the organic waste decreases and the overall matrix begins to settle (as seen in “shrinking” compost piles) due to the force of gravity (Hudgins and Harper, 1999). The CO_2 and water losses can amount to half the weight of the initial materials, thereby reducing the volume and mass of the final product (Pace et al., 1995).

The following general formulas illustrate the inputs and outputs for the conversion of organic matter in the presence of oxygen:

Organic matter + O_2 + micro-organisms + nutrients → new cells + stabilized organic matter + CO_2 + H_2O + NH_3 + SO_4^{2-} +…+ heat (Hoornweg et al., 2000; McEachren et al., 2004)

The addition of fresh organic matter to the soil results in a change of ecosystem in which the crop is developing. Fresh organic matter when placed in the soil will be degraded by microflora, resulting in a production of intermediate metabolites which are not compatible with normal plant growth. Other disadvantages are competition for nitrogen between micro-organisms and roots, a high carbon to nitrogen ratio (C/N), and the production of ammonia in the soil. The use of compost is therefore a possibility to overcome all of these problems (Bertoldi de and Schnappinger, 2002).

The use of compost has several advantages. These include (Baldwin and Greenfield, 2000; Bertoldi de and Schnappinger, 2002):

- improving soil structure: helps soil particles to bond and form soil aggregates, helps to create better porosity providing opportunities for deeper root penetration, drainage, and for soil aeration (fertilizers provide nutrients but do not improve soil structure)
- compost is low in soluble nutrients and has a slow release of nutrients improving plant nutrient availability; fertilizers have highly soluble nutrients and can easily dissolve in rainwater and wash away. On the other hand plants may take up more nutrients due to excessive amounts available from fertilizer; excess nitrogen makes plant susceptible to attack by pest and diseases
- compost protects plants from soil-borne plant pathogens because of increased activity and greater biomass of the general soil microflora

(microbial activity) in compost-amended soils that fight disease (reduce the need for pesticides)

- compost forms humic acid which stimulates plant growth, it improves soil quality by adding nutrients helping to produce better yields (reduce the need for fertilizers)
- compost increases the water holding capacity; it holds water in time of drought and holds enough air to prevent plants from drowning when it rains heavily and helps controlling soil erosion.

Composting can have some disadvantages (Tiquia et al., 2002 and Baldwin and Greenfield, 2000). These include:

- nutrient loss during composting through volatilization of gaseous ammonia and leaching
- equipment and labour requirements depending on the size of operation
- possible odours during composting
- the cost of land depending on the size of operation.

6.2.2 Composting systems

Hot (active) composting

Hot composting is the most efficient method for producing quality compost in a relatively short time. In addition, it favors the destruction of weed seeds, fly larvae and pathogens. While hot composting, using the windrow or bin method, requires a high degree of management (turning, watering); hot composting, using the in-vessel method, requires a shorter period of management (Misra and Roy, 2003).

Cold (passive) composting

This method is ideal for adding organic matter around trees, in garden plots, in eroded areas etc. The time required to decompose organic matter using this method is governed, to a large extent, by environmental conditions and could take two years or more. Cold composting is characteristic of the natural decomposition of organic waste (Misra and Roy, 2003).

6.2.3 Composting methods/operations

There is considerable variation in composting techniques for the organic waste stream. There are three main methods for active composting (Déportes et al., 1995; Poulsen, 2003):

- backyard composting: individual households compost at home (Dickerson, 2002):
  There are three basic types of backyard composting:
  - sheet composting: involves applying raw composting material directly on top of soil in layers
  - trench composting: involves digging a trench and filling it up with shredded organic waste
  - bin composting: layers of organic materials are laid down in specially constructed bins.
- on-site composting: industrial, commercial and institutional sectors manage their organic wastes and avoid disposal costs. On-site composting employs three composting methodologies: passive system, windrow system and aerated static pile (see below) (Rynk, 2000)
- centralized composting: collection and transport of organic waste and composted at a centralized facility. There are three basic types of centralized composting processes or methods (Misra and Roy, 2003):

- In-vessel method: the organic material is composted inside a drum, silo, agitated bed, covered or open channel, batch container or other structure. The process conditions are closely monitored and controlled and the material is aerated and mechanically turned or agitated. This type of composter can produce compost in 28 days. The final step is to unload the composted material and either apply it or pile it to allow it to cure
- Aerated static pile method: involves forming compostable materials into large piles, which are aerated by drawing air through the pile or forcing air out through the pile. Mechanical turning is not required
- Windrow method: compostable material is formed into elongated piles, known as windrows, which are turned mechanically on a regular basis.

The success of composting is not dependent on the selected composting method, but on feedstock and general management.

Selection of the most suitable composting method is dependent on (Guanzon and Holmer, 2003):

- space availability and composition of substratum
- composition and potential pathogen contamination of organic waste (e.g. faeces, sand)
- amount of organic waste per time unit
- availability and specific knowledge of workers
- availability of capital
- emissions and the danger of pollution nuisance to residents caused by composting
- climatic conditions.

6.2.4 The composting process

Composting may begin as soon as the raw materials are mixed together and when the proper conditions exist. During the initial stages of the process, oxygen and the easily degradable components of the raw materials are rapidly consumed by micro-organisms. The bio-oxidative composting process is exothermic and substantial quantities of heat are produced in the initial part of the process, causing the temperature to rise. This, in turn, vaporizes off the moisture, thereby reducing the weight and volume of the substrate (WHO, 1991-1993). The temperature is directly related to the micro-organism activity and is a good indicator of what is going on inside the compost pile (Pace et al., 1995; WHO, 1991-1993).

The phases of the composting process with respect to temperature, classes of microbes and oxygen uptake are shown below (Pullicino, 2002; WHO, 1991 – 1993, Ghazifard et al., 2001, Baldwin and Greenfield, 2000; Poulsen, 2003):

- Phase I: Mesophiles - medium temperature microbes (up to 40-45^{0}C) micro-organisms rapidly invade the mass of substrate, first assimilating the more easily metabolized substances such as sugars, soluble proteins, starch and organic acids. During this stage, the oxygen consumption and CO_2 production by microbial metabolism is very high.
- Phase II: Thermophiles - high temperature microbes (up to 55 – 60 ^{0}C), (high oxygen uptake rates). The high metabolic activity and exothermic processes cause the temperature of the composting mass to rise. Highly biodegradable, volatile solids reductions characterize this high rate phase. When the readily assimilated substrates have been metabolized, the rate of microbial activity decreases and the temperature starts to decline.
- Phase III: Psychrophiles - low temperature microbes (up to 25 °C) (lower oxygen uptake rates). This phase is characterized by lower temperature and lower oxygen uptake rates. This maturation phase

allows time for degradation of refractory organics and reestablishment of psychrophilic microbial populations.

A curing period usually follows the active composting period whereby the temperature declines (44-30°C) during this period. During the curing period, the materials will continue to slowly decompose, because the rapidly degradable components are consumed. Materials continue to break down until the last easily decomposed raw materials are consumed by the remaining micro-organisms. At this point, the material is no longer self-heating, and the compost becomes relatively stable and easy to handle (Pace, 1995; Hudgins and Harper, 1999; Sundberg, 2003).

In figure 6.1 the different phases or stages of the compost process are represented.

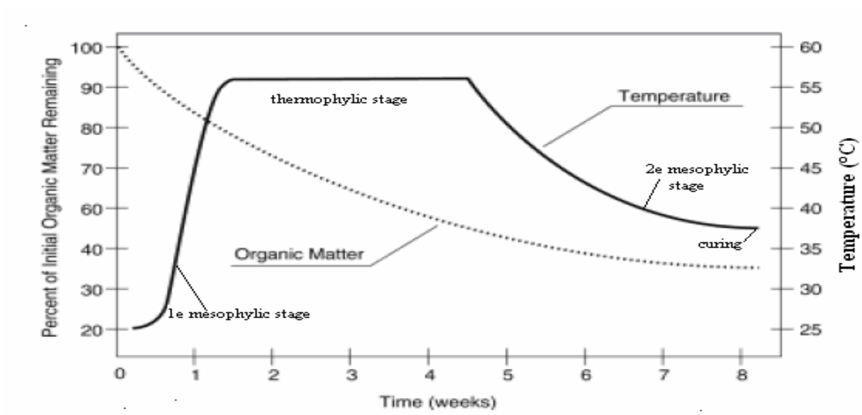


Figure 6.1: Stages and major events in composting (USEPA, 1998a)

Factors influencing composting

A range of factors influence the speed and completeness of composting. The basic parameters that influence the composting process are: temperature, moisture content, oxygen content, particle size, carbon-nitrogen ratio, degree of mixing or turning and activity of microbial populations. If any of these elements are lacking, or if they are not provided in the proper proportion, the micro-organisms will not flourish and will not provide adequate heat. A composting process that operates at optimum performance will convert organic matter into stable compost that is odour and pathogen free, and a poor breeding substrate for flies and other insects (Lekasi, et al., 2003; Poulsen, 2003; Vallini et al., 2002).

Temperature

Temperature is both a necessity for and a result of micro-organisms' work. The warmer the pile, the faster the micro-organisms work and the more heat they produce. The temperature rapidly rises in the initial composting stages and eventually decreases as the biodegradable organic carbon is consumed. Temperature is directly proportional to the biological activity within the composting system. As the metabolic rate of the microbes accelerates the temperature within the system will increase. Conversely, as the metabolic rate of the microbes decreases, the system temperature decreases. The heat produced during composting can either remain in the compost mass or leave it. If all the energy released during decomposition were to remain in the compost, the temperature would rapidly rise above the maximum temperature of microbial survival. From the decomposition of 1 gr of organic matter, 15 – 29 kJ heat is released (Sundberg, 2003). In process terms, temperatures of 35 – 40 ^{0}C maximize microbial diversity and temperatures of 45 – 55 ^{0}C maximize the biodegradation rate. Maintaining a temperature of 55- 60 (65)^{0}C for more than 3 to 4 days favours the destruction of weed seeds, fly larvae and plant pathogens (maximize sanitation). Temperatures above 65 ^{0}C may result in the destruction of certain microbial populations. In this case temperature may rapidly decline. Temperature will slowly rise again as the microbe population regenerates (WHO, 1991-1993; Hoornweg et al., 2000; Dalzel et al., 1987).

Particle Size

The individual pieces of organic material must be small enough so they have a greater surface area for microbial attack. On the other hand, small particles of the same size tend to pack tightly together, reducing the supply of oxygen, and hindering the release of carbon dioxide. The ideal particle size is around 1 – 5 cm with artificial ventilation and 5 – 10 cm with natural ventilation. For material larger than this size, the material can be chopped. Mixing materials of different sizes and textures helps aerate the compost pile (Guanzon and Holmer, 2003; Dalzel et al., 1987).

Oxygen/ Turning

The micro-organisms that break down organic matter are aerobic; so all areas of a compost pile must have good aeration to supply oxygen (by turning) for microbial respiration and flush out carbon dioxide and water vapour that is produced. Oxygen is usually supplied as air which reaches the organisms by diffusion. If the supply of oxygen is limited, the composting process may turn anaerobic, which is a much slower and odorous process and favours the formation of methane. The slower anaerobic process does not produce enough heat to disinfect the material or to kill weed seeds and.

The consumption of oxygen is greatest during the early stages and gradually decreases as the process continues to maturity. During the composting process oxygen is used up quickly by the microbes as they metabolize the organic matter. As the oxygen becomes depleted the composting process slows down and temperatures decline. Aerating the compost by turning should ensure an adequate supply of oxygen to the microbes (WHO, 1991-1993; Gouleke, 1972).

Micro-organisms

Micro-organisms and invertebrates (ants, centipedes, spider, beetles, and worms) are an essential component of the composting process since they are responsible for the biological conversion of the organic matter. Different micro-organisms contribute to the decomposition of organic waste at various stages in the composting process. The primary micro-organisms involved are bacteria, fungi, (mesophilic conditions) and actinomycetes (thermophilic conditions) operating according to their specific temperature range (Mitchell 2001; Dalzel et al., 1987). Many organisms have different purposes in the composting process. The micro-organisms, for example algae, break down the bulk of the organic material. This is one of the most important aspects of composting. The protozoa feed on the micro-organisms; insects feed on the protozoa and other small insects. Finally, larger organisms, like worms, speed up the composting process by mixing materials and reducing the particle size of the compost (McEachren et al., 2004).

Moisture content

Micro-organisms require water as a medium for chemical reactions, to transport nutrients, and to move about. Water is produced during the composting process by microbial activity and is lost by evaporation in the air stream. Moisture dissipates heat and serves as a medium to transport critical nutrients. Moisture content varies with particle size and physical characteristics of the raw materials. The preferred moisture content for composting is between 40 and 60 percent in order to compensate for water loss through evaporation. A low moisture content (below 40 percent) will slow down the composting process whereas a high moisture content (above 65 percent) will restrict air movement through the pore spaces because water will fill the interstices between the particles, thereby reducing the interstitial oxygen. This will result in anaerobic conditions because no oxygen is available to the organism, the generation of foul odours, a rapid fall in temperature and slowing down of the composting process. Excess leachate may also be produced if the moisture content is too high (by e.g. rain) (Richard, 1995; WHO, 1991-1993; Gouleke, 1972; Dalzel et al., 1987).

Carbon to Nitrogen ratio (Nutrients)

The primary nutrients required for micro-organism growth are carbon, nitrogen, phosphorous, and potassium. Of the primary nutrients, carbon and nitrogen play the most important role in the composting process. The microbes in compost use carbon for energy and growth, and nitrogen for protein synthesis, cell building and reproduction. The proportion of these two elements required by the microbes averages about 30 parts carbon to 1 part nitrogen ((C:N) is 30 : 1 (measured on a dry weight basis)). Low C:N ratio may result in excessive nitrogen losses through ammonia volatilization and is emitted from the pile resulting in odours, especially at high pH and temperature. The high pH fosters ammonia formation and the high temperature accelerates the volatilization of ammonia, and the aeration drives off the volatilized ammonia. At high C:N ratio the micro-organisms must go through many life cycles, oxidizing the excess carbon until a more convenient C:N ratio is reached for metabolism and hence increasing the time required for decomposition. The low nitrogen supply can limit microbial activity resulting in slow decomposition and lower temperatures. This ratio governs the speed at which the microbes decompose organic waste. This optimum C/N ratio can be attained by combining various organic wastes (WHO, 1991-1993; Gouleke, 1972).

6.2.5 Source material for composting

The composting process is essentially a biological reorganization of the carbon fraction of organic matter. All organic material will decompose; however, some materials are more suitable for composting than others. The raw materials which are most appropriate for composting include: vegetable and fruit waste, farm waste, crop residues, yard waste, sawdust, and household kitchen waste. Animal waste and meat can be used as well but they are likely to attract unwanted vermin and generate odours. Other organic matter such as wood, bones, coconut shells decompose very slowly and hinder the composting process (WHO, 1991-1993). The organic material is a mixture of sugars, proteins, hemicelluloses, cellulose, lignin and minerals. Organic compounds that are simple in form and easily soluble in water (such as sugars) can be readily taken in by micro-organisms, providing energy and being built up into polymers. Substances with large molecules, such as hemicellulose and cellulose, are fist chopped up by enzymes before they can be used. Lignin is a woody material and its structural heterogeneity makes it particularly difficult for microorganisms to break it down (highly resistant); it decomposes after a very long period of time (Dalzel et al., 1987).

6.2.6 Curing and final conditioning

Curing prevents the use of immature compost by allowing the compost to mature until stable. It occurs at lower temperatures, consumes less oxygen, generates less heat and reduces moisture evaporation. Curing starts when the temperature of the pile does not re-heat after turning. The compost becomes mature as the temperature approaches ambient conditions. Conditioning improves the final quality and appearance of the mature compost by screening into different grades (Hoornweg, et al., 2000).

6.2.7 Compost quality

Compost quality is defined by its maturity and stability (Pullicino, 2002). Compost quality is influenced by the properties of the input material and is dependent on proper process control. The degree of completion of the composting process can be evaluated by measuring various changes in the chemical, physical and biological properties of the substrate. The terms compost “maturity” and “stability” are the important factors affecting the successful use of compost. However, at present, there are no well-accepted, official definitions of compost stability/maturity within the compost industry and research community (Wu et al., 2000).

6.2.7.1 Assessing compost stability and maturity

The term "stable" is often used to indicate the condition in the material based on (Butler, et al., 2001; Wu et al., 2000; Pullicino, 2002; Spanos et al., 1998):

- the degree of decomposition: the compost is not undergoing rapid decomposition and its nutrients are relatively available for release into the soil; unstable compost, in contrast, can tie up nitrogen from the soil.
- the level of activity of the microbial system.

The term "mature" refers to agriculture properties of compost based on (Butler, et al., 2001; Pullicino, 2002):

- the degree of phytotoxicity of a compost
- the degree of completion of the composting process
- the degree of humification of the material.

Composts which are still active or not fully composted are considered to be immature and unstable. Problems associated with immature compost (Butler et al., 2001) are:

- continued decomposition of immature compost in soil can induce anaerobic conditions as the microbial biomass utilizes oxygen in the soil pores to break down the material. This in turn can deprive plant roots from oxygen, and lead to the generation of hydrogen sulphide (H_2S) and nitrite (NO_2)
- depletion of available nitrogen; high C/N ratio can induce nitrogen starvation in plants as microbes scavenging soil N to make up the deficit resulting in slow plant growth and damage of crops (Wu et al., 2000)

- phytotoxicity: due to the presence of organic acids as the intermediate by products of continuing decomposition, acetic acid and phenolic compounds in particular, may suppress seed germination, inhibit root growth, or suppress crop yields. However, phytotoxicity can also be caused by other factors, such as excess soluble salts or high heavy metal concentrations (Wu et al., 2000).

6.2.7.2 Compost stability

The compost stability can be defined according to the following indicators (Wu et al., 2000; Wu and Ma, 2001; Bio-Logic, 2001):

1. Temperature of the compost. If the temperature of the compost is more than 8 degrees C higher than the ambient air, the compost is still fairly unstable.
2. Respiration rate. The carbon dioxide respiration rate procedure entails the incubation of a compost sample at 30^0C and subsequent daily determination of the weight of CO_2 – carbon. The limit value of >5 mg CO_2/g compost carbon / day indicates that the compost is unstable.
3. Length of compost processing. In general, the raw material should be processed for a minimum of 60 to 90 days to produce ”finished" compost. "Finished" means usable, but not fully stable. However, compost processed in a minimum of 90 to 120 days should be considered "stable." This is sometimes referred to as being "cured".
4. Carbon:Nitrogen (C:N) ratio. The C:N ratio decreases as compost becomes more mature or stable. Consequently, the C:N is sometimes used as an indicator of compost stability. However, for this ratio to be meaningful, one needs to know the C:N ratio at the beginning and the end of the compost process. Ideally, the C:N should be approximately 30:1 at the beginning of the compost process. If the C:N ratio is low at the beginning of the compost process, a low C:N at the end of the

process may not be a meaningful indicator of compost stability. Assuming the beginning C:N is approximately 30:1, the C:N of a moderately stable finished compost will be between 15:1 and 20:1. A very stable compost will have a C:N between 10:1 and 14:1 at the end of the composting process. A final C:N ratio above 20:1 may not readily release nitrogen. A final C:N of greater than or equal to 30:1 is thought to inhibit mineralization of nitrogen and may actually tie up nitrogen from the soil.

5. Visual/Olfactory inspection. Although not a reliable method, one can do a cursory assessment of compost by look and smell. In general, mature compost will not contain recognizable feedstock material and should smell like rich soil. It should not smell foul or ammonia. Immature compost will contain more growth-inhibiting compounds than mature compost. Compost that is immature may, for example, produce short-chain organic acids that are phytotoxic.

6.2.7.3 Mature compost

The following indicators are used to define the compost maturity (Wu and Ma, 2001):

1. Seed germination**.** The seed germination procedure entails the germination of seeds in a compost-water extract. A germination index is produced by taking the product of percent germination and root elongation and dividing by 100. An index below 60 is an indication the compost is not completely stable and when used may inhibit plant growth.
2. Maturity index**.** Characterizes the C:N ratio of the finished compost and report at least the carbon dioxide evolution and oxygen demand.
3. CEC (Cationic Exchange Capacity). The CEC in an organic material increases as a function of humification due to the formation of carboxyl

and phenolic functional groups. CEC ≥ 60 cmol/mg expressed on ash free basis to be sufficiently mature for application to the soil (Butler et al., 2001).

Mature compost should meet the following parameters to ensure that it is stable (Hoornweg et al., 2000)**:**

- should have a C/N ratio of less than 22 to be safe for agriculture use
- should reduce volume of raw organic material by at least 60 %.

6.2.8 Applications

The use of the compost determines what quality characteristics are required, and whether given compost is poor, good or great quality. Compost can be used in a variety of applications. High quality compost can be used in horticulture and home gardening. Medium quality compost can be used in applications such as erosion control and roadside landscaping. Low quality compost can be used as a landfill cover or in land reclamation projects.

Compost for amending agricultural fields should have lots of organic matter and/or nutrients (depending on its purpose) plus a consistent texture that allows it to be evenly spread. It may not need to be very mature (some odour and physical contamination can be acceptable). A compost as a potting soil component must be stable and have low salts concentrations. The ability to suppress soil-borne diseases might be a key factor in this case (Dalzel et al., 1987).

6.3 Methodology

6.3.1 Introduction

A field demonstration of low technology composting (bin composting) for kitchen waste has been completed in the period June – October 2003 (20 weeks) and May – August 2004 (15 weeks). This paragraph describes the methodology used for composting the organic food waste.

The participating institutions in accomplishing the objectives of this study were the:

- Anton the Kom University (Faculty of Technology), in Paramaribo which facilitated the project team with transport and building of compost bins
- the Environmental Department which accommodated the survey with students who conducted parts of the survey as a curricula item and
- the Chemistry-, Environmental and Soil Laboratory of the Ghent University and the University of Suriname where analyzing the waste and compost samples occurred.

The study design included the following steps:

- lecture in composting by L. Zuilen, the coordinator of the project
- building compost bins
- selection of collection sources
- collection of organic food waste
- managing the composting process
- laboratory analysis of compost samples

This research project was carried out in three stages, each dealing with different aspects of kitchen waste composting:

- the first part of the work concerned the study of the process of kitchen waste separation / collection and the awareness/attitude of the people at the different sources
- the second part of this research project was to determine the effect that different operational procedures have on the composting process

- the third phase of the project is focused on laboratory analysis to assess stability and determine the point of the process at which the composting material has become 'compost'.

There are different ways of composting organic kitchen waste. For this study the compost bin has been chosen for the following reasons:

- space availability and site dependence
- amount of organic waste per time unit
- availability and specific knowledge and workers (first trial)
- availability of capital and equipment
- emissions and the danger of pollution nuisance

The advantage of this method is that limited space and waste are required, it gives also a cleaner impression but turning was quite difficult.

6.3.2 Building the compost bin

Two bins (bin1 and bin 2) were constructed of wooden pallets and chicken wire fastened at the inside. Each bin had a size of 1 x 1 x 1 meter (photo 6.1).

Photo 6.1: Compost bin

The chicken wire keeps the material inside and prevents pests entering into the waste. A size of $1m^3$ was chosen because it holds sufficient material to compost efficiently. The bins were built by the Technical Service of the University of Suriname and construction wood was received free of charge from a saw mill. The bins were placed on bare soil to allow direct contact of the waste material with soil micro-organisms. The following "recipe" for constructing the compost heap was used:

- 1st layer: saw dust (wood curls)
- 2nd layer: fresh grass clippings and green garden plants (mainly leaves)
- 3rd layer: kitchen waste
- 4th layer: fresh grass clippings
- 5th layer: repeated steps 2 (1) – 4 until the bin was full

A plastic cover was placed over the filled bins with the purpose to reduce nuisance of pest and to protect the waste from rain and sun (photo 6.2a). The waste was also covered with a grass layer to reduce pest access such as flies. The use of plastics was not a success so in 2004 the bins were covered at the top and sides with Aluzinc plates to prevent incoming rainwater and windblown effects (photo 6.2b).


Photo 6.2: a - bins covered with plastic **b - bins covered with Al-Zn corrugated plates**

6.3.3 Study site

The site chosen for this study was located at the University Campus. The location for the installations of the compost bins was dependent on the following factors:

- reachability: the research group had to monitor daily and because of the nearby availability of the laboratory facilities
- high grounds, to prevent water-logging near the bins during rainy days.

6.3.4 Equipment and supplies

Equipment and supplies (photo 6.3) necessary for completing the process monitoring activities included the following:

- temperature measurement digital Ni-Cr-Ni temperature meter
- pH measurement: Vermico rapitest pH meter
- salt meter: Vermico rapitest salt meter
- moisture meter: Vermico rapitest moisture meter
- sampling equipment: bucket, hand trowel, latex gloves, dust mask, spade, auger bore
- pile dimension: stick, measuring tape
- a turning spade and weighing: digital balance (6 and 10 kg).

Photo 6.3: Measuring equipment used during composting process

6.3.5 Material sources

A collection program for source separated food waste was coordinated by the project team. To gather enough kitchen waste, several institutions were visited or phoned to ask for their participation in the composting project. An explanation was given about the purpose of the project and also information was distributed about the kind of kitchen waste that had to be separated. The participants were motivated to separate their waste into organic – and non-organic waste and dispose of their organic waste for our research. The waste was collected by the project team and transported to the University campus (from monday – friday). Staff of the Faculty and members of the project team also brought there kitchen waste from home. The collection went on until both bins were completely filled. The material of the various sources was limited to:

- fruit and vegetable waste/remains
- egg and nut shells
- coffee ground (with filters)
- flowers, garden plants
- leaves
- potato peelings
- bread
- tea bags
- tissue/paper
- saw dust

The food waste was collected from several different types of sources (table 6.1):

- 4 children homes
- 2 old people’s homes
- Faculty staff and students from the Environmental Department
- 2 food processing companies in 2004

Yard waste (grass clipping) was gathered from the campus area and sawdust (wood curls) was provided by a furniture factory and a wood market and was used to absorb liquids and also as a source for carbon rich material.

Table 6.1: Feedstock collection and schedule

Feed stock (waste)	Source	Waste description	Collection dates	
			2003	2004
Kitchen waste	FTeW staff/students	Vegetable waste, fruit waste, bread, egg shells, tea bags	2, 3 ,4, 6, 9 June	
	FTeW and children homes	idem	10 – 23 June	
	FTeW; children homes; old people's homes	idem	24 June – 11 July	3, 4, 5, 6, 7, 10, 11, 12, 13, 17 May
Saw dust (wood curls)	Furniture factory	Wood curls	2, 18, 30 June and 4 July	3, 5, 14, 17 May
Garden waste	Students/ Campus area	Grass clippings; leaves of garden plants	2, 6, 10, 13, 17, 19 June and 2, 10 July	3, 4, 5 May
Process waste	Juice factories	Fruit waste		4, 6, 11, 17 May

Every feedstock received was inspected for contaminants, such as plastic and aluminium foil, and weighed in the laboratory with a digital balance before it was placed in the bins.

6.3.6 Monitoring composting process

The filling of the two bins did not occur simultaneously, because of the lack of sufficient waste material. This is a disadvantage because there is no guarantee that the composition of the two bins is similar. In the 8th week the content of the second bin was mixed with the content of the first bin, the so called 'mixing bin'. The composting cycle lasted 16 weeks. Table 6.2 gives an overview of the activity schedule.

Table 6.2: Activity schedule

Activity	Bin 1		Bin 2		Mix Bin	
	2003	2004	2003	2004	2003	2004
Filling	2 – 27 June	3 – 4 and 17 May	20 June – 11 July	5 – 13 and 17 May		
Monitoring Composting process	28 June – 31 July	5 May - 11 June	12 – 31 July	18 May – 11 June	1 August – 28 October	12 June – 13 August
Mixing	31 July 2003 (mixing content bin 1 and bin 2) 11 June 2004 (mixing content bin 1 and bin 2)					

The process monitoring data included field measurement of several parameters. The purpose of field monitoring was to:

- determine appropriate process adjustments
- provide a quantitative means of assessing the composting conditions and how the process was progressing
- document the ability of the process
- determine the value of the product as a soil amendment.

The following parameters were measured in the field:

- temperature
- pile height
- pH
- moisture content
- visual observations: decomposition of components in food waste (change in colour), organism activity, weather conditions
- smell problems

The measurements were conducted daily for 13 weeks, followed by weekly measurements. During the first weeks the piles were turned at least three times per week with a spade and further at intervals sufficient to maintain adequate aeration and to prevent odours. These intervals are not less frequent than once every week (see table 6.3 and 6.4).

Table 6.3: Turning schedule 2004

Date	**Pile age (days)**	**Turning**			**Sampling**
		Bin 1	**Bin 2**	**Mix bin**	
		Filling date	Filling date	Mix date	
		3 May	5 May	11 June	
5 May					x
21 May	19	x	x		
28 May	26	x	x		
1 June	30				x
4 June	33	x	x		
11 June	40	x	x		
18 June	47			x	
24 June	53			x	
2 July	61			x	x
9 July	68			x	
23 July	82			x	
29 July	88				x
30 July	89			x	
4 Sept	124				x
10 August	100			x	

Table 6.4: Turning schedule 2003

Date	Pile age (days)	Turning			Sampling
		Bin 1	Bin 2	Mix bin	
		filling date	filling date	mix date	
		02-Jun	30-Jun	31-Jul	
13-Jun	12	x			
16-Jun	15	x			
19-Jun	18	x			
20-Jun	19	x			
27-Jun	26	x			
30-Jun	29	x			
04-Jul	34	x			
07-Jul	37	x			
11-Jul	41	x			
15-Jul	45/16	x	x		
24-Jul	54/25	x	x		
30-Jul	60				x (bin 1)
31-Jul	61	x			
06-Aug	67			x	
15-Aug	76			x	
25-Aug	86			x	
26-Aug	87				x (mix bin)
30-Aug	91			x	
03-Sep	95			x	
09-Sep	101			x	
16-Sep	108			x	x (mix bin)
06-Oct	128			x	
17-Oct	139			x	x (mix bin)

Each compost pile was monitored for temperature by inserting a 50 cm long temperature Ni-Cr-Ni probe into the five monitoring locations in the bin. The five monitoring locations were located at the four corners of the bin and in the middle (named: centre, FL (front left), FR (front right), BR (back right), BL (back left)). The probe was inserted into the pile half way its length. The pH and moisture monitoring were conducted according to the temperature measurements, using respectively a 10.6 cm long pH probe and a 10.4 cm long moisture probe.

The moisture meter is intended as a relative indicator of the moisture level. It provides an instantaneous reading, giving in a number between 0 (dry) and 10 (wet).

The units of the rapitest moisture meter were as follows:

- 0 – 3 : dry (moisture content below 20%)
- 3 – 6 : moist (moisture content 20 - 50%)
- 6 – 8 : moist – wet (moisture content 50 - 80%)
- 8 – 10 : wet (moisture content above 80%)

The scale of the rapitest pH meter was as follows:

- 3.5 – 5.5 : acid
- 5.5 – 7 : acid – neutral
- > 7 : alkaline

The measuring locations were the monitoring points for all the parameters at a varying depth depending on the length of the probe. The pile dimension was determined at the beginning, during and at the end of the composting process by measuring the height of the pile with a stick. The team determined the weight of the initial mass of the content of each bin using a digital balance and the final mass of the combined pile (mix of bin 1 and 2) at the end of the period using also a digital balance.

6.3.7 Laboratory analysis

6.3.7.1 Sampling procedure

Sampling occurred according to the compost sampling for laboratory analysis (Woods End Research laboratory, 2000).

Two types of sampling were used:

- grab sampling: specific locations of the mass. Occurred in June 2003 and was abandoned because it was not representative
- composite sampling: material is representative of the general mass. Occurred in August, September, October 2003 and in July and September 2004.

Composite sampling method:

- The pile was thoroughly turned with a spade
- With an auger bore samples were taken from 9 locations. The sampling location included the five monitoring points and the middle of each side of the bin. Each sample was taken over the entire depth of the pile.
- The samples were thoroughly mixed in a bucket by stirring with a trowel.

Sampling frequency:

Sampling of the compost occurred according to the schedule mentioned in the tables 6.3 and 6.4.

6.3.7.2 Analysis of compost material

Immediately after sampling the samples were divided into 5 sub-samples, weighed, put into oven-dried petri dishes of which four were dried at 105 ^{0}C and one at 40 ^{0}C for nitrogen determination. After drying, the moisture content of the samples was measured followed by grinding. The samples were chemically analyzed using different standard methods (table 6.5).

Table 6.5: Test methods for compost characterization

Compost parameter	Unit	Description test method	Reference
pH	-	Measuring water extracts with electronic pH meter. 1:5 and 1:10 slurry method	Cornell Composting (CC) (Trautmann and Richard, 1995)
Soluble salts (Electrical Conductivity)	mS/cm	Measuring water extracts with electrical conductivity meter 1:5 and 1:2 slurry method.	Recommended soluble salts tests (Gartley, 1995)
Total Nitrogen	%	Total nitrogen by Kjeldahl digestion	Soil & Plant Analysis Laboratory Manual (ICARDA) (Ryan et al., 2001)
Phosphorus	%	Atomic Absorption spectrometer (AAS)	ICARDA
Potassium	%	AAS	ICARDA
Calcium	%	AAS	ICARDA
Magnesium	%	AAS	ICARDA
Moisture content	%, wet weight basis	Oven drying at 105 ^{0}C for 24 hr; sand box – and pressure method	- ICARDA - CC (Trautmann and Richard , 1995)
Maturity	%	Seed germination and relative growth of root length with distilled water and compost extracts	Wu and Ma, 2001
Organic matter	%, dry weight basis	Loss on ignition (LOI) at 550 ^{0}C for 3 hrs	Recommended soil organic matter test (Schulte, 1995)
Organic carbon	%, wet basis	Walkley-Black titration method	- ICARDA - Recommended soil organic matter test (Schulte, 1995)
Heavy metal (Zn, Cu)	ppm	AAS	ICARDA

6.3.8 Sanitation procedures

To prevent contamination between samples, sampling equipment was sanitized (cleaned) after the samples were collected. After each turning of a bin the equipment was also cleaned to prevent mixing of material of the two bins. The measuring equipments were also cleaned after each daily routine monitoring.

The sanitation procedures entailed:

- scrubbing the probe of measuring equipment with clean soft tissues
- thoroughly rinsing with tap water the sampling trowel, bucket, spade and auger bore
- wearing of gloves and dust masks by all the members of the project team

6.4 Results

A comprehensive monitoring program was completed to document the performance of the composting process. The results of the monitoring program are provided in the following discussion.

6.4.1 Initial materials, mixing and pile weight

The mass balance for the organic - and the composted material is presented in the Tables 6.6 - 6.9. In 2003 in total 708 kg of waste was collected and composted; 60 kg compost was produced. In 2004 in total 866 kg of waste was collected and composted; 92 kg of compost was produced (table 6.6).

Table 6.6: Total feed stock quantification

Feedstock	Quantity (kg) (wet weight) 2003	Quantity (kg) (wet weight) 2004
Food waste (FW)	660.47	501.82
Sawdust (SW)	15.37	39.18
Yard waste (grass) (GW)	32.37	9.97
Process waste (PW)	-	314.85
Total	708.21	865.82

The organic waste mixture composted had the following rates (wet weight):

- 2003: KW : SW : GW – 93 % : 2 % : 5 %

- 2004: KW : SW : GW : PW – 58 % : 5 % : 1 % : 36 %

It is obvious from these tables that kitchen waste (food waste) is the dominant waste component. This was because the series of composting runs was done mainly on residential organic waste. Wood shavings were added to act as a bulking agent to enhance aeration and to adsorb excess liquids.

Table 6.7: Mass balance 2004

Date	Type of waste/amount (kg)				Bin no.		Total (kg)
	KW	SW	GW	PW	1	2	
3 May	59.83	6.65	4.6		x		**71.08**
4 may	57.78		0.39	74.2	x		**132.36**
5 may	19.13	7.73	4.99			x	**31.85**
6 May	11.63			9.65		x	**21.29**
7 May	47.59					x	**47.59**
10 may	41.11					x	**41.11**
11 May	34.5			25.5		x	**60**
12 May	56.77					x	**56.77**
13 May	61.60	4.1				x	**65.70**
14 may		4.7					**4.7**
!7 may	48.83 63.24	10.5 5.5		205.5	x	x	**59.33** **274.24**
Total (gr)	**501.82**	**39.18**	**9.98**	**314.85**			**865.73**

Table 6.8: Mass balance 2003

Date	Type of waste/amount (kg)			Bin no.		Total (kg)
	KW	SW	GW	1	2	
06/02/2003	2.48	5.41	11.23	x		**19.12**
03-Jun	3.96			x		**3.96**
04-Jun	4.99			x		**4.99**
06-Jun	5.62		6.98	x		**12.6**
09-Jun	6.58			x		**6.58**
10-Jun	16.41		1.61	x		**18.02**
11-Jun	12.23			x		**12.23**
12-Jun	17.65			x		**17.65**
13-Jun	22.81		1.53	x		**24.34**
14-Jun	2.83			x		**2.83**
16-Jun	39.48			x		**39.48**
17-Jun	17.24		2.63	x		**19.87**
18-Jun	12.39	6.48		x		**13.03**
19-Jun	10.87		2.8	x		**13.67**
20-Jun	26.19			x		**26.19**
23-Jun	17.84			x		**17.84**
24-Jun	21.6			x		**21.6**
25-Jun	28.28			x		**28.28**
26-Jun	25.76	2.41		x		**28.17**
27-Jun	31.44			x		**31.44**
30-Jun	38.72	3.69		x		**42.41**
02-Jul	19.96		2.97		x	**22.93**
03-Jul	22.74				x	**22.74**
04-Jul	41.18	3.21			x	**44.39**
07-Jul	67.80				x	**67.80**
08-Jul	19.78				x	**19.78**
09-Jul	72.73				x	**72.73**
10-Jul	47.29		2.63		x	**49.92**
11-Jul	3.63				x	**3.63**
Total (gr)	**660.47**	**15.37**	**32.37**			**708.21**

Table 6.9: Change in weight from fresh (initial) waste to final compost

	$W_{initial}$ waste 2003 (kg)	$W_{initial}$ waste 2004 (kg)	W_{final} compost 2003 (kg)	W_{final} compost 2004 (kg)
Bin 1	404.29	482.19		
Bin 2	303.92	383.54		
Total	708.21	865.73	60.10	91.76
Mass reduction (%)			91.5	89.4

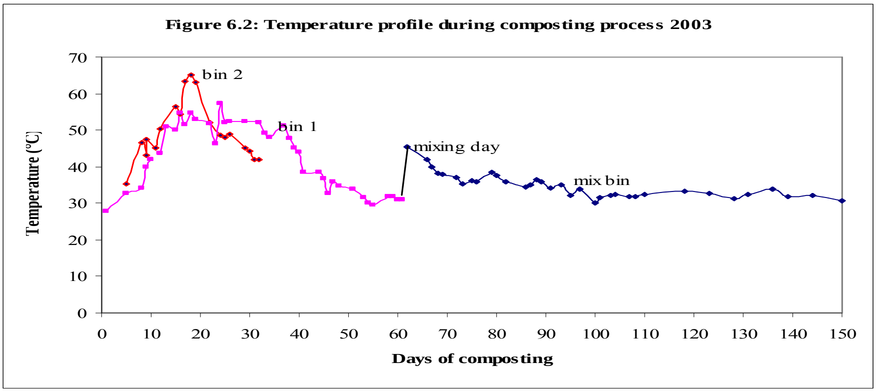
At the end, the global mass (708 kg in 2003 and 866 kg in 2004) had been reduced to about 60 respectively 92 kg (table 6.9). Based on these data it is calculated that an average mass reduction of 90 % was achieved. According to WHO (1991-1993), from 1 ton of waste, 350-500 kg of compost can be produced depending on waste composition and climate. The compost produced was far below this figure which indicated that a lot of material was lost by evaporation, gas conversion and leaching. Some material was also lost through the openings of the wire at the bottom of the bin.

6.4.2 Composting process

The composting process was tracked by monitoring critical parameters (moisture content, temperature, pH, salinity) on a routine basis.

6.4.2.1 Temperature

The temperature readings were recorded every day during the composting operations. In 2003, the temperature (centre) for bin 1 was in the range 31 - 45 ^{0}C from day 1 to day 12 (figure 6.2), which is well close to the optimum range of 15 – 40 ^{0}C for mesophilic bacteria which colonize the compost during this period. For bin 2 this temperature range was found from day 1 to day 9. From day 12 to day 39 the temperature range was 45 – 57.4 ^{0}C (bin 1), which is close to the range for thermophilic bacteria and fungi to colonize and degrade the waste. It is noted that temperatures above 50 ^{0}C were maintained for 12 days. For bin 2 this temperature range was 45 – 65 ^{0}C from day 10 to day 26. From day 39 to day 61 the temperature was in the range 30 – 44 ^{0}C (bin 1) and after day 26 the temperature of bin 2 dropped to 42 ^{0}C.



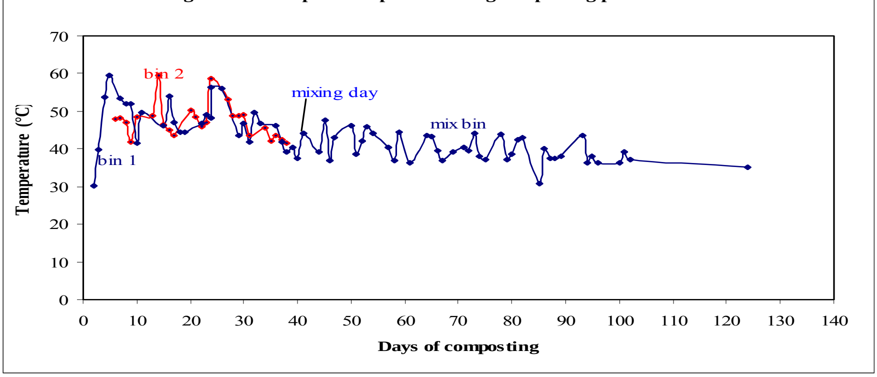
Bin 1 represents the temperature profile for bin 1; Bin 2 represents the temperature profile for bin2 and Mix bin represents the temperature profile after mixing bin 1 and 2 at day 62.

In this period the content of both bins was drastically dropped therefore not favouring the temperature to rise and the increase of microbial action. At this point (day 62) the content of bin1 and 2 were mixed to create a mix bin. The pattern of the temperature of this mix bin was measured to follow the stabilization of the compost. The intensity of microbial action subsided with stabilization of the waste towards the end of the composting process. At mixing, the temperature increased to 45 ^{0}C. Due to the final levelling off of the temperature (31 ^{0}C), black colour and absence of odours it was assumed that the exhaustion of readily biodegradable compost feed components was achieved. It was assumed that the waste was ripened after day 100.

In 2004 the same trend in the temperature profile could be observed (figure 6.3). In both bins the temperature increased (± 60 ^{0}C) followed by a decrease (38 ^{0}C). For 10 days the temperature maintained above 50 ^{0}C. Also here the content of the two bins was mixed (day 41), whereby the temperature increased (44 ^{0}C) to finally levelling off (35 ^{0}C).

As noted earlier, the temperature profile is a reflection of intensity of aerobic microbial activity. As such, the temperature profile can be used to assess the speed as well as the extent of the composting process. According to Nelles et al. (2004) and Hogg et al. (2002), temperature levels of ≥ 55°C must maintain for longer time (14 days) or above 65°C for 7 days to produce good compost. In 2003 the temperature levels of ≥ 55°C was for 5 days and in 2004 this temperature level was maintained just for 3 days which is not enough to produce a mature compost as will be explained in paragraph 6.4.3. The reason for not achieving prolonged high temperatures can mainly be ascribed to the size of the pile.

Figure 6.3: Temperature profile during composting process 2004



Bin 1 represents the temperature profile for bin 1; Bin 2 represents the temperature profile for bin 2 and mix bin represents the temperature profile after mixing bin 1 and 2 at day 41.

6.4.2.2 pH

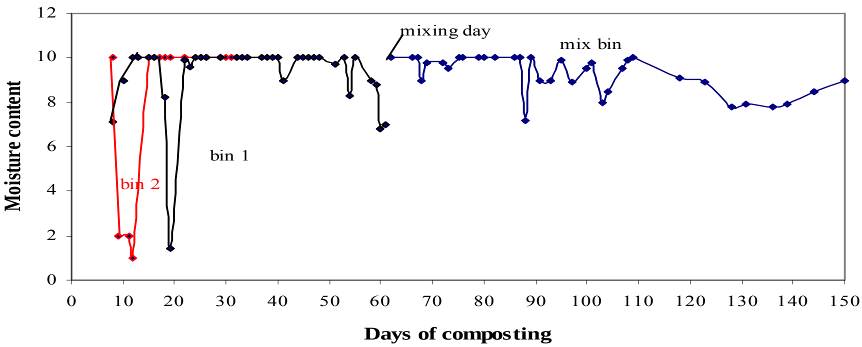
The pH for raw waste (feed material) was around 7, and during composting the pH measured in the bins ranged between 7 – 7.5; both were close to neutral. It can be noted that the final product had a pH of 7.5 (Fuchs et al., 2001). The pH measured at the end of the process in the bins and the pH of the final product measured in the laboratory (pH > 8) was not corresponding. This could be ascribed to the apparatus used during monitoring; in the laboratory an extract was used to measure the pH and in the compost bin a compost pH meter was used.

6.4.2.3 Moisture content

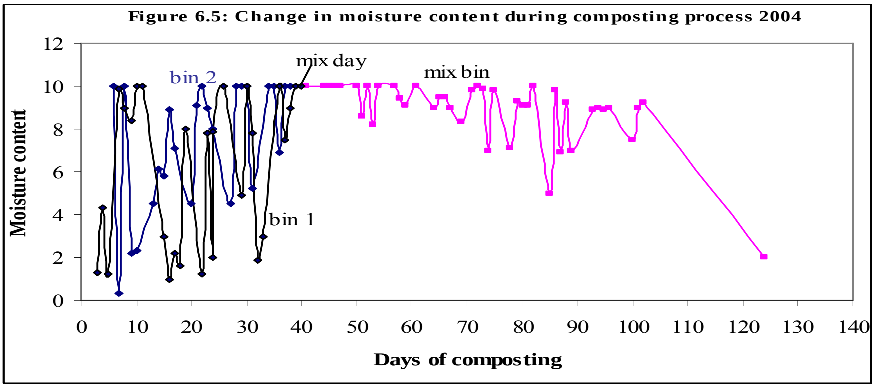
In 2003 the moisture content at the beginning of the compost process was 7 (moisture content: 50 – 80%) and during composting mainly around 10 (>80%) for both of the bins (figure 6.4). This high moisture content was ascribed to rainwater percolating the compost because the bins were not adequately closed (covered with plastic sheets). During windy days the sheets were blown away. If too much water (rainwater) enters the pile, there will be insufficient oxygen to the bacteria, thereby reverting the decay process to anaerobic. This was the reason that in 2003 a high leachate production was observed (photo 6.4) and problems with offensive odours were encountered. At the end of the process the moisture content dropped to 8 (50 – 80%) to increase again to 9 (>80%) although that period represented the dry season (September).

In the laboratory the moisture content of the final product was measured at 56 %. The difference is ascribed to the method applied and apparatus used to measure the moisture content. The moisture content in the laboratory was done according to the thermo-gravimetric measurement technique (direct method) using a sample taken over the whole profile of the compost pile. The moisture content measures the ratio between the weight of the water in the compost sample and the weight of the compost sample. The moisture meter (probe) used in the field measures the moisture by using the dielectrical constant (indirect method). According to Rynk (2000b), the precision and repeatability of these moisture sensors (probes) are not nearly as good as properly conducted gravimetric methods. The probe averages the water content over the entire length of the probe (15 cm). Contact between compost and probe creates an electrical circuit; changes in the circuit frequency (amplitude) are a measure of the water content in compost (Muñoz-Carpena, 2004). The surface dielectrical constant is a function of the surface soil moisture: the wetter the surface, the higher the dielectric constant. The effect of the influx of rainwater was probably measured by the probe because of the higher dielectric constant of water (80) compared with organic matter (4) (Atkins et al., 1998). The outliers (moisture content ≤ 2) measured were probably due to misreading, because before reading, the probe must stay for longer than one minute in the compost to stabilize. Another reason is attributed to the bad compost-probe contact, which can be explained by the surface roughness and relatively dry surface of the fresh waste during filling. Surface with exceeding roughness or a loose medium yields less accurate results.

Figure 6.4: Change in moisture content during composting 2003

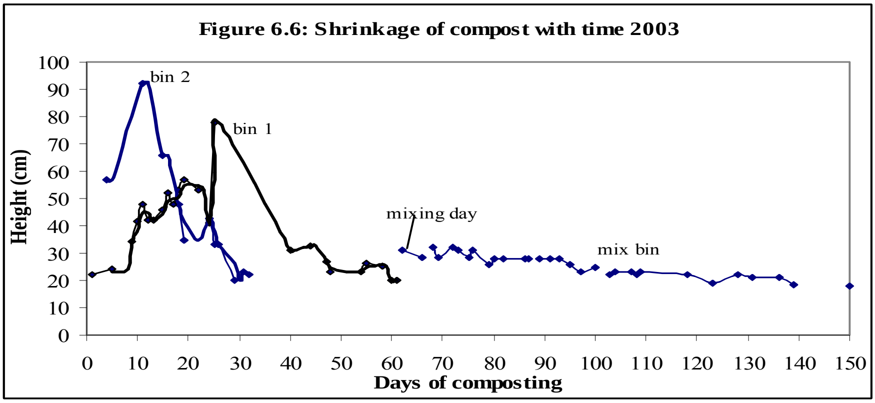


In 2004 the start material was very dry (moisture content below 20%) and during the process it reached values of 10 (>80%) with a sharp decrease to 2 (< 20%) (figure 6.5). The moisture content of the final product measured in the laboratory had a value of 55%. Also here the moisture content at the end of the process and the final product were not comparable. The same mechanisms as ascribed for 2003 are applicable for 2004, except for the fact that in 2004 we had no problem with rainwater. Lower values can be explained by the dryer surface of the compost. The moisture contents of bin 1 and 2 varied strongly before mixing, this can be attributed to the daily addition of fresh material which had a relative dryer surface leading to lower dielectric constant. The loose structure of the fresh waste resulted also into a bad contact between probe and the material which limits the probe's effectiveness at measuring.

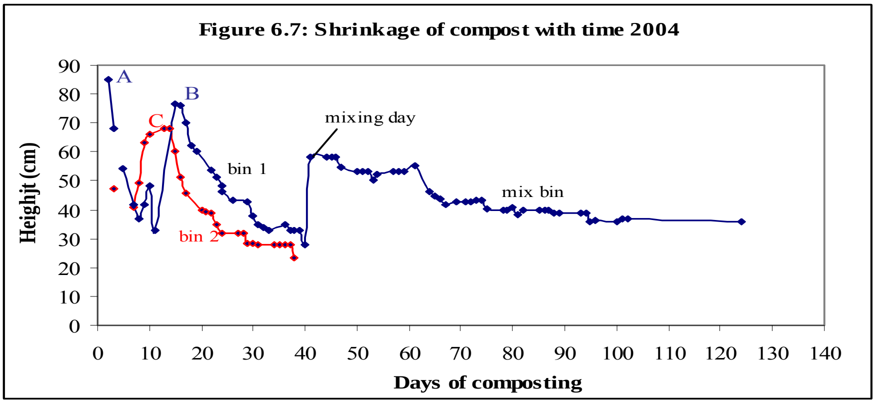


6.4.2.4 Shrinkage of compost

With the progress of the composting process, the volume and weight of the compost decreased. Data obtained after monitoring the changes in the reduction of the compost are presented in figure 6.6 for 2003. It can be noted from figure 6.6 that on day 25 bin 1 was completely filled up to 78 cm. During filling the waste mass (bin 1) started to decrease and turning caused a little increase in height of the mass. After day 60 the waste shrunk drastically (20 cm) and on day 62 the mixing of bin 1 and 2 was necessary to maintain higher temperature levels. The pile increased to 32 cm to drop to 18 cm at the end of the process. A volume reduction of 77 % was achieved. This implies that composting facilitates a very considerable reduction of the volume of waste. It can further be noted that the high shrinkage is observed for solid waste that contained relatively easily biodegradable waste components.



In 2004 the same waste reduction trend was observed (figure 6.7). On day 2 bin 1 was completely filled (85 cm) but due to the fast decomposition the bin was refilled (77 cm) on day 15. On day 13 bin 2 was completely filled up to 71 cm followed by a reduction up to 29 cm on day 34. On day 41 bin 2 was mixed with the content of bin 1 increasing the height up to 57 cm to decrease afterwards to 34.5 cm on day 124.



A: bin 1 completely filled; B: bin 1 refilled; C: bin 2 completely filled

6.4.2.5 Indicator organisms

There is a complex food web at work in the compost pile. No microbiology laboratory work was done for organisms because it felt beyond the scope of this study and besides none of our laboratories did this kind of research on the various micro-organisms in waste material. Only a listing is made of the observed organisms in the pile.

The following organisms were observed:

Micro-organism	**Invertebrate**
- Actinomycetes (filaments that look like gray spider webs stretching through the compost)	- worms/maggots (explosive increase in week 2 – 8, followed by a decrease. At the end of the process no maggots were observed)
- Fungi (grow as white fuzzy colonies on the compost surface)	- snails
	-spiders
	- millipedes were observed from the beginning until the end of the composting process
	- beetles
	- small cockroaches were observed from the beginning until the end of the composting process
	- ants were observed from the beginning until the end of the composting process
	- flies after 4 - 6 weeks the population of flies reduced strongly for disappearing totally
	- small frogs could be noticed in the first weeks

Noted comments of concern on field data in 2003 were the following:

- increase of odour in process weeks 2- 8 (especially during turning)
- leachate very strong in weeks 5 – 8 (photo 6.4)
- explosive increase of maggots/worms in weeks 2 – 6
- flies: nuisance of flies in the surrounding until week 6.

In 2004 there were no problems with odours and leachate formation.

Photo 6.4: Leachate production during composting in 2003

6.4.3 Compost quality

The product quality was measured to control the completion of the composting process. Several samples were taken in different periods. In the chemistry and soil laboratory a comprehensive series of analyses for compost were implemented. The results (of the last measuring period) are compared with quality criteria for composts and are presented below.

Germination test for compost maturity

Maturity of the compost was assessed according to the seed germination assay (Wu and Ma, 2001). Capucijner seeds (*Vigna sinensis savi*) were sown on filter paper moistened with extracts of compost (ratio 1:8; 1:25 and 1:5 extract dilution) for three days. Germinated seeds were counted (G) and radicle growth (L) measured (table 6.10). The germination index was calculated according to the formula $Gi = G/G_0 \times L/L_0 \times 100$, where G_0 and L_0 are values obtained using distilled water (control) (Gariglio et al., 2002; Burger et al., 1999). The global germination index is the average of 1:8, 1:5 and 1:25 extract dilution (water : dry compost). From the results of the seed germination test (table 6.10a-b) it can be concluded that the germination rate is good meaning the compost is ready to use. On the other hand it can also be noticed that the water-treated seeds germinated much better then the seeds in compost extract, meaning that the compost has a high phytotoxicity. If we look for differences in how long it took for the radicles to emerge (to reach a length of 2-4 cm) (table 10 e-f), we noticed that there is a substantial delay in the seeds in compost extract and also the germination index was far below the desirable limit which indicates that the compost is not ready for use yet (agriculture purposes). Another feature that was observed is that most of the compost treated seeds get mildew and died off after three days. The compost needs to sit and 'cure' or 'age' for a longer time, with exposure to air (dry and aerobic) to break down the phytotoxic effect.

Table 6.10a: Germination test 2003

Seed germination at different time (hours) intervals						
Compost extract	24 hrs	48 hrs	72 hrs	96 hrs	Average	Average germination rate (%) (G)**
Aug/03 (extract I - 1:5)	19	19	19	Dried, 1 mildew	19 of 20	95
Sep/03 (extract II - 1:5)	19	19	19	dried	19 of 20	95
Oct/03 (extract III - 1:5)	19	19	19	Dried, 1 mildew	19 of 20	95
Control DW	18	18	18	18, Elongation of radicles	18 of 20	90 (G_0)
Limit value*						>75

*Hogg et al., 2002
**G = seeds germinated/total seeds x 100

Table 6.10b: Germination test 2004

Seed germination at different time (hours) intervals						
Compost extract	24 hrs	48 hrs	72 hrs	96 hrs	Average	Average germination rate (%) (G)
Extract II (1:8)	7	7	7	Elongation of radicles	7 of 10	70
Extract III (1:25)	8	9	9	idem	9 of 10	90
Extract IV (1:5)	10	10	10	idem	10 of 10	100
Control DW	10	10	10	idem	10 of 10	100 (G_0)
Limit value						>75

Test of unblended and blended compost (2004) with crest seeds (*Lepidium sativum*) done in the laboratory of the Department Soil Management and Soil Care (Ghent University) showed the opposite results (table 6.10c-d). The germination rate was very low which indicated a high phytotoxicity which is dangerous for plant growth. This high phytotoxicity could be ascribed to the high salt content (high EC value in table 6.11) and the presence of heavy metals (table 6.16) (Stoffela et al., 1997). The test showed that the germination rate changed significantly after blending the compost with soil as seen in tables 6.10c-d.

Table 6.10c: Germination test – unblended compost 2005 (with compost produced in 2004)

Seed germination at different time (hours) intervals					
Compost mix	Day 1	Day 5	Day 7	average	Average germination rate (%) (G)
Fine compost A	0	17	Dried out	17 over 50	34
Fine compost B	1	20	Dried out	20 over 50	40
Coarse compost A	1	25	Dried out	25 over 50	50
Coarse compost B	3	15	Dried out	15 over 50	30
Distilled water A	48	48		48 over 50	96 (G_0)
Distilled water B	50	50		50 over 50	100 (G_0)
Limit value					> 75

Note: radicle length of both composts was shorter than 1 cm.

Table 6.10d: Germination test – blended compost 2005 (with compost produced in 2004)

Seed germination at different time (hours) intervals					
Compost mix	72 (day 2)	96 (day 4)	120 (day 5)	average	Average germination rate (%) (G)
Fine compost and soil (1:1) A	7	10	18	18 over 50	36
Fine compost and soil (1:1) B	4	5	17	17 over 50	34
Coarse compost and soil (1:1) A	13	20	29	29 over 50	58
Coarse compost and soil (1:1) B	12	18	30	30 over 50	60
Soil	34	47	49	49 over 50	98 (G_0)
Distilled water	49	49	49	49 over 50	98 (G_0)
Limit value					> 75

Note: germinated seeds on the fine compost: soil mix died of after one week. Germinated seeds on the coarse compost-soil mix were still alive after two weeks. The coarse compost was moist and the presence of fruit kernels led to a relatively low amount of compost in contrast with the dry fine compost which represented a higher amount in the mixture (1:1). The relatively higher amount of fine compost in the mixture resulted in higher phytotoxic effects leading to the dying of the germinated seeds (lower germination rate).

Table 6.10e: Germination index 2003

Radicle length at different time (hours) intervals					
Compost extract	24 hrs	48 hrs	72hrs	96 hrs	Germination index (%) (Gi)
Aug/03 (extract I)	Radicle emerge		0-1 cm (11) 1-2 cm (4) 2-3 cm (4)	Elongation of radicles (> 12 cm)	35
Sep/03 (extract II)	idem		0-1 cm (11) 1-2 cm (8)	idem	
Oct/03 (extract III)	idem		0-1 cm (4) 1-2 cm (12) 2-3 cm (3)	idem	26
Control DW (L_o)	idem		0-1 cm (1) 1-2 cm (5) 2-3 cm (12)	idem	
Limit value					> 90

Table 10f: Germination index 2004

Radicle length at different time (hours) intervals					
Compost extract	24 hrs	48 hrs	72 hrs	96 hrs	Germination index (%) (Gi)
Extract II (1:8)	5 mm (2) 10 mm (4) 12 mm (1)	7 mm (2) 15 mm (2) 22 mm (3)	7 mm (2) 20 mm (2) 30 mm (2) 40 mm (1)	Brown colouring	43.75
Extract III (1:25)	10 mm (4) 15 mm (4)	15 mm (3) 17 mm (3) 26 mm (3)	15 mm (4) 25 mm (3) 30 mm (2)	Brown colouring	56.25
Extract IV (1:5)	10 mm (4) 15 mm (6)	12 mm (5) 17 mm (4) 20 mm (1)	12 mm (5) 17 mm (4) 20 mm (1)	Mildew Brown colouring	12.5
Control DW (L_0)	5 mm (4) 10 mm (6)	7mm (1) 10 mm (4) 12 mm (1) 20 mm (4)	10 mm (2) 20 mm (4) 25 mm (1) 30 mm (2) 40 mm (1)	Elongation of radicles	

Counting of the radicle length of the numbers of germinated crest seeds (blended compost) showed the following results:

- on the average 12 germinated seeds of coarse soil-compost blend had a length of $\geq$ than 2 cm

- 45 germinated seeds of the control (distilled water and soil) had a length of ≥ than 2 cm.

Table 6.10g presents a global view of the germination rate and germination index.

Table 6.10g: General results germination test

Extract	Germination rate (%)			Global Gi (%)		
	2003	**2004**	**2005**	**2003**	**2004**	**2005**
Control	90	100	98			
Compost	95	87	59	31	37.50	16
Limit value	>75			> 90		

The difference in the results of 2003 and 2004 against 2005 is attributed to the fact that in 2003 and 2004 different types of seeds, 'capucijner', were used in comparison with 2005 where crest seeds were used. The last are very small in comparison with the first one and this could influence the germination. Crest seeds are internationally applied for germination rate tests, so it can be concluded that the results obtained from the cress seeds are reliable.

Electrical Conductivity (EC)

With regard to soluble salt (measured as electrical conductivity) the results were far above from limits (table 6.11). The compost was diluted with water using a mass ratio of 5:1 (water : dry compost), shaked for one hour, filtered and the EC of the filtrate was measured. According to Johnsson et al. (2005), high dilution rate (≥ 5:1) has at least two advantages compared to the saturation paste method, (1) the dilution is homogenous throughout the sample which makes the EC measurement more accurate and repeatable and (ii) at a dilution ratio gravity filtration could be used rather than vacuum filtration for collecting the extracts which made the analyses fairly simple. At low dilution ratio salts do not diffuse fast enough from the particle interiors to the water extractant (salt is incompletely extracted) (Johnsson et al., 2005).

High EC of compost indicates high salt content, which could be due to high soluble salt content (Na, K, chloride, nitrate, sulphate, and ammonia) in the waste. A high concentration of soluble salts in the plant growth medium is detrimental to germinating seeds and to plant growth because seeds/plants can not obtain water from the soil or medium. This is approved because after day three of the seed germination test most of the radicles (with small leaves) showed burning features (they died of). In general the EC values decrease with time due to decomposition of organic material (Wu et al., 2000). According to Dickerson (1999) and Fuchs et al. (2001), EC may not exceed 3.5 mS/cm because even plants considered to be robust do not germinate well. Letting the compost cure in exposed piles for several months can reduce salt content (Mazza et al., 2001).

Table 6.11: Conductivity measurements in mS/cm

period	**2003 (start June)**	**2004 (start May)**
	1:5 (C:W)	**1:5 (C:W)**
August	11.72	
September	10.02	7.12
October	10.26	
Limit value*	2.7	

* VLACO: www.vlaco.be/images/content/TF_akkerbouw.pdf; Fuchs et al., 2001

Organic carbon and organic matter

The fresh material used for the composting process had a moisture content of 75.5 % with an organic matter content of 77 % and a carbon content of 45 %. The carbon content of the compost samples were measured according to the Walkley - Black method. The carbon content declined during composting to 29 % in 2003. The carbon content of the compost decreased rapidly in the beginning, when most of the organic matter decomposed, and then reached a constant value at the end of the composting period. In general total nitrogen content would then increase but according to Table 6.12 there is a slight decrease. This means that the C/N ratio decreased during composting (Pullicino, 2002). In 2004 the carbon content was still high which indicated that the materials were not adequately broken down (reduced carbon mineralization). This can be attributed to the higher presence of wood shavings and kernels from process (fruit) waste. Wood shavings contain a higher portion of lignin, a complex polymer, which is proven to be resistant to microbial degradation (Richard, 1995). After degradation of the easily degradable compounds (the kitchen waste) the more resistant carbon components (lignin) are left, presenting a residual amount of carbon in the compost. This component will take therefore more time to decompose, hence, the high carbon content measured in the compost.

Table 6.12: Carbon content (%)

period	2003 (start June)	2004 (start May)
July		46.8
August	33.7	
September	29.9	44.42
October	29.2	
Limit value*	25	

* VLACO**:** www.vlaco.be/images/content/TF_akkerbouw.pdf

pH

The results of the pH analysis showed that the compost had high pH values (table 6.13). This elevated pH will limit the availability of micronutrients (Cu, Fe, Zn and Mn) to the plants and can impair the development. This pH is generally a sign of insufficiently mature compost (Fuchs et al., 2001). Aging the compost for three to four months will lower its pH (CIWMB, 2001).

Table 6.13: pH measurements

period	2003 (start June)	2004 (start May)
August	8.7	
September	8.67	8.59
October	8.41	
Limit value*	7.5	

* Fuchs et al., 2001

Nutrients

The nutrient analysis showed high nutrient values (table 6.14). The nutrient levels were quite high; enough to degrade the organic carbon present in the compost, but the temperature of 55°C did not last long enough at that level which hindered complete degradation.

Table 6.14 a: Nutrient measurements (%)

period	2003 (start June)			2004 (start May)		
	N-tot	P-tot	K-tot	N-tot	P-tot	K-tot
August	1.67	1.70	3.64			
September	1.75	2.0	3.58	1.92	0.765	3.02
October	1.62	2.1	3.57			
Limit value*	1.2	0.6	1.1	1.2	0.6	1.1

Table 6.14 b: Ca-Mg measurements (%)

period	2003 (start June)		2004 (start May)	
	Ca tot	Mgtot	Ca tot	Mgtot
August	4.71	4.21		
September	5.35	5.39	2.33	5.08
October	5.48	5.1		
Limit value*	2.6	0.4	2.6	0.4

***** VLACO**:** www.vlaco.be/images/content/TF_akkerbouw.pdf

C/N ratio

The results of the C/N ratio measurements (table 6.15) are close to the recommended range, but are still above the limit. When compost with a high C/N ratio is used, the micro-organisms will sequester some of the nitrogen available in the soil to degrade the organic carbon of the compost and causing a nitrogen deficit for the plants (Fuchs et al., 2001). Again, it is clear that the compost needs to be aged for longer time.

Table 6.15: C/N ratio measurements

period	2003 (start June)	2004 (start May)
August	20.18	-
September	17.09	23
October	18.02	-
Limit value*	<20	

***** VLACO**:** www.vlaco.be/images/content/TF_akkerbouw.pdf

Moisture content

According to literature the moisture contents were outside the desired range (table 6.16).

Table 6.16: Moisture content measurement (%)

period	2003 (start June)	2004 (start May)
Start	75.5	84.45
July	72.78	66.31
August	65.48	62.03
September	65.55	55
October	56.37	
Desired range*	28 - 48	

* Johnsson et al., 2005

In 2004 the waste material was dark and wet after one month, with no leachate production and no initial material could be recognized. This fast decomposition can mainly be ascribed to the fact that the compost bins in 2004 were covered from all sides with corrugated Aluzinc plates compared with 2003 where the bins were covered with plastic bags but not efficiently enough to prevent rain water entering the bins. Rain water could easily percolate into the compost with the result that the excess of water slowed down the composting process. The excess of water created problems with leachate production and malodours during composting. This leakage water was set free due to saturation condition.

Heavy metals

The Cu (copper) concentration was below the limit value as set by USEPA (Dickerson, 1999) (table 6.17). For Zn (zinc) the concentration was far above the limit (table 6.17). The heavy metal content is determined by the nature and origin of the waste (Huang, et al., 2005). Probably some food crops accumulate heavy metal (zinc) by the uptake from the soil matrix or from the fertilizer (manure) applied. It is not clear from which agriculture area the vegetables came so it is difficult to make a correlation between applied fertilizer and region. It is observed that the metal contents of Cu and Zn significantly increased during the composting process; according to Huang et al. (2005) and Woodbury (1993), this increase may be explained by the loss of mass due to oxidizing of organic matter during the biochemical decomposition.

Table 6.17: Heavy metal measurements - AAS (ppm*)

Period	2003 (start June)			Period	2004 (start May)		
	Zn	Mn	Cu		Zn	Mn	Cu
August	527	174	19	May	52	65	8.7
September	641	168	12	July	425	155	21.3
October	637	210	15	September	598	185	24.5
Limit value**	400		165		400		165

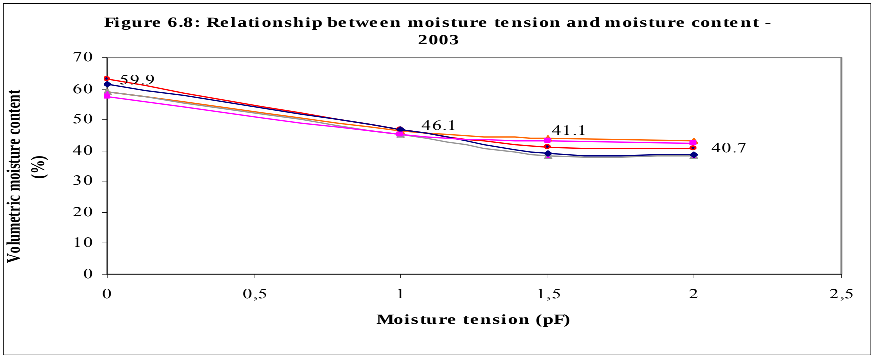
*values are in weight basis and can be transformed to volume basis by taking into account bulk density of compost ($0.27 gr/cm^3$)

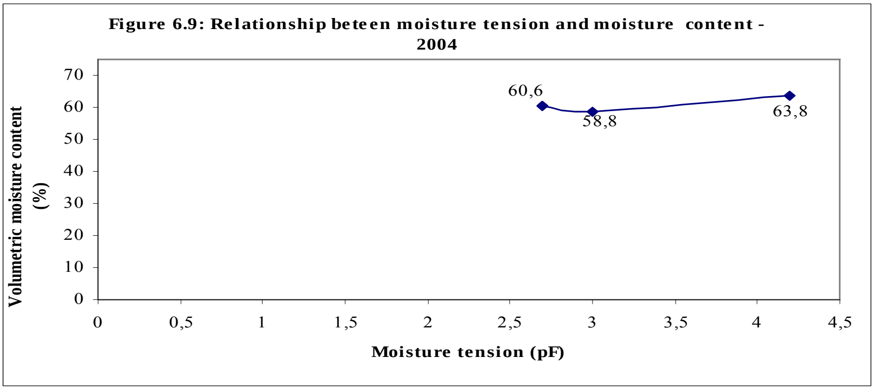
** Dickerson, 1999; Fuchs et al., 2001

The compost samples were also analysed with the HACH spectrophotometer, the results showed a big difference with the analyses done in the soil lab with the AAS. This could be due to the different equipment used, condition of the equipment and the influence of human mistakes. The metal content was as follows: nickel 0.052 μg/l; cadmium 2 μg/l; copper (Cu) 111.68 μg/l and Lead 36 μg/l. Other results were: Calcium 0.005 mg/l; phosphorous 0 mg/l; Manganese 0.0015 mg/l and Magnesium 0.005 mg/l. According to Gibbs (1994), both techniques (AAS and HACH) produce reliable results but the results can strongly be influenced by the level of skill of the laboratory personnel. Measurements with the AAS were done by an experienced laboratory assistant, so it is believed that these measurements are more reliable.

Moisture retention

Figures 6.8 and 6.9 show soil moisture curves for compost produced in 2003 and 2004 for different samples. The soil moisture tension test of 2003 was done in the soil laboratory of the University of Suriname with the sandbox method and the test done in 2004 was done in the laboratory of the Ghent University with the ceramic plates (pressure method). From the figures it is noticed that in 2003 the maximum reading for the moisture content was 59.9 % (saturation, 0 atm (atmosphere) = pF 0) and the minimum reading is 40.6 % (pF 2) and stays more or less stable at that point. These values are averages of four replicas. Based on the data presented in figure 6.8 it can be estimated that 'easy available water' is 5 %. This is the percentage moisture (% volume) that releases when the pressure height decreases from -10 cm (pF 1) to -50 cm (pF1.7): 46.1 to 41.1%. According to Abad et al. (1992), the optimum value has to be 55-70% at -10 cm and 31-40% at -50 cm. The calculated 'buffer capacity' was valued at 0.4%. This is the percentage moisture (% volume) that releases when the pressure height decreases from -50 cm (pF 1.7) to -100 cm (pF 2): 41.1 – 40.7%. According to Abad et al. (1992), the optimum value has to be 25-31% at -100 cm. Both parameters were below the limits which can be ascribed to the dimension of the particles of the compost. The tested compost had a maximum grain size of 5 mm and the ideal particle size for the soil moisture tension test is 0.25-2.50 mm. At higher grain size the water is easily drains off at increasing pressure resulting in very low moisture content which does not represent the real moisture condition of the compost. It is clear that grain size played an important role in this test. The compost of 2004 shows a totally different reading, in this case a maximum reading of 63.8 % (15 atm = pF 4.2) and a minimum reading of 60.6 % (pF 2.7) was observed for the moisture content. The percentage moisture at lower pF could not be measured because the amount of compost was not enough. The results in figure 6.9 show high moisture content which is due to the high content of organic material. According to Devitt and Morris (1997), changes in the soil moisture tension which result in small moisture changes indicate a high organic content of the compost. The results of figure 6.9 do not present high changes in the water content which indicated indeed on high content of organic matter. It is remarkable that instead of decreasing, the value of soil moisture at pF 4.2 increased; probably the compost samples shrunk away from the ceramic plates in 15 atm extraction and the reduced flow area would not permit the sample to reach equilibrium. Compost is a loose material, by drying it becomes more crumbled creating a bad contact between compost and plates.





6.5 Other findings and lessons from the study

The year 2003 was the first time we started our experiment and we experienced a lot of problems. At the beginning of the composting process in 2003, the heap produced a bad smell. Staff and students complained about the smell. By turning the compost the smell was reduced and disappeared with the onset of dark colour of the waste and the levelling off of the temperature. In 2004 we had no problems with offensive odours; only during turning we observed some rotting smell. The main problem in the composting process was water which slowed down the composting process and created offensive odours. The test was done in the rainy season and therefore, we had problems of water seeping into the bins. To prevent these problems the bins had to be covered.

For composting to make an impact on solid waste management in Suriname, a larger area of operation needs to be incorporated. Such a measure will also improve economics of scale.

Many people may not be aware of composting, so for composting to take off successfully training of composting plant operators and individuals is needed.

MSW composting as an element of integrated solid waste management should be seen as a technology option for our solid waste problem. Further research is needed to improve compost quality that can be used for agricultural purposes because there will be no market for compost with a bad quality. However, this study does not justify its economic perspective but for encouraging composting the following factors need to be considered:

- the environmental hazards due to dumping
- the development of a fee system for collection and landfilling
- development of mandated waste diversion requirements
- the community perception; if a community perceives MSW composting to be more environmentally friendly and/or less damaging to local environment and property values than land disposal, it may be easier to site an MSW composting facility than a landfill
- the excessive use of chemical fertilizer and pesticides, the price and their impacts on the environment.

For future research, the use of two bins is not recommended because high temperatures can not last long enough. In case the bin method will be applied, at least four bins are advised (to have enough material for mixing) or the best method for future research is the use of the windrow technique (2 elongated heaps)

All homes and individuals who participated in the project had a positive attitude, especially regarding separation of the wastes. The door-to-door waste collection system was used in the study to suit research purposes but was very costly. For future composting projects to be successful, a number of problems have to be tackled:

- co-operation of households/institutions has to be sought in respect of separation of waste; a test collection period of 3-month must be started to investigate the possibilities of source separation combined with an intensive education program,
- availability of waste and accessibility to collection areas have to be improved to enable waste collection vehicles (open trucks) to reach the households easily otherwise costs for hiring or operating waste collection vehicles will go up
- storage of organic waste and containers, in-house preferably, has to be ensured to avoid contamination and scavenging of the waste by animals
- to make composting more attractive and profitable, markets for compost have to be sought and promoted.

6.6 Conclusions

The research showed no successful results. According to the data provided above, none of the waste mixtures of 2003 and 2004 reached maturation by the end of the active composting process. The compost is immature for it contains high levels of organics, extreme pH value and high salt content. The poor overall performance was likely due, in part, to incomplete composting which can be attributed to:

- the temperature: did not reach levels of 55°C long enough (14 days) or 65°C for 7 days to produce good quality compost due to the size of the bin
- the use of wood shavings: these components have lignin in the plant structure. During composting, temperatures did not last long enough at high temperature for the complete degradation of lignin. Due to this incomplete degradation, a residual amount of C was measured.

Results indicated that the compost can not be used for horticulture purposes; it had to be aged for some more time. An important aspect approved by this research is that through active composting we could reach temperatures above 50°C for some days which is one of the limiting parameters in the composting process. Readily degradable materials, such as food wastes and paper products had been significantly composted to a brown-to-black, humic-rich material with minimal odours. This research presented also ideas how to manage the composting process such as the addition of bulking agents (saw dust), turning frequency, and how to reduce odours and too high moisture content. Moreover, it is obvious that with composting of organic waste a mass reduction of 90% can be achieved and that a mix of compost and soil will give better germination results. Finally it may be concluded that composting is technologically acceptable for Suriname because with simple means a valuable product can be produced, but more research is needed in this area. An important aspect will be the management of a compost project, despite the low technology managerial aspects must not be underrated because these can lead to failure of the project.

Chapter 7

Mechanisms to strengthen integrated solid waste management

Chapter 7

Mechanisms to strengthen integrated solid waste management

With this chapter an effort is done to outline challenges and ways to improve the current solid waste management (SWM) system in Suriname. The analyses presented in the following paragraphs will provide a basis for the creation of an integrated waste management system that is affordable and which can contribute to sustainable development as well as achieve improved environmental and human health protection. The ideas presented are based on observations made during the field studies and from waste management literature.

7.1 Introduction

The Surinamese government is responsible for management of solid wastes. However, except for a few cases, the performance of the existing solid waste system is quite low. A wide range of factors accounts for this situation (low performance) as explained in previous chapters. The challenge facing the government and its Ministries (involved with waste management) today is the reorientation of policies, strategies and instruments of municipal solid waste management in order to improve the efficiency of solid waste services.

The objective of this analysis is to provide the government with tools to move away from fragmented and uncoordinated waste management to integrated waste management.

The analysis does not include all possible alternatives for the government but it is expected that this analysis will generate valuable information on otherwise isolated waste information and waste handling practices and will open new avenues for further work in this area.

A sound waste management system is important because:

- solid waste is visible and a politically sensitive service,
- inadequacies in the service has severe implications for the credibility of the government,
- waste management absorbs a considerable share of the Ministry budget and is a provider of public sector employment,
- proper waste management is important for public health and environment.

Figure 7.1 represents the waste management system for long term sustainable development, developed for Suriname. The ISWM system consists of physical – and non-physical components. The physical components (triangle) are a combination of waste management methods: disposal (sanitary landfilling; prevalent method), composting and recycling. Right down the line waste minimization must be promoted. These methods must be supported by the non-physical - or strategic components (circular arrows), otherwise no improvement of the SWM will achieve. Sound waste management will only be possible with:

- appropriate regulatory instruments (waste act, policies, etc.)
- necessary institutional strengthening (trained staff, waste institute)
- structured education campaigns and public participation
- development and establishment of a database system and training of solid waste managers
- pressures to reduce environmental burden (legislation, incentives)
- technical innovations and aspects (improvement of SW collection, good infrastructure)
- access to funds: investments, loans, user charges, etc.

This framework is presented in a circle indicating that the different components will influence each other. If one component is weak or not adequately implemented the system will fail; therefore, the system must be evaluated and updated periodically.

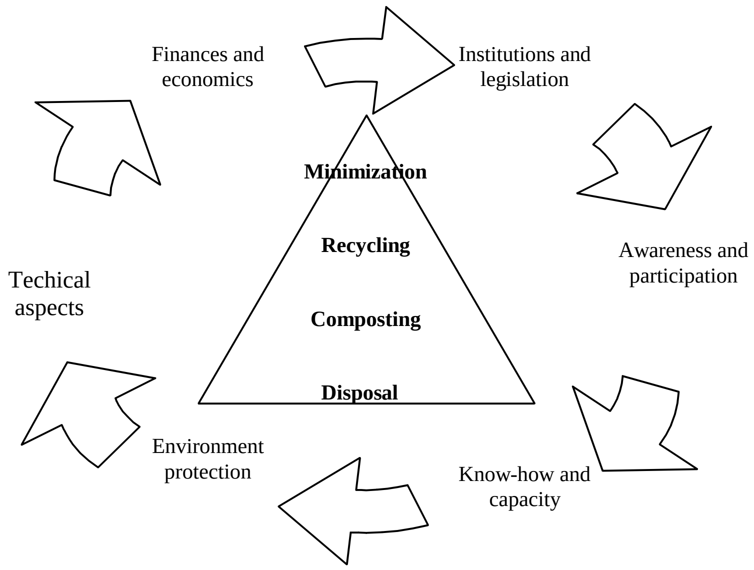


Figure 7.1: Waste management hierarchy for Suriname (priority from top to bottom)

The following areas for improvement of the ISWM system will be discussed below.

7.2 Waste management plan

Municipal solid waste must be managed based upon a government prepared ISWM plan. This plan must assess each portion of the municipal solid waste stream. This will assure that all wastes are managed to protect human health and environment (SWANA, 1994).

VOV must adopt a solid waste management plan to improve the waste management system. The waste plan must consider the country's waste management needs both short term - and long term objectives, consistent with anticipated growth in our population and local economy, including anticipated regulatory and technological developments over the planning period. This long-range view will help VOV to identify sound strategies to manage the waste in a safe, reliable and cost-effective manner, while holding negative environmental impacts to a minimum. This plan has to be updated every five years providing an opportunity to review the efficacy of existing or future laws, regulations and technologies.

The waste management plan must contain the mission, goal, strategies and action areas as required by the government waste or environmental act. The last one is a problem because the waste act is not enacted yet, but despite this limitation the Ministry must take the responsibility to develop such a plan with a planning time horizon of 20 years.

An essential prerequisite for ISWM to be successful is to activate the waste act whereby the waste management plan and the resulting activities require a legal base. A waste act is already formulated but it is not yet ratified by the President. The waste act will help Suriname to move from ‘dealing with waste’ to ‘solid waste management’. In developing the waste management plan VOV should survey existing strengths and weaknesses in the waste management system and include participation of stakeholders to represent the variety of interdisciplinary interest, including public health, economics, engineering and environmental conservation. Involved stakeholders can be: different government agencies, environmental organizations, private sector enterprises, researchers and the general public. Involving multiple stakeholders in the planning process can:

- ensure a suitable combination of waste management alternatives and technologies to meet community needs, environmental protection, legislative requirements, etc.
- provide a sense of belonging and ownership to the waste management options.

Goal

The purpose of the waste management plan is:

- to ensure that solid waste is managed in the most appropriate manner at environmentally sound facilities,
- to protect the health and safety of residents,
- to ensure that effective and practical solutions to reduce Suriname's generation and disposal of solid wastes are implemented
- to minimize waste streams, and
- to identify funding for the solid waste management system.

The plan will assist the NV SAVEB to operate the collection, transportation and disposal of solid waste in an orderly manner and to elaborate strategies for waste recycling and reduction.

Mission statement

Any good waste management system should be preceded by an obviously formulated mission statement. VOV has already formulated a mission statement (3.3.1) but it is very limited which in practice limits the implementation of her responsibilities. Therefore, a new mission statement is formulated.

The mission statement:

VOV is responsible for maintaining the cleanliness and healthful condition of Greater Paramaribo by providing an efficient, structured, environmentally safe, and regulated collection, recycling and disposal of solid waste to society. The department is also responsible for ensuring compliance with environmental laws and regulations.

The responsibilities of VOV include, but are not limited to the following:

- to provide environmentally safe and efficient solid waste collection, recycling, and disposal for our customers,
- to provide public education on the solid waste programs operated and managed by VOV,
- to provide information on developing solid waste programs,
- to provide programs for special wastes, such as medical and household hazardous materials,
- to research and develop processes and policies that will allow efficient and safe solid waste operations,
- to select and maintain equipment and processes that will provide Greater Paramaribo with an efficient, safe, and effective solid waste program,
- to assist customers, officials, and other neighboring communities in solid waste issues,
- to assist students in the study of environmental issues,
- to provide training for employees, customers, and others in the proper and safe methods of dealing with solid waste,
- to license waste haulers and waste disposal facilities,
- to develop guidelines for waste generators to handle, transport and dispose of specific types of waste.

Strategies

To achieve socially and environmentally sound solid waste management, it is essential to formulate strategies on solid waste management.

These strategies might include:

- reducing the damage to environment from waste generation and disposal
- increasing economic benefit by more efficient use of materials
- target for waste minimization
- to remove organic matter from the waste stream and to use it beneficially
- to license all waste operators in order to achieve a high level of service

- extensive input from the public and other stakeholders
- improving waste collection service
- develop and operate recycling facilities
- establishment of a pricing structure for funding solid waste management
- selection and application of appropriate waste management techniques
- promotion of public awareness.

To implement these strategies VOV must take account of economic, environmental, social and institutional aspects not only in the waste production stage but also in its up and downstream stages. The integration can take place at various levels:

1) the use of a range of different collection and treatment options,
2) the involvement and participation of all the stakeholders, and
3) the interactions between the waste system and other relevant systems such as industry, agriculture, etc.

Waste hierarchy

Integrated SWM means also the selection and application of appropriate techniques. The waste management hierarchy is a useful waste management policy tool within the (selection) decision making process. The hierarchy cannot be followed rigidly, since in particular situations, the costs of a prescribed activity may exceed the benefits, when all of the financial, social and environmental considerations are taken into account (Thomas, 2001). The government of Suriname can adopt this policy tool based on its national conditions. The following integrated solid waste hierarchy can be developed for Suriname:

- minimization (source reduction)
- recycling
- composting
- sanitary landfilling (main method)

Waste Authority

It is recommended that the Ministry changes the status of VOV into an independent authority (with clear understanding responsibilities), as was originally planned by the Ministry hereby decreasing the strong political influence on solid waste management. Steps towards this approach were already taken by the creation of NV SAVEB but due to politics this institute had a poor performance. Because of its bad image in the society consultants advised to change the name NV SAVEB into WACOS NV (new start, new image). The Ministry must approve an ordinance that authorizes the creation and independence of this autonomous enterprise. This authority will be the work arm of the Ministry regarding ISWM and should be responsible for all phases of solid waste management (including involvement in the planning process) and must be able to operate its own funds. A business plan is already written for this waste authority (Selikor NV, 2005). This does not mean that with the establishment of this authority the role of the government (the Ministry) will disappear. The government can take the facilitator role for planning, upgrading waste act, making ordinance and controlling the authority's activities in compliance with legal regulations.

7.3 Waste information system

Creation of a waste information system (WIS) is an alternative to the lack of solid waste data because it is important and obligatory for stakeholders to know who produces what types of waste and how much of it. All generators (industrial, institutes, etc.) of waste must be required to register with the WIS. Reporting of this waste information must be published to the general public on a yearly basis. The info must also be submitted to other departments (e.g. Health -; Environmental department) for their data processing, their spot checks, environmental state audit - and state of environment report. The waste authority or a consultant should be responsible for data management and data gathering should perform according reliable data recording procedures (scales, methods in estimating of waste quantities). WIS can also contribute to:

- waste awareness and recycling campaigns
- continuous monitoring of waste streams
- advocating for clean technologies
- lobby and pressure government to take actions

7.4 Solid waste collection

VOV makes significant effort to provide collection service to the majority of residents with their limited resources but waste collection coverage is still low. On the basis of observation suggestions are made about how to improve solid waste services in the country.

It is recommended that NV SAVEB changes the waste collection practices in the problematic areas. One option to consider is to require residents to carry their waste to containers placed at communal collection points located near the narrow or inaccessible streets, instead of creating a garbage heap at the corner of the streets. Communal collection points could help NV SAVEB to provide more efficient and consistent collection services to areas that are difficult to access. Sound practices in communal collection ensure that there is an adequate number of containers that are appropriately sized and easy to access and use and to be emptied by a compactor. The design of the containers used for communal collection should also control waste picking activities and prevent animals from accessing the waste. NV SAVEB must place the containers in a reliable location, provide frequent collection (at least two times a week) and be committed to maintaining the site, which includes cleaning up any overflow waste.

As previously described waste is generally disposed of in plastic bags, buckets, etc. There are problems with animals tearing the plastic bags and rainwater filling the open buckets. It must be required that households of Greater Paramaribo store their waste in special sized garbage bags which help to alleviate some problems encountered. The expected advantages are that the bags are light and the workers can easily dump them in a truck with less mess and fuss in comparison with open buckets. The following solutions are possible in order to reduce mess caused by animals:

- to install metal racks to store garbage out of the reach of animals, as is routinely done in many middle-/high class neighborhoods,
- to promote the habit of putting out the garbage in the morning on the day of collection and not the night or days before,
- to introduce occasional fines for littering or when waste is placed before the set out time..

It is very unlikely that the poorer residents could afford to purchase these types of garbage bags. NV SAVEB could investigate the possibility of subsidizing these garbage bags (special purchase price). It is important that the NV SAVEB promotes the use and distribution of these plastic bags. The requirements of trash cans with lids might also help but emptying these trash cans in open garbage trucks can create problems. A solution is to use wheeled containers which can be attached to compactors for emptying, thereby, avoiding any lifting. This means that every household must be supplied with such a container and that waste collection will only occur with compactors at least in the accessible areas. Considering the price NV SAVEB has to finance the purchase of these containers, which can be earned back with the fee system.

It is also recommended that NV SAVEB review the working conditions of the waste collection vehicle drivers and collectors. Standard boots, gloves, long-sleeve shirts and pants should be issued by the NV SAVEB or waste collection company to improve their health and safety while on-route. Although many collectors are provided with protective clothing they do not wear them always, here is clearly one of the tasks of NV SAVEB to control the operational workforce. Uniforms would also signify a higher status and appreciation for the workers within the communities, giving them more pride in their line of work.

Lack of funding and resources to maintain and expand existing waste collection services are other important aspects being faced by NV SAVEB. It becomes necessary for NV SAVEB to consider implementing and enforcing a collection fee system. The fee should be based on system costs in relation to the amount of waste generated in the city. The public should be informed about this approach to prevent that people protest against suddenly created charges. However, opposition may be minimized if a transparent and accountable fee system is implemented and there is visible improvement within the collection system. As previously discussed, several community members interviewed, said that they are willing to pay a monthly collection fee if the money is actually used to improve the waste management system. A flat fee system is advisable; the private households pay a fixed amount of money per year for the collection of HSW. The fee can be collected via existing official services, e.g. water – or electricity bill.

It was observed that a number of garbage trucks are depreciated or out of service. In purchasing garbage trucks NV SAVEB must take into account that the trucks can be locally repaired and serviced and for which parts are readily available. A commercial bank can be encouraged to finance the purchase of trucks, with e.g. three-year loans to be paid off with a monthly deduction from fees paid by the waste generators. NV SAVEB can operate a combined garbage truck fleet meaning that waste collection will occur with open trucks and compactors whereby evaluating the operating conditions such as road conditions, haul distance, waste density, trips per shift, effective size of loads, and maintenance and repair programs.

The routing problem (route path of a collection vehicle in a collection area) is one of the problems of waste collection. To operate our collection service in an efficient way it is suggested that a suitable micro-routing system is developed for Greater Paramaribo, it must not be determined only by the truck driver. The introduction of a computer routing system based on Geographic Information System (GIS) is recommended to create street maps which indicate every street in a jurisdiction, paved surfaces, road weight limitations or turning restrictions, etc. With GIS, any change in a collection zone or establishment of new residential areas, the maps can be easily updated.

The integration of waste pickers into the solid waste management system will improve the waste recovery. They should be involved in the separate collection program instead of scavenging at the dumpsite hereby improving their legal status and work conditions.

Due to long distances between the waste sources (expanding residential areas) and the disposal facility, establishment of a transfer station for reducing transportation costs should be considered. At the transfer station waste is passed from one form of transport (open truck) to another (compactor) in order to optimize productivity of the collection equipment and crew. The transfer station can provide also possibilities for sorting and recycling. Based on distribution of the communities, available land, and environmental consideration at least one transfer station should be established for waste collection in Paramaribo North. Since the concept of transfer station is new in Suriname, effective plans for collection, transportation, disposal, choice location and investment are needed before the project is implemented. The first two criteria that should be assessed in the implementation of a transfer station are the travel times and distance to disposal site. As a general rule of thumb, if the one-way travel distance to the disposal is over 15 km and the roundtrip travel time is over 45 minutes, implementation of transfer stations should be assessed (Cointreau, 1982).

7.5 Recycling

A positive aspect of our waste management is the recycling of PET bottles. As previously discussed, recycling is conducted on a small scale by the private sector, residents, collection workers and waste pickers with no support of the government. Implementing a recycling program might be an appropriate option if the existing recovery practices are strengthened rather than duplicating recycling projects. Implementing and operating a recycling program requires significant financial, physical and institutional resources so it is recommended that NV SAVEB must not implement a recycling program but encourage the private sector to participate in such programs. Therefore, NV SAVEB has to assess the following options to support and encourage current recycling activities:

- promote public education to encourage support of recycling activities and raise
  awareness of their contribution,
- conduct research on markets for materials,
- provide assistance to the private sector through supplying low-rent space for depot, provisions of loans for small-scale enterprises,
- regulate waste picking.

Research on household solid waste streams indicated that PET and HDPE plastic bottles have good recycling potential. Implementing and operating a small-scale plant should be less capital-intensive and simple, consisting of a covered shed, to provide protection from the sun and rain, a conveyor belt, a baler and a chipper and storage facilities.

To reduce the littering of PET and HDPE bottles the government can introduce a deposit-refund system. When a product (e.g. in PET bottle) is purchased a deposit (certain % of the costs) is made and the latter is refunded when the empty bottle is returned.

7.6 Composting

Composting can be a viable option for Greater Paramaribo to divert the large organic fraction from final disposal. According to data previously presented, food wastes comprise between 50 and 60 percent of the household waste stream. In Suriname, we do not have a composting history based on municipal solid waste, except for some compost projects based on garden waste. There might be a role for this technology to reduce the amount of organic matter being collected and disposed of. There are several designs of a composting system but considering the community needs, economic requirements, market demand and technical capacity a windrow system would be more successful. A windrow is a pile that is generally 1.5–2 times as wide as it is high, with its length determined by the amount of material available (Ashworth, 1996). This system is a low technology system and does not require significant capital investment or rely on highly mechanized equipment and has a decreased need for technical training. Composting at this scale could use source separated wastes from houses and commercial enterprises (restaurants, hotels) and have the site located in an accessible area. The operation could be contracted to the private sector, especially small-scale enterprises that tend to be more efficient than public operations and could benefit from additional employment opportunities. It is important for the government to recognize that composting rarely generates profits on its own. In general, compost is more expensive in contrary to chemical fertilizers. However, if composting is viewed as a component of an integrated solid waste management plan, it could provide economic and environmental benefits on a much larger scale. Since organic materials comprise well over half the trash thrown out by urban households in Suriname, composting represents a major opportunity to reduce expenditures by reducing the amount of waste requiring collection, transport and disposal. The extent of these savings are dependent on how the existing waste management system is adapted to incorporate composting activities, such as public education, awareness, and participation, separate collection, availability of land, market for compost. On the other hand compost reduces the need for fertilizers and pesticides and on the long term also the costs involved. Therefore, good quality compost in adequate amounts must be available and farmers must be willing to reduce the use of chemical fertilizers either by an import quota or high import tax on these products supported by awareness programs.

7.7 Source separation

It is recommended that NV SAVEB investigate the possibility of requiring households to separate their waste into compostables (fruit and vegetable waste) and recyclables (PET/HDPE plastics) to enhance current recycling and future composting activities. Residents have indicated that they would be willing to separate their household waste to facilitate waste collection and recycling activities. Source separation can be difficult to implement because it requires a high degree of public cooperation and action. Therefore, successful source separation programs require public education campaigns about how to properly source separate wastes (which are accepted, which are not), to understand the value of it and to educate citizens about the important role waste pickers play. Equipment such as different colouring and labeling of bags and bins are needed to keep recyclable waste separated. An adequate supply of these bins and bags reduces the mixing of wastes, and enables the operation. Several benefits can be realized from source separation as part of an integrated plan with composting and recycling activities:

- reduced contamination of recyclables;
- higher selling price of cleaner recyclable materials;
- improved quality of compost.

7.8 Final disposal

The government must close the existing open dump and set up a sanitary landfill. Suriname has to develop detailed regulations specifying the minimally acceptable technical criteria for a sanitary landfill. These technical criteria must be vigorously enforced and must also be used to screen out unacceptable locations. There is already a detailed study about the construction and operation of a sanitary landfill (personal communication, Mr. Gerard - Ministry of Public Works). It is necessary that this study is re-evaluated based on international guidelines (URS, 2001; Malarin and Vaughan, 1997) because currently we do not have our own guidelines. The government has to look for funds to implement this project. These funds can be from international organizations, local banks and our national budget.

The way part of the medical waste is disposed of is not healthy for the society, especially the workers and scavengers; therefore, hospitals in Suriname must take into consideration the construction of a medical waste incinerator that will operate according (international) environmental guidelines.

7.9 Privatization of waste services

It is recommended that the government considers the involvement of the private sector to solid waste management services. Privatization is seen primarily as a way to help relieve the government of the financial burden in providing such services. NV SAVEB can start with a joint venture of public and private sector, 50 : 50 - public : private. Both stakeholders will contribute to construction and operation of waste management facilities.
Therefore, reasonable disposal fees should be based on the net system cost which can be divided into four main categories:

- waste collection and transportation costs
- facility operating costs (sanitary landfill)
- total capital costs for development and expansion
- revenues from waste disposal

Gradually the government (NV SAVEB) can cast off its share changing the service to a private entity, the private sector works directly to the householder. Private investment generally expects high profit from projects, thus high rates of charges tend to be used, and in that case the government must still have clear monitoring responsibilities supported by legal regulations.

NV SAVEB and the government will always be responsible for planning and monitoring the quality of the service and performance of the contractors. Further, the government must still ensure appropriate standards, co-ordinate provision, provide a competitive environment, avoid monopoly control by private providers, and minimize corruption and inequity.

7.10 Training and education

Environmental educational activities for waste haulers, government officials and general public should be conducted to:

- understand the ISWM system
- understand the health and safety aspects of waste management
- disseminate better waste management practices
- encourage waste minimization, source separation, recycling and composting
- avoid the NIMBY-syndrome and
- discourage littering and open dumping.

Environmental awareness should be raised through training programs. The training programs should be appropriate and aim at modifying attitudes, knowledge, skills and abilities to improve the program's performance. After training, there should be follow-up activities and positive reinforcement of proper behaviour (e.g. awards, recognition, etc.). Educational materials such as brochures, posters, publications and videos should be prepared. For the training and education programs, activities such as workshops, informal discussion and field trips to the open dump (sanitary landfill), illegal dumpsites, polluted waterways and recycling or composting companies would be effective. Community involvement is very important because they will feel that they are valued and will be inclined to become more involved in improving the program. Currently, NGO's use video production to increase the public environmental awareness but topics that reflect the interest of the people and active participation are missing. Education programmes need to be improved and will be more effective when the overall framework for the ISWM is established, and the necessary infrastructure and institutional arrangements are in place.

7.11 Future research directions

Due to the complex nature of SWM systems extensive data for different scenarios are required. Therefore, further investigations and verification are needed. Directions for future research emerging from this study include:

- a solid waste characterization study of other sources (industrial, commercial, institutional) in the waste stream and to other locations in the country.
- a health study of waste workers: would increase knowledge about the impact on health of working with waste streams. The study could include: identifying and assessing health concerns and causes of health effects, evaluating the adequacy of protective equipment, and comparing occupational risks from various professions. Findings from the study could be integrated in the health and safety program to increase health awareness and develop strategies to reduce health risks.
- feasibility study of recycling, composting and energy recovery: A feasibility study could investigate markets for final products, financing, technical options, environmental impacts and social issues.
- establishment of a transfer station: A feasibility study could investigate financing, technical options, environmental impacts and social issues.

Chapter 8

Conclusions

Chapter 8

Conclusions

In summary, despite the problems encountered, the results of the study provide a defensible and reasonable assessment of the residential solid waste stream that met the objectives of the research.

8.1 Waste problem

The Ministry of Public Works (VOV) is unable to cope with growing solid waste problems. The current waste management system is characterized by technical –, financial -, institutional -, economic -, and social constraints and lack of adequate environmental protection and their relationships. The key issues that were identified were:

- Lack of adequate collection and disposal of solid waste
- Littering and illegal dumping
- The need for organisational change
- The need for a cost recovery mechanism.

Studying of the current SWM produced the following results:

- 0 % composted (except for individual efforts)
- 0 % recycled (except for private companies efforts)
- 80 % open dumps
- 0 % incinerated (except some of the hospital waste)
- 2 % open burning
- 18 % illegal dumping
- Current SWM costs: US$ 29/Ton

8.2 HSW characterization

Waste generation rate

The waste characterization study in Greater Paramaribo showed that household waste generation in the study areas varies which is related to the economical condition and the standard of education in the areas:

- high income area (MonPlasir): 0.77 ± 0.15 kg/capita/day
- medium income area (Cupido): 0.5 ± 0.09 kg/capita/day
- Low income area (Tamenga and Blauwgrond): 0.35 ± 0.15 kg/capita/day

The results showed that the overall weighted average HSW generation rate for Greater Paramaribo is: 0.47 ± 0.06 kg/capita/day and the average HSW production is valued at 46.364 T per year.

This study provides a model (direct waste sampling) to implement waste characterization studies and thereby contributed towards sustainable solid waste management in Suriname. Replication and adaptation of the model to other locations and for other waste sources may be needed to pursue this research. The experiences and challenges concerning the conduct of research about SWM in Suriname will be useful to other researchers in this field.

The waste generation rate is considerably high when compared with many cities in developing countries (0.25 – 0.45 kg/capita/day). Another comment is that the value of 0.47 kg/capita/day is based on the waste that the households offered during sampling. Waste that was dumped or burned is not included, so the real generation rate for households is probably somewhat higher (0.53 kg/capita/day). Calculating the MSW generation rate (including other sources) would probably be higher than the average for developing countries.

The study revealed that the high income areas produced more waste than the low income areas which can be ascribed to the fact that the quantity and composition of solid waste depend on how developed the community is and the state of its economy.

Waste composition

The study showed the following household waste composition for the main components:

- high income area: compostables (61%), plastics (8%)
- medium income area: compostables (59%), plastics (11%)
- low income area: compostables (54%), plastics (12%)

The analysis showed that the proportion of organic wastes is higher (60%) than the proportion of glass, paper, plastics, and metal which indicates that Suriname is categorized to the developing countries (percentage of food waste: 40 – 85%). The figures for plastic (8-12%) showed the opposite, the measured pattern is higher compared with the trend of low income countries (1-5%) and consistent with the high income countries (2 – 10%). This can be ascribed to the low price for plastic in Suriname which increases the consumption of plastic, mainly as packaging material. Plastics bags are free or sometimes a shopkeeper can charge 4 US$ cent for a bag.

Required number of garbage trucks for waste collection

Based on data of the time and motion survey of vehicle trucks a calculation is made of the trucks needed to collect all household waste in Greater Paramaribo. Considering the accessibility of the collection areas and the condition of the roads a truck fleet consisting of compactors (9) and open trucks (12) is recommended. The costs associated with waste collection are valued between US$ 18 - US$ 26 per ton; the associated collection costs for households vary between US$ 13 – 19 per year. These costs do not include the disposal costs.

8.3 Resource recovery potential

Plastic recycling and composting

The study found that plastic films, e.g., plastic bags, were the types of plastics most prevalent in the waste stream. Because PET and HDPE bottles were found to be the only materials that recycling businesses would purchase; therefore, these plastics were targeted for recycling. The recyclable content of plastic waste is calculated to be 17%, meaning that the maximum amount of PET and HDPE plastic that can be recycled is 1 Ton per day or 300 Ton per year.

The high portion of biodegradable waste (food waste) in the household waste stream is a good measure for compost production. The recycled content for food waste is calculated to be 17 % which equals an input of 11 Ton per day against an output of 2.5 Ton of compost per day corresponding with 750 Ton compost annually.

Energy recovery from landfills

With the current dumping methods the recovery of landfill gas (methane) is not feasible; therefore, calculations for methane gas recovery are made for future sanitary landfills. Based on the waste characterization study it is calculated that between 9 – 14 GWh of energy can be produced annually. Energy recovery through methane generation can not cover the energy demand in Suriname (850 GWh); the energy generation is even much lower than through combustion.

Besides energy generation this study illustrates that energy recovery has a positive impact on greenhouse gas emissions. With the capture of methane a reduction of 13 – 20 x 10^3 Ton in methane emission (equivalent to CO_2) is achieved annually.

High additional investment and the low energy production make energy recovery not feasible. Instead of energy recovery or emitting the landfill gases to the atmosphere the generated landfill gases can better be flared. Flaring of methane is more beneficial than emitting the gas into the atmosphere because the global warming potential of methane is much greater than that of carbon dioxide.

Energy recovery from incineration

Energy recovery through combustion of waste is never seriously considered in Suriname. Calculation showed that household waste has a caloric value of 11 MJ/kg of waste which justified the energy generation from incineration (minimum value 7MJ/kg of waste). This energy content is quite high despite the high moisture content of our waste. Based on this caloric value and the average waste generated it is calculated that through incineration the total amount of energy produced is between 140 – 217 GWh. This amount of energy cannot cover the national energy demand.

The downside of burning plastics is that they emit great amounts of CO_2 and N_2O which are well known green house gases. High moisture content and the high investment costs demonstrate that the combustion of waste is not a promising waste management technique for Suriname.

Open burning

Open burning of household waste is widespread in Suriname, Greater Paramaribo. It is calculated that yearly 1044 Ton of waste is burned with a total emission load of 39 Ton TSP, 0.5 Ton SO_2, 40 Ton CO, 3 Ton NO_x (as NO_2), 18 Ton PM_{10}, 16.5 Ton $PM_{2.5}$ and 4 Ton VOC per year. Based on this data it may be concluded that the air quality has reached an unhealthy level in Paramaribo. To tackle this problem successfully, it is important that appropriate waste management strategies and technologies together with public education program are implemented.

8.4 Composting experiment

The composting process was studied through the compost bin method. Bin composting is a simple and effective method at very low cost. The poor overall performance of the bin composting process and its final product was likely due to incomplete composting. The produced compost was immature for it contains high levels of organics, extreme pH value and high salt content.

The results showed that due to the high content of organic material and the high moisture content (75%) a reduction of mass of approximate 90% and a volume reduction of 77% of the input material was achieved. This proves that higher content of organic materials indicates for higher total settlement in a landfill which can lead to a damage of the gas and leachate collection system.

Lessons learned from the pilot composting project showed that good quality compost is achieved by: regular checks and maintenance of aeration, moisture and nutrient levels, optimal mix of various waste elements (C:N ratio), pH values and 14-day temperature level > 55°C or 7-days > 65°C throughout the entire compost process. In addition, regular laboratory tests must be made to evaluate the metal content and phyto-hygienic safety of the compost produced. Other important findings were that the numbers of bins must be increased and the mixing of the compost with soil produced better germination results.

8.5 Integrated solid waste management

No single technology option will be sufficient to take care of emerging problems of solid waste. The adverse impacts of waste management are best addressed by developing and implementing integrated sustainable programs. Results of this study indicated that a sanitary landfill and a small-scale recycling- and composting plant are methods to achieve a sound SWM in Suriname but feasibility studies need to be carried out. Integrated waste management will be conditioned and improved by the effectiveness of legislation, policies, monitoring and enforcement activities, institutional system, involvement of public and private sectors, finance, public education, etc. Regardless of the type of waste management selected for Suriname, neither urban planning nor strategies will translate into reality unless the government takes the required initiatives and makes the necessary inputs available.

8.6 MSW management in developing countries in relation to Suriname

The conditions, issues and problems of urban waste management in Suriname and developing countries are similar. Formal waste collection and disposal services are provided to only a portion of the population and most of the waste is disposed of in open dumps. In many developing countries the first priority is still to get the refuse out from under the roof (conventional approach) and often relies on high-cost, bureaucratic, and centralized alternatives. Currently, Suriname has the same solid waste policy. In many developing countries, deficiencies in the provision for waste services are the results of inadequate financial resources, lacking management and technical skills, strong political interference, limited communication with stakeholders, etc. The SWM in Suriname shows similar deficiencies. SWM will continue to be a problem in developing countries because it is obviously multi-faceted and approaching the problems is not an easy task. Integrated approach using appropriate technology is a major component to ensure that solid waste problems are addressed in a manner which provides for the greatest common benefit. In developing countries, individual countries are at various stages in this gradual evolution towards "modern" standards of waste management. Some are in the stage of developing solid waste management programs and a few make the shift from open dump to sanitary landfill. With this doctoral thesis it can be said that Suriname is at the outset in developing an ISWM. Although in theory there is insufficient reason to assume the integrated concept can be effective in developing countries in practice it is not always the case. In many instances, particularly in developing countries, the greatest barriers to efficient and environmentally sound handling of SWM issues are managerial, rather than technical therefore, governments should learn about new opportunities how to use their limited resources in an effective manner to improve SWM.

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Samenvatting

De overheid in Suriname, met name het Ministerie van Openbare Werken – de Dienst Vuilophaal en Verwerking, heeft in toenemende mate problemen met de inzameling en verwijdering (vuilophaal en verwerking) van vast afval. Naast de financiële kosten nemen de milieuproblemen steeds meer toe. Dit is toe te schrijven aan de stijgende hoeveelheden afval die zijn oorzaak vindt in een groeiende import economie, snelle urbanisatie, de snelle uitbreiding van Paramaribo, het niet beschikken over recyclage mogelijkheden en het ongecontroleerd storten van afval. Ons huidig statisch afvalbeheersysteem heeft geen pas kunnen houden met deze dynamische sociaal-economische ontwikkelingen. Hoewel de overheid al sinds een aantal jaren bezig is met de verbetering van de vuilophaal heeft zij weinig resultaten geboekt. Het falen van het overheidsbeleid gericht op vuilophaal en verwerking is toe te wijzen aan een aantal verstoringen zoals:

- corruptie
- het gebrek aan informatie over kosten en kwantificeerbare informatie over vast afval. Door dit gebrek aan inzicht in kosten/data is het voor de overheid zeer complex om een duidelijk afvalbeleid te ontwikkelen
- gebrek aan financiën voor het uitvoeren van een adequate vuilophaal en het opzetten van een adequaat verwerkingssysteem
- gebrek aan planning op het gebied van afvalbeheer, waardoor vele handelingen van de overheid meer een ad-hoc karakter hebben en geen effect hebben op verbetering
- afvalbeheer is volledig de verantwoordelijkheid van de overheid. De betrokkenheid van verschillende actoren wordt genegeerd waardoor zij zich niet verantwoordelijk voelen voor het gegenereerde afval en ook niet participeren in afvalbeheerprojecten
- het gebrek aan regelgeving, handhaving en controle op het gebied van afval. Hierdoor kunnen vervuilers moeilijk gesanctioneerd worden

- nazorgtraject en logistieke organisatie ontbreken bij de aanschaf van materieel en hierdoor ontstaan er al snel problemen met de voertuigen zodra ze in gebruik zijn genomen
- onze huidige afvalverwerking geschiedt in ongecontroleerde stortplaatsen; ze vervuilen het milieu en leiden tot gezondheidsrisico's. Verder worden alle vaste afvalstoffen, van huishoudelijk afval tot ziekenhuis afval, ongescheiden gestort. Bovendien zorgen veranderde consumptiepatronen voor een stijging in moeilijk verwerkbaar afval
- door een inadequate ophaalcapaciteit vindt in bepaalde wijken beperkte afval collectie plaats waardoor bewoners al gauw over gaan tot het illegaal storten en verbranden van afval. Dit leidt tot onhygiënische situaties, gezondheidsrisico's voor de bewoners en milieuproblemen in bepaalde wijken.

Ons huidig afvalbeheersysteem is duidelijk aan verandering toe. Het behoeft niet altijd geld en materieel te zijn die tot verbetering van ons huidig afvalbeheer systeem zullen leiden maar ook de verandering van sociale, institutionele, legale en politieke condities zijn vereist. De introductie van een duurzaam afvalbeheer systeem kan de kern zijn tot de oplossing van ons afvalproblematiek. In Suriname is er nooit een gedetailleerd onderzoek gedaan naar de introductie van een 'geïntegreerd afvalbeheersysteem'. Om de duurzaamheid van dit systeem te kunnen garanderen moet er aandacht besteed worden aan de kennis en inzicht in het potentieel van dit systeem.

De eerste stap tot verbetering van het afvalbeheersysteem en met het oog op de toekomst is het verkrijgen van inzicht in de type en hoeveelheid afvalstoffen die worden gegenereerd en in de mogeljkheden tot het terugwinnen van afval. Dit proefschrift richt zich daarom op de analyse van een geïntegreerd afvalbeheer systeem en hoe die in Suriname toegepast kan worden met het oog op het bereiken van duurzame ontwikkeling.

Het hoofddoel van dit onderzoek is mechanismen aan te bevelen om het huidig afvalbeheersysteem in Groot Paramaribo te verbeteren. De belangrijkste sub-doelstellingen die worden nagestreefd zijn:

- inventarisatie van de kwaliteit en kwantiteit van het afval gegenereerd in Groot Paramaribo ('meten is weten')
- uitwisseling van kennis en ervaring naar andere lokaties en bronnen op het gebied van afvalbeheer
- meer aandacht en kennis voor de duurzaamheid van projecten op het gebied van afvalbeheer: recycleren en composteren
- capaciteitsversterking van ambtenaren / bestuurders van afvalbeheer.

Deze studie is de eerste uitgebreide naar de afvalproblematiek in Groot Paramaribo en kan als basis gebruikt worden voor verdere afval studies. De studie omvatte het inzamelen van data (hoeveelheden en samenstelling) met betrekking tot huishoudelijke afvalstromen in Groot Paramaribo. Van 2002 tot en met 2004 werden afval karakterisering studies uitgevoerd op basis van de 'direct sampling method' (analyseren van afval bij de huishoudens). Dit onderzoek is ondersteund met data verkregen uit 'time and motion survey' van afval trucks (volgen en analyseren van afval trucks tijdens vuilophaal) en 'sociale-milieu studie' op de stortplaats. Groot Paramaribo werd verdeeld in hoog, midden en laag inkomens gebieden en op basis van socio-economische en demografische condities werden 4 studiegebieden gekozen voor de representativiteit van het onderzoek. Het afval werd in het veld opgesplitst in 18 individuele componenten en voor studie doeleinden gegroepeerd in 6 hoofdgroepen: organische afval, papier, plastic, glas, metaal, en rest afval. Naast het verkrijgen van inzicht in de samenstelling en hoeveelheid van de afvalstromen zijn de data ook gebruikt om het recyclage potentieel te bepalen en om de vraag te beantwoorden: in hoeverre kan energie uit afval de nationale energie behoefte dekken.

Samenvattend heeft dit onderzoek een aantal inzichten opgeleverd.

1. afval generatie per capita door de huishouden bedraagt 0.47 kg per dag met een aanvankelijke toename van 3.9 % per jaar. Organisch afval is de grootste component (61%) in het huishoudelijk afval gevolgd door plastic (8 -12%)
2. verbetering van vuilophaal kan bereikt worden door de inzet van 9 kraakperswagens en 12 open trucks elk met een capaciteit van 9 Ton. De geassocieerde kosten varieren tussen US$ 18 - 26 per ton
3. op basis van huishoudelijk afval kan een gecontroleerde stortplaats 9 – 14 GWh energie per jaar produceren met een reductie van CH_4 emissie van 13 – 20 $x10^3$ Ton per jaar (equivalent aan CO_2). Energie opwekking op basis van afvalverbranding bedraagt 140 – 217 GWh. Opwekking van energie heeft een positief effect op de reductie van broeikasgassen (CH_4) maar de opgewekte energie voldoet bij lange na niet aan de energie vraag. Technisch-economische studies zijn vereist alvorens tot de uitvoering van een afval-energie project over te gaan
4. Gebaseerd op een recycling potentieel van 17 %, zal het mogelijk zijn om 1 Ton plastic (HDPE en PET) en 11 Ton organisch materiaal per dag te verwerken. Ondanks deze positieve vooruitzichten zal recyclage sterk afhankelijk zijn van: collectie programma, voorlichting en participatie van het publiek, aanwezigheid van markten, en de kosten
5. het rijpen van compost heeft een grote invloed op de kwaliteit van de compost, hetgeen bleek uit de verkregen resultaten. Verder werden de beste ontkiemings-resultaten bereikt door de compost met grond te mengen
6. Er wordt jaarlijks 1044 Ton afval illegaal verbrand met een hoge emissie van de volgende stoffen zoals: CO (40 T/jaar), TSP (39 T/jaar), NO_x (3 T/jaar), PM_{10} (18 T/jaar), VOV (4 T/jaar) en SO_2 (0.5 T/jaar).

Gebaseerd op deze data en evaluatie van het huidig afvalbeheersysteem is een duurzaam geïntegreerd systeem geformuleerd tot oplossing van de afval problematiek. Bij de formulering zijn in acht genomen: legale, economische, institutionele en technologische factoren en anderzijds, de bijdrage van de verschillende partijen die betrokken zijn bij afvalbeheer. Gebaseerd op deze aspecten is de volgende lange termijn visie met betrekking tot het afval hierarchisch systeem geformuleerd: aan de top afval reductie gevolgd door recycleren, composteren, en gecontroleerd storten aan de basis als belangrijkste verwijderingsmethode.

In het onderzoek zijn een groot aantal aspecten van afvalbeheer beschreven maar verder onderzoek is vereist om een complete gedetailleerde visie te hebben over een ‘geïntegreerd afvalbeheersysteem’.

- Dit onderzoek zou uitgebreid kunnen worden met de overige afvalstromen en ook naar andere locaties. Kennis en expertise uit dit onderzoek kunnen gebruikt, eventueel aangepast worden bij het onderzoek naar andere afvalstromen.
- Het uitvoeren van technisch-economische haalbaarheidsstudies van composteren, recycleren en energie opwekking.
- Het uitvoeren van een studie naar de gezondheidsaspecten van de afvalwerkers. Zij werken onder zeer milieu-onvriendelijke omstandigheden waardoor het risico wordt vergroot voor het oplopen van ‘gevaarlijke ziekten’.
- Het uitvoeren van een onderzoek naar de opzet van een overslag station voor afval vooral met oog op de uitbreiding van het ophaalgebied waardoor steeds grotere afstanden afgelegd moeten worden.

Summary/Samenvatting

Summary

The Government of Suriname, particularly, the Ministry of Public Works – Department of Waste Collection and Disposal, has serious problems in managing the solid waste streams produced. Waste collection and disposal not only cost our society a lot of money, but also creates environmental problems. Increasing cost and environmental problems are ascribed to increasing waste streams resulting from the growing import economy, urbanization, the fast expanding of Paramaribo, the lack of recycling facilities, and the uncontrolled dumping of waste. Our static waste management system could not keep up pace with these dynamic socio-economic developments. Although the government has tried to upgrade the waste collection services, the results are not promising. The failure to manage the solid waste streams has been caused by a number of distortions, such as:

- corruption
- lack of data about costs and waste stream quantity. Owing to this the government can not formulate a clear waste policy
- lack of finance to implement waste management projects
- lack of planning concerning waste management, because of this the activities of the Ministry have an ad-hoc character without any approved success
- the government is the only responsible for waste management; other stakeholders are not involved and therefore they do not feel responsible and are not motivated to participate in waste projects
- lack of updated legislation and enforcement to sanction polluters
- lack of (management of) equipment
- lack of adequate disposal facilities; waste is dumped in open pits which pollute the environment and form a risk for human health. Also waste is dumped commingled and is becoming more toxic
- inadequate waste collection leading to illegal burning and disposal resulting in unhygienic situations and health risk in problem areas.

It is clear, Suriname - Greater Paramaribo is in need of an improved waste management. It is not money or equipment that provide always solutions, but rather changing social, institutional, legal or political conditions. The introduction of a sustainable integrated waste management system can be the root to the solution of our waste problem. In Suriname there exists a lacuna with respect to a comprehensive study on integrated waste management; therefore, it is important to gain knowledge and insight in the potential of this system.

To manage our current waste effectively and to plan for the future, the government needs to understand both the existing solid waste stream and its possibility for resource recovery. This approach was chosen as a study case for this doctoral thesis exploring the potential of an integrated solid waste management and to provide information how it can be applied in Suriname in order to reach sustainable development.

The main purpose of this research was to suggest mechanisms to strengthen the waste management practices in Greater Paramaribo. Other objectives of this study were:

- to carry out a comprehensive waste characterization study for Greater Paramaribo and lay the foundation for extending this work to other areas and sectors in the country
- to build local capacities to deal with waste management
- to explore possibilities of resource recovery of waste with adapted technologies (recycling, composting, energy from waste)
- to disseminate information about an integrated solid waste management system.

This study was the first of this magnitude and can be used as a baseline for further waste studies. It encompassed gathering data (quantity and composition) from residential waste stream throughout Greater Paramaribo. Between 2002 and 2004 data were collected at the waste generation site (households) using the ‘direct sampling method’, supported by ‘time and motion survey’ of waste collection vehicle and ‘social environmental survey’ at the disposal site in 2005. For study purposes, Greater Paramaribo was divided into high -, medium -, and low – income areas, and based on socio-economic and demographic features four study areas were chosen to ensure adequate representation of the research. The waste characterization study divided each waste sample into 18 individual materials, grouped into six main material classes: compostables (organic kitchen waste), paper, plastics, glass, metals, and others. In addition the study was designed to determine an estimate of the amount of waste that can be recycled and composted. This information is needed to calculate the recycling rate. Also data were gathered to provide insight into a key question: can energy from waste be generated to satisfy the energy demand of Suriname?

In summary, the study provides some views.

1. household solid waste generation of the Greater Paramaribo is high, 0.47 kg/capita/day with a maximum yearly increase of 3.9%. The waste composition results showed that compostables and plastics offer excellent opportunities for composting and recycling. The compostables represent the largest share (61%) and plastics comprised the second largest share (8-12%).
2. the study identified that efficient collection coverage for all household solid waste in Greater Paramaribo can be achieved by the input of 9 compactor trucks and 12 open trucks, each with a capacity of 9 T. The associated cost for waste collection varies between US$ 18 - 26 per ton.
3. the results indicated that a landfill (not an open dump) will generate 9 –14 GWh energy per year and avoid the release of 13 – 20 x 10^3 Ton CH_4 annually (equivalent to CO_2). Producing electricity from incineration will result in the generation of 140 - 217 GWh energy. This study illustrates that there is a positive impact on green house

gas emission but the energy generated is not sufficient to meet local demands. Further economic and technical studies are needed for a detailed assessment.

4. the estimated recycling rate is calculated to be 17%. The study indicated that based on HSW data, 1 Ton of plastic (HDPE and PET) can be recycled and 11 Ton of kitchen can be composted daily. Despite the positive prospect of this recovery system, implementation depends on some important conditions such as the collection program, public education and participation, market and cost for recycling/composting.
5. the compost quality test showed that the compost, produced with the compost bin method must be cured for some time more to meet safety standards. To have better germination results the compost must be mixed with other organic material such as soil before application.
6. People in Paramaribo burn a lot of waste although the collection service attends the collection areas twice a week. An estimate of open burning of 1,044 Ton per year was calculated. The annual emission load due to TSP and CO (39 T/y and 40 T/y) are observed to be the highest amongst the other pollutants namely NO_x (3 T/y), PM_{10} (18 T/y), VOC (4 T/y) and SO_2 (0.5 T/y).

Based on the data above and evaluation of the current waste management system a sustainable solid waste management (SWM) is advised for the improvement of our SWM. SWM is complex; therefore, it is appropriate to use a sustainable integrated approach that recognizes the various stakeholders, activities (appropriate technologies) and perspectives (legal, institutional, financial) involved. This improved system must be appropriate to the local conditions and feasible from a technical, environmental, social, economic, financial, institutional and political perspective. Therefore the following waste hierarchy system is advised for long term development for the country: at the top waste minimization followed by recycling, composting, and landfilling at the bottom as the main disposal method.

In this thesis several aspects of solid waste management are described, however, some more aspects could be added to have a complete detailed vision about integrated solid waste management. Based on the research findings the following recommendations are presented:

- to expand waste characterization studies to other resources (industrial, institutional, etc.) and locations in the country. Knowledge and experience from this research, eventually adapted, can be used for these studies
- to develop feasibility studies for composting, recycling and energy recovery projects
- to study the health impacts of waste workers, including the waste pickers because they work under unhygienic conditions so there are susceptible for diseases
- to study the implementation for a transfer station focusing on the intensive extension of the collection area which are attended with increasing distances.

APPENDIX

APPENDIX I: FIELD DATA SOLID WASTE GENERATION SURVEY

APPENDIX I-1: Total solid waste generation in residential area Blauwgrond (LI area)

	Sep/ 04		Oct/ 04		Sep/03		Oct/02	
Waste category	**Total kg**	**%**	**Total kg**	**%**	**Total kg**	**%**	**Total**	**%**
fresh veg/fr	31,7	33,2	29,9	40,7	39,3	29	29,2	34,7
cooked	18,9	19,8	15,5	21,1	36,9	27,3	11,3	13,4
other	0,66	0,69	0,4	0,55	2,6	1,92	6,45	7,66
paper	6,18	6,47	4,01	5,46	4,19	3,1	3,45	4,1
cardboard	1,83	1,92	1,61	2,2	2,83	2,1	1,04	1,23
carton cont	0,4	0,42	0,18	0,24	0,43	0,32	0,12	0,14
plastic PET	3,92	4,1	3,17	4,32	2,06	1,52	1,93	2,29
plastic HDPE	0,99	1,03	0,91	1,24	2,01	1,48	0,74	0,87
plastic other	7,63	7,99	5,91	8,05	8,73	6,46	6,37	7,57
glass co/bo	2,34	2,45	1,62	2,2	8,45	6,25	4,17	4,95
other glass	1,83	1,92	0		0,24	0,18	0,19	0,23
textiles	1,87	1,95	1,34	1,83	1,08	0,8	0,8	0,95
Al cans	3,05	3,19	1,59	2,17	3,29	2,44	1,7	2,02
other metals	0,44	0,46	0,16	0,22	0,54	0,4	0,49	0,58
yard waste	2,67	2,79	0		5,44	4,02	0,72	0,86
wood	0,63	0,66	0,03	0,04	0,09	0,07	0,15	0,18
batteries	0		0,02	0,02	0,15	0,11	1,58	1,88
rest	10,4	10,9	7,11	9,69	16,9	12,5	13,8	16,4
Total (kg)	95,5		73,4		135		84,2	
# Hholds	15		14		14		18	
Hhold size	60		52		71		91	
Total part. day	78		67		75		99	

APPENDIX I-2: Total solid waste generation in residential area Cupido (MI area)

	Jun/Jul04		Jul/Aug04		June / 03		Jun/Jul02		Jul/Aug02		Aug/Sep02	
Waste category	**Total** kg	**%**	**Total** kg	**%**	**Total** (kg)	**%**	**Total** kg	**%**	**Total** kg	**%**	**Total** kg	**%**
fresh veg/fr	41,7	36	34,4	35	25,4	35,4	109	51,6	90	51	45,6	25,1
cooked	16,4	14,2	20,2	20,6	14,9	20,7					30,9	17
other	3,69	3,19	0,47	0,48	1,24	1,73	2,08	0,99	1,7	0,96	5,88	3,23
paper	6,56	5,67	5,17	5,27	4,83	6,72	14,8	7,01	6,8	3,85	10,1	5,55
cardboard	3,01	2,6	3,19	3,25	1,13	1,57	2,38	1,13	2,36	1,34	1,91	1,05
carton cont	0,43	0,37	0,46	0,47	0						0,28	0,15
Plastic PET	2,92	2,53	3,92	3,99	0,88	1,22	1,27	0,6	2,8	1,59	1,72	0,94
Plastic HDPE	0,85	0,74	1,08	1,1	0,5	0,69	20,8	9,88	11,4	6,44	1,3	0,72
Plastic other	10,5	9,1	10,3	10,5	5,6	7,8					15,3	8,43
glass co/bo	7,62	6,59	4,94	5,03	5,07	7,05	13,2	6,26	12,1	6,87	6,02	3,31
other glass	0,57	0,49	0,97	0,99	0,26	0,37					2,81	1,54
textiles	1,36	1,18	0,85	0,86	0,22	0,31	6,65	3,15	2,77	1,57	5,19	2,85
Al cans	3	2,59	1,7	1,73	1,27	1,77	4,45	2,11	3,22	1,83	2,14	1,18
other metals	0,67	0,58	0,38	0,38	0,1	0,15	1,03	0,49	1,25	0,71	2,24	1,23
yard waste	0,35	0,3	0,11	0,11	0,53	0,74	0,55	0,26	4,09	2,32	1,82	1
wood	1,52	1,32	0,07	0,07	0,04	0,06	0,24	0,11	0,14	0,08	0,72	0,4
batteries	0,58	0,5	0,09	0,09	0,16	0,23	0,11	0,05	0,09	0,05	0,15	0,08
rest	13,9	12	9,88	10,1	9,72	13,5	34,4	16,3	37,8	21,4	47,7	26,2
Total (kg)	116		98,2		71,9		211		176		182	
# Hholds	14		14		13		18		19		16	
Hhold size	53		45		48		74		74		64	
Total part. day	79		71		70		102		102		83	

APPENDIX I-3: Total solid waste generation in residential area MonPlasir (HI area)

	Aug/ 04		**Sept/Oct04**		**July/ 03**		**Aug/ 02**		**Sept/Aug02**	
Waste Category	**Total kg**	**%**	**Total kg**	**%**	**Total kg**	%	**Total kg**	**%**	**Total kg**	%
fresh veg/fr	35,2	34,7	36,2	39,2	51,8	32,3	42,6	38,6	53,1	54,5
cooked	19,7	19,4	18,7	20,2	32,4	20,2	12,4	11,2	14,5	14,9
other	0,41	0,4	1,64	1,78	1,14	0,71	11,5	10,4	5,75	5,9
paper	7,47	7,36	2,95	3,19	7,01	4,36	6,73	6,11	2,89	2,96
cardboard	1,64	1,62	2,21	2,4	3,34	2,08	1,51	1,37	1,01	1,03
carton cont	0,09	0,09	0,56	0,61	0,85	0,53	0,21	0,19	0,08	0,08
Plastic PET	2,39	2,35	2,2	2,39	2,6	1,62	0,58	0,53	1,08	1,11
Plastic HDPE	1,1	1,09	0,94	1,02	2,67	1,66	1,05	0,96	0,52	0,53
Plastic other	6,41	6,32	6,24	6,76	9,83	6,12	5,21	4,73	4,74	4,87
glass co/bo	4,31	4,24	4,87	5,28	6,85	4,27	3,06	2,78	5,81	5,96
other glass	0		1,44	1,56	3,01	1,87	0,67	0,61	0,29	0,3
textiles	2,78	2,74	0,51	0,55	2,82	1,76	1,84	1,67	0,12	0,12
Al cans	1,17	1,15	1,84	1,99	3,79	2,36	1,34	1,22	1,66	1,7
other metals	0,18	0,17	0,15	0,16	0,63	0,39	3,4	3,09	0,29	0,3
yard waste	0,04	0,04	0		9,91	6,17	5,35	4,85	0,36	0,37
wood	0,06	0,06	1,03	1,11	0,98	0,61	0,34	0,31	0	
batteries	0,06	0,06	0,05	0,05	0,11	0,07	0,19	0,18	0,1	0,1
rest	18,4	18,2	10,8	11,7	20,8	13	12,3	11,2	5,19	5,32
Total (kg)	101		92,3		161		110		97,5	
# Hholds	9		7		10		9			6
Hhold size	33		30		38		37			37
Total part. day	46		34		51		47			31

APPENDIX I-4: Total solid waste generation in residential area Tamenga (LI area)

	July//04		Aug//04		Sept /03		Aug//02		Sep//02		Jul//02	
Waste category	**Total kg**	**%**	**Total kg**	**%**	**total kg**	**%**	**Total kg**	**%**	**Total kg**	**%**	**Total kg**	**%**
fresh veg/fr	59,7	33,6	42,7	25,8	25,4	23,4	25,8	20,8	27,5	20,4	46	48,3
cooked	31,3	17,6	43,6	26,4	27,3	25,1	37,3	30,1	31,6	23,4	4,51	4,73
other	1,29	0,73	1,79	1,08	2,14	1,96	6,24	5,04	6,8	5,04		
paper	7,42	4,18	5,1	3,08	3,95	3,64	3,82	3,09	8,64	6,41	2,97	3,11
cardboard	2,68	1,51	2,37	1,43	2,7	2,49	2,88	2,33	2,08	1,54	1,57	1,65
carton cont	0,49	0,28	0,56	0,34	0,76	0,7	0,3	0,25	0,1	0,08		
Plastic PET	6,55	3,69	5,7	3,45	4,46	4,1	0,9	0,73	2,04	1,51	0,6	0,63
Plastic HDPE	1,28	0,72	0,5	0,3	1,96	1,8	1,18	0,95	1,36	1,01	9,25	9,71
Plastic other	13,1	6,49	12,6	7,61	8,66	10,4	8,81	7,11	9,73	7,22		
glass co/bo	11,5	6,49	6,49	3,93	11,3	10,4	5	4,03	6,69	4,96	4,35	4,57
other glass	0,34	0,19	1,25	0,76	0,55	0,51	0,09	0,07	0,29	0,22		
textiles	6,97	3,93	2,74	1,66	0,73	0,67	2,77	2,24	4,03	2,99	6,05	6,35
Al cans	2,5	1,41	3,17	1,92	2,15	1,98	1,76	1,42	2	1,48	2,21	2,32
other metals	0,58	0,33	0,38	0,23	0,23	0,21	0,32	0,26	0,81	0,6	0,17	0,18
yard waste	7,49	4,22	7,06	4,27	10,4	9,6	13,8	11,1	19,2	14,2	6,65	6,98
wood	0,55	0,31	0,15	0,09	0,17	0,16	0,24	0,19	0,51	0,38	0,49	0,52
batteries	0,08	0,05	0,07	0,04	0,05	0,04	0,16	0,13	0,76	0,57	2,11	2,22
rest	23,8	13,4	29,1	17,6	5,74	5,28	12,6	10,1	10,8	7,98	8,34	8,75
Total (kg)	178		165		109		124		135		95,3	
# Hholds	19		19		14		15		13		15	
Hhold size	105		105		55		93		83		96	
Total part. day	94		90		79		78		66		79	

APPENDIX II: STATISTICS

II-1 Parametric test (ANOVA) and Non-parametric test (Kruskal-Wallis)

Consider the following problem:
The results of the waste generation rate measured each period per year show clear differences among the different income groups. The question is: do the measured values differ significantly from each other?

Data were tested:

- Using one-way ANOVA (Excel Microsoft 2003) to determine if there were significant effects
- Considering transforming the data to square root because the distribution was not clearly bell-shaped (use of ANOVA)
- Using a non-parametric test (Kruskal-Wallis test) because of outliers, missing of Gaussian distribution, small sample size (< 12), and lack of homogeneity of variances.

Hypothesis: $H_0 = \mu_1 = \mu_2 = \mu_3 = \ldots\ldots\ldots\ldots \mu_p$ (ANOVA)
Hypothesis true: no differences (can not reject H_0)
95 % confidence interval
$\alpha = 0.05$, $p > \alpha = 0.05$: differences between measured waste generation rate not statistically significant
$F_{obs} < F_{crit}$: differences between measured waste generation rate not statistically significant (can not reject H_0; there is insufficient evidence to indicate a difference)

Results

SUMMARY

	ANOVA original data			**ANOVA transformed data**			**Kruskal-Wallis test**		
	F_{obs}	F_{crit}	**P-value**	F_{obs}	F_{crit}	**P-value**	**H**	**Chi**	**P-value**
Cupido	1.095	2.318	0.369	1.526	2.318	0,19	9.08	11.07	0.05
	No significance difference			**No significance difference**			**No significance difference**		
MonPlasir	0.619	2.634	0.652	0.538	2.633	0.709	9.31	9.49	0.05
	No significance difference			**No significance difference**			**No significance difference**		
Blauwgrond	1.856	2.779	0.148	2.821	2.779	0.048	8.72	7.82	0.0499
	No significance difference			**Significance difference**			**Significance difference**		
Tamenga	2.257	2.324	.,056	2.437	2.324	0.041	11.61	11.07	0.05
	No significance difference			**Significance difference**			**Significance difference**		

BLAUWGROND

Anova: Single Factor

Blauwgrond original data

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Sept 2004	14	5.32	0.38	0.176
Oct 2004	11	2.68	0.24	0.019
2003	14	6.34	0.45	0.256
2002	18	3.44	0.19	0.026

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.657	3	0.219	1.856	0.148	2.779
Within Groups	6.254	53	0.118			
Total	6.911	56				

F < Fcrit: no significance difference

Anova: Single Factor

Blauwgrond transformed data

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Sept 2004	14	7.94	0.567	0.064
Oct 2004	11	5.27	0.479	0.016
2003	14	8.58	0.613	0.083
2002	18	7.27	0.404	0.028

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.407	3	0.136	2.821	0.048	2.779
Within Groups	2.549	53	0.048			
Total	2.956	56				

F > Fcrit: significance difference

Kruskal-Wallis test - Blauwgrond

Level	**N (sample size)**	**Median**	**Average rank**
Sept 2004 - A	14	0.26	33.21
Oct 2004 - B	11	0.24	28.32
2003 - C	14	0.32	36.5
2002 - D	18	0.15	20.31
Total	57		29

H=8,72 df=3 chi-square = 7,82 p=0.0499

H is greater than chi: significant difference

p=α this difference is considered statistically significant

TAMENGA

Anova: Single Factor

Tamenga: original data

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
July 2004	17	7.42	0.44	0.081
Aug 2004	15	6.13	0.41	0.044
2003	14	7.11	0.51	0.214
July 2002	15	2.93	0.2	0.013
Aug 2002	15	4.4	0.3	0.049
Sept 2002	13	5.06	0.39	0.098

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.914	5	0.183	2.257	0.056	2.324
Within Groups	6.723	83	0.081			
Total	7.637	88				

F < Fcrit: no significant difference

Anova: Single Factor

Tamenga transformed data

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
July 2004	17	10.65	0.626	0.047
Aug 2004	15	9.3	0.62	0.026
2003	14	9.02	0.644	0.093
July 2002	15	6.39	0.426	0.015
Aug 2002	15	7.58	0.505	0.040
Sept 2002	13	7.6	0.585	0.052

ANOVA

Source of Variation		*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups		0.545	5	0.109	2.437	0.041	2.324
Within Groups		3.713	83	0.045			
Total		4.258	88				

F > Fcrit: significant difference

Kruskal-Wallis test - Tamenga

Level	N (sample size)	Median	Average rank
July 2004 - A	17	0.35	52.3
Aug 2004 - B	15	0.36	52.97
2003 - C	14	0.44	51
July 2002 - D	15	0.16	27.2
Aug 2002 - E	15	0.21	38.87
Sept 2002 - F	13	0.37	47.4
Total	89		45

H = 11.61 df=5 chi-square = 11.07 p=0.05

H is greater than chi: significant difference

p=α this difference is considered to be not quite statistically significant

CUPIDO

Anova: Single Factor

Cupido original data

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
June/July 2004	14	6.89	0.5	0.177
July/Aug 2004	14	7.42	0.53	0.093
2003	13	4.34	0.34	0.052
June/July 2002	18	11.21	0.62	0.134
July/Aug 2002	19	9.33	0.49	0.126
Aug/Sept 2002	16	8.35	0.52	0.118

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.65	5	0.13	1.095	0.369	2.318
Within Groups	10.443	88	0.119			
Total	11.093	93				

F < Fcrit: no significance difference

Anova: Single Factor

Cupido transformed data

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
June/July 2004	14	9.19	0.656	0.065
July/Aug 2004	14	9.8	0.7	0.041
2003	13	7.11	0.547	0.038
June/July 2002	18	13.65	0.758	0.046
July/Aug 2002	19	12.71	0.669	0.046
Aug/Sept 2002	16	11.07	0.692	0.044

ANOVA

Source of Variation		*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups		0.357	5	0.071	1.526	0.190	2.318
Within Groups		4.119	88	0.047			
Total		4.476	93				

F < Fcrit: no significance difference

Kruskal-Wallis test - Cupido

Level	**N (sample size)**	**Median**	**Average rank**
June/July 2004 - A	14	0.32	42.25
July/Aug 2004 - B	14	0.45	50.36
2003 - C	13	0.25	31
June/July 2002 - D	18	0.54	59.61
July/Aug 2002 - E	19	0.37	46.03
Aug/Sept 2002 - F	16	0.4	51.13
Total	94		47.5

H = 9.31 df=5 chi-square = 11.07 p=0.05

H is smaller than chi: no significant difference

p=α this difference is considered to be not quite statistically significant

MONPLASIR

Anova: Single Factor

MonPlasir: original data

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Aug 2004	9	5.44	0.61	0.109
Sept/Oct 2004	7	5.59	0.80	0.484
2003	10	8.99	.90	0.341
Aug 2002	9	5.72	0.64	0.069
Sept/Oct 2002	6	5.57	0.93	0.6410

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.730	4	0.183	0.619	0.652	2.634
Within Groups	10.609	36	0.295			
Total	11.339	40				

F < Fcrit: no significant differences

Anova: Single Factor

MonPlasir: transformed data

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Aug 2004	9	6.76	0.751	0.042
Sept/Oct 2004	7	5.87	0.839	0.109
2003	10	9.07	0.907	0.085
Aug 2002	9	7.02	0.78	0.028
Sept/Oct 2002	6	5.37	0.895	0.151

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.164	4	0.041	0.538	0.709	2.634
Within Groups	2.736	36	0.076			
Total	2.900	40				

F < Fcrit: no significant differences

Kruskal-Wallis test - MonPlasir

Level	**N (sample size)**	**Median**	**Average rank**
Aug 2004 - A	9	0.54	18.5
Sept/Oct 2004 - B	7	0.62	20.29
2003 - C	10	0.7	23.9
Aug 2002 - D	9	0.61	20.78
Sept/Oct 2002 - E	6	0.64	20.92
Total	41		20.98

H = 9.31 df=4 chi-square = 9.49 p=0.05

H is smaller than chi: no significant difference

p=α this difference is considered to be statistically significant

Conclusion:

- As indicated above the data did not comply with conditions to apply ANOVA but still the application of ANOVA and the Kruskal-Wallis test was demonstrated. The Kruskal-Wallis test is the non-parametric version of the one-way analysis of variance by ranks. The ANOVA test compares the component of the total variation which is due to a difference in sample means and the Kruskal-Wallis test compares the median. Non-parametric test are in general less powerful in comparison with the parametric test such as ANOVA
- The results demonstrated that the outcomes of ANOVA transformed data and Kruskal-Wallis are the same.
- The results demonstrated that there are significant differences in waste generation in the low income classes (Tamenga and Blauwgrond) which can be ascribed to people’s behaviour (dumping or burning of waste)

- In the high income - (MonPlasir) and medium income area there is no significant difference. The sample size of MonPlasir was very small (less than seven); in that case it is difficult to observe significant statistical differences.

It may be concluded that the ANOVA test results are influenced by the sample size (small) and the sample size (# of household) was not equally distributed over all economic classes. The low participation in this research can be ascribed to unfamiliarity with this type of research in Suriname. More research in this area (waste generation) is recommended.

II -2. CORRELATION

Consider the following problem: is there is a relationship between the variables: household size and waste generation rate
Correlation: waste generation rate increases with household size?
95 % confidence interval
α =0,05

BLAUWGROND – LINEAR CORRELATION

Groups	df	$r_{calculated}$ (correlation coefficient)	r^2 (coefficient of determination)	Trendline equation	$p_{computed}$ (p from r)	r_{tab}	Note
Sept 2004	12	- 0.43	0.18	y = -0.11x + 0.84	0.13	0.532	ns – weak
October 2004	9	- 0.12	0.02	y = -0.01x + 0.29	0.72	0.602	ns - weak
2003	12	- 0.50	0.25	y = -0.12x + 1.08	0.07	0.532	(nqs)– moderate
2002	16	- 0.50	0.25	y = -0.05x + 0.42	0.03	0.468	(*)

BLAUWGROND – NON-LINEAR CORRELATION (Power/Log)

Groups	df	$r_{calculated}$ (correlation coefficient)	r^2 (coefficient of determination)	Trendline equation	$p_{computed}$ (p from r)	r_{tab}	Note
Sept 2004	12	- 0.47 - 0.49	0.22 0.24	$y = 0.87x^{-0.85}$ y=-0.51 ln(x) +1.06	0.09 0.08	0.532	nqs
October 2004	9	- 0.01 - 0.09	0.0001 0.009	$y = 0.22x^{-0.02}$ y=-0.04 ln(x) +0.29	0.98 0.79	0.602	ns - weak
2003	12	- 0.44 - 0.71	0.19 0.51	$y = 0.85x^{-0.65}$ y=-0.65 ln(x) +1.43	0.12 0.04	0.532	ns- weak (**)
2002	16	- 0.48 - 0.49	0.23 0.24	$y = 0.49x^{-0.81}$ y=-0.17 ln(x) +0.45	0.04 0.04	0.468	(*)

ns = difference is considered to be *not statistically significant::* correlation weak ($p > \alpha$ or $r_{cal} < r_{tab}$)
nqs = difference is considered to be *not quite statistically significant::* correlation moderate
(*) = difference is considered to be *statistically significant*: correlation strong ($p < \alpha$ or $r_{cal} < r_{tab}$)
(**) = difference is considered to be very *statistically significant*: correlation very strong ($p < \alpha$ or $r_{cal} > r_{tab}$)

TAMENGA – LINEAR CORRELATION

Groups	df	$r_{calculated}$ (correlation coefficient)	r^2 (coefficient of determination)	Trendline equation	$p_{computed}$ (p from r)	r_{tab}	Note
Aug 2004	14	- 0.47	0.22	y = -0.07x + 0.75	0.07	0.497	nqs
July 2004	11	- 0.36	0.13	y = -0.04x + 0.58	0.02	0.553	ns – weak
2003	12	- 0.52	0.27	y = -0.09x + 0.85	0.06	0.532	nqs
July 2002	12	- 0.09	0.01	y = -0.005x + 0.17	0.75	0.532	ns
Aug 2002	12	- 0.47	0.22	y = -0.04x + 0.54	0.09	0.532	nqs
Sept 2002	10	- 0.62	0.38	y = -0.09x + 0.87	0.03	0.576	(*)

TAMENGA – NON-LINEAR CORRELATION (Power/Log)

Groups	df	$r_{calculated}$ (correlation coefficient)	r^2 (coefficient of determination)	Trendline equation	$p_{computed}$ (p from r)	r_{tab}	Note
Aug 2004	14	- 0.47 - 0.46	0.22 0.21	$y = 0.74x^{-0.54}$ y=-0.20 ln(x) +0.72	0.07 0.07	0.497	nqs
July 2004	11	-0.33 - 0.37	0.11 0.14	$y = 0.51x^{-0.25}$ y=-0.11 ln(x) +0.56	0.27 0.21	0.553	ns – weak
2003	12	- 0.63 - 0.55	0.4 0.3	$y = 0.86x^{-0.84}$ y=-0.33 ln(x) +0.88	0.02 0.04	0.532	(*)
July 2002	12	- 0.12 - 0.05	0.02 0.0023	$y = 0.21x^{-0.12}$ y=-0.01 ln(x) +0.21	0.68 0.87	0.532	ns
Aug 2002	12	- 0.44 - 0.54	0.19 0.29	$y = 0.51x^{-0.52}$ y=-0.17 ln(x) +0.56	0.12 0.05	0.532	ns (*)
Sept 2002	10	- 0.49 - 0.53	0.24 0.28	$y = 0.78x^{-0.59}$ y=-0.23 ln(x) +0.77	0.11 0.08	0.576	ns nqs

ns = difference is considered to be *not statistically significant::* correlation weak ($p > \alpha$ or $r_{cal} < r_{tab}$)
nqs = difference is considered to be *not quite statistically significant::* correlation moderate
(*) = difference is considered to be *statistically significant*: correlation strong ($p < \alpha$ or $r_{cal} < r_{tab}$)
(**) = difference is considered to be very *statistically significant*: correlation very strong ($p < \alpha$ or $r_{cal} > r_{tab}$)

CUPIDO – LINEAR CORRELATION

Groups	df	$r_{calculated}$ (correlation coefficient)	r^2 (coefficient of determination)	Trendline equation	$p_{computed}$ (p from r)	r_{tab}	Note
June/July 2004 (inclusive HHS=16)	12	- 0.31	0.1	y = -0.03x + 0.62	0.28	0.532	ns
June/July 2004 (exclusive HHS=16)	11	- 0.35	0.12	y = -0.09x + 0.78	0.25	0.552	ns
June/Aug 2004	12	- 0.64	0.41	y = -0.12x + 0.93	0.01	0.532	(*)
2003	11	- 0.39	0.15	y = -0.04x + 0.48	0.19	0.553	ns
June/July 2002	16	- 0.54	0.29	y = -0.09x + 0.96	0.02	0.468	(*)
JulyAug 2002	17	- 0.32	0.10	y = -0.05x + 0.68	0.18	0.456	ns
Aug/Sept 2002	14	- 0.04	0.00	y = -0.01x + 0.55	0.89	0.497	ns

CUPIDO – NON-LINEAR CORRELATION (Power/Log)

Groups	df	$r_{calculated}$ (correlation coefficient)	r^2 (coefficient of determination)	Trendline equation	$p_{computed}$ (p from r)	r_{tab}	Note
June/July 2004 (inclusive HHS=16)	12	- 0.45 - 0.37	0.20 0.14	$y = 0.61x^{-0.43}$ y=-0.21 ln(x) +0.73	0.11 0.19	0.532	ns
June/Aug 2004	12	- 0.72 - 0.72	0.52 0.52	$y = 1.08x^{-0.82}$ y=-0.43 ln(x) +0.99	0.004 0.004	0.532	(**)
2003	11	- 0.52 - 0.37	0.27 0.14	$y = 0.49x^{-0.58}$ y=-0.11 ln(x) +0.46	0.07 0.21	0.553	nqs ns - weak
June/July 2002	16	- 0.39 0.39	0.39 0.39	$y = 1.03x^{-0.54}$ y=-0.35 ln(x) +1.05	0.006 0.006	0.468	(**)
JulyAug 2002	17	- 0.36 - 0.35	0.13 0.12	$y = 0.60x^{-0.32}$ y=-0.19 ln(x)+0.72	0.21 0.22	0.456	ns
Aug/Sept 2002	14	- 0.0008 - 0.024	6E-07 0.0006	$y = 0.44x^{-0.0007}$ y=-0.01 ln(x) +0.51	0.99 0.93	0.497	ns

ns = difference is considered to be *not statistically significant::* correlation weak ($p > \alpha$ or $r_{cal} < r_{tab}$)
nqs = difference is considered to be *not quite statistically significant::* correlation moderate
(*) = difference is considered to be *statistically significant*: correlation strong ($p < \alpha$ or $r_{cal} < r_{tab}$)
(**) = difference is considered to be very *statistically significant*: correlation very strong ($p < \alpha$ or $r_{cal} > r_{tab}$)

MONPLASIR – LINEAR CORRELATION

Groups	df	$r_{calculated}$ (correlation coefficient)	r^2 (coefficient of determination)	Trendline equation	$p_{computed}$ (p from r)	r_{tab}	Note
Aug 2004	7	0.01	0	y = -0.001x+0.60	0.98	0.666	ns
Sept/Oct 2004	5	- 0.18	0.03	y = -0.07x + 1.08	0.70	0.755	ns
2003	8	- 0.24	0.06	y = -0.07x + 1.17	0.51	0.632	ns
Aug 2002	7	- 0.40	0.16	y = -0.05x + 0.84	0.28	0.666	ns
Sept/Oct 2002	4	- 0.52	0.27	y = -0.20x + 1.78	0.29	0.811	ns

MONPLASIR – NON-LINEAR CORRELATION (Power/Log)

Groups	df	$r_{calculated}$ (correlation coefficient)	r^2 (coefficient of determination)	Trendline equation	$p_{computed}$ (p from r)	r_{tab}	Note
Aug 2004	7	- 0.04 - 0.26	0.0014 0.07	$y = 0.55x^{-0.03}$ y=-0.14 ln(x) +0.77	0.92 0.499	0.666	ns
Sept/Oct 2004	5	- 0.17 - 0.06	0.03 0.004	$y = 0.93x^{-0.28}$ y=-0.51 ln(x) +1.06	0.72 0.9	0.755	ns
2003	8	- 0.2 - 0.2	0.04 0.04	$y = 1.02x^{-0.25}$ y=-0.24 ln(x) +1.19	0.58 0.58	0.632	ns
Aug 2002	7	- 0.44 - 0.47	0.19 0.22	$y = 1.01x^{-0.42}$ y=-0.27 ln(x) +0.99	0.24 0.20	0.666	ns
Sept/Oct 2002	4	- 0.67 - 0.55	0.45 0.30	$y = 4.35x^{-1.37}$ y=-1.07 ln(x) +2.37	0.15 0.26	0.811	ns

ns = difference is considered to be *not statistically significant::* correlation weak ($p > \alpha$ or $r_{cal} < r_{tab}$)
nqs = difference is considered to be *not quite statistically significant::* correlation moderate
(*) = difference is considered to be *statistically significant*: correlation strong ($p < \alpha$ or $r_{cal} < r_{tab}$)
(**) = difference is considered to be very *statistically significant*: correlation very strong ($p < \alpha$ or $r_{cal} > r_{tab}$)

Conclusions

It can be concluded from the magnitude of r that with a few exceptions there is a weak correlation between household size and waste generation and that the sign of r is mainly negative meaning that the variables are inversely related.

APPENDIX III: ESTIMATED COSTS (€) FOR RESIDENTIAL WASTE COLLECTION BASED ON DIFFERENT CONTAINERS SYSTEMS

Assumptions	20 m^3 compactor*	9 Ton open truck*	20 m^3 compactor*	9 Ton open truck*	20 m^3 compactor*	20 m^3 compactor*	20 m^3 compactor*	9 Ton open truck*	20 m^3 compactor*	9 Ton open truck*
	2 trips per day	2 trips per day	2 trips per day	2 trips per day	2 trips per day	2 trips per day	2 trips per day	2 trips per day	2 trips per day	2 trips per day
	7-year life (N)	7-year life (N)	7-year life (N)	7-year life (N)	7-year life (N)	7-year life (N)	7-year life (N)	7-year life (N)	7-year life (N)	7-year life (N)
	38.000 € / truck x 9 (A)	16.500 € / truck x 12 (A)	38.000 € / truck x 9 (A)	16.500 € / truck x 12 (A)	38.000 € / truck x 15 (A)	38.000 € / truck x 15 (A)	38.000 € / truck x 13 (A)***	16.500 € / truck x 16 (A)***	38.000 € / truck x 13 (A)***	16.500 € / truck x 16 (A)***
	Plastic garbage bags	Plastic garbage bags	Mini containers	Plastic garbage bags	Mini containers / Communal containers	Plastic garbage bags / Communal containers	Plastic garbage bags	Plastic garbage bags	Mini containers	Plastic garbage bags
Collection costs										
Annual depreciation (A/N) **	48.857	28.286	48.857	28.286	81.429	81.429	70.571	37.714	70.571	37.714
Spare part cost (0.53xA/N)	25.895	14.992	25.895	14.992	43.157	43.157	37.403	19.989	37.403	19.989
Maintenance cost (0.13xA/N)	6.351	3.677	6.351	3.677	10.586	10.586	9174	4.903	9174	4.903
Insurance cost (0.008xA)	2.736	1.584	2.736	1.584	4.560	4.560	3952	2.112	3952	2.112
Transport cost (0.02xA)	6.840	3.960	6.840	3.960	11.400	11.400	9880	5.280	9880	5.280
Fuel volume (0.18xHP) (litre/vehicle)	396	528	396	528	660	660	572	704	572	704
Garbage container	15.833	-	326.800	6.333	326.800 / 65.910	9.500 / 65.910	15.833	-	326.800	6.333
Driver + crew salary	95.294	167.143	95.294	167.143	160.714	160.714	95.294	167.143	95.294	167.143
Administrative costs	209.525	-	209.525	-	209.525	209.525	209.525	-	209.525	-
Total operation costs	**411.727**	**220.170**	**722.694**	**226.503**	**914.741**	**597.441**	**452.204**	**237.845**	**763.171**	**244.178**
Collection costs/ton	8.88	4.75	15.59	4.89	19.73	12.88	9.75	5.13	16.46	5.27
Total collection costs/ton	13.62 € (US$ 16.36)		20.48 € (US$ 24.58)		19.73 € US$ 23.68	12.88 € US$ 15.47	14.88 € US$ 17.86		21.73 € US$ 26.08	
Collection cost per HH per year	US$ 11.97		US$ 17.98		US$ 17.33	US$ 11.31	US$ 13.07		US$ 19.09	

* Date of manufacture: 1995 (used trucks)

** Karadag Dogan and Sakar Suleyman, 2003

***Standby trucks in case of breakdown or calamity are included in the truck fleet

Curriculum Vitae

1 Personal information

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2 Education

1980 – 1986:	Licentiate (Lsc) Diploma in Mining Anton de Kom University of Suriname Faculty of Technology – Department of Mining
1988 – 1990:	Master of Science (M.Sc.) Diploma in Engineering Geology Free University of Brussel - Department of Geology, Belgium
1991 – 1994:	M.Sc. (Drs.) Diploma in Environmental Engineering State University of Utrecht – Faculty of Geosciences – Department on Innovation and Environmental Sciences, The Netherlands

3 Work experience

October 199 - August 2006:
Lecturer at the Environmental Department, University of Suriname, Faculty of Technology
Courses: Environmental impact assessment, Solid waste management and technology

January 1997 – September 2001:
Head of the Environmental Department, University of Suriname, Faculty of Technology

4 Implemented projects

October 2004 – October 2005:
Limited environmental impact assessment in the MUMA's (Multiple Use Management Areas) in relation to migratory birds – LBB (s'Land Bos Beheer – Suriname Forest Service)

September 2004 - September 2005:
Environmental impact assessment of (illegal) legal logging in Brokopondo area and Pattamaca – WWF (World Wildife Fund)

April – June 2004:
Research to the oil leakage of oil station – Kwattaweg - TEXACO Suriname

March – October 2003:
Impact assessment of the transport sector - Transport Sector Policy study in Suriname – ILACO (Internationaal Landaanwinnings Consultants Bureau)

March – October 2001:
The use and impact of wood preservatives used in the forestry sector – LBB (s'Lands Bos Beheer – Suriname Forest Service)

May – July 2000:
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