MASTER

Dissemination of constructed wetlands technology for improved sanitation in Tanzania
strategic niche management

de Ruijter, R.D.W.

Award date:
2009

Eindhoven University of Technology
Technology Management

Dissemination of Constructed Wetlands technology for improved sanitation in Tanzania

Strategic Niche Management

Master of Science thesis

ing. Ralph D. W. de Ruijter

Student identity number: *574353*
Faculty: *Technology Management, MSc Technology Policy*
Specialization: *Technology and Development Studies*
Eindhoven University of Technology, the Netherlands

Under supervision of:

dr. H. A. Romijn
dr. ir. A.M.C. Lemmens
dr. ir. A.J. Balkema

Research in co-operation with:
College of Engineering and Technology
University of Dar es Salaam, United Republic of Tanzania

Local supervisor:

dr. K.N. Njau

Dissemination of Constructed Wetlands technology for improved sanitation in Tanzania

Strategic Niche Management

Ralph de Ruijter 16-01-2009

Section of Technology and Development Studies
Faculty of Technology Management
Eindhoven University of Technology

Eindhoven University of Technology
Department of Technology Management
Technology & Policy

Dissemination of Constructed Wetlands technology for improved sanitation in Tanzania

Strategic Niche Management

by:
ing. Ralph D. W. de Ruijter

date:
January, 2009

Under supervision of:
dr. H. A. Romijn
dr. ir. A.M.C. Lemmens
dr. ir. A.J. Balkema

Local supervisor:
dr. K.N. Njau

Preface

This thesis is written for the fulfillment of the Master Innovation Sciences, Technology and Policy for Developing Economies at the Eindhoven University of Technology. For this thesis I conducted a field study of four months in Tanzania, from September till December 2006. The beginning of my journey to Tanzania was rather different than the original planning. Instead of going to Tanzania for a year with my partner and daughter, an unforeseen family incident occurred, which altered the plans, and made me go on my own on this shorted journey. After this unfortunate start, I consider myself very lucky with all the support and help I received. I am great in dept to many of the people which I have met in Tanzania and who made me feel welcome and have contributed to this paper. First I would like to thank Mr. Njau, who has helped me and has given guidance right from the start of the challenge of my field research. I would also like to thank all the people which I have interviewed, who all were very enthusiastic to spend time and put effort in answering my questions, even at the occasions when I came unannounced. The kindness and willingness to cooperate of all these people have contributed enormously to the realization of this thesis.

Once back in the Netherlands the second challenge of writing this thesis began. It was at sometimes difficult to find the right direction and combination of all gathered information, ideas and theories. My first supervisor Henny Romijn has given me excellent guidance in structuring and building this thesis. I am grateful for all the interesting discussions we had and her great enthusiasm and confidence in this research, which have motivated me tremendously and helped me to overcome difficulties. I also like to thank my second supervisor L. Lemmens, and third supervisor A. Balkema for their valuable contributions to this thesis.

This research has been a very interesting journey in many perspectives, mentally and physically. Looking back at this journey I realize that I have learned in many ways and am hopeful that this research will contribute to more sustainable development of the Tanzanian sanitation systems.

I hope that you will enjoy reading this thesis,

Ralph de Ruijter,

Poppel, 2009

Summary

This thesis focuses on the adoption and dissemination of the environmentally sustainable wastewater treatment technology of Constructed Wetlands, and how this technology can contribute to improving sanitation facilities in Tanzania. Adequate domestic wastewater treatment as a part of sanitation is of great importance in addressing public health, economy and environment issues. Domestic wastewater treatment also plays an important role with respect to poverty alleviation. Today, more than 40 per cent of the world population lives without proper sanitation facilities.

The University of Dar es Salaam (UDSM) started with research on Constructed Wetlands as an alternative wastewater treatment technology in 1998. Since then the university has implemented seven different Constructed Wetland projects. Despite the technical soundness, low operating and maintenance costs, within Tanzania this technology has not been diffused to other locations than the pilot projects initiated by the UDSM.

The main research questions which are answered in this thesis are:

- Which factor(s) are hindering successful dissemination of Constructed Wetlands in Tanzania?
- What arrangements (within UDSM) are necessary for effective transfer of this technology?

The theory of Strategic Niche Management in combination with a Cost Benefit Analysis forms the theoretical framework. The multi-level perspective of the Strategic Niche Management framework distinguishes three heuristic levels: landscape, regime, and niche.

At each of these levels, a broad socio-technical analysis was undertaken regarding developments in Constructed Wetland technology, science, markets, user practices, regulation, infrastructure, cultural meaning, perceptions of problems and visions. The Cost Benefit Analysis was used to reveal the actual financial and societal costs and benefits of the Constructed Wetland technology, and to identify the beneficiaries. The data for the research were acquired by interviewing key actors during four months of field research in Tanzania (from September till December 2006), and were also gathered from secondary sources.

The research findings on the first research question at the landscape and regime level are that the current (malfunctioning) wastewater treatment regimes in Tanzania are environmentally and economically unsustainable and that the cost of water pollution is often not covered by the polluter. In Tanzania 6 to 6.5 million people currently live in areas which have no or little connection to community services, such as water and electricity. However, in many cases the Constructed Wetland cannot provide a feasible solution for Tanzania's sanitation problems. This is because the technology requires a basic level of technology in the current regime before it can enter this regime. The Wetlands need water to function properly, and should be connected to a water borne sanitation system. This implies unfortunately that the two technological regimes which cause the greatest direct health hazard, pit latrines and illegal dumping of excreta, which are used by about 80% of the population, are unsuitable for direct implementation of Constructed Wetland technology. The lack of basic infrastructure cannot be directly solved by Constructed Wetlands. Therefore only about 20% of the Tanzanian population can be directly seen as potential adopters of the

Constructed Wetland technology; at the same time the technology can be expected to have a much broader impact on Tanzanian society because its beneficial impacts extend well beyond the immediate areas in which the wetlands are located.

The niche level analysis of the technological Constructed Wetland projects reveals lack of a clear vision by the stakeholders in some of these projects. This has been an important factor contributing to failure of these projects. Visions on sanitation and responsibility for the environment have also been crucial determinants of performance. In the less successful cases, the Kleruu Teacher's collage and KIBO paper mill the reason for adopting Constructed Wetland technology was driven by complaints from the environment, instead of own environmental concerns; hence the enthusiasm and commitment to the Constructed Wetland project was not optimal and led to failure. External pressure to adopt the Constructed Wetland technology, without complete commitment, and consciousness about the importance of the technology-adopting party, led to failure of these projects because essential maintenance and proper operation after the construction phase was not undertaken. By neglecting this, the Wetlands will malfunction, and the project will fail in the long term. Lack of financial feasibility, especially due to the great discrepancy between limited private and large societal net benefits of the adoption of Constructed Wetland technology was also found to hinder the dissemination of Constructed Wetlands.

The main conclusions from the study are that the niche technology of Constructed Wetlands might yet solve some of the sustainability problems in current sanitation regimes, but it cannot become an independent new technological regime. Hence, further research is needed to identify specific potential technology adopters for whom the technology is suitable. These adopters can be found in two extant regimes:

- The central wastewater treatment plants, which can be upgraded by CW technology because the effluent of some of the Waste Stabilization Ponds, if not sufficient cleaned, can be a source of bacterial contamination since it is discharged in local rivers; the addition of a Constructed Wetland to the WSP's can improve the quality of the effluent.

- The septic tanks at the governmental buildings such as schools and hospitals, which are not connected to the piped sewage system; these systems can be improved by installing Constructed Wetland technology.

The inventory of factors which are hindering successful dissemination leads to conclusions regarding the second research question, the arrangements that UDSM will have to make in order to enhance the transfer of Constructed Wetland technology: The UDSM needs to contact schools, governmental institutions and UWASA's to search for the potential adopters. Once these potential adopters are found, further research needs to be done concerning site-specific circumstances such as current sanitation system malfunctioning, financial means, and dedication to environmental issues. Constructed Wetlands at private institutions such as schools may be already feasible from a financial point of view, even though there are many more benefits to society from such a project. Financing of this type of projects should therefore not be a problem, nevertheless UDSM should point out the financial feasibility to these potential adopters and create awareness to this fact.
The CW projects at domestic wastewater treatment plants are not feasible from a financial point of view. Therefore a socio-economic Cost Benefit Analysis is necessary to reveal the societal benefit of this improved wastewater treatment technology. NGO's, international aid donors, the local population and the

Tanzanian government could be persuaded by the figures from the socio-economic CBA to invest in such public Constructed Wetland projects.
This thesis recommends the University of Dar es Salaam to use the Constructed Wetland technology in a university-wide multidisciplinary dissemination project. This project could identify potential technology adopters, create awareness among government communities, and help them in fundraising and design of the Constructed Wetlands.

Table of Contents

Acronyms and definitions

Acronyms

CBO	Community Based Organization
CWSSA	Clustered Water Supply and Sanitation Authority
CW	Constructed Wetland
DUWSA	District Urban Water and Sewerage Authority
LGRP	Local Government Reform Policy
MDG	Millennium Development Goals
MoH	Ministry of Health
NGO	Non-governmental Organization
NPES	National Poverty Eradication Strategy
PRS	Poverty Reduction Strategy
SADC	Southern African Development Community
TSh	Tanzania Shillings
UWSA	Urban Water and Sewerage Authority
WCA	Water Consumers Association
WSS	Water supply and sanitation

Definitions

Authority: An autonomous organization established by or under an Act of Parliament to carry out specific functions within defined areas, accountable to a Minister through a Board of Directors.

Community: A group of households, hamlets or villages which are served by common water facilities.

Disability Adjusted Life Year (DALY) is a measure of a year of life lost due to premature death, and illness and injuries weighted by severity and duration.

Non-community Owned: Ownership of water supply assets is transferred to autonomous legally established organizations (c.f. Authorities) with responsibility for water supply and sanitation services and the organizations have full responsibility and accountability for the maintenance, protection and expansion of the assets.

Peri-urban Areas: Emerging settlements outside the formal housing areas of an urban area. In these settlements there is lack of basic services such as water supply and sanitation facilities. Generally the people living in these areas are in the low income group with limited ability to pay for water and sanitation services.

Public Tap: A tap or water distribution point which is used by a number of different consumers who pay for water drawn, and which is commonly found in peri-urban areas, informal settlements, and rural water supplies.

Regulation: The activities involved in ensuring consumers receive the most cost effective level of service that they have been led to expect and are prepared to pay for. Specifically this involves: protecting consumers; assuring a demand driven approach; improving efficiencies and effectiveness of service providers; protecting assets; and promoting competition.

Sanitation: Whilst a broad definition of sanitation covers the state of cleanliness of the environment and includes a wide range of waste management activities, within the context of this report sanitation is defined as the provision of appropriate facilities and services for the disposal of human excreta and waste waters. These include sewerage systems, on-site human excreta systems, and public education on water related hygienic principles.

Service Provider: The institution or organization with actual or delegated responsibility for providing water supply and sewerage or sanitation services to consumers. Service Providers include inter *alia* Urban Water and Sewerage Authorities, District Urban Water and Sewerage Authorities, District Councils, Township Councils, Water User Associations, Water User Trusts, Non-Government Organizations, and private operators.

Sewerage: Human excreta disposal systems which rely on water as a transporting medium for the waste.

Small Towns: Secondary emerging settlements (mainly in rural areas) that have transformed from village status into small township status. A settlement can be identified as a small town if the population is 10,000 or above, with a higher housing density than in a rural situation, and commercial facilities such as shops and markets.

Urban Area: Urban Area means an area within the jurisdiction of an authority.

Waste Stabilization Ponds (WSPs) are large, shallow basins in which raw sewage is treated entirely by natural processes involving both algae and bacteria.

Constructed Wetlands (CWs) are planned systems designed and constructed to employ wetland vegetation to assist in treating wastewater in a more controlled way

1 Introduction

This research is concerned with the diffusion and adoption of sustainable waste water treatment technologies in developing countries. This chapter provides background information on the research problem and some of the general characteristics of Tanzania. The research aim and research questions are elaborated as well as the limitations of the research and structure of this thesis.

1.1 Costs of improper domestic wastewater treatment

Adequate domestic wastewater treatment as a part of sanitation, is of great importance in addressing public health, economy and environment issues. Domestic wastewater treatment also plays an important role with respect to poverty alleviation. Today, more than 40 per cent[i] of the world population lives without proper sanitation facilities. It is estimated that 88%[i] of the global burden of disease is attributable to unsafe water supply, lack of proper sanitation and hygiene and is mostly concentrated on children in developing countries. Every day, this contributes to the deaths of 5,000 children from largely preventable causes, such as diarrheal diseases.[i]

Improved sanitation facilities prevent the transfer of bacteria, viruses and parasites in human excreta which can spread through water and soil, contaminating everything in which it contacts, including food and drinking water. Illness as a result of improper sanitation, reduces productivity due to workers taking sick leave which reduces economic output and creates an extra burden on health services. Unsafe sanitary practices translate into economic costs in the tens of billions of dollars and threaten future progress.[i]

> *"Lack of sanitation is a silent global crisis affecting human health and poverty and is one of the single biggest challenges facing the world. Starting today, we have the opportunity to put this issue at the forefront of the international agenda which is vital if we are to reach the Millennium Development Goal target on sanitation."*

UN-WATER chairman Pasquale Steduto[1]

In addition to this, lack of proper sanitation facilities exposes women and girls to violence and abuse as some of them are only able to defecate after nightfall and in secluded areas for the sake of privacy[i]. Schools without proper facilities prevent children, especially girls reaching puberty, to remain in the educational system. If current trends continue, there will be 2.4 billion people without basic sanitation in 2015, with children continuing to pay the price in lost lives, missed schooling, disease, malnutrition and poverty.

According to Faechem and Cairncross (1978)[ii], sanitary disposal of human wastes is perhaps of greater importance than the provision of safe water supply. Because if disposal of human excreta is correctly managed, there will be little risk of human waste contaminating domestic water sources.

[1] At the opening of the year of sanitation 2008

The world wide improvement of sanitation, which includes the construction and improvement of existing facilities, as well as wastewater management and hygiene promotion requires an global investment of under $10 billion per year with an estimated economic return of $9.1 for each invested $1.[i]

1.2 Tanzanian situation

As a consequence of the rapid urbanization in Tanzania, it is foreseen that the urban population in Tanzania will increase at a rate of more than 10% per year, communities of very poor people are now living in the inner city or periphery of those rapidly growing cities. The increasing population, combined with increasing water consumption and the rise of waterborne sanitation applications, create widespread wastewater disposal problems.

In many cases, wastewater is discharged locally onto open ground and vacant plots, creating ponds of smelling stagnant water[iii], causing threat to human health and economic losses. Health risks are increased by the fact that household and surface water drainage systems are combined, so that floodwater becomes contaminated with human excreta. In addition to this, mosquitoes and other pests breed in blocked drains and ponds, spreading diseases. About 60% of the health complaints in Tanzania, are related to groundwater contamination (Chaggu *et al.*, 1993)[iv].

Sustainable sanitation is required as one of the factors to ensure public health, but is challenging for reasons such as insecure tenure, lack of political will, financing problems, cost recovery problems and lack of choice of technical options.

1.3 Research problem

Many developing countries are currently experiencing rapid population and economic growth. Without appropriate means of wastewater collection and treatment more cases of cholera and other water borne diseases are likely to occur. The public and private investments in domestic wastewater treatment systems lag behind in Tanzania and the currently used systems are inadequate. Due to poor maintenance and unsustainable technologies, most wastewater treatment facilities are not functioning properly.

The University of Dar es Salaam started in 1998 with research for alternative wastewater treatment technology: Constructed Wetlands. Since then the university has implemented this technology at seven different projects. Constructed wetland treatment systems, see figure 1, are engineered systems which have been designed and Constructed to utilize natural processes for reduction of hazardous pathogens in domestic wastewater. In municipal applications Constructed Wetlands can provide low-cost and appropriate technology for the treatment of domestic wastewater and faecal sludges.[v]

However, despite the technical soundness, low operating and maintenance costs, within Tanzania this technology has not been diffused to other locations than the pilot projects initiated by the UDSM.[vi] Key question is: What prevents the broader uptake of this promising technology in Tanzania?

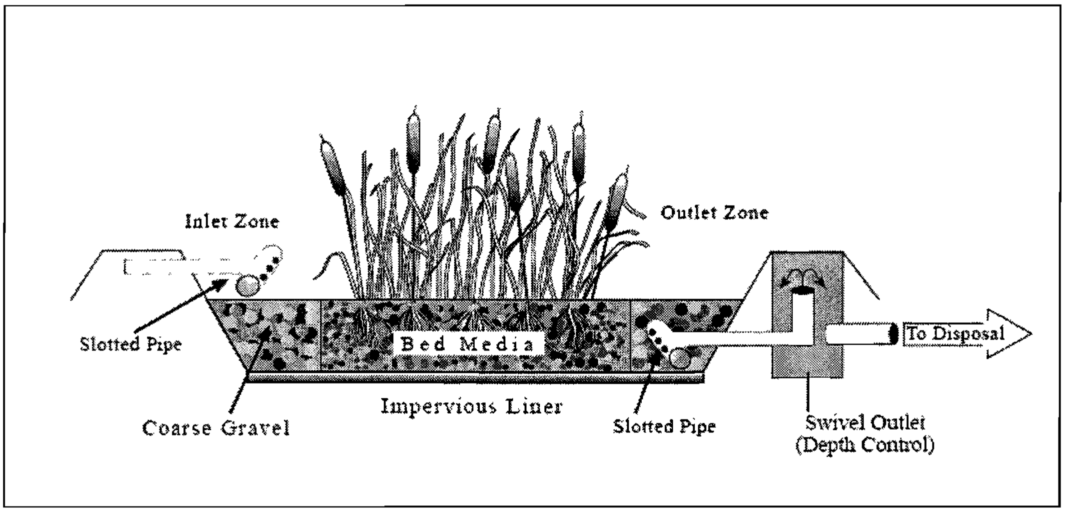


Figure 1 diagram of a Constructed wetland

1.4 Research context

This section provides some specific relevant background information on the situation in Tanzania, because this is the geographical focus of this research.

1.4.1 General Information Tanzania

Tanzania, (see figure 2) has an area of about 937,000 km^2 land and has common borders with Kenya, Uganda, Rwanda and Burundi in the north, the Democratic Republic of Congo in the west and Zambia, Malawi and Mozambique in the south. The country has a narrow highly indented coast line of some 800 km long occupying the eastern seaboard. Tanzania is relatively dry with more than half of the country receiving, on average, less than 800 mm of rainfall per year.

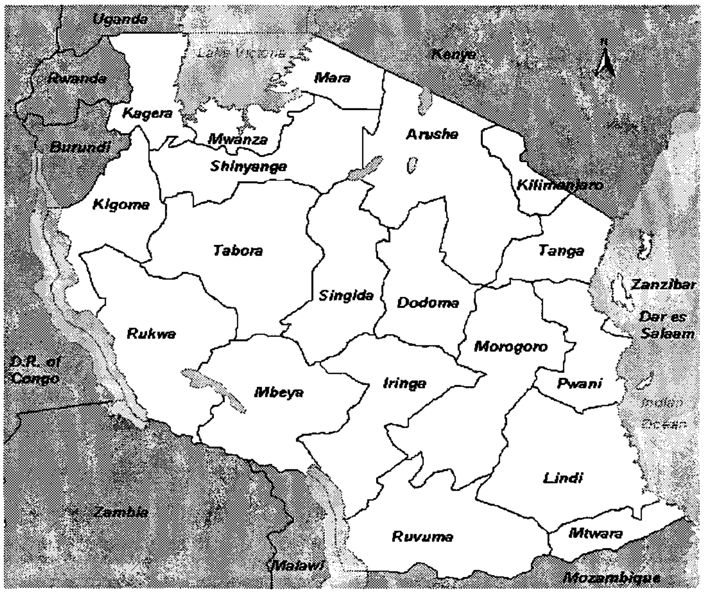


Figure 2 Tanzania and its neighboring countries

Tanzania is one of the poorest countries in the world; it is ranked 226 on a GDP per capita list of 232 countries in declining order[viii]. It has a population of about 35.5 million,[vii] of which 36% lives below the poverty line.[viii] GDP/capita in 2007 was USD 700. A large share of the population, over 77%, lives in rural areas[ix]. The urban-poor is estimated as constituting 80 per cent of the urban population. They are characterized by low-income levels (less than US$1 a day) as well as high rates of water-borne diseases[x]. Diseases as cholera did not occur in Tanzania until three decades ago, these endemic disease can be related to the increasing population density in combination with poor sanitation.

1.4.2 Child mortality in Tanzania

As mentioned in section 1.1 dehydration caused by severe diarrhea is a major cause of morbidity and mortality among young children. Diarrheal diseases globally kill an estimated 1.8 million people each year[xi]. Among children under five years in developing countries, diarrhea accounts for 17% of all deaths[xii]. Exposure to diarrheal disease-causing agents is frequently a result of the use of contaminated water and unhygienic practices related to food preparation, excreta disposal and hence improper domestic wastewater treatment.

Table 1 shows neonatal[2], post neonatal, infant, child, and under-five mortality rates in Tanzania, measured over the period 2004-2005[xiii]. The infant mortality rate is 68

[2] Neonatal mortality (NN): the probability of dying within the first month of life
Post neonatal mortality (PNN): the difference between infant and neonatal mortality
Infant mortality (1q0): the probability of dying before the first birthday
Child mortality (4q1): the probability of dying between the first and fifth birthday
Under-five mortality (5q0): the probability of dying between birth and fifth birthday.

per 1,000 live births. The under-five mortality rate for the period is 112 per 1,000. Thus, one out of nine Tanzanian children dies before the fifth birthday.

Years preceding the survey	Neonatal mortality (NN)	Postneonatal mortality[1] (PNN)	Infant mortality ($_1q_0$)	Child mortality ($_4q_1$)	Under-five mortality ($_5q_0$)
0-4	32	36	68	47	112
5-9	36	64	100	63	156
10-14	35	59	94	74	161

Table 1 child mortality in Tanzania

Diarrheal disease is also an enormous economic burden, resulting in significant direct costs to the health sector and patients for treatment as well as in lost time at school, work and other productive activities[xiv].

1.5 Research aim and approach

In Tanzania, and other developing countries, the population landscape is changing; the number of inhabitants is rising and correspondingly the amount of produced domestic wastewater. This seems to be a window of opportunity for technological niches such as Constructed Wetlands. However, the successful introduction of technological innovations does not only involve technical innovations, but also changes in broader socio-technical context. Therefore transitions at this level should not only be studied as technological discontinuities, but also as co-evolution of technology and society.

The analytical framework of Strategic Niche Management (SNM) provides a framework for examination of contextual factors at the meso and macro levels that constrain or enhance development and dissemination of a new technology.[xv] SNM focuses on the socio-technical, co-evolutionary processes which combine insights from different disciplinary backgrounds: sociology of technology, history of technology, evolutionary economics and innovation studies.

Therefore the technical matter of the construction, principle and operation of the sustainable technology of Constructed Wetlands will be analyzed; secondly actor-related mechanisms and the influence of social, cultural, economic and political contexts will be assessed. This combined approach gives insight in the co - evolutionary development processes of technology and society, hence this research will contribute to shifting the focus from a predominantly technological driven approach (the predominant approach of USDM) for the waste water problem towards societal embedding and adoption of environmental sustainable technology in a new environment.

The secondary goal of this research is to assess the appropriateness of SNM- theory in developing countries, since the current literature on SNM handles foremost state-of-the-art technologies in developed countries. This research aims to extend the use of the SNM framework to the introduction of new, low-tech, environmental, social, and financial sustainable technologies in developing countries. The insights from this research are expected to increase knowledge of socio-technical development processes in developing countries, which can translate into useful tools for policy makers.

1.6 Research questions

There are two main research questions in this thesis:

1. Which factor(s) are hindering successful dissemination of Constructed Wetlands in Tanzania?

2. What arrangements (within UDSM) are necessary for effective transfer of this technology?

The answer to the main questions should contribute to a practical strategy for improved dissemination of the Constructed Wetlands or another sustainable technology in this water and sanitation field.

1.7 1.7 Limitations of the research

This research was conducted to fulfil the requirements of an MSc degree. Inevitably, that created time and financial constraints which affected the extent and depth of the research. Two pilot projects are not evaluated because they were located at Tanzanian prison, and there was no permission to visit these sites.

Constructed Wetlands are not a complete new sanitation system, but merely an addition to or an improvement of existing waterborne sanitation systems, therefore this study will not handle the issue if it is desired to use waterborne sanitation systems.

1.8 Research Method

The case study of the dissemination of Constructed Wetlands is analyzed empirically with the SNM Multi Level Perspective framework, which discriminates three heuristic levels (landscape, regime, niche). At each of these levels, a broad socio-technical analysis is made, regarding:

- Ongoing developments in technology, science, markets, user practices, regulation, infrastructure, cultural meaning are determined.
- Types of actors involved, their activities, perceptions of problems, prioritization of problem agendas, and possibly visions about the future.
- Social networks among actors
- A Cost Benefit Analysis to reveal the cost and who benefits of the Constructed Wetland technology

Data acquisition is conducted by:

- Interviewing key actors
- Secondary sources

This analysis will result in:

- multi-level model which increases knowledge of failure and success of non-linear development paths of waste water treatment technologies from a socio-technical perspective
- a practical strategy for improved dissemination of Constructed Wetlands. Furthermore this strategy might yield insights for promotion strategies of other sustainable technologies in developing countries more generally
- A new field of use for the SMN- theory.

1.9 Structure of the thesis

Chapter 2 explains the Strategic Niche Management theory, discusses this theory and elaborates the Cost Benefit Analysis method. Chapter 3 describes the Constructed Wetlands theory, the internal wetland processes, the operation and maintenance and the (dis)advantages of this wastewater treatment technology. Chapter 4 presents the landscape analysis. Chapter 5 is the sanitation regime analysis and the window of opportunity for new environmental sustainable technology. Chapter 6 analyzes the Constructed Wetland niche projects in Tanzania. Chapter 7 is the Cost Benefit Analysis of the niche projects and chapter 8 represents the conclusions and recommendations of this research.

2 Theoretical framework

This thesis, dissemination of Constructed Wetlands in Tanzania, utilizes the theoretical framework of Strategic Niche Management (SNM). This SNM theory is a novel analytical method which aims to facilitate the introduction and diffusion of "new" sustainable technologies through societal experiments.

Strategic Niche Management (SNM) is developed as a tool for simultaneously managing technical and institutional change and to encourage diffusion of sustainable technologies. Potentially useful sustainable technologies often fail to get fully developed, or to catch on in the market, even though they promise superior performance compared to incumbent technologies. This chapter describes the SNM research model, its shortcomings and how the addition of a Cost Benefit Analysis can overcome most of these shortcomings.

2.1 SNM research model

According to SNM, sustainable wastewater treatment and other types of radical innovations, have to be created through interaction between different actors within a specific socio-cultural environment. This environment and the relations between actors can constrain or facilitate a shift towards sustainable development. These actors (e.g. policymakers at different governmental levels, advisors, research institutes, control and inspection services, consumers and interest groups) are participating in different, often overlapping social networks creating a diversified social order in time and space, an order that is produced and reproduced by routine and objectification (i.e., institutionalization) of shared ways of doing, thinking and feeling and functions as a social setting for actors.

Strategic Niche Management distinguishes three analytical levels (see Figure3) to order the multi disciplinary dynamics of (socio-) technical change:

- The micro-level of technological niches, in which new technologies incubate and are tested in a protected space;
- The meso-level of regimes;
- The macro-level of landscape, reflecting structural developments.

Novel sustainable technologies are developed in niches, protected from developments at regime and landscape level, although these developments have an influence on the niches. Policies and legislation for example, influence strategies and expectations in niches. At the same time expectations and the creation of novelties influence developments at the regime and landscape level, see figure 1. This multiple and dynamic connection between the levels is an important feature of technical change.

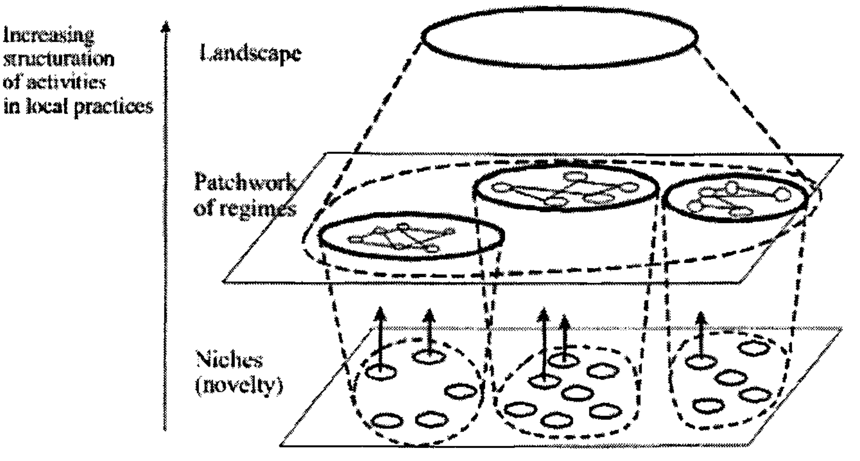


Figure 3 Multi level perspective [xvi]

Innovations with radically new features, especially related to environmental and social sustainability, are not easily accepted in the dominant socio-technical regime. Hence, their successful development, market introduction and dissemination require simultaneous change in different aspects of the regime.

In turn, the regime is embedded in a wider contextual landscape, which consists of material and immaterial societal factors which evolve and change slowly over time (Raven, 2005b)[xvii]. One can think of demography, political culture, change of lifestyle and economy as typical landscape factors. Mature incumbent technologies are an integral part of the dominant regime (and the overarching landscape), as a result of a long process of incremental co-evolution of technological and societal factors in which they get attuned to one another.

The relation between the three levels is dynamic. The different levels mutually shape and re-shape each other. Figure 4 represents the overall SNM framework and how the three analytical levels are interrelated over time.

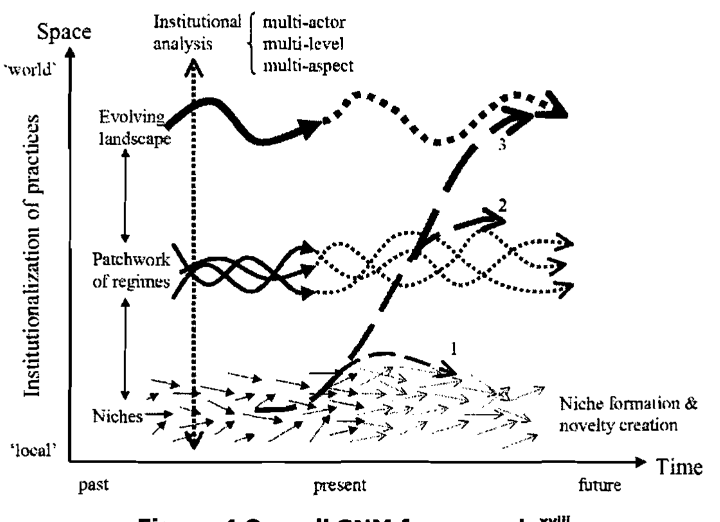


Figure 4 Overall SNM framework [xviii]

2.1.1 Landscape

The landscape provides the overall multi-dimensional context for technical change. It describes long lasting structural technical and institutional evolution. This landscape can constrain or enable sustainable technical change because structural developments can put pressure on existing regimes (e.g. environment pollution caused by unsustainable technology), creating a window of opportunity for new sustainable technology. Therefore landscape trends can be a source of tension for technological regimes. On the other hand landscapes can also constrain technological development by influencing logic and dynamics of the regime selection environment (Schot, 1998[xix]).

> *"The socio - technical landscape relates to material and immaterial elements at the macro level: material infrastructure, political culture and coalitions, social values, world views and paradigms, the macro economy, demography and the natural environment."*

Rothmans, van Asselt and Kemp (2001)[xx]

The outcome of the landscape analysis should provide insights on whether development at this level will hamper or give thrust to the dissemination of the novel niche technology.

2.1.2 Regime

Regimes are shared sets of cognitive, social and technical rules that guide or govern technical change along certain technological paths or trajectories. Eventually these rules (as a kind of social code) become materially embedded in techniques. Regimes are produced and reproduced in social interaction, in more informal networks and in formalized organizational structures (programs, projects, research institutes, and regulations).

The technological regime concept developed is built on the assumption that technological choices and decisions are strongly influenced by a set of rules or logic that derives from the accumulated knowledge, past investments and established practices that serve a social function[xxiii].

Technological regimes tend to filter expectations and constrain the possible or 'realistic'. Thus innovations and technical change tend to follow a trajectory set by the regime. Once new regimes are underway, theory suggests they revert to trajectories which are path dependent and which constrain subsequent technological development[xxi].

Dominant regimes, with all their actors and different interests, are obstructing a breakthrough of radical changes and tend to create ignorance with respect to alternative technological trajectories.
Understanding these challenges generates lessons about obstacles and opportunities for transitions to different sustainable regimes.

A (socio-technological) regime is "the grammar or rule-set comprised in the coherent complex of scientific knowledge, engineering practices, production process technologies, product characteristics, skills and procedures, ways of handling relevant artifacts and persons, ways of defining problems – all of them embedded in institutions and infrastructures."

Rip & Kemp (1998)[xxii]

A regime describes the 'normal way of doing things, 'and according to Raven (2005a[xvi]) the room for niches within a regime, and hence for a transition, is increased by a decrease of alignment (high level of uncertainty and tensions between the technological configuration, the actors and the set of rules), an increase of permeability (reduced resistance from the dominant regime against a certain niche development) and an increase in the vision that problems are no longer solvable within the current regime. A transition is facilitated by a regime that is open to new developments in niches.

2.1.3 Niche

Experimentation and testing in niche markets is a fundamental step in the innovation process for successful introduction of sustainable technology in society[xxiii]. Niche markets can be special geographical locations, but also specific application domains, which act as stepping stones for wider diffusion. To create and develop novel sustainable technologies, change agents (e.g. researchers, engineers, policy-makers) build niches to experiment with these novel technologies outside the market, in order to make them more robust.

A niche is "a specific application domain where actors are prepared to work with specific functionalities, accept teething problems, higher costs, and are willing to invest in improving the novelty and the development of a new market."

Hoogma et al., (2002)[xv]

Sustainable technologies require markets to be created in a process of co-evolution of market and technology. This can be done by temporarily protecting the innovation from too harsh selection, for example with investment grants, tax exemptions or other forms of protection, To distinguish these protected space from regular market niches, Kemp et al. (1998)[xxiv] called them 'technological niches'. Technological niches can serve as a test bed for learning with the aim of wider societal embedding. Knowledge and expertise of users and other actors, like policy-makers, researchers or representatives of public interests, are brought into the technology development process, conceptualized as smart experimentation[xxv].

SNM is an important tool in managing long-term societal transformations or transitions. The management of niches can be done by firms, governments, and other social actors (operating as change agents), but not necessarily in a systematic and coordinated matter**Fout! Bladwijzer niet gedefinieerd.**. Different actors have different interests, technological capabilities, powers, belief systems and expectations. Moreover, there are usually several technological options or paths to go that can compete with each other.

Niche processes

Niche formation and maintenance to facilitate experimentation and learning processes located within niches are crucial for radical technical-institutional change. There are three main processes within the niche processes as identified by Raven (2005a[xvi] and 2005b[xvii]):

- Voicing and shaping of expectations.
- Network building
- Learning processes

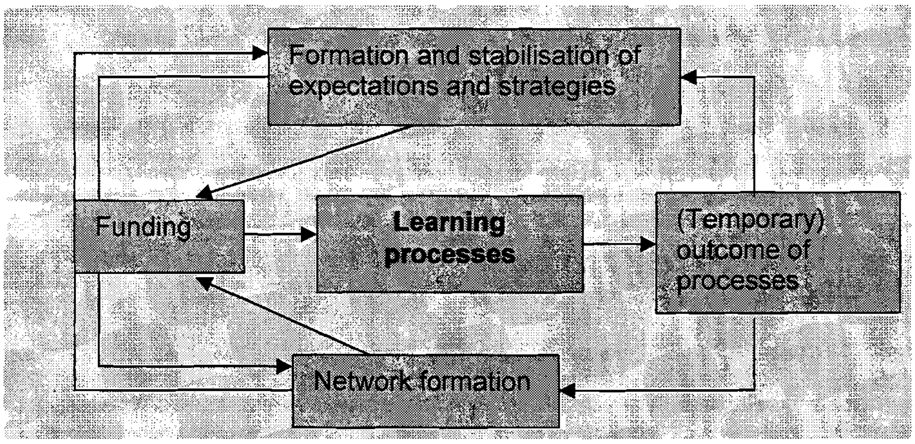


Figure 5 Linkages between internal niche processes[xxvi]

Internal niche processes influence each other (see figure 5). Expectations can change due to network composition change, but can also change due to the outcome of learning processes. When a certain novel technological niche performs well and the users are satisfied, the expectations around the technology will become more specific and better "aligned" between actors. This will facilitate the expansion of the actor network. Because of these higher expectations and the expanded network, more money will become available for further learning processes. Eventually a new stable socio-technical regime will appear. The expansion of the actor network is important because participation in the niche from a wide set of actors is needed if the lessons are to be effective, according to Hoogma et al. (2002)[xv].

Voicing and shaping of expectations

Firms, users, policymakers, entrepreneurs and other relevant actors participate in niche projects on the basis of their expectations. Articulating expectations is important to attract resources as well as new actors. Expectations also provide direction to development: they act as cognitive frames for making choices in the design process. The process of voicing and shaping of expectations is considered to be good[xxvii] when:

- A clear vision is developed and expectations are made explicit. Also, it is recommended, to stimulate other relevant actors to develop a clear vision and expectations. One should play an exemplary role.

- Formulating a vision requires acknowledging that different actors may have very different ideas and expectations, resulting in conflicting situations between different actors. It is not advisable to try to force consensus (or one single vision), but rather to make explicit the differences and use the differences constructively, for example by defining multiple experiments to learn about the feasibility and desirability of the different expectations. Some expectations might already have a firm ground in previous experiments, Other expectations such as assumptions about markets or user preferences might not exist or not have been verified at all. Such insights are useful when defining learning objectives. Expectations often end in disappointment when initial expectations were very high. Failures to meet these expectations subsequently led to disappointments and shifts in attention[xxviii]. Therefore one should strive for tangible expectations.

- Options are kept open during formulating visions and expectations. Focusing too much on one option can exclude others. One should aim to collect as much information and experience as possible instead of making choices beforehand, forcing the technology in to society.[xxix]. Technology forcing occurs when public authorities exert external pressure on industries to develop technologies with certain (sustainable) characteristics, by a specific deadline, which forces firms to develop radical alternatives without a thorough analysis of the pro's and con's of different alternatives.

- Monitoring is required during experiments if and how expectations change. Do actors learn from experiments? How do experiments change expectations? The relation between experiment results and change of expectations is difficult to accomplish and requires dedicated work and efforts, for example through regular meetings between participants[xxiii]

Network building

In particular in early phases of an innovation's life cycle, the social network is still very fragile. Experimentation in niche markets can bring new actors together and make new social networks emerge. Building social networks is considered good when [xxvii]:

- A broad network including all relevant actors (e.g. industrial actors, but also users, scientists, societal organizations (NGOs) and relevant policy makers) is developed. The individuals involved should not be outsiders within their own institutions, they should be able to bring in relevant resources or expand experiences into their own network

- Competent actors are included in the network, in particular actors from dominant regimes. These actors often have much resources, knowledge and experiences and know "the rules of the game".

- New actors are included, such as small innovative firms. These firms can bring in new innovative ideas and be a source of creativity.

- Network alignment is organized through regular meetings and discussions. Emerging networks require dedicated efforts to be maintained. This can be done by a dedicated network builder, whose explicit task is to organize the meetings and bring actors together[xvii].

- "Reinvention of the wheel" is prevented by sharing experiences between experiments. One should try to arrange visits between experiments, and to organize people traveling between experiments.

Learning processes

A good learning process enables adjustment of the technology and/or societal embedding which increase chances of successful dissemination. A good learning process is broad focused, not only on techno-economic optimization, but also on alignment between the technical and the social.
Van der Laak et al., (2007)[xxvii] state that in order to achieve a good learning process one should:

- Create and stimulate diversity between experiments so that lessons can be learned on various designs in various use environments. In particular in early stages of niche development, variety is crucial to make balanced choices in the future.

- Aim to learn about many different dimensions including technology, infrastructure, regulations, user preferences, and cultural and societal acceptance.

- Create possibilities to share lessons between experiments, for example through platforms, regular meetings and symposia. Also developing a newsletter with monitoring results and experiences from different experiments can contribute to sharing lessons. In general an infrastructure for sharing lessons is an important condition for successful niche development.

- Create possibilities to share lessons between different types of actors. Stimulate interactions between users, producers, policy makers, scientists and other relevant actors. Aim to learn from each other, for example to improve policy on the basis of experiment results, or improve design on the basis of user feedback or new scientific insights.

- Use lessons to adjust and reformulate vision and expectations. Past experiments should be seen as a valuable input for adjusting one's vision, reformulating policy and designing new experiments.

The interaction between these three processes in combination with the landscape and regime factors form the basis within SNM for understanding success and failure of sustainable technology dissemination.

2.2 *Comments on SNM*

The SNM framework has proven to be useful for the analysis of success and failure of experiments with a range of radical sustainable innovations, such as wind energy, and biomass energy. However after studying the existing SNM literature there are a few comments to be made:

- SNM has been developed only recently, and experiences with low tech innovations in a development setting are limited. In LDC countries there should be an increased focus on the existing basic technical infrastructure, such as electricity and water, due to the fact that this infrastructure is often lacking or malfunctioning.

- Existing regimes may also create a window of opportunity for alternatives, due to the use of unsustainable technology which can cause public pressure for change. Therefore this research will also analyze dynamics in established (unsustainable) regimes in order to explain the success or failure of sustainable technology innovations.

- SNM is until now used as a method to explain afterwards why an experiment succeeded or failed. This research aims to extend the possibilities of SNM theory as a policy tool, and therefore not only looks into the past but also into the future. If SNM proves also to be able give advice on how things could be adjusted or changed to make projects successful, the value of SNM as a policy tool will tremendously increase.

- The major limitation of SNM is its lack of focus on economic processes; therefore, in this thesis, the SNM framework is expanded with a Cost Benefit Analysis (CBA) to measure societal benefits and costs.

The costs involved in improving domestic wastewater treatment by the use of Constructed Wetlands, might at first sight appear to be high, but continuous discharge of untreated wastewater causes health risks and costs money. This pollution is associated with costs to the existing economy and (missed) benefits. The next chapter will describe the CBA framework for improved wastewater treatment.

2.3 Cost-Benefit Analysis

Cost Benefit Analysis (CBA) provides inputs for decision makers on how much capital investment is justified in relation to the expected benefits[xxx]. The application of Cost-Benefit Analysis in addition to the SNM framework helps to build up awareness of the economic importance of improved wastewater treatment and create a common perception of the societal consequences. The contribution of Cost-Benefit Analysis to consensus-building among actors with different interests and goals, arises from the fact that the impacts on the quality of the environment is translated into socio-economic gains due to resource productivity changes, rise of income, health effects, poverty reduction and economic development. Under ideal conditions, decisions should focus on technologies and measures that maximize net social benefit. In terms of financing these interventions, it is important to make a clear distinction between public and private investments and benefits. Questions that arise are:

- Should sanitation be provided at zero or subsidized cost by the government, or should the beneficiary pay the full cost?
- Are there other agencies that are able to bear some of the cost, such as non-governmental organizations or the private sector?

Therefore cost-benefit analysis should not only aim to provide information on economic efficiency, but also provide information on who benefits and, consequently, who may be willing to contribute to the financing of interventions[xxxi].

2.3.1 Improved wastewater treatment costs en benefits

The incremental costs consist of all resources required to put in place and maintain the domestic wastewater treatment system, as well as other costs that result from this intervention. These costs are divided into investment and recurrent costs.[xxxi]

Investment costs include: planning and supervision, hardware, construction and system alteration, protection of water sources and education that accompanies an investment in hardware.

Recurrent costs include: operating materials to provide a service, maintenance of hardware and replacement of parts, emptying of septic tanks, and latrines and continuous education activities.

The financial benefits of improved wastewater treatment are avoided costs of alternative clean up costs.

2.3.2 Societal economic benefits of wastewater treatment

Societal economic benefits can be divided in health related benefits and non-health benefits.

Health benefits

Knowledge of health benefits of wastewater treatment is important for cost-benefit analysis because some the major economic benefits depend on estimates of health effects. Water-borne and water-washed diseases are responsible for the greatest proportion of the water and sanitation-related disease burden. [xxxi]

Water-borne and water-washed diseases consist mainly of infectious diarrhea.[xxxi] By improving wastewater quality, the health benefits of Constructed Wetlands consist of:

- Reduction in illness rates (theoretical number of cases per year)
- Reduction in mortality rates (theoretical number of deaths per year)

Non-health benefits

There are many potential non-health benefits associated with improved wastewater treatment, ranging from easily identifiable and quantifiable to intangible and difficult to measure.[xxxii] Benefits consist of reductions in costs and additional benefits resulting from the intervention, over and above those that occur under current conditions.[xxxiii] The CBA in this thesis does not include all the benefits, but attempts to capture the most tangible and measurable ones and, identifies the beneficiaries.

In the case of improving of domestic wastewater treatment, the main benefits relate to healthcare and other costs avoided due to fewer cases of diarrhea and other water associated diseases. Cost saving in healthcare relates mainly to the reduction in treatments of diarrheal cases.[xxxiv]

A second type of benefit stated by Gold et al.[xxxv] is the productivity effect of improving health. These are traditionally split into two main types: gains related to lower morbidity and gains related to fewer deaths. The valuation of the time that would be spent ill reflects its opportunity cost.

The total societal economic benefit of improved domestic wastewater treatment is the sum of:

- Patient expenses avoided due to avoided illness
- Value of deaths avoided
- Value of days of school attendance gained of those with avoided illness
- Value of child days gained of those with avoided illness

3 Constructed Wetlands

This chapter discusses the Constructed Wetland technology, advantages and disadvantages of CW's, the configuration of CW's, system layout, and operation and maintenance of the Wetlands.

Constructed Wetland treatment systems are engineered systems that have been designed and Constructed to utilize the natural processes involving wetland vegetation, soils, and their associated microbial assemblages to assist in treating wastewater. Hammer[xxxvi] defines Constructed Wetlands as a designed, manmade complex of saturated substrate, emergent and submerged vegetation, animal life, and water that simulate Wetlands for human uses and benefits. Constructed Wetlands are an "eco-friendly" alternative for secondary and tertiary municipal and industrial wastewater treatment. They are designed to take advantage of many of the same processes that occur in natural Wetlands, but do so within a more controlled environment thus allowing the establishment of experimental treatment facilities with a well-defined composition of substrate, type of vegetation and flow pattern. In addition, Constructed Wetlands offer several additional advantages compared to natural Wetlands including site selection, flexibility in sizing and most importantly, control over the hydraulic pathways and retention time[xxxvii].

Constructed Wetlands have proven to be a very effective method for the treatment of municipal wastewater. For a small community with limited funds for expanding or updating wastewater treatment plants, Constructed Wetlands are an attractive option.[xxxviii] Once the Wetlands are designed the systems provide effective and reliable wastewater treatment and they are easy to maintain. In addition; they are relatively tolerant to fluctuating hydrologic and contaminant loading rates; and they may provide indirect benefits such as green space, wildlife habitats and recreational and educational areas[xxxix].

Wetland treatment is a long-term technology intended to operate continuously for years. The design considerations for Constructed Wetlands systems are varied and site dependent. Municipal wastewater treatment systems are most concerned with the reduction of suspended solids, organic matter, pathogens, phosphates, ammonium and organic nitrogen. Treated wastewater emerging from the wetland is either discharged to a surface stream or applied to land as irrigation water. The pollutants removed by CW's include organic materials, suspended solids, nutrients, pathogens, heavy metals and other toxic or hazardous pollutants.

Constructed Wetlands can provide a low-cost and appropriate technology for the treatment of domestic wastewater and faecal sludges[xl] but will require pre-treatment and so can only be considered as a secondary treatment option. This implies that Wetlands can be used inline with septic tank systems and that Wetlands should not be used to treat raw sewage.

3.1 Technology

Constructed Wetlands for wastewater treatment can be categorized as either Free Water Surface (FWS) or Subsurface Flow (SSF) systems. In FWS systems, the flow of water is above the ground, and plants are rooted in the sediment layer at the base of water column (Figure 6). In SSF systems, water flows though a porous media such as gravels or aggregates, in which the plants are rooted (Figure 7). Table 2 illustrates the type of Wetlands, vegetation types and water column contacts in Constructed Wetlands

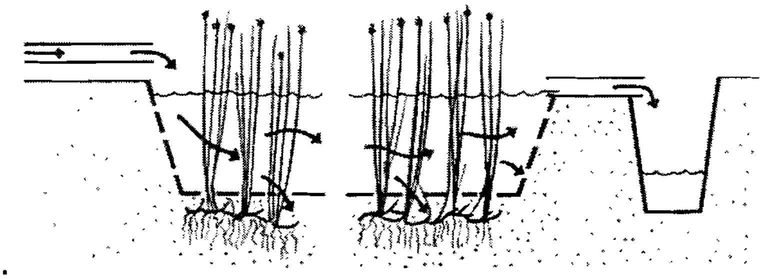


Figure 6 Emergent macrophytes treatment system with free surface flow[xii]

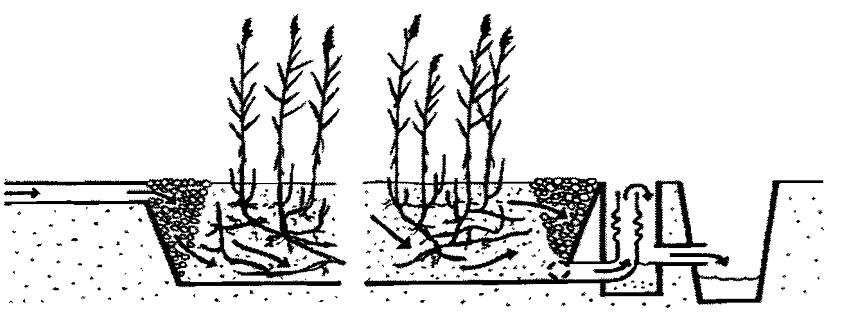


Figure 7 Emergent macrophyte treatment system with horizontal sub-surface flow[Fout! Bladwijzer niet gedefinieerd.]

Constructed wetland type	Type of vegetation	Section in contact with water column
Free water surface (FWS)	Emergent	Stem, limited leaf contact
	Floating	Root zone, some stem / tubers
	Submerged	Photosynthetic part, possibly root zone
Sub-surface flow (SSF)	Emergent	Rhizome and root zone

Table 2 Types of Wetlands and their vegetation

SSF systems are most appropriate for treating wastewater, because there is no direct contact between the water column and the atmosphere. There is no opportunity for vermin, such as malaria mosquitoes to breed, and the system is safer from a public health perspective. The system is particularly useful for treating septic tank effluent or grey water, landfill leachate and other wastes that require removal of high concentrations organic materials, suspended solids, nitrate, pathogens and other pollutants. The environment within the SSF bed is anaerobic. Oxygen is supplied by the roots of the emergent plants and is used up in the biofilm growing directly on the roots and rhizomes, being unlikely to penetrate very far into the water column itself. SSF systems are suitable for nitrate removal (denitrification), but not for ammonia oxidation (nitrification), since oxygen availability is the limiting step in nitrification. There are two types of SSF systems: horizontal flow SSF (hSSF) and vertical flow SSF (vSSF). The most common problem with hSSF is blockage, particularly around the inlet zone, leading either to short circuiting, surface flow or both. This occurs because of poor hydraulic design, insufficient flow distribution at the inlet, and inappropriate choice of porous media for the inlet zone. Properly-designed SSF systems are very reliable. The microbial film grows on all available plant surfaces, and is the main mechanism of pollutant removal. FWS usually exhibits more biodiversity than SSF systems do.

The objective of using CWs is to remove organic matter, suspended solids, pathogenic organisms, and nutrients such as ammonia and other forms of nitrogen and phosphorus. The growing interest in wetland system is due in part to recognition that natural systems offer advantages over conventional activated sludge and trickling filter systems. When the same biochemical and physical processes occur in a more natural environment, instead of reactor tanks and basins, the resulting system often consumes less energy, is more reliable, requires less operation and maintenance and, as a result costs less.

3.2 Advantages and disadvantages of Constructed Wetlands

The main advantages and disadvantages of Constructed Wetlands are according to Brix[xli]:

Advantages

- Compared to conventional wastewater treatment system inexpensive to construct and operate;
- Easy to maintain;
- Provide effective and reliable wastewater treatment;
- Relatively tolerant of fluctuating hydrologic and contaminant loading rates, (optimal size for anticipated waste load)
- Provide indirect benefits such as green space, wildlife habitats and recreational and educational areas.

Disadvantages

- The land requirements, cost and availability of suitable land;
- Current imprecise design and operation criteria;
- Biological and hydrological complexity and our lack of understanding of important process dynamics;
- The costs of gravel or other fills, and site grading during the construction period;
- Possible problems with pests. Mosquitoes and other pests could be a problem for an improperly designed and managed SSF.

3.3 Configuration of Constructed Wetlands

Most Constructed Wetlands are built up in zones: inlet zone, treatment zone, and outlet zones. The components associated in each zone include substrates with various rates of hydraulic conductivity, plants, a water column, and an aerobic and anaerobic microbial population. The water flow is maintained approximately 15 - 30 cm below the bed surface. Plants in wastewater systems are considered as nutrient storage compartments where nutrient uptake is related to plant growth and production. Harvesting permanently removes nutrients from the systems. Within the water column, the stems and roots of wetland plants significantly provide the surface area for the attachment of microbial population. Wetland plants have the ability to transport atmospheric oxygen and other gases down into the root to the water column. Most media used include crushed stones, gravels, and different soils, either alone or in combination. Most beds are underlain by impermeable materials to prevent water seepage and assure water level control. Wastewater flows laterally, being purified during contact with media surface and vegetation roots.

3.3.1 Processes in Sub-surface Flow Constructed Wetlands

Wetlands can effectively remove or convert large quantities of pollutants from point sources (municipal, industrial and agricultural wastewater) and non-point sources (mines, agriculture and urban runoff), including organic matter, suspended solids, metals and nutrients. The focus on wastewater treatment by Constructed Wetlands is to optimize the contact of microbial species with substrate, the final objective being the bioconversion to carbon dioxide, biomass and water.

Wetlands are characterized by a range of properties that make them attractive for managing pollutants in water[xlii]. These properties include high plant productivity, large adsorptive capacity of the sediments, high rates of oxidation by micro flora associated with plant biomass, and a large buffering capacity for nutrients and pollutants. Table 3, provides an overview of pollutant removal mechanisms in Constructed Wetlands[xliii].

Pollutant	Removal Processes
Organic material (measured as BOD)	Biological degradation, sedimentation, microbial uptake
Organic contaminants (e.g., pesticides)	Adsorption, volatilization, photolysis, and biotic/abiotic degradation
Suspended solids	Sedimentation, filtration
Nitrogen	Sedimentation, nitrification/denitrification, microbial uptake, volatilization
Phosphorous	Sedimentation, filtration, adsorption, plant and microbial uptake
Pathogens	Natural die-off, sedimentation, filtration, predation, UV degradation, adsorption
Heavy metals	Sedimentation, adsorption, plant uptake

Table 3 The pollutants and removal processes in a Constructed Wetland

Biological processes
There are six major biological reactions involved in the performance of Constructed Wetlands: photosynthesis, respiration, fermentation, nitrification, de-nitrification and microbial phosphorus removal[xliv].

- Photosynthesis is performed by wetland plants and algae, with the process adding carbon and oxygen to the wetland. Both carbon and oxygen drive the nitrification process. Plants transfer oxygen to their roots, where it passes to the root zones (rhizosphere).
- Respiration is the oxidation of organic carbon, and is performed by all living organisms, leading to the formation of carbon dioxide and water. The common microorganisms in the CW are bacteria, fungi, algae and protozoa. The maintenance of optimal conditions in the system is required for the proper functioning of wetland organisms.
- Fermentation is the decomposition of organic carbon in the absence of oxygen, producing energy-rich compounds (e.g. methane, alcohol, volatile fatty acids). This process is often undertaken by microbial activity.
- Nitrogen removal by nitrification/de-nitrification is the process mediated by microorganisms. The physical process of volatilization is also important in nitrogen removal. Plants take up the dissolved nutrients and other pollutants from the water, using them to produce additional plant biomass. The nutrients and pollutants then move through the plant body to underground storage organs when the plants senesce, being deposited in the bottom sediments through litter and peat accretion when the plants die.
- Wetland micro-organisms, including bacteria and fungi, remove soluble organic matter, coagulate colloidal material, stabilize organic matter, and convert organic matter into various gases and new cell tissue[xliii] Many of the microorganisms are the same as those occurring in conventional wastewater treatment systems. Different types of organisms, however, have specific tolerances and requirements for dissolved oxygen, temperature ranges and nutrients.

Physical processes
Sedimentation and filtration are the main physical processes which remove wastewater pollutants. The effectiveness of all processes (biological, chemical, physical) varies with the water residence time (i.e., the length of time the water stays in the wetland). Longer retention times accelerate the remove of more contaminants, although too-long retention times can have negative effects.

Nitrogen processes
The most important nitrogen forms in Wetlands are dissolved ammonia (NH^+_4), nitrite (NO^-_2), and nitrate (NO^-_3). Other forms include nitrous oxide gas (N_2O), nitrogen gas (N_2), urea (organic), amino acids and amine[xxxvii]. Total nitrogen in any system is referred to as the sum of organic nitrogen, ammonia, nitrate and nitrous gas (Organic-N + NH^+_4 + NO^-_3 + N_2O).
The various nitrogen forms are continually involved in transformations from inorganic to organic compounds, and vice-versa. Many of these transformations are biotic, being carried out by nitro bacter[xxxvii]. As it undergoes its various transformations, nitrogen is taken up by wetland plants and micro flora (preferentially as NH^+_4, and NO^-_3), some is leached to the subsoil, some is liberated as gas to the atmosphere, and some flows out of the wetland, normally in a dissolved form. Organic nitrogen comprises a significant fraction of wetland biota, soils, sediments and dissolved solids[xxxvii]. It is not directly assimilated by aquatic plants, but must be converted to

NH^+_4, or NO^-_3 through multiple conversions requiring long reaction time[xxxvii]. The process of biological nitrogen removal follows several sequences:

- Nitrification first takes place, generally in the biofilms (aerobic process).
- De-nitrification may then follow, occurring in soils and below the oxidized micro zone at the soil/water interface, as it is an anaerobic process[xlv]

Nitrification is a two-step process catalyzed by Nitrosomonas and nitrobacter bacteria. In the first step, ammonia is oxidized to nitrite in an aerobic reaction catalyzed by Nitrosomonas bacteria, as shown in equation 1.

$$NH^+_4 + O_2 \xrightarrow{+\text{Nitrosomonas}} H^- + NO^-_2 + H_2O$$

Equation 1

The nitrite produced is oxidized aerobically by nitrobacter bacteria, forming nitrate according to equation 2.

$$NO^-_2 + O_2 \xrightarrow{\text{Nitrobacter}} NO^-_3$$

Equation 2

The first reaction produces hydroxonium ions (acid pH), which react with natural carbonate to decrease the alkalinity[xliii]. In order to perform nitrification, the nitrosomonas must compete with heterotrophic bacteria for oxygen. The BOD of the water must be less than 20 mg/l before significant nitrification can occur[xlvi]. Temperatures and water retention times also may affect the rate of nitrification in the wetland. De-nitrification is the process in which nitrate is reduced in anaerobic conditions by the benthos to a gaseous form. The reaction is catalyzed by the denitrifying bacteria Pseudomonas spp. and other bacteria, presented in equation 3.

$$NO^-_3 + \text{Organic-C} \xrightarrow{\text{Denitrifying Bacteria}} N_2\,(NO\ \&N_2O)_{(G)} + CO_{2(G)} + H_2O$$

Equation 3

Phosphorus removal
Phosphorus is an essential requirement for biological growth. An excess of phosphorus can have secondary effects by triggering eutrophication within a wetland, and leading to algal blooms and other water quality problems. Phosphorus may enter a wetland in dissolved and particulate forms. It exits Wetlands in outflows, by leaching into the sub-soil, and by removal by plant and animals. Phosphorus removal in Wetlands is based on the phosphorous cycle, and can involve a number of processes. Primary phosphorus removal mechanisms include adsorption, filtration and sedimentation. Particulate phosphorus is removed by sedimentation, along with suspended solids. The configuration of Constructed Wetlands should provide extensive uptake by Biofilm and plant growth, as well as by sedimentation and filtration of suspended materials. Phosphorus is stored in the sediments, biota, (plants, Biofilm and fauna), and in the water.

Suspended solids
Solids may be derived from outside a wetland (e.g., inflows and atmospheric inputs), and from within a wetland from plankton (zooplankton and phytoplankton), and plant and animal detritus. With low wetland water velocities and appropriate composition of influent solids, suspended solids will settle from the water column within the wetland. Sediment re-suspension not only releases pollutants from the sediments, it increases the turbidity and reduces light penetration. The physical processes responsible for removing suspended solids include sedimentation, filtration, and adsorption onto Biofilm. Wetland plants increase the area of substrate available for development of the Biofilm. The surface area of the plant stems also traps fine materials within its rough structure.

Pathogen removal
Pathogens are disease-causing organisms (e.g., bacteria, viruses, fungi, protozoa, helminthes). Wetlands are very effective at removing pathogens, typically reducing pathogen number by up to five orders of magnitude from wetland inflows[xlvi]. The processes that may remove pathogens in Wetlands include natural die-off, sedimentation, filtration, ultra-violet light ionization, temperature effects, predation by other organisms and pH[xxxvii]. Kadlec and Knight[xxxvii] showed that vegetated Wetlands seem more effective in pathogen removal, since they allow a variety of microorganisms to grow which may be predators to pathogens. This effective pathogen removal characteristic of vegetated Constructed Wetland makes them particulary suitable for domestic wastewater treatment.

Limitations of wetland processes
The chemical and biological processes occur at a rate dependent on environmental factors, including temperature, oxygen and pH. Metabolic activities are decreased by low temperature, reducing the effectiveness of pollutant uptake processes relying on biological activity. Low oxygen concentrations limit the processes involving aerobic respiration within the water column, and may enhance anaerobic processes, which can cause further degradation of water quality. Many metabolic activities are pH-dependent, being less effective if the pH is too high or low.

The capacity of Wetlands to treat wastewater is limited, both in terms of the quantity of water, and the total quantity of the pollutants. Hydraulic overloading occurs when the water flow exceeds the design capacity, causing a reduction in water retention time that affects the rate of pollutant removal. Pollutant overloading occurs when the pollutant input exceeds the process removal rates within the wetland[xlvii]. Hydraulic overloading may be compensated for by using surcharge mechanisms, or the design may be based on a flush principle, whereby large water flows bypass the wetland when used for storm water treatment[Lxii]. Inflow variations are typically less extreme for Wetlands treating municipal wastewaters, with incoming pollutant loads also being more defined and uniform.

3.4 Operation and maintenance of Constructed Wetlands

There are four different subjects regarding operation and maintenance in de lifecycle of a Constructed Wetland namely, commissioning, operation, monitoring and decommissioning and refitting

Commissioning

Commissioning of the wetland is referred as the time from planting to the date where the wetland is considered operational. Operation during this period should ensure an adequate cover of the wetland vegetation. The water level within the wetland during this time needs to be controlled carefully, to prevent seedling from being desiccated or drowned. Once the plants are established, the water level may be raised to operational level. Plant loss may occur during the commissioning, therefore requiring transplanting.

Operation

The operation of a Constructed Wetland depends on the type of Wetland, and the preliminary treatment used for wastewater treatment. Constructed Wetlands are designed to be passive and low maintenance, thereby not requiring continual upkeep. Constructed wetland, however, are dynamic ecosystems, with many variables that require managing. If not, problems may occur when the operator does not understand the needed operation and maintenance, the wetland is either hydraulically or organically overloaded, unavoidable disasters (e.g., flooding, drought) occur, the wetland can be plagued by weed problems and/or if excessive quantities of sediments, litter and pollutants accumulate and are not removed from the wetland. The management of the Constructed Wetlands consists of four tasks, as outlined below in Table 4. Not all Constructed Wetlands are the same, given that they can be designed for a range of objectives. These objectives will determine the kind of operation and management activities needed to be undertaken. Thus, the operation and management of a Constructed wetland must be tailored to a particular Constructed wetland, reflecting desired objectives and site-specific constraints, including local hydrology, climate and relevant aspects of public safety.

Tasks	Example
Operational control	Varying water level
Monitoring	Water quality, habitat, flora and fauna
Inspection	Structures and embankments
Maintenance	Repair damage to the structures and control weeds

Table 4 The management tasks of Constructed Wetlands

The operation of a Constructed wetland after commissioning must include:

- Maintaining the embankments;
- Removing litter and debris;
- Checking the water inflow rate;
- Removing any blockages in the inlet and outlet works;
- Replacing plants as required;
- Removing any unwanted weed species from the Constructed wetland;
- Checking the plants for any sign of diseases;
- Protecting the deep open water;
- Correcting erosion and slumping; and
- Checking for any signs of over-flooding.

These tasks may be addressed in the form of a checklist to direct the required maintenance, and to identify who should be immediately contacted in the event of problems.

Monitoring
Monitoring selected performance parameters should provide sufficient information to measure performance in meeting water quality improvement. The performance indicator should either be presented as a concentration or load at the outlet, or a comparison of inflow and outflows, also in terms of concentrations or loads. If monitoring results indicate that the system is not working according to the objectives, corrective measures must be applied. Improvement of water quality may be assessed by monitoring a range of inflow and outflow water-quality parameters. Useful parameters for monitoring wetland performance include dissolved oxygen (DO), BOD, COD, total phosphorus, orthophosphorus, total nitrogen, total Kjeldhal nitrogen, ammonia nitrogen, oxidized nitrogen, faecal coliform, pH, suspended solids, electrical conductivity, and heavy metal concentrations. Water flow rates to and from the Constructed wetland also must be measured. The sampling may be done using either an automatic or manual sampler. Samples within the wetland must sometimes be taken for the purpose of comparison.

Decommissioning and refitting
Decommissioning and refitting of a Constructed wetland may take place if its design lifetime is over. At the end of its design life, a wetland will be either be refitted, or decommissioned if no longer required. Refitting may be required when the accumulation of wetland sediments is adversely affecting wetland performance, or when changing catchment conditions require modifications of the wetland. Major refits may include the removal of accumulated peat, including aquatic plants, and replacements of substrates. Decommissioning of a wetland may be required if the land supporting it is utilized for other purposes, or if the wetland functioning is unable to achieve the original design objective.

4 Landscape analysis

This chapter describes the exogenous factors which influence the current sanitation regime in Tanzania. First a short overview of the general political history of Tanzania over the past five decades is presented. Secondly the current economic situation is elaborated, and then thirdly the consequences of urbanization are explained. Fourth the specific cultural aspects which influence people's behavior and attitude towards sanitation issues are described. Part five handles problems with the measuring of performance of institutions. The sixth part handles the influence of the international donor community on Tanzanian sanitation policies.

4.1 Tanzanian political history

Mainland Tanzania, known previously as Tanganyika, gained its independence from the United Kingdom in 1961. In 1964, a violent revolution followed in neighboring Zanzibar Island. Tanganyika united with Zanzibar in April 1964 to form the United Republic of Tanzania.

Tanzania's post-independence economic history is divided into three distinct phases. The first phase (1961 to 1986) is characterized by state socialism, the second phase (1986 to 1995) by structural adjustments, and the third phase (1995 to the present) by renewed macro-economic reforms[xlviii]. Post-independence, Tanzania adopted a form of state socialism known as *Ujamaa*. It was formally launched in 1967 with the Arusha Declaration, which declared that all the major means of production and exchange were to be owned by the peasants and workers through their government. Land, forests, minerals, banks, import and export trade, wholesale trade, cement, fertilizer, textile industries, insurance, news media, electricity and the iron and steel industries were all nationalized. During this period, the country operated a centrally planned economy commanded by the ruling party. The ruling party and state, with its administrative machinery, mass organizations, state-owned enterprises, state-directed cooperatives, government-owned banks and a web of public holdings, ran the economy and controlled both prices and the distribution of all essential goods and services.

Tanzania's adoption of Ujamaa was a response to the economic and market imbalances created during the colonial era in East Africa where Kenya was favored as the location for industrial and business enterprises. The government took over the small and relatively fragile private sector, which had flourished during the colonial period. Many basic services such as health, education, agricultural extension and water were delivered free of charge or at subsided prices. However, during this period, the economy suffered from external shocks such as sudden rises in oil prices, the collapse of commodity prices, droughts, the break-up of the East African Community and the Uganda war. The poor macro-economic policies, weak economic management and increasing foreign debt resulted in a severe economic crisis in the early 1980s. Weakened by this crisis, Ujamaa ended in 1986 with the signing of an IMF/World Bank Structural Adjustment Program.

The second phase of development was marked by an externally supervised economy by the IMF, World Bank and other donors. Economic and public sector reforms were implemented to dismantle the state-controlled economy and develop a market economy. Trade, price control, exchange rates and interest rates were all liberalized. Agriculture was also liberalized and subsidies on fertilizers and other inputs were removed. It was during this phase that user fees, cost sharing and co-financing of health care, education and water were introduced. But rather than improvement, these changes brought severe deterioration in the delivery of health and education services. New policies were developed for mixed service delivery systems in which the private, non-government and community sectors were given greater freedom to deliver services. The expenditure by the Tanzanian government on social services was dramatically cut. Basic needs poverty levels in mainland Tanzania rose significantly to just under 53 per cent of the population.[lii] Serious policy differences between donors and the Tanzanian government emerged. This, along with unresolved problems in management, poor tax collection and resistance to some changes being proposed, led to an impasse in 1993-1995. In 1995, the IMF and World Bank decided to withdraw support to the country.

The break with donors was resolved when a new "third phase" government came into office. Substantial public expenditure cuts were implemented. Macro-economic stability set in, with inflation dropping from 30 per cent in 1995 to 6.6 per cent in 2000.[lii] To further improve fiscal stability, the government moved to a cash budgeting system. This brought public sector finances under the strict control of the Treasury and Bank of Tanzania. This stringent fiscal regime however left public services with virtually no funds for development while access to loan capital for major infrastructure investment was tightly regulated. New commercial legislation favoring foreign investment coupled with tax exemptions was implemented. In addition, public and local government reforms were implemented, which meant rationalization, streamlining and decentralization of functions, structures and staff. New budgeting and financial management systems were introduced to both central and local government to enable better tracking of public expenditure. The third phase continues today, but the results generally appear to be mixed. This is seen in the case of sanitation, where so far problems remain too difficult to be resolved. Table 5, summarizes the key events in recent Tanzanian history.

Key events

1961	Tanzania gains independence and centralises service provision
1967	Arusha declaration increases emphasis on policies of equality and self-reliance while also signalling further state control over social and economic development
1967-76	Villagisation. People moved into 'Ujamaa' villages where large-scale programmes are attempted to deliver improved health, water and education services. Increasingly authoritarian measures see 70% of mainland rural people registered in villages by 1977
1977-83	Following the break up of the East African Community, growing trade imbalances and the war against Amin's Uganda, Tanzania falls into economic crisis
1983-86	Combination of internal and external shocks creates commodity scarcities. People in many parts of Tanzania leave 'Ujamaa' villages and return to their homesteads
1986	IMF and Tanzania agree a programme of structural adjustment
1995	The Tanzania Revenue Authority is formed
1999-2000	HIPC completion point reached, Poverty Reduction Strategy Paper (PRSP) drafted, and, Medium Term Expenditure Framework (MTEF) introduced
2000	Millennium Development Goals set, including target to halve by 2015 the proportion of people without access to safe water
2002	World Summit on Sustainable Development agrees corollary sanitation to halve the proportion of people without access to sanitation by 2015
2003-4	PRSP revised

Table 5 key events in recent Tanzanian history[lii]

The changes in the Tanzanian politics have strongly influenced the saniation regime. During the Ujamaa period water and sanitation were delivered at no direct charge to the people. The central state took care of everything hence, the end-users were not involved in making decisions whether which sanitation technology should be used and had no insights in the actual cost of sanitation. The political move towards the externally supervised, structural adjustment economy which introduced user fees and cost sharing caused problems for the sanitation sector. People became confronted with bills for services which were first for free. The willingness to pay for these services was low and too little money was made in the santaion sector to properly maintain the infrastructure. The third phase in the political evolution made the problems in the sanitation sector even worse, public expenditure was dramatically cut and the sector has no budget for development and expansion of their services for the growing urban population.

4.2 Current economic situation

In 2008, Tanzania was ranked 159 of 177 countries in the Human Development Index (HDI) due to the widespread level of poverty[xlix]. More than half of the population (51%) lived on less than US$1/day; about half or 42% of these live in absolute poverty (less than US$0.75/day); 81% of the people are underemployed and minimally skilled (UNDP 2000)[l]. This means inadequate availability of funds for sanitary facilities. People are living from hand to mouth; what they earn only partially provides a day's meal.

Economic reforms, especially those since 1995, have improved macro-economic performance and stability. However, these macro-economic achievements have not translated into significant benefits for the vast majority of Tanzanians. The 2000 Household Budget Survey[li] estimated that there has been only a small reduction in the numbers of people living below the basic needs poverty line (36%; 39% in 1991) and the food poverty line (19%; 22% in 1991). Since 2000 Tanzania has benefited from debt relief under the enhanced Highly Indebted Poor Countries (HIPC) initiative. In the first Poverty Reduction Strategy Paper (PRSP) Tanzania included water and health as two of five key sectors that were prioritized (others were education, agriculture and roads). Progress aligned with the Millennium Development Goals MDGs (targets agreed by all world governments to reduce poverty by 2015) is variable, for instance the number of children going to school is significantly up, but there are now more children dying before their fifth birthday and more mothers dying while giving birth[lii].

This current financial situation, in which 51% of the population lives under the poverty line, indicates that these 18.1 million people do not have enough financial means for proper, privately funded and owned sanitation facilities. The rise of the mortality rate of young children is suspected to be related to deteriorating W&S practices, since young children are particularly vulnerable to waterborne diseases which are spread as a consequence of insufficient sanitation.

4.3 Urbanization

Urbanization is one of the most important demographic trends of the twenty-first century, and growth is particularly rapid in lower-income countries[liii].The majority of urban growth is associated with the rapid expansion of smaller urban centers and peri-urban developments[liv]. Much of this growth is unplanned and informal, with community members and informal-sector developers taking advantage of the fact that the regulatory capacity of government authorities is weak, particularly in those areas that are outside official municipal boundaries. Settlements are generally inhabited by communities of different economic status relating to land prices, which are affected by location in relation to the city, and which are considerably higher than in rural areas[lvi]. Many industries locate on the edge of the city because land there is relatively cheap and not subject to stringent development controls and, at present, the waste they produce rarely receives adequate treatment[lv].

Due to ongoing development, peri-urban areas are generally in a state of rapid transition that may result in social and environmental tensions[lvi]. The limited infrastructure facilities are often inadequate, and the result is a poor and often deteriorating environment. Provision of infrastructure and services tends to occur in a piecemeal fashion, either through the efforts of residents themselves or as a result of pressure from civil society on elected representatives and government officials. Electricity and water supply are usually provided first, with sanitation, drainage and solid-waste collection services following later[lv]. However, the majority of settlements in peri-urban areas, particularly those inhabited by poorer communities, do not have access to adequate water supply and sanitation facilities. Even where household sanitation and localized drainage facilities do exist, often there is a lack of a comprehensive system for the collection and disposal of wastewater. In many cases, wastewater is discharged locally onto open ground and vacant plots, creating ponds of smelling stagnant water.

Health risks are increased by the fact that household and surface water drainage systems are combined, so that floodwater becomes contaminated with excreta. Mosquitoes and other pests breed in blocked drains and ponds, spreading diseases such as cholera. This is a particular problem where piped water is provided before drainage infrastructure[lv]. The lack of infrastructure and services and effective systems for managing wastewater has led to widespread pollution of surface water and groundwater and deterioration in environmental health conditions. The range of environmental health problems in peri-urban areas includes those associated with both urban and rural living[lvi].

The rapid urbanization of Tanzania has increased pressure on the infrastructure and services, much of which has not been properly maintained or expanded to cope with the rapid urban growth. In addition to these, there has been inadequate shelter delivery to cater for the urban population, a situation that has led to extensive development of unplanned peri-urban areas accounting to about 60-70% of the urban population,[lvii] which means that 6 to 6.5 million people in Tanzania currently live in these unplanned peri-urban areas. The increasing urbanization causes pressure on urban infrastructure and services, growth of unplanned settlements, unemployment, poverty[lviii], and deteriorating urban social services.

4.4 Cultural aspects

This section will elaborate the cultural aspects of sanitation and their contribution to the current situation.

The taboo of sanitation

People all around the world are in general not comfortable to talk about sanitation practices. Young children are taught that faeces and urine are dirty and mentioning them is using "bad language". For this reason people avoid talking about the life-threatening menace of insufficient and inadequate sanitation. Nor do great figures and celebrities rally to this cause. They are happy to lend their names to clean water but they do not mention the reason why "dirty water" poses a threat to child health.[lix] Even programs for Water and Sanitation spend the lion share of their resources on water: 95%[lix], in Madagascar, for example leaving just $0.05 per head a year to spend on sanitation.

Acceptation of problems

In Tanzania people have gotten used to malfunction of social services, e.g. tap water for those who are connected is only available a few hours a week in Dar es Salaam. In addition to this, the delivery of electricity is also very unreliable[3]. Therefore the trust in public services is very low. People cope with these problems by installing back-up water tanks on their roofs and use diesel generators for power supply. These unreliable services damage the economy due to loss of production hours and cause air pollution in the cities from the generators.

Denial of problems

It is a public secret that the functioning of public sector institutions is sub-optimal. Interviews with representatives of UNICEF and DAWASA, Dar es Salaam Water and Sanitation, Ministry of Health and the Ministry of Water indicated a gap between paper-reality and the real world. For instance DAWASA claims that there are no problems with water supply and measures its performance by the number of taps connected to the waternet, irrespective of whether there is water running through these taps. In doing so there is no figure of how many people are actually serviced. UNICEF, likewise, uses indicators which do not reflect the situation correctly; it measures the number of pit latrines per inhabitant assuming that these latrines are properly used. This indicator does not consider the hazard of groundwater contamination due to overflowing latrines and bad sanitation practices (e.g. failure to wash hands). This implies that the number of latrines does not necessary represent whether people have safe sanitation. When studying the sanitation regime in Tanzania one must keep in mind that figures and statistics do not necessarily represent the real problems and that the actual situation might be much worse.

Increasing role of women

Women want and need sanitation facilities but they are uncomfortable in discussing so.[lx] Access to a toilet is essential for female dignity, especially in cultures which demand high standards of modesty. While men and boys can be seen sitting on their heels on the roadsides this is unthinkable for women and girls. Women are therefore obliged to wait until nightfall to go outside and relieve themselves. The stress and

[3] This malfunctioning of water supply and electricity were experienced during the field research in Dar es Salaam.

pain can be acute, especially for pregnant, elderly or disabled women.[lx] Sexual exposure and possible sexual harassment form part of the embarrassment.
In the past, households used to be headed mainly by men, although women were breadwinners as well. The trend is changing and women are heading the households more often[li]. Although this change in head of household is caused by the disastrous consequences of AIDS, this could be beneficial for the attention spent on sanitation because when women are the head of the household the priority will shift more towards sanitation. With women in charge of the household budget it is likely that more money will be spent on improving sanitation.

Link between education and sanitation
The education level of most occupants in the poor urban areas is very low which emphasizes the need for educational campaigns for any project's sustainability.[lxi] Low education is the reason for low-paying jobs, resulting in households with insufficient financial resources for daily subsistence and investment into good excreta disposal facilities. Lack of proper sanitation facilities in schools can be disastrous for a girl's education. As girls grow up many parents withdraw their daughters from school out of concern for their modesty. For millions of girls lack of attention to their adolescent needs leads to their leaving school and often to early marriage[lx].

4.5 International donor presence and influence

The evolution of Water & Sanitation policy in Tanzania is heavily linked to international priorities in water governance. The influence of the international donor community on Tanzanian water policies originates from the tremendous financial inputs of these donors. For W&S projects it is common that 80% is financed by donors and 20% by the Tanzanian government. The influence of NGOs is also substantial because they were responsible for local W&S projects during the free water period, outside the official government's purview (see appendix 1 for an elaborated overview of the evolution of international priorities). The policies in Tanzania are following the international policies closely, because of the power of donor countries. One can conclude that W&S policies have evolved greatly over time and that the focus has changed from a top-down model with state-owned facilities to community participation and privately-owned facilities (details about the content of the policies are discussed in the Regime Analysis). However, in both policies, international and Tanzanian, the lack of attention for sanitation is remarkable.

5 Regime analysis

Water and Sanitation (W&S) are closely related to each other, and have both social and technical considerations. Past experience has proved that, without adequate attention to the social aspects, whatever technology that is developed and instituted in the country may be bound to fail.[lxi] This chapter describes the current W&S regime, its characteristics and its weaknesses, and pinpoints important actors in this current W&S regime in Tanzania.
First de evolution of the Tanzanian W&S policies is discussed, followed by the hazards which are caused by improper sanitation. Then the four different technology-based regimes are discussed. Finally the window of opportunity for new technologies is described.

5.1 Evolution of Water and Sanitation policy Tanzania

From a policy point of view it is virtually impossible to separate Water and Sanitation, since these policies have a huge overlap, often is sanitation seen as a part of the water policy, therefore, in this section the focus is on Water & Sanitation policies.
Since colonial times Tanzania has taken several steps aimed at improving water supply and sanitation. This section will provide an overview of important policy changes over the last 70 years, starting with the pre-independence cost-sharing approach, the free water era and the current return to cost-sharing.

Cost-sharing during the colonial period
Systematic water supply development began around 1930 in Tanzania, when the colonial government started to use public funds for the development of water supplies to areas and the Department of Water Development was founded in 1945. The first water supply systems were located in townships, mission stations, large estates and trading centers. After the construction these water supply systems were managed on a self-supporting basis and all users were required to pay for the amount of water they used. Some local governments were able to collect enough money to pay for new water supplies and to operate and maintain the existing water supply installations within their jurisdictions while others could not. In particular, under the program of cost sharing between the Central Government and Local Authorities, poor local governments could not make much progress in the development of rural water supplies.

The "free water" era
From 1964, the Tanzanian government moved towards socialist social policies and put basic needs (e.g. health, water, education, food supply) high on the agenda and encouraged equitable development. However, there were no clear guidelines regarding which villages should have priority in water development. Later, the *ujamaa* villages were given priority, but there was otherwise no clear prioritizing mechanism. Generally, the most geographically marginal people were neglected. From 1965 the central government provided funding for all capital and maintenance costs of water distribution development. Local Authorities continued to pay for operational costs. In 1969 however, even these operational costs were covered by the central government. Thus, by 1970, the only Tanzanians paying for water were those who had private water connections. There has been much direct involvement of foreign NGOs in the water sector. By 1986 the ratio of external to internal funding of the rural water sector was 80/20 and donors had a corresponding amount of power in program planning and project design. Through direct financing of projects,

which were implemented by NGOs or private contractors, rather than going through government departments, donors could control the use of the funds. In general, donor funded projects which didn't involve ministry staff were completed more quickly than those that did, partly due to their superior access to equipment. However, there were a number of key problems with this 'bypass' project approach, including the tendency to use Tanzania as an experimental testing-ground for new strategies, possibly at the expense of best practice.

In 1971, a new Ministry of Water Development and Power was formed and charged with the responsibility of planning and developing water resources in the country. This ministry was responsible for urban and rural water supply development as well as the energy development throughout the country. The ruling Party at that time, The Tanganyika African National Union (TANU), committed the Government to provide water in all rural areas so that every rural inhabitant could have easy access to a source of adequate and potable water by 1991.

In 1980 the Tanzanian government adopted the UN goals for the Water Decade, and mobilized external assistance to prepare regional water schedules and facilitate rapid construction of water supply schemes. Foreign donors responded favorably, and 12 of the country's 20 regions were assigned to various donors. Despite of these efforts by the Tanzanian government and donor countries, the target of providing every rural dweller with adequate potable water within easy reach was not achieved by 1991.

In many areas the rate of system failure exceeded the rate of new construction, resulting lower water supply coverage despite the high capital investment in hardware. Over 90% of piped schemes ceased operation, mainly due to an inability to provide the required fuel for pumping and to keep the motors and pumps in operating condition. In addition, most of the hand-pumps on shallow wells stopped operating for lack of timely maintenance of repair. The installed capacity of Constructed schemes could serve only 48% of rural people[lxii].

Sanitation becomes for the first time a policy issue for the Tanzanian government in 1973. The government introduced a 'latrinization' campaign under a program called *"Mtu ni Afya"* (You are your health) aimed at ensuring each household would have a latrine. The campaign was given added priority due to a cholera outbreak in 1977. Latrine coverage increased from 20-50 percent between 1973 and 1980[lxiii]. Since the *'Mtu ni Afya'* campaign very little has been achieved in improving basic sanitation. Cholera remains endemic to Tanzania. Outbreaks are frequent in urban areas, particularly the larger cities and in rapidly expanding unplanned areas.

The evaluation of the Tanzanian W&S policy in the free water period has highlighted the problems of a supply-driven approach to W&S. These problems can be summarized into three general issues: insufficient coverage, high cost and poor utilization[lxiv].

The conclusion can be drawn that the supply driven "free water for all" approach did not meet the intended water supply targets and sanitation has not been a priority before and since 1980.

Return to cost sharing
In 1986 a conference was organized to review the experiences and the problems encountered during the preceding 20 years of implementation of the rural water supply program. The conference resulted in the formulation of a New Water Policy, which was approved by the Tanzanian parliament in 1991. The policy ends the "free water era" by the introduction of cost sharing in rural areas and full cost recovery in urban areas. In rural areas village governments were given the responsibility of running their small water supply systems, while the management of larger systems remained the responsibility of regional and in some cases national authorities.

Liberalization
Currently, Tanzania is continuing to hand-over responsibility for existing water supply schemes to communities. Independent status has been granted to many organizations and there is now some space for the private sector in service provision. It is becoming more common for wealthy Tanzanians, individually or in small groups, to hire contractors to construct private wells, and some NGOs are converting themselves into private companies to take advantage of this trend. Sanitation is still not a priority. Since the late 1980s, the Ministry of Water has "shifted from providing services to being an enabler, regulator, controller, and monitor." [lxv] There are a number of reasons for such changes. Firstly, Tanzania's economy has suffered badly over the last two decades, and the government can no longer afford to provide free services, secondly Tanzania is able to secure donor funding by creating space for NGOs to operate.

The target of the National Development Vision 2025 for water and sanitation sector is universal access to safe water by 2025 through involvement of the private sector, empowering local government and communities, and promotion of broad based grass roots participation in mobilization of resources, knowledge and experiences with a view to stimulating initiatives at all levels of the society.

The 2002 water policy document places considerable emphasis on the decentralization of decision-making. In particular, it stresses the participation of water users and local communities in driving projects/programs; managing water and cost-bearing; and in working with NGOs, private sector and other external agents. Community ownership, embodied in village water user entities, is seen as a means of achieving sustainability through community investment and commitment to their schemes.

The policy expects local communities to pay a portion of capital costs, for rehabilitation and extension of existing schemes. Communities are also expected to pay, through user fees, the full cost of operation and maintenance. This echoes the tendency in the international water consensus to reframe drinking water as an economic, as well as a social, good. Because of the shift towards participatory planning and implementation of water projects, many NGOs have moved from working mainly with non-state organizations, to support the work of government departments. However, the fact remains that government management style in general is top-down and directive.

The evolution of W&S policies is mainly based on negative experiences; after the failure of one policy a new policy is introduced and sometimes it seems to go back in time. Old theories are adjusted and combined in new paradigms. Much needs to be done in order to meet the Millennium Development Goals, and the continuous change of development strategy is not helping. The policy shifts are enormous and Tanzania is still trying to implement policies and institutional changes which should have done years ago. And just when they seem to catch up with this implementation the donor community changes policy again. Learning from (policy) mistakes in the past is of course a good idea but the policy changes and adjustments should be made more gradually, in smaller steps. These major shifts in W&S policy now include: water as basic need, also for the poorest of the poor until the 1990's to water as a capital good in the 2000. Changes like these seem almost to beg for complications and can create great social disasters. The financial dependencies on donors create instability in W&S governance. Tanzania should strive to gain more autonomous power in policy making, which will create more stability in W&S.

Conclusions W&S policy Tanzania

The evolution of water policy in Tanzania mirrors the evolution of the Tanzanian State and changing policy in other sectors, such as agriculture[lxvi]. Tanzanian approaches also reflect international priorities in water governance, characterized by a shift from the state intervening[lxvii] towards implementing water policy through liberalization and good governance.[lxviii] Following the Arusha Declaration of 1967, there was heavy investment in Water and Sanitation Supply during the 1960s and 1970s, which resulted in the proportion of the population with access to improved water supply rising from 12 to 46%, in the period from 1971-1980. Water was recognized as a public good and the Government covered all capital costs of investment. However these early investments could not be maintained and many installations fell into disrepair. Whilst there is some recognition that the Government (and donor funded) investment was piecemeal and not sustained, more of the blame for failure tends to be placed on a lack of community participation in (appropriate) design and management. Table 6 summarizes the key developments in Tanzanian W&S policies.

Sanitation has always, and is still lacking attention in the mind of policymakers, the bulk of efforts and policies have gone towards water supply.

Key development in water related policies Tanzania
1967—Abolition of water user fee
1971—Launching of 20-year rural water supply program 1972—Abolition of local governments 1974—Introduction of Water Utilization Act (control and regulation) 1975—Separation of Water Department and Irrigation Department
1981—Amendments of Water Utilization Act (control and regulation) 1981—Designation of Tanzania into 9 Water Basins
1991—Institution of National Water Policy 1994—Review of water user fee 1995—World Bank Appraisal 1999—Draft New National Water Policy (poverty reduction) 2001—Merge Ministry of Water with Livestock

Table 6 Key events in Tanzanian W&S policy

5.2 Sanitation related hazards

Natural surroundings
The Tanzanian climate is tropical and humid; this climate creates an environment in which bacteria and viruses rapidly multiply causing potential health hazards.

Spread of bacteria
People living in underprivileged urban and peri-urban areas have rarely benefited from adequate water supply and sanitation services. These areas generally have dense concentrations of low-cost housing, and are often informal settlements unsuited to conventional wastewater transportation and treatment systems. People build their, often illegal, houses dangerously (70% of the Tanzanian city residents live in unplanned settlements). Additionally, in e.g. Dar es Salaam, 45% of the city area has a high water table and floods in the rainy season[lxix], which cause bacteria from pit latrines to spread. In Tanzania, there has been an outbreak of fatal diseases: cholera, typhus and diarrhea. The most extensive wave in East and Central Africa started in 1977 in Twasalie, a delta island village on the Tanzania Indian Ocean Coastline in Rufiji District.[lxx] It entered the country from the Middle East and since then, it has spread to different parts of the country and by 1984 to neighboring countries: Uganda, Rwanda, Burundi, Zaire, Zambia, Malawi and Mozambique. The severity of diseases has been growing day by day with maximum occurrence during the rainy season where pathogen spread by water is eminent. Malaria, which is the most fatal disease in Tanzania with ~3% deaths and ~15% hospital attendances also increases with poor sanitation as mosquitoes breed even in wet pits[lxxi]

Contaminated water sources
The common sources of water for domestic use are public taps or kiosks, water vendors, or shallow wells. Although the unit cost of water in these areas is often higher than those from conventional water supply systems and is more susceptible to local market forces, per capita consumption is lower. Alternatives, such as the use of unprotected shallow wells, present increased risks to health. Faced with inadequate access to water supply services, illegal practices with water supply infrastructure are frequently reported. People cut water supply pipes, and create leaks which can cause malfunctioning, due to the drop of pressure and contamination of the water further on in the water supply system.

Marine pollution
Domestic sewage waste is one of the leading sources of marine pollution in the city of Dar es Salaam. The waste generated by 15% of the city residents who are connected to the sewer system is discharged into the sea untreated.[lxxii] As a result, the coastal waters of the city, especially the harbor area, are heavily polluted. High faecal and total coliform levels are a result of this sewage pollution. The situation is made worse by broken sewer pipes which discharge untreated sewage on mud flats near the harbor. This is threatening invertebrates and fish resources in those areas. Seaweed blooms are a regular feature in the waters off the northern end of the beach of Ocean Road in Dar es Salaam.

5.3 Aid organizations in Tanzania

Interviews with UNICEF, WaterAID, the World Bank, UNICEF, the World Health Organization, NETWAS, Evironmental Engenering and Pollution Control Organization (EEPCO) revealed that NGO's in Tanzania in general focus on the poor majority of the Tanzanian population (appendix 3 lists the interviewed persons and organizations). These organizations do not consider new technology as a part of the solution to the sanitation problem:

- UNICEF does not, and has no intention to fund sanitation facilities; they only inform people on sanitation technology. UNICEF promotes the pit latrine technology, from the cheapest, a concrete pit, to a pit with a building for privacy on top. Despite the fact that this technology is unsuitable for High Water Table areas no alternative technology is considered to be necessary;
- WaterAID, has its own improved pit larine technology, which separates liquid and solid waste.
- The World Bank does financial contribute to several Water and Sanitation projects in rural and urban Tanzania, for a total sum of $ 164,000,000 in 2009. These projects are planned and technical designed years ago, and new technology even if it is more sustainable is no option.

5.4 Sanitation technologies

In Tanzania households have adopted one of several basic solutions to the problem of disposing human waste, depending on the physical conditions and on how much money one can spend for construction and periodic cleaning. The solutions range from a simple pit latrine, to a water closet with provision for flushing with a soak pit for the wastewater or a connection to the piped sewage system. Low income groups cannot afford to collect their waste water and excreta and hygienically dispose it, or they do not have access to these facilities. In Tanzania virtually all poor households deal with their own waste by building their own latrines or septic tanks or hiring others to do it[lxxiii]. Since the public sector is generally not involved in this area, private providers dominate the market and offer services tailored to customers' needs and incomes, for the tasks that households choose not carry out themselves: constructors who build latrines, manual latrine pit cleaners, suction truck operators for septic tanks, and manual or mechanized drain and latrine ditch cleaning services.

As mentioned before statistics and up-to-date figures on sanitation in Tanzania are not always available. The most recent data source on the sanitation situation is the 2002 WATSAN report[lxxiv]. WATSAN stipulates that *"... the percentages of households using toilet facilities is not likely to be as high as the figures indicate. Perhaps we are seeing the vyoo vya bwana afya - toilets of the health officers, which were built but never used, or were said to exist when they didn't, to satisfy by-laws on sanitation established even before independence."* The graph below (figure 8) shows that in the 12 year period 1988-1999 the sanitation situation in Tanzania hardly changed. About 87% of the people in Tanzania use pit latrines, 12% do not have any access to toilet facilities and only about 1.5% of the people have a flush toilet.

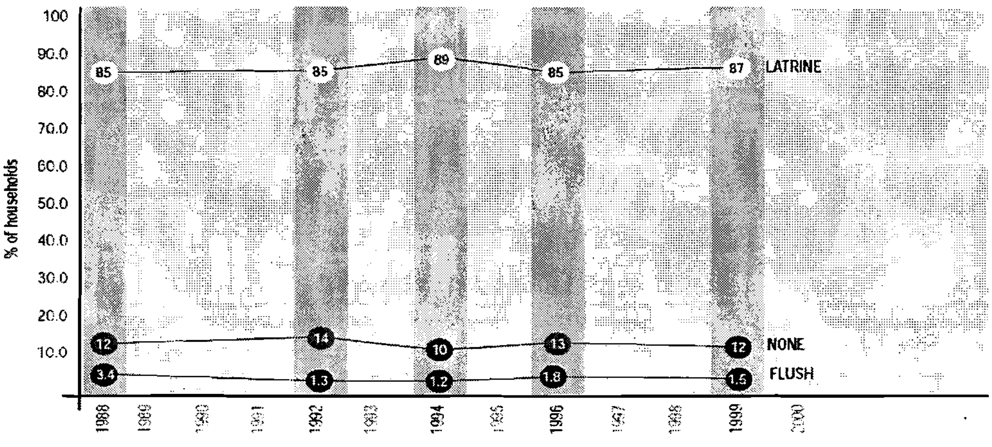


Figure 8 Percentage of households in Tanzania using different toilet facilities over time.[lxxiv]

The choice of sanitation technology mainly depends on two items: family income and location. Figure 9 summarizes this and categorizes four types of secondary wastewater treatment: wastewater treatment plant, regulated septic disposal, unregulated dumping and on-site sludge burying. These sanitation options constitute four technological regimes (I, II, III, IV), which are discussed separately.

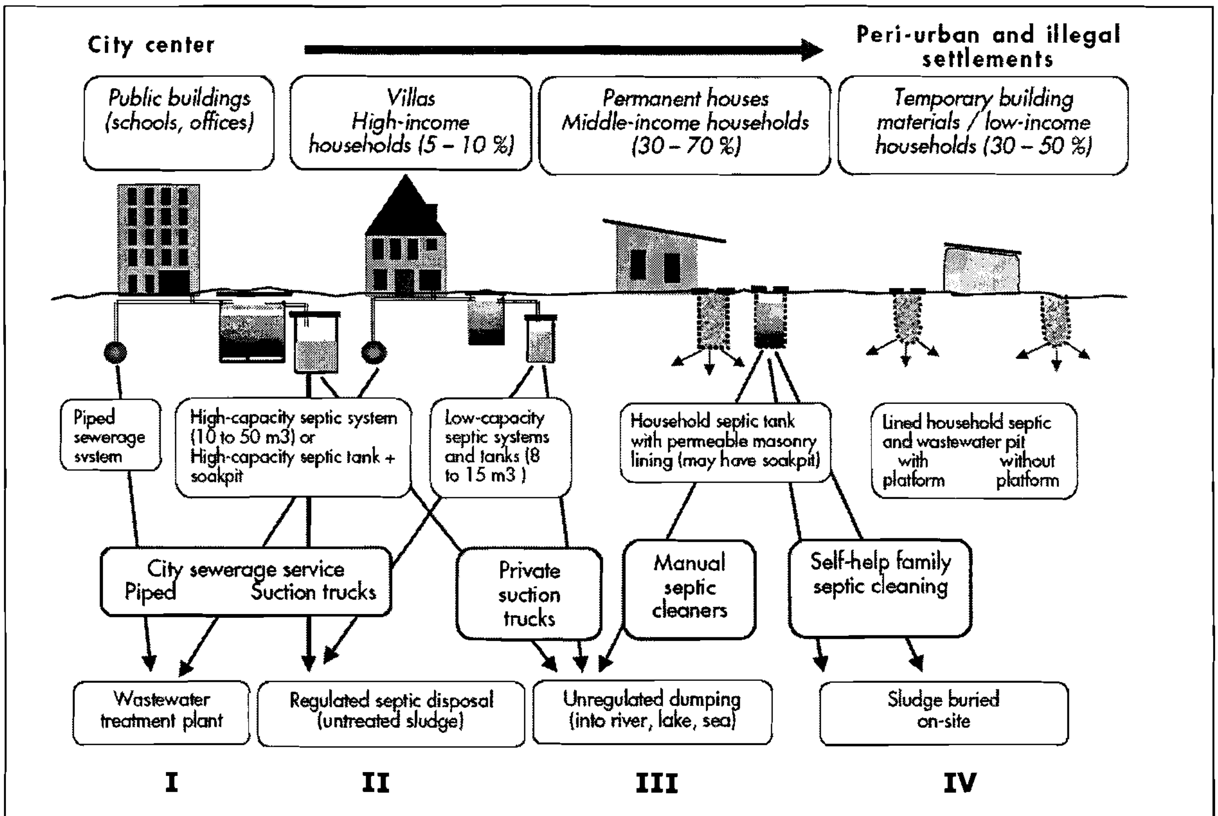


Figure 9 Different technologies for human waste treatment[lxxiii]

5.4.1 Wastewater treatment plant (I)

The first sewerage system in Tanzania was Constructed in Dar es Salaam, in the 1940s and since then no adequate operation and maintenance has been done. The city did have public flush toilets which were connected to this sewerage system in the 1960s, but they fell into disuse by 1990[lxxv]. Currently, there are quite a number of privately managed public toilets in different locations of the city which are connected to the sewage system.
A central waste water treatment plant combined with a piped sewage system is the most complicated of the four regimes, and is only applicable in city centers because of the expensive piping system and the availability of water for flushing the toilets. In major urban centers in Tanzania, the sewerage services to the public buildings (such as schools and offices) and private villas of the high-income part of the population are provided by the Urban Water and Sewerage Authorities (UWASA). The coverage of sewerage systems, measured in these urban centers is considerably less than that of the water supply systems, being about 17%[lii] compared with 73%[lii] for water supply, in whole Tanzania the coverage of sewerage system is even much lower: 1.5 %. This low coverage is partly caused by the shortage of sewerage system infrastructure, and partly by the reluctance by some users to be connected to sewerage systems because of the cost involved. The malfunction of these systems is not accounted for in these figures.

In Iringa[4] (109 632 inhabitants) malfunctioning of the sewage system is a serious problem; they suffer from approximately 20 blockages a month, caused by people who flush plastic bags, cloth etc. The other serious problem is that the ability to pay is very low which hinders the expansion of the system. A connection to the sewage system costs TSh. 1500/month and IRUWASA constantly has people on the road to collect money. They experience that once people are connected to the system the willingness to pay decreases dramatically, hence IRUWASA has not made a profit since its foundation.

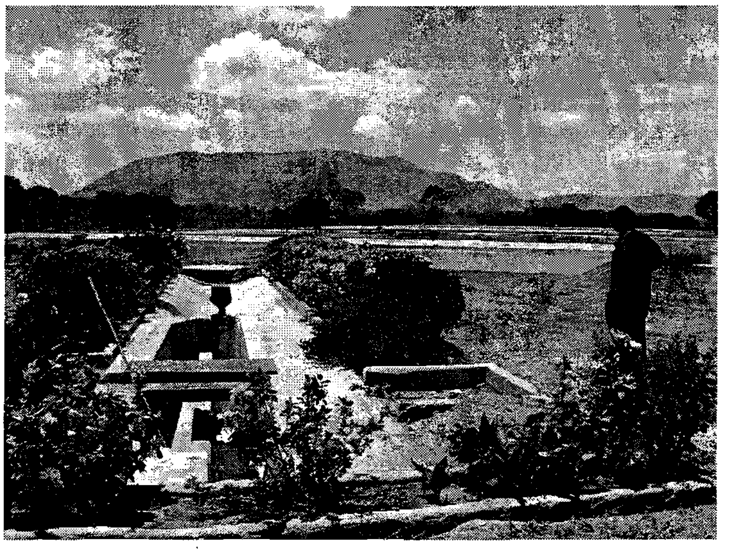


Figure 10 Waste stabilization ponds at the Iringa wastewater treatment plant

[4] The facts and figures of IRUWASA were collected from interviews with Mr. Moshy Kinyogoly, Health Officer Iringa Municipal and Mr. Joohana Buganda, Sewage Technician IRUWASA

Key technology: Waste stabilization ponds

The wastewater treatment plant in Iringa (see Figure 10) for instance, uses waste stabilization ponds (WSP). WSP's are man-made earthen basins, comprising of one or more series of anaerobic, facultative and, depending on the effluent quality required, maturation ponds on one location. Although this technology seems to be suitable for developing countries because of its technical simplicity and relative low electricity demand there are some serious downsides:

- Since the waste stabilization ponds are open basins they are a breading bed for malaria-spreading mosquitoes, see Figure 11, taken at the University of Dar es Salaam;
- The open ponds can create a horrible smell which makes the surroundings less attractive;
- WSP require large plots of land.

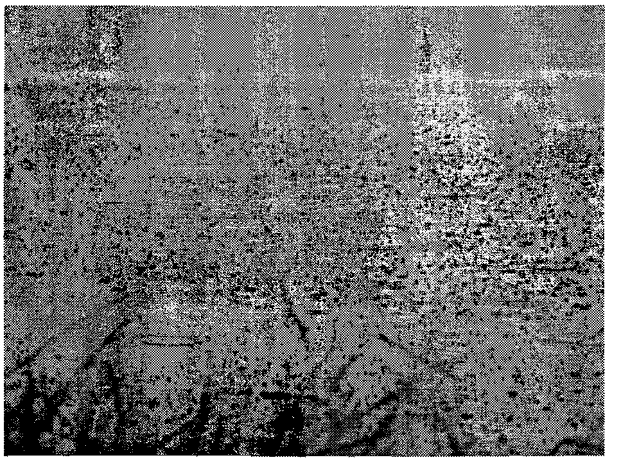
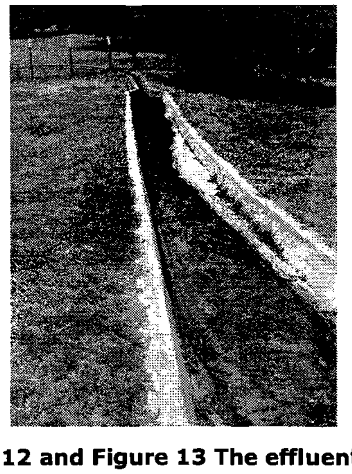


Figure 11 Mosquito hazard at the waste stabilization ponds at UDSM

The WSP's in Iringa discharge their effluent into a nearby river, which is used by the local people for bathing and clothes washing (see Figure 12 and 13). This would not be a problem if the pathogen levels were frequently monitored and kept under control. However IRUASA never had the proper (expensive) chemicals to check the effluent of the waste stabilization ponds, hence this effluent causes a potential contamination hazard.



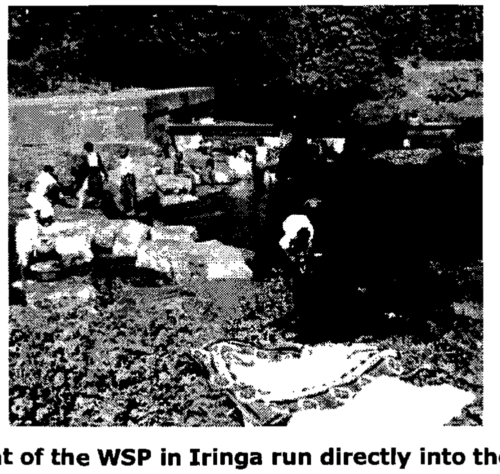


Figure 12 and Figure 13 The effluent of the WSP in Iringa run directly into the river

5.4.2 Regulated septic disposal (II)

Sludge can be removed from septic tanks and lined pit latrines by local city sewage service providers. These municipal suction trucks mainly provide service to governmental buildings and high income houses which are not connected to the piped sewage system. The suction trucks bring their sludge to the wastewater treatment plant were it is further processed. These municipal service providers charge TSh 25,000 per load and are creating a steady income for municipalities. An interview with the municipal health officer of Iringa, indicated that municipalities have no incentive to promote alternative sanitation methods because then they will lose their income and jobs generated by the suction trucks. These suction trucks make about 90-100 trips a month. Figure 14 shows a municipal owned suction truck discharging at the IRUWASA waste water plant. The use of these suction trucks can be very costly for the end users, especially in areas with a high water table, where septic tanks must be emptied several times a year.

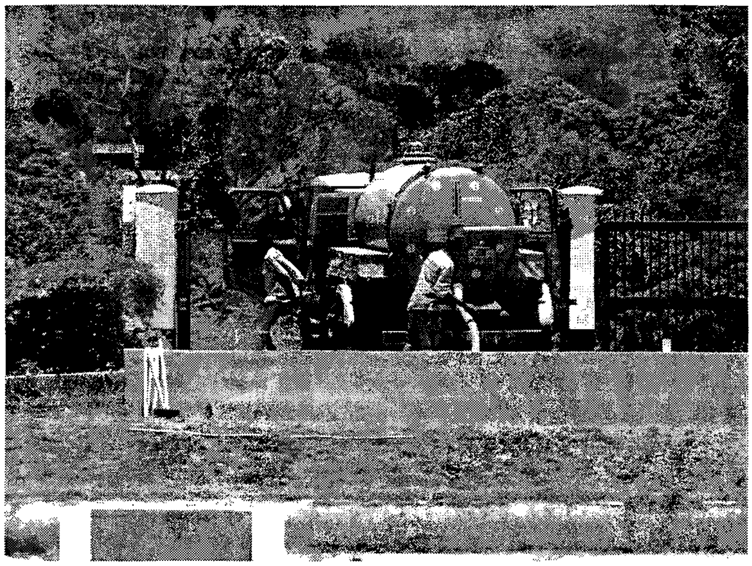


Figure 14 The Iringa Municipal sewage truck emptying its load at IRUWASA

5.4.3 Unregulated dumping (III)

Just like many African countries, unplanned settlements have kept increasing in many Tanzanian towns; in Dar Es Salaam in particular there are more than ten and there are no immediate means to upgrade these settlements[lxxvi]. Over the last decade informal settlements have become increasingly denser as people have continued to move to Dar es Salaam and have tried to settle in those areas closer to job opportunities (often the older unplanned settlements). Accompanying this influx into a restricted area of land, people have also been starting to live on land that was previously less attractive. In low-lying Dar es Salaam this includes many areas prone to flooding. This has led to both more latrines and more loading on the existing latrines. Higher loading reduces the treatment that takes place in-site in latrines, and latrines fill faster. The challenge of emptying latrines has grown. Higher densities also mean more and more settlements where traditional vacuum trucks cannot reach.

Key technology: the pit latrine

The traditional sanitation method used by low-income communities is the pit latrine, in Tanzania about 87% of the population depends on this technology. The function of the pit latrine is to separate the liquid part of human waste and to decompose the solid parts. The pit latrine consists of a hand dug pit in the ground with a squatting slab on top. When necessary, the pit is lined with stones or bricks to prevent it from collapsing. A superstructure is built around it for privacy. In certain circumstances pits have to be emptied more frequently. In Dar es Salaam, for example, there are pits that need regular emptying in less than 12 months. Pit latrines are the most common, but not necessarily the cheapest sanitation system to operate. A large, deep pit with brick lining is expensive, which is one reason for emptying and re-using a pit rather than constructing a new one. Nevertheless, pit latrines are widely used in the Tanzanian (peri-)urban areas. Major obstacles to latrine construction are high population density and space requirements, a high water table, an inappropriate soil structure (rock, sand), and the danger of ground water contamination. Improperly Constructed pit latrines can collapse.

Building pit latrines

Most Tanzanian households deal with their own waste by building their own latrines or septic tanks or hiring others to do it. Since the public sector is generally not involved in this area, private providers dominate the market and offer services tailored to customers' needs and incomes, for the tasks that households choose not carry out themselves: masons who build latrines, manual latrine pit cleaners, suction truck operators for septic tanks, and manual or mechanized drain and latrine ditch cleaning services.

People living in small towns and peri-urban areas primarily depend on these pit latrines, which are emptied by local authority or private operators. In rural communities the coverage of sanitation is stated to be about 84%, through the construction of pit latrines by individual households. However the standard of latrines leaves much to be desired as they are frequently in a poor state and as a consequence, over 70% of diseases attended to in health facilities are water and sanitation related. Figure 15 shows a deteriorated, but still used pit latrine in Temeke, Dar es Salaam.

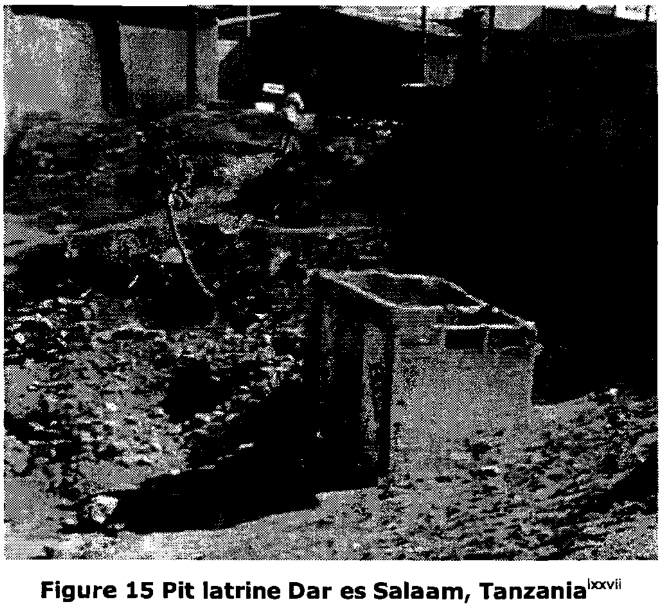


Figure 15 Pit latrine Dar es Salaam, Tanzania[lxxvii]

Emptying of pit latrines
Emptying of pit latrines can be done by manual or by mechanical methods. Manual methods, employing scoops and buckets, are applied to the more fluid type of waste, while thicker sludge has to be dug out by hand. This can involve hard work and almost total immersion in the sludge, as, for instance, by the "vyura" (frogmen) of Dar es Salaam[lii]. The frogmen are professional private pit latrine cleaners who work mostly on the small latrines. The small latrines are often located in places inaccessible to pit-emptying trucks, hence the need for frogmen. Frogmen work in groups of two to four, and can be seen pouring a black liquid solution into overflowing pit latrines to kill the stench. They will then manually empty the latrines using buckets, and bury the sludge in a hole they have dug nearby. Because of the lack of space in crowded urban settings, pit latrine emptying has become a small trade in places like Temeke. The frogmen get paid around TSh20,000 for each latrine emptied.

Mechanical methods revolve almost entirely around the use of privately owned vacuum trucks, where atmospheric pressure forces the pit contents along a hose pipe into a tank under vacuum (see also the discussion under II, above). Again, the thicker sludge can present problems, such as blocking the hose pipe, so that in some cases addition of water and agitation of the contents may be necessary to increase viscosity and induce flow. The privately owned pit emptying services using conventional vacuum trucks, developed in industrialized countries, have proved inappropriate. In particular this is because of difficult access to old city slums and peri-urban settlements and high fuel consumption. Pit emptying by sludge trucks, where possible, costs about TSh25,000.
Both, the frogmen and the privately owned suction trucks discharge the sludge into rivers, lakes and the sea, creating a potential health hazard.

Illegal flushing
Increased flooding and lower lying settlements have led to an increased problem of seasonal 'flushing', whereby poor residents use the floodwater to help empty the top part of their latrines (raised perhaps a meter off the ground) during the biannual rains, flushing raw sewage into the immediate environment. The Municipality of Temeke has health inspectors which have the authority to fine people up to TSh. 60,000 for flushing illegally. However, these penalties are ineffective. People flush illegally because they are not able to pay for sanitation services; a fine on top of this will not improve behavior in the future.

5.4.4 Sludge buried on-site (IV)
In both urban and rural areas, pit latrines are usually relocated when they are full. This is uneconomic for the house owners, when the latrines are well built. As urban land becomes scarce, plot sizes are reduced and it becomes both technically difficult and expensive to re-excavate pits and to move superstructures. Under these conditions, which are often found in fringe and urban low-income areas, it is necessary to empty the pit latrine. The sludge in the courtyard is collected by adults in shovels or in dust-collecting device and dumped hazardly in solid waste heap.

In the poorest areas people often do not have access to basic sanitation. The houses they live in are often rented and there is no space to build a latrine. Disposal of faeces in plastic bags, **"flying toilets",** is not uncommon[lii]. Flooding due to inadequate storm drainage exacerbates the problem, spontaneously spreading the contents of poorly Constructed latrines around whole neighborhoods. Cholera also gets exported to rural areas with fatal consequences.

5.5 Landscape and Regime: the Window of opportunity

This chapter analyses how the main characteristics of the landscape and the four sanitation regimes, create opportunities and constraints for a novel sustainable technology to enter these regimes.

5.5.1 Main conclusions from the landscape and regime analysis

Landscape conclusions

More than half of the population (51%) lives on less than US$1/day, which makes it virtually impossible for this part of the population to pay for proper sanitation technologies. In Tanzania 6 to 6.5 million people currently live in unplanned peri-urban areas which have no or little connection to community services, such as water and electricity. Furthermore we can conclude that:

- Sanitation is an unpopular subject to discuss and worldwide it receives little attention;
- Policies rather focus on water supply than on sanitation;
- In Tanzania people have gotten used to and do accept malfunction of social services;
- There is a strong relation between lack of quality of sanitation facilities on schools and the drop out rate of young girls;
- Tanzanian W&S policy is heavily linked to international priorities in water governance, which causes the national policy to change frequently. Tanzania is still trying to implement policies and institutional changes which should have been done years ago. And just when they seem to catch up with this implementation the donor community changes policy again.

Regime conclusions

There is no national sanitation policy at the moment. Sanitation aspects are included in the main health policy which just mention without further details about promotion of the construction of pit latrines and their use in all households, health facilities and public institutions.[lxxviii] Responsibility for sanitation is scattered; in cities the UWASA's are responsible for the central sewage systems, for on-site sanitation the municipals are responsible. In the areas outside the cities the districts are responsible for sanitation. This causes problems in the peri-urban areas where the governmental responsibility is unclear, and virtually no control of illegal dumping of sewage exists. In addition to this, schools, hospitals and other governmental buildings are responsible for their own sanitation. The interviewed NGO's were not open to new more sustainable sanitation technology, and continue to follow their own path.

I wastewater treatment plant

A wastewater treatment plant combined with a piped sewage system is the most technical complicated and expensive system to build. It requires at private expense connection to a water tap combined with flush toilets. The private yearly cost of connection to the sewage system is TSh. 18,000. Just about 1,5 % of the people of Tanzania are serviced by a piped sewage system, this expensive system is not very likely to expand fast enough to catch up with the population growth rate, because of the complexity of the system and the high costs of the construction and maintenance. Waste Stabilization Ponds (WSP), which are a common technology for wastewater treatment plants create three potential health hazards:

- WSP's are a potential breeding place for malaria mosquitoes;
- WSP's can spread a very bad smell, which deteriorates the direct environment;
- The effluent of WSP's, if not sufficient cleaned, can be a source of bacterial contamination since it is discharged in local rivers.

The wastewater treatment plant moves the sanitation hazards far away from the direct users to the environment. Hence the health hazards are minimized for these individual users.

II regulated dumping
Higher income residential areas, and governmental buildings such as school and hospitals, which are not connected to the piped sewage system use septic tanks, which are usually cement-lined and water-tight. This technology is the second most complicated sanitation technology, since it also requires flush toilets and water connection. Sludge removal form the septic tanks is done by suction truck and carried off to disposal sites.
This technological option is a more expensive solution for the users than connection to a piped sewage system because of the higher fixed yearly costs. Septic tanks must be emptied more frequently (in some Tanzanian cities, twice or more a year, depending on load, size and height of the water table) at TSh 20,000-25,000 (US$20 to 25) per visit.
Proper use of septic tanks, are from a health hazard perspective, the second best option for the individual user. When the septic tanks are not frequently emptied they overflow, creating a health hazard of bacterial contamination for the area surrounding the users.

III illegal dumping
Illegal dumping of sludge is mostly related to the pit toilet technology.

- The use of pit latrines for sanitation requires fairly low tech technology since no connection to the water system needed.
- Pit latrines are not a viable solution for high density urban areas as they depend on the permeability of soil and multiple systems can overload the infiltration capacity of the local soil.
- People hire local private entrepreneurs to empty the pits. These private service providers discharge the sludge into rivers, lakes and the sea, creating a potential health hazard.
- The private companies charge about TSh 25,000, which is too much for some people. They illegally flush their pit latrines during rain season.

IV burying
In peri-urban areas of larger cities, low-income households organize family manual labor to dig new latrine pits, dig out the sludge when full, and either rebury it or simply dig another pit when lot size permits. In denser low-income areas, often closer to downtown, pit latrines are generally not lined and liquid waste is absorbed through the earth walls, leaving a compact mass that is generally removed with a bucket and shovel. This low tech method causes a health hazard directly for the users because the sludge can contaminate the ground water.

Figure 16 summarizes the level of health hazard and the sophistication of the four technological regimes. The low-tech regimes (III and IV) which are used by the vast majority of the Tanzanian population cause the biggest health hazards for the user. The more sophisticate regimes (I and II) are the less hazardous for the direct environment.

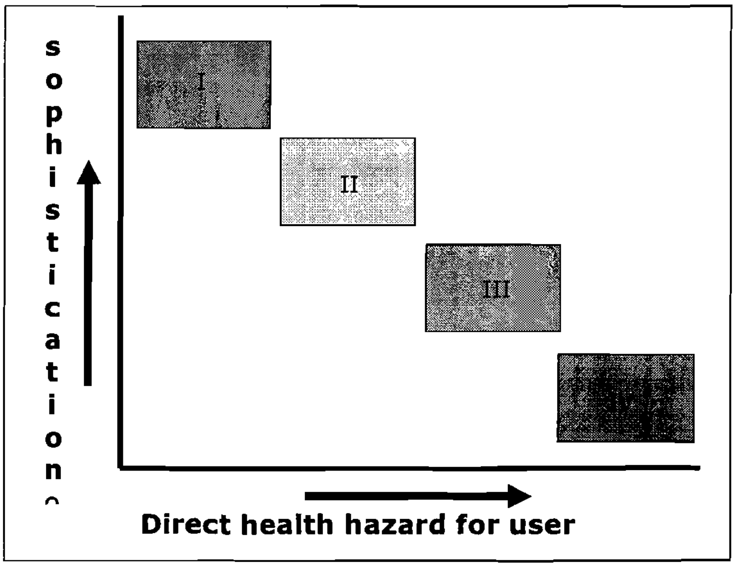


Figure 16 Sophistication and health hazards of the sanitation regimes

5.5.2 The window of opportunity

The current sanitation situation in Tanzania is unsustainable which possibly creates opportunities for novel niche technologies to enter the current regimes. The niche technology of Constructed Wetlands (see chapter 3 for detailed description) might solve some of the sustainability problems in these current regimes, but it will not become a new regime.

The Constructed Wetland technology requires a basic level of technology in the current regime before it can enter this regime. The Wetlands do need water to function properly, and should be connected to a water born sanitation system. This implies unfortunately that the two regimes which cause the greatest direct health hazard, and are used by about 80% of the population (regime III and IV) are unsuitable for implementation of Constructed Wetland technology. The lack of infrastructure at sanitation regime III and IV cannot be directly solved by Constructed Wetlands. These regimes might be improved with other technologies and services or completely replaced by other systems. On the other hand upgrading of regime I and II has also a positive effect on the part of the population which uses low-tech sanitation because, it reduces the number sources of bacterial contamination and creates new safe areas where people can live. Figure 19 shows the windows of opportunity for Constructed Wetlands.

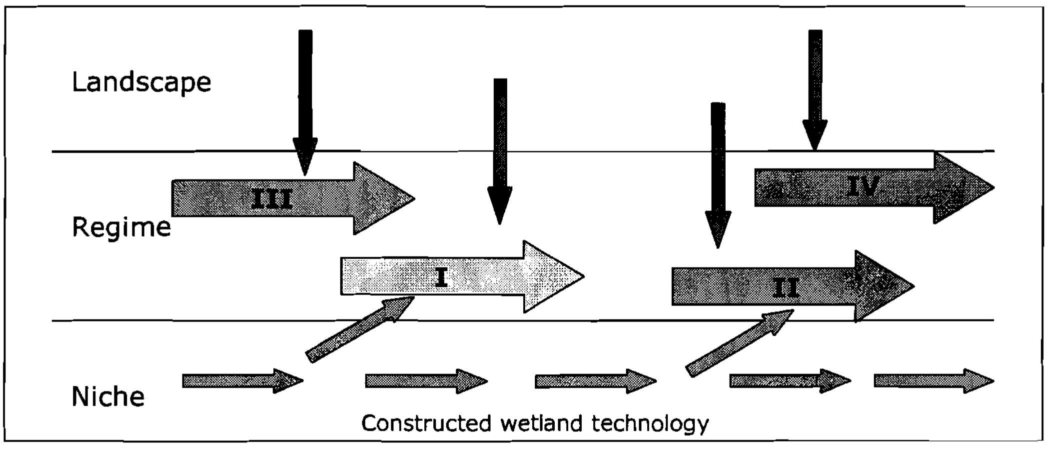


Figure 17 The window of opportunity for Constructed Wetland technology

The first window of opportunity for Constructed Wetlands is at the centrally wastewater treatment plants (regime I).

- The currently used Wastewater Stabilization Ponds have large still water surfaces, which create an ideal breeding place for mosquitoes. CW's do not have surface water, and replacement of these ponds with CW'S would tackle this problem.
- The WSP's can spread an awful stench, which makes the surroundings very unattractive to live; Constructed Wetlands are odor less, replacement of the WSP with CW's makes the environment surrounding the wastewater treatment plant more attractive to live;
- The effluent of WSP's, if not sufficient cleaned, can be a source of bacterial contamination since it is discharged in local rivers; addition of a CW to the WSP's can improve the quality of the effluent

The second window of opportunity is the septic tanks at the governmental buildings such as school and hospitals, which are not connected to the piped sewage system (technical regime II). The frequent emptying of septic tanks is costly and overflowing tanks create a health hazard of bacterial contamination for the direct environment.

- A Constructed Wetland can be directly connected to the septic tank (because schools and hospitals have in general some spare land) and clean the overflowing water making it suitable for reuse.
- The addition of a Constructed Wetland can reduce the cleaning costs and save water because it will be reused.

The next chapter will verify whether the conclusions about the window of opportunity analysis are consistent with the results of the niche analysis of the Constructed Wetlands.

6 Niche analysis

There have been seven technical experiments with Constructed Wetlands in Tanzania. These experiments are executed throughout Tanzania. The first pilot wetland was Constructed at the University of Dar es Salaam, further there are Constructed Wetlands built at the Ruaha secondary school and the Kleruu teachers' college in Iringa, the prisons of Shinyanga and Kahama, the MUWASA (Moshi Urban Water and Sewage Authority) and at an industrial wastewater treatment plant at the KIBO paper factory in Moshi. Five of these niche experiments are a part of this research, because of the fact that two experiments were done at Tanzanian prison which did not give permission for research. All data and facts in the niche analyses are obtained from the field research interviews (see appendix 3 for interviewed persons), unless specifically stated differently.

6.1 University of Dar es Salaam

background
The university of Dar es Salaam (UDSM) is the oldest and biggest public university in Tanzania. It is situated on the western side of the city of Dar es salaam, occupying 1,625 acres on the observation hill, 13 kilometers from the city centre. UDSM was established on the 1st of July 1970. Prior to 1970, the University College, Dar es Salaam had started on 1st July 1961 as an associate college of the University of London. It had only one faculty- the faculty of Law, with 14 enrolled students. In 1963 the University College became a part of the university of East Africa together with Makerere University College in Uganda and Nairobi University College in Kenya. Since 1961, the University of Dar es Salaam has grown in terms of student intake, academic units and academic (international) programs. In academic year 2006/2007 there were 11,512 students at UDSM.[5]

Situation prior to Constructed Wetland technology adoption
The piped sewage system, including the Waste Stabilization Ponds at UDSM (see figure 18), were built in 1987. These ponds were Constructed according to the conventional traditional design of Waste Stabilization Ponds, which does not consider the ecological processes which take place in the ponds. These WSP's at UDSM received most of the wastewater from the University community. The system was designed to serve 5,000 people, but now serves more than 6,000. The influent is mainly of domestic origin and from the laboratories, workshops and a health centre. The Wastewater Stabilization Ponds at UDSM combine to a small wastewater treatment system consisting of seven ponds. This is a typical pond system for wastewater treatment in Tanzania which can be found on numerous sites throughout the country. The effluent from the Waste Stabilization Ponds was and is discharged into a nearby stream because it is not suitable for reuse, such as irrigation purposes. Table 8 shows that the level of BOD_5 and the total Coliform count are to high according to the Tanzanian Temporary Standards (TTS). These TTS are represented in Appendix III and show that there are many more water quality standards which should be met, but in practice these are rarely measured.

[5] http://www.udsm.ac.tz/about/facts.html

	BOD5 (mg/l)	Ammonia (mg/l)	Coliform (count MPN/100ml)
Influent	252	11.89	17,500,000
Effluent	184	6.58	7700
Effluent Standards	~35	10	400 - 1000[6]

Table 7 the water conditions of the UDSM Waste Stabilization Ponds[7]

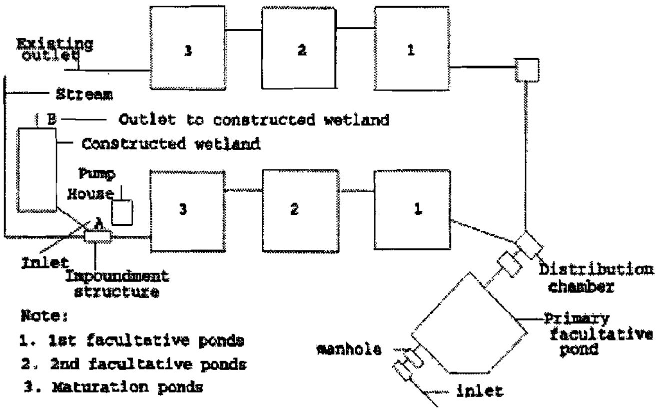


Figure 18 Waste Stabilization Ponds and the position of the Constructed Wetland at UDSM

The first contact with Constructed Wetland technology

In 1995 UDSM started a research project in cooperation with the University of Denmark which focused on wastewater treatment using Waste Stabilization Ponds (WSP), six researchers worked on this project, three from the UDSM and three from the Danish University. This project lasted 3 years. The WSP technology was already well known in Tanzania, but there was a lack of knowledge on how these WSP's should be designed, operated and maintained. The WSP research project resulted in a design manual for the Waste Stabilization Ponds.

In 1997 the WSP project entered a new phase, after the project members participated in a workshop on Constructed Wetlands in Denmark. There the idea was born to expand the WSP project by researching the optimal technical design of a Constructed Wetland and its performance regarding wastewater treatment. The Constructed Wetland technology was new to Tanzania, and worldwide very little was known about the application of Constructed Wetlands for wastewater treatment in a tropical environment.

In 1999 the first pilot CW in Tanzania was built at the UDSM, this wetland was connected to the WSP's at the University's wastewater treatment plant (see figure 18 for location and figure 20 for the design of the Wetland).

6 The Most Probably Number of Fecal Coliform is stated to be 400 in the Temporary Standards of Tanzania, however the WHO has set this number to 1000 for water that is used for irrigation
7 All measured data is supplied by UDSM

Figure 19 Birds in the reeds at the UDSM CW

Performance of the pilot Constructed Wetland at UDSM

There has been extensive research on the performance of the pilot Constructed Wetland at UDSM. In general the performance of the Wetland was promising, although the frequent shortage of chemicals made it difficult to measure BOD_5 and Ammonia over an extended period of time. Table 8 illustrates that regarding the BOD_5 level, the level of Ammonia and the Coliform count of the Wetland the effluent is suitable for irrigation. This is a significant improvement on wastewater treatment without the addition of a CW, in which the effluent is not suitable for irrigation.

	BOD_5 (mg/l)	Ammonia (mg/l)	Coliform (count MPN/100ml)
Influent	120	10.5	107000
Effluent	< 30	<1.5	<1000
Effluent Standards	~35	10	400 - 1000[8]

Table 8 the water conditions of the UDSM pilot Constructed Wetland[9]

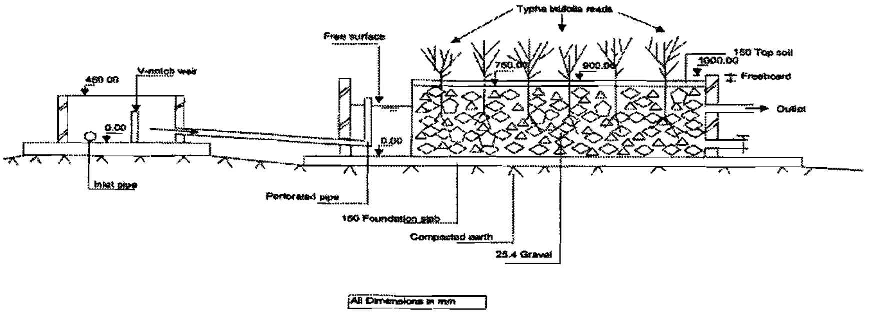


Figure 20 the design of the Constructed Wetland at UDSM[lxxix]

[8] The Most Probable Number of Fecal Coliform is stated to be 400 in the Temporary Standards, however the WHO has set this number to 1000 for water that is used for irrigation

[9] All measured data is supplied by UDSM

Findings of the pilot project

The main results and conclusions of the research project were:

- Constructed Wetlands can be used to upgrade the quality of WSP effluent to an acceptable level, if the system is properly designed, maintained and operated and will result in high quality effluent for water reuse such as irrigation[lxxix].

- The research resulted in a manual for the design of Waste Stabilization Ponds and Constructed Wetlands. This manual has been adopted and supported by UNEP.

- The pilot Constructed Wetland did not only prove to be a sustainable method for the reduction of pathogens in wastewater, it also improves the environment aesthetically and biologically, because birds breed in the reeds on the CW (see picture 19).

- The Wetlands are odorless and mosquitoes cannot breed in the Constructed Wetland since there is no surface water.

- Constructed Wetlands might also work in combination with septic tanks.

6.2 Ruaha secondary school

Background
The Iringa Ruaha secondary school (figure 21) was founded in 1986 as a day school serving a few students and has grown since to over 750 boarding students. Due to this population growth the amount of wastewater has risen and the sewage treatment system became insufficient.

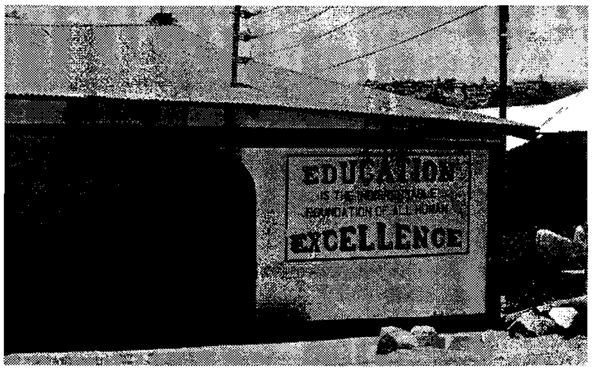


Figure 21 The Iringa Ruaha secondary school

Organizational Structure
The National Spiritual Assembly of the Bahá'ís of Tanzania is responsible for establishing the central goals of the school and for guiding and supervising its development. The Government of Tanzania, the Ministry of Education and Culture licenses the school and establishes laws and guidelines. The Policy Committee oversees the school's operation and establishes policy for the school within the framework of guidance provided by the National Spiritual Assembly. The Board of Governors ensures that legal requirements are being met. The Principal recommends goals and policies, supervises staff, and runs the school. The Education and Moral Education Department is responsible for ensuring that all academic requirements are met. The Projects Department is responsible for the development and management of social and economic development projects.

Goals & Objectives
The three main objectives of the Ruaha secondary school are:

- to provide a service to the people of Iringa;
- to become an exemplary institution of education according to Baha'i principles and teachings and;
- to empower students to become contributing members, and agents of change in their communities.

In these objectives one can find the motivation for the Ruaha secondary school to become one of the first in Tanzania to apply Constructed Wetlands technology into their sanitation system. The old sanitation system had become hazardous and insufficient to treat the increased amount of wastewater, caused by the growth of the number of pupils. Ruaha secondary school did take their responsibility to the environment and confronted this problem, with the help from the University of Dar es Salaam.

Situation prior to Constructed Wetland technology adoption
The sanitation system at the Ruaha secondary school is water based; it consists of flush toilets, a piped sewage system which is connected to a septic tank for the solids, equipped with an overflow for liquid waste. Proper maintenance had become very expensive because the school is situated in an area with a High Water Table (HWT). This HWT combined with the growth of the student population caused the system to overflow. The High Water Table prevented the wastewater to soak away in the soil. At one point the school had to hire the Municipal suction trucks to empty the septic tank every two weeks, the trucks had to make 2 runs per turn, adding up to a monthly cost of TSh. 100,000.

The first contact with Constructed Wetland technology
At this point the Ruaha School started to search for a cost effective sustainable solution for this domestic wastewater problem. They read about the Constructed Wetlands experiments at the University of Dar es Salaam in a national newspaper. The article stated that the Constructed Wetland technology made reuse of domestic wastewater for irrigation possible. In the ideal case domestic wastewater is recycled (see figure 22) as follows:

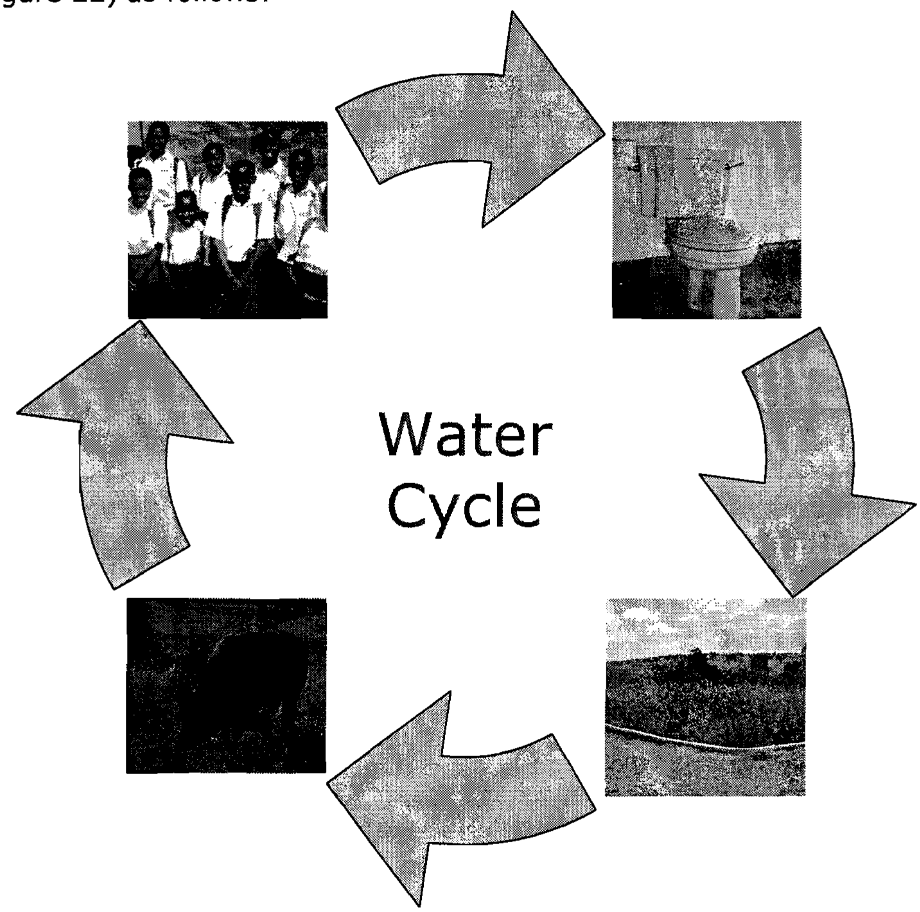


Figure 22 The ideal water recycling situation

The schoolchildren drink water (from milk and other liquids) and use the sanitation facilities. Then the urine is diluted with water from the flush toilets. This wastewater runs through the Constructed Wetland where it is treated and pathogens are removed. The clean water runs onto the land where it irrigates grass which is consumed by cows. These cows in their turn produce milk, which is consumed by the children. In this situation no water is wasted. The management of the Ruaha School was curious after this technology and contacted the University. The University was willing to cooperate, realizing that this would be a good opportunity for a technological niche project in which a CW could be connected to a septic tank.

Financing and building the Constructed Wetland

The Constructed Wetland at the Ruaha Secondary School is designed by the University of Dar es Salaam and built on self-help basis, with local constructors and students. In order to finance this project Ruaha applied for a grant at the American embassy and at the embassy of Luxembourg. The American embassy granted $2,500 and the embassy of Luxembourg supplied the raw materials, such as bricks and concrete. This together was sufficient for the construction of the Wetland (figure 23). The Wetland was opened by the mayor of Iringa and the press was very interested in the project. Since then the attention for the Wetland in the media has died away.

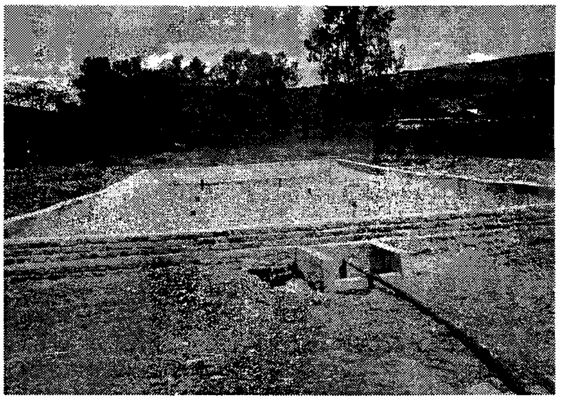


Figure 23 construction of the Wetland

Performance and operational cost of the Ruaha Constructed Wetland

During the first operational year (2004- 2005) of the Wetland its performance was measured frequently by students of UDSM. Due to the high traveling costs for student from Dar es Salaam to Iringa this measuring has been discontinued and no follow-up has taken place. The average of the measurements is summarized in table 9[10]. The levels of BOD_5 and Ammonia are lower that de Temporary Standards (appendix III) require. The level of Fecal Coliform is also within the limits for irrigation. Although the characteristics of the effluent are not frequently measured the Constructed Wetland seems to operate properly.

	BOD_5 (mg/l)	Ammonia (mg/l)	Coliform (count MPN/100ml)
Influent	118	10.5	107000
Effluent	26.8	<1.5	<1000
Effluent Standards	~35	10	400 - 1000[11]

Table 9 the water conditions of the Ruaha Constructed Wetland

[10] All measurements are executed and provided by UDSM

[11] The Most Probable Number of Fecal Coliform is stated to be 400 in the Temporary Standards, however the WHO has set this number to 1000 for water that is used for irrigation

The current condition of the Wetland is represented in figure 24 and 25. The effluent is clear and the reeds in the Wetland are full-grown. The Constructed Wetland at Ruaha Secondary School is well maintained and the environment looks tidy.

Figure 24 the Constructed Wetland at Ruaha

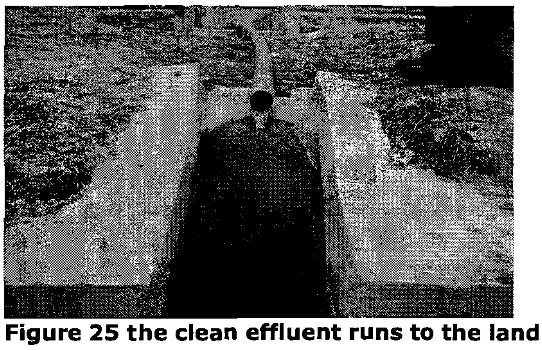


Figure 25 the clean effluent runs to the land

The maintenance of the CW, which is essential for its performance, does not require highly skilled employees and can be done by a well instructed gardener. The gardener needs to cut back the reeds and check the influent and effluent pipes for clogging, furthermore he is responsible for weed control around the wetland. The monthly costs for a gardener, which is only needed on a part-time base, are approximate TSh. 35,000. The Municipal sewage truck is now only needed once a year.

Findings of the niche project

Looking back at the technological niche project at Ruaha secondary school one can conclude the following:

- The structure and division of responsibilities at the school suggest that schools are complex, somewhat bureaucratic institutions; there are several policies to which the institution must comply, institutional, national and international. However, in this case, people took their responsibilities, instead of moving away. The sense of responsibility to the environment and the health of the students prevailed over bureaucratic ignorance, which enabled the adoption of the novel Constructed Wetland technology.

- It is feasible to treat domestic wastewater sufficiently for reuse as irrigation water, with a Constructed Wetland, combined with a septic tank.

- The financial support of the embassy's of Luxembourg and the United States, facilitated the introduction of CW technology at Ruaha secondary school.

- Designed Constructed Wetlands can be built properly with local workforce, on the condition that they are guided by a skilled foreman.

- The CW has become completely integrated in the sanitation system and has lowered operating and maintenance costs from Tsh 2.400.000 (~$1.930) to Tsh 445.000 (~$360) a year, which is a factor 5.4.

- The Constructed Wetland is also adopted in the educational program and used to teach students about the environment and good sanitation practices.
- Ruaha is very pleased with the Wetland and has built a second one on own expenses, to deal with future population growth.

6.3 Kleruu teachers' college

Background
The Kleruu Teachers' College (KTC) is located in Iringa municipality and was erected in the early 1970's. The current population of the campus, including staff and family, is 600.

Goals & Objectives
The main objective of the college is to train teachers at diploma level and provide in-service courses for practicing teachers. The college has no special attention or programs regarding the environment or sustainability.

Situation prior to Constructed Wetland technology adoption
The college sewage was collected and treated in a mechanical aeration chamber which was leading the wastewater to a Waste Stabilization Pond. All staff houses and the campus buildings are connected to this sewerage system. From the 1990's the performance of the Waste Stabilization Pond started to deteriorate due to the accumulation of the sludge in the pond. Moreover, the cost of electricity for running the mechanical aeration of wastewater became too high and therefore unaffordable. Consequently the mechanical system did not run continuous as it was designed to do. Instead it was operated only 15 minutes a day and sometimes it was not operated at all. This increased the wastewater treatment problems. Later on the effluent to the pond was by-passed and the sewage was directly discharged into the river, this caused more concern to the down stream population. Figure 26 and 27 show the hazardous, unappealing situation around the WSP and the aeration chamber in this period. The Waste Stabilization Pond was located next to the KTC main administration block. This ghastly situation resulted in complains by neighbors of the college about the awful smell and, in addition of this, the community at KTC started to complain about mosquitoes which massively bred in the deteriorated aerator.


Figure 26 Waste Stabilization Pond at Kleruu **Figure 27 the overflowing aeration chamber**

The first contact with Constructed Wetland technology
Due to the pressure of the neighbors, the college started to look for an alternative method that would improve the wastewater treatment, eliminate odors, mosquitoes and health hazards to the community. The KTC however, had neither funds nor the technical expertise for wastewater treatment. KTC requested the University of Dar es Salaam for feasible solutions.

Financing and building the Constructed Wetland

UDSM advised KTC to convert the Waste Stabilization Pond into a Constructed Wetland and to abolish the mechanical aeration system. The college obtained funds from DANIDA through the Sustainable Iringa Project (SIP) for the construction of the wetland.

A Constructed Wetland was considered to be the best alternative for wastewater treatment at KTC because it would eliminate all existing sanitation problems at KTC:

- There would be no mosquitoes breeding;
- There will be no electricity needed to operate the Wetland;
- There will be no odor;
- The health hazard to the downstream population will be minimized.

The construction of the Wetland started in October 2003 and was completed by January 2004. The total area of the Constructed Wetland is $625m^2$. The system can serve a future population of 800. Figure 28 shows the construction of the Kleruu Constructed Wetland.

Figure 28 Subsurface Constructed wetland at Kleruu before planting

The total cost for the construction of the Constructed Wetland at KTC was budgeted at TSh 17,849,447. The KTC contributed to the project by providing unskilled labor especially during the preparation of the site that involved removing debris from the abandoned waste stabilization ponds, desludging the pond and refilling the ponds to the required depth for the construction of the Wetland. The costs for the low skilled labor were TSh 2,212,500. The work was supervised by the University of Dar es Salaam. UDSM also assisted the college as a contractor because of serious lack in the management of the construction works. Resulting in a total cost for the project at KTC of TSh 18,716,947 (~$ 15,000).

Performance and operational cost of the Kleruu Wetland

The performance of the Kleruu Wetland was measured several times by students of UMDS in the first year. As presented in table 10 the three main parameters of the effluent of the Constructed Wetland are within the limits for reusing the water for irrigation purposes. In de same period there were no mosquito outbreaks and there were no complaints from the neighboring village reported. At this time the system worked properly.

	BOD_5 (mg/l)	Ammonia (mg/l)	Coliform (count MPN/100ml)
Influent	124	10.5	107000
Effluent	12.6	<1.5	<1000
Effluent Standards	~35	10	400 - 1000[11]

Table 10 the water conditions of the Kleruu Constructed Wetland

Unfortunately this situation has changed at the present time, the Constructed Wetland is currently in a bad condition (figure 29). The Wetland is clogged and overflowing causing about 25% of the reeds to die up to this point. This indicates that the CW is functioning suboptimalyl.

The operation and maintenance costs of the Kleruu Wetland are estimated at TSh. 50.000 (~$50) a month for a trained gardener.

Figure 29 dying reeds due to poor maintenance of the CW

Findings of the niche project at Kleruu

The conclusions of the implementation Constructed Wetland technology at the Kleruu Teachers' College are less optimistic than the conclusions of the previous two niche projects. The sustainability of this niche project depends on three key issues:

- First of al the design of the sanitation system, including the CW, needs to be correct, as seen on figure 31, the Wetland is cluttered with sludge, which could indicate the need for a bigger septic tank.
- Secondly there is a lack of commitment and priorities of the KTC management: sanitation and environmental sustainability seem not to be very high at the priority list of this management. The hazardous situation before the introduction of the CW had already completely run out of control causing a great risk to students, the surrounding village and to themselves.
- Thirdly the financial situation of the KTC is important: lack of financial means puts the management in a very difficult situation and decisions have to be made: for instance the choice between proper maintenance of sanitation facilities and firing a teacher.

6.4 Moshi piped sewage system

Background
Moshi (figure 30) has an area of 58km^2 and is situated on the Southern slopes of Mt. Kilimanjaro. It is the administrative, commercial and tourist centre of Kilimanjaro Region and the entire Northeast Tanzania. The population of Moshi has grown from 8,048 inhabitants in 1948, to a ~144.000 in 2005. The population is doubling every decade. The estimated number of households is 21.600, with an average of five people per house.

Figure 30 Moshi Municipality at the foot of mount Kilimanjaro

The municipal sewerage system
The Moshi Urban Water and Sanitation (MUWASA) Authority is since 1998 responsible for running a conventional system of collection, treatment and disposal of sewage from domestic, commercial, institutional and industrial centers within the Moshi Municipality. In 1999 improvements were made to the central sewerage system. This involved the construction of waste stabilization ponds. The general condition of sewage pipes was poor. Of the remaining (un-rehabilitated) system some parts are still not functioning well due to poor design and material. The increase in population is resulting in frequent leakages and blockages in the system. The problems are caused by the aging of the pipes, since the original system was established in 1954. These problems increased due to population growth and poor planning, have led to haphazard construction of residential units done on top of sewerage pipes and on top of manholes.

Goals & Objectives
MUWASA has the task and objective to:

- To manage and develop water supply and sanitation assets;
- To prepare business plans to provide water supply and sanitation services, including capital investment plans;
- And to secure finance for capital investment, and relevant subsidies.

MUWASA is the key player in the Moshi area regarding infrastructure and technological knowledge.

Situation prior to Constructed Wetland technology adoption
The sewerage network coverage is about 4 out of the total 58km^2 of Moshi Municipality. This coverage is realized after the support from The Urban Sector Rehabilitation Project (USRP) for rehabilitation of 5000m of the existing network and construction of new network of about 8400m that aimed at improving the status of services provided and increasing the number of customers connected to the services. Following its expansion, the population that is served with sewerage services in Moshi Municipality, has increased to app. 45.000 people, this is about 31% of the urban population.

The piped sewage system is directed southwards of the town into the Mabogini area. Here the wastewater is treated in a wastewater treatment plant which consists of a number of Waste Stabilization Ponds. The effluent from the WSP's is discharged into the river Rau, from the river it runs into the Pangani basin, finally ending up in the Indian Ocean. Although no exact measuring data was proved, the management of MUWASA stated that the effluent of the wastewater treatment plant prior to the construction of the Constructed Wetland was insufficiently treated, since the color of this effluent was green, which indicated high levels of nutrients in the water.
According to MUWSA, a regular quality control, once a month, and monitoring is done concerning the amount of suspended solids. The parameters are tested according to the (WHO) and Tanzania Temporary Standards (TTS). Unfortunately not all recommended parameters are measured due to lack of laboratory apparatus and chemicals. Moreover the municipal health department is also responsible for testing the effluent quality. According to the Town's health officer this is conducted every three months, although no data could be provided.

The first contact with Constructed Wetland technology
MUWASA was concerned about the high nutrient levels in the effluent of the wastewater treatment plant and turned to the UDSM for advice. MUWASA already had contacts within the UDSM from previous projects with the WSP's and the sewage system. The UDSM calculated a design of a Constructed Wetland, based on the experiments with the CW at the university. This CW is placed inline, after the last WSP and should provide sufficient aftertreatment of the wastewater to discharge it legally.

Financing and building the Constructed Wetland
This design study resulted in the building of a Constructed Wetland in 2002. The Constructed Wetland was completely funded by MUWASA and built with local contractors. The total construction costs were TSh. 24,000,000. (~$ 19,260).

Performance and operational cost of the Constructed Wetland at MUWASA
The technical performance of the Wetland is regularly measured (if equipment is available). The results of some of these measurements as presented in table 11. The BOD^5 removal performance is 89% and Ammonia and Coliform levels are also within the Tanzanian Temporary Standards. The effluent from the Wetland is no longer green but instead it is clear, colorless and odorless, see figure 31.

	BOD^5 (mg/l)	Ammonia (mg/l)	Coliform (count/100ml)
Influent	193	17.3	107000
Effluent	21	3.4	<1000
Effluent Standards	~35	10	<400[8]

Table 11 the water conditions of the Moshi Constructed Wetland

The operational costs for operation and maintenance of the Constructed Wetland are ~ TSh. 600,000 a month, including the costs for effluent measurements. The occasional costs for desludging of the Wetland which, in the MUWASA case has to done every 5 years are estimated on TSh. 300,000.

Figure 31 The clear colorless and odorless effluent of the MUWASA CW

Findings of the niche project

- The niche project at MUWASA is from a technical point of view a success. The discharged water from the wastewater treatment plant is, at least on measured parameters, safer to public health and the environment;
- MUWASA is an organization with a high level of knowledge on wastewater treatment. This knowledge has been very beneficial to the introduction of the new niche technology, because the adopters of the CW technology understood the necessity of improvement of the current WSP technology
- The high knowledge level is also beneficial for the sustainability of the project because, the operators know how to maintain the Wetlands and are relatively well paid.
- The budget of MUWASA for improvement of wastewater treatment in Moshi results in a research to possibilities for building decentralized systems in more remote areas of the Moshi district, based on the Constructed Wetland technology.
- Constructed Wetlands have become an integrated technology at MUWASA and is considered as one of the options for wastewater management.

6.5 KIBO pulp and paperboard mill

Background

The KIBO Paper mill Ltd is established in 1965 and is located in Moshi. KIBO produces a variety of paper and cardboard, its performance mainly depends on the presence and quality of raw materials, such as water and recycled paper, collected from various institutions. Water is a main raw material for the production of paper. The water source for KIBO Paper Mill Ltd is the River Karanga. Water is pumped from the river direct to the circular clarifier where sometimes alum ($KAl(SO^4)2.12H_2O$) is added to remove turbidity. This water is mainly used for waste paper re-pulping and at refining processes.

Goals & Objectives

The main objective of the KIBO paperboard mill is to produce paper and paperboard. There is no special attention for environmental issues apart from environmental and health regulations; therefore KIBO is looking for a economically viable technology to keep the pollution in the effluent within limitations.

Situation prior to adoption of Constructed Wetland technology

The Waste Stabilization Ponds used for wastewater treatment before the introduction of Constructed Wetlands were not performing well due to many reasons ranging from engineering design to daily maintenance and operation practices. However, the KIBO paper mill has to comply to the environmental regulations, therefore the current wastewater treatment plant needed to be upgraded to meet these standards.

The wastewater from the production process is collected by an open channel and is discharged in the Waste Stabilization Ponds. There are five identical ponds which are used for industrial wastewater treatment. From the first pond to the last pond the color of the water is almost the same indicating that if there is any treatment, then it is due to the suspended solid removal only. Any common operating Waste Stabilization Pond contains algae and bacteria. However, for the industrial ponds at Moshi paper mill factory there was no sign of algae; therefore the ponds are not operating as Waste Stabilization Ponds. The outlets of all ponds are in series and it appears that water flows direct from the inlet to outlet without being retained for sufficient time. This causes a health hazard for the people surrounding the factory, as figure 33 shows, farmers harvesting spinach next to the factory.

Figure 32 farmers next to KIBO factory

The first contact with Constructed Wetland technology
The management at the KIBO paper plant turned in 2003 to the local wastewater treatment authority, MUWASA for advice on how to improve the wastewater treatment at the factory. MUWASA at the time had just started the Constructed Wetland project and was very enthusiastic about this technology. They advised the management of KIBO to go to the University of Dar es Salaam. After a field study and measurements of the wastewater, the UDSM designed a Constructed Wetland system.

Financing and building the Constructed Wetland
The total cost for construction of the treatment plant were TSh 65,763,659, being divided into supervision and labor charges that amount to TSh 15,176,229 and for actual construction TSh. 50,587,430. These costs were completely covered by the KIBO paper mill company.

Performance and operational cost of the Constructed Wetland at KIBO
For the design of the CW the composition of the wastewater was obtained from the samples collected from the wastewater leaving the factory. The usual practice should be to take samples for twenty four hours at an interval of an hour and analyses for its composition. The parameters used for design are, BOD_5 (180 mg/l), flow rate (1980m3/day) and temperature (26°C). The flow rate was not determined for twenty four hours but is based on the amount of water used for production and experience of the production manager on the water utility for the factory. The targeted effluent quality was set to 10mg/l BOD_5. Faecal coliform concentration was not considered as the influent does not combine the domestic wastewater with industrial wastewaters.

The performance of the Wetland, although within standards are somewhat disappointing as table 12 shows, the designed BOD_5 value was not met even at the stage where the Constructed Wetland had just become opertional. Further inspection of the CW found the reason for the under performance of the Wetland. Figure 32 depicts the dying vegetation in the Wetland, caused by improper operation and maintenance. The wetland is cluttered by particles of paper and blocked. The dying of the reeds could be caused by chemicals in the wastewater, such as colorants which are not measured.

	BOD_5 (mg/l)	Ammonia (mg/l)
Influent	180	17.3
Effluent	24	3.4
Effluent Standards	~35	10

Table 12 the water conditions of the KIBO Constructed Wetlands

The wastewater treatment plant is operated by a staff of 2 who live on-site. This staff was not trained on how to operate and maintain the wetland. The monthly O&M cost are ~ TSh 80,000.

Figure 33 Poorly managed CW at KIBO factory

Findings of the niche project

The niche project at the KIBO paper mill has not been as successful as expected:

- At this moment the Wetland will continue to deteriorate and finally completely be blocked and died off.
- The management of KIBO is disappointed by the performance of the Wetland
- Although the performance of the CW is at the time of the measurements within limitations for BOD_5 this will quickly change, other important parameters, such as heavy metals, are not measured
- The chemicals in the wastewater are a potential danger for the environment and can be a health treat to the local population which grows crops next to the water treatment plant
- More detailed analysis of industrial wastewater streams is required to determinate if Constructed Wetlands are suitable to treat the water
- Training of the staff on operation and maintenance of the Wetland is very important, neglecting this harms the lifetime and performance of the Wetland

6.6 Conclusions Niches

As stated in section 5.5.5, the window of opportunity, technological regime I (wastewater treatment plants) and II (septic tanks), are possible places to introduce the Constructed Wetland technology, however this does not guarantee the successful performance of these projects.

The three niche processes as described in chapter 2, voicing, network building and learning, are according to the theory indicators for success of the niche projects. This section examines these processes in the niche projects in order to find out if these processes indeed can explain the success or failure of the projects.

Voicing and shaping of expectations
Actors participate in niche projects on the basis of their expectations and individual motivations.

- A clear **vision** on the niche project and the results of this project is important for the success of this project. The vision on sanitation and responsibility for the environment has been crucial factors for success of the niche projects. In the success cases of Ruaha secondary school and MUWASA the technology adopting actors have a strong affinity with the environment and hence, with wastewater treatment. They adopted the technology without any pressure from others, such as complaining neighbors. In the less successful cases, the Kleruu Teacher's collage and KIBO paper mill the reason for adopting Constructed Wetland technology was not driven by own environmental concerns, hence the enthusiasm and commitment to the Constructed Wetland project was less and led to failure of the projects. Therefore one can conclude that the motivation and commitment to the niche project of the technology adopting actors is a crucial factor.

- **External pressure** of adopting a novel technology, in this case the Constructed Wetland technology, without complete commitment, and consciousness of importance led the technology adopting party to failure of these projects because after the construction phase, maintenance and proper operation is required. By neglecting this, the Wetlands will malfunction, and the project will fail in the long term.

- **Monitoring** of the projects by UDSM is, due to lack of financial means, not frequently done. This has not caused problems for the two project with the most commitment to the project but frequent evaluation and monitoring of the project could have benefited the other less successful projects.

Learning

A good learning process enables adjustment of the technology and/or societal embedding which increase chances of successful dissemination.

- **Knowledge transfer**: In the successful cases of the Ruaha School and the project at MUWASA, the knowledge of how the Constructed Wetland should be operated and maintained was transferred to and adopted by the participants. This was not so much the case in the less successful niches at the Kleruu Teacher's collage and the KIBO paper factory where the knowledge absorption went difficult.
- **Technological embedding**: at the Ruaha secondary school, one of the successful niches, the Constructed Wetland technology has been embedded in the institution; the gardeners are properly trained to maintain the Wetland and the Wetland has become a part in the environmental and hygiene education of the pupils. This strong embedding of the CW technology anchors the technology in the institution and ensures the sustainability of the project. Similar embedding has taken place at the MUWASA; technicians are trained and MUWASA plans to use the CW technology in future wastewater treatment projects. In the less successful project there has been no technological embedding, and the CW has not become a part of "daily life".

Network building

In particular in early phases of an innovation's life cycle, the social network is still very fragile. Experimentation in niche markets can bring new actors together and make new social networks emerge. At this time the niche projects have been isolated projects and no real network building has taken place. However network building will be crucial for further dissemination of CW technology. In spite of this we are seeing some successful experiments.

- MUWASA became very engaged at the CW project, they even send staff to UDSM to get trained in designing Constructed Wetlands. Their good project results and enthusiasm can be used to spread out the CW technology to other UWASAs. This can also be the case for the Ruaha School; this project could be a show case for other schools to adopt the Constructed Wetland technology.

Although not all the items which are summed up in chapter 2 are appropriate for the Constructed Wetland project analysis, the niche processes are useful to examine these projects.

7 Cost Benefit Analysis

This chapter analyses the financial feasibility and the societal benefits of the introduction of Constructed Wetlands in technological regime I, the wastewater treatment plants and in technological regime II, the septic tank which is emptied by the municipal sewage suction trucks. For regime I, the CW niche project of the wastewater treatment plant in Moshi is analyzed and for regime II, the CW project at the Ruaha secondary school in Iringa. The CBA methodology, on which this chapter is built, is developed by the World Bank[xxxi], [xxxii] and is used to assess the financial feasibility of projects.

The technologies of septic tanks and Waste Stabilization Ponds (technological regime I and II) are in general considered as improved sanitation facilities[lxxx]. This thesis states that this might be true from a strict theoretic technology point of view, but in Tanzania some of these improved systems are malfunctioning (see chapter 5, the regime analysis). These malfunctioning systems pose the same or, in the case of a poor performing wastewater treatment plant, a bigger threat to the public health than the unimproved sanitation systems, such as conventional pit latrines and bucket latrines.

In the niche projects of this thesis, existing underperforming sanitation systems are improved by the addition of a Constructed Wetland. In the successful niche projects the effluent of the sanitation systems has improved, and health hazards are reduced, hence the introduction of Constructed Wetland technology is not only beneficial for the users of the Wetlands, but these CW's have broader societal effects. Therefore this Cost Benefit Analysis (CBA) does not only aim to provide information on economic operational efficiency, but also provides relevant information on who benefits from the introduction of Constructed Wetlands and, for this reason, who may be willing to contribute to the financing of these systems.

In the case of improving sanitation systems by the addition of Constructed Wetlands, there are several considerations to keep in mind:

- In terms of financing the Constructed Wetland technology, it is important to make a clear distinction between public and private expenses. Should sanitation be provided at zero or subsidized cost by the Tanzanian government, or should it be the case that the beneficiary pays the full cost? Are there other agencies able to bear some of the construction and maintenance costs, such as non-governmental organizations or the private sector?

- In terms of who receives the benefits of the addition of Constructed Wetlands to the sanitation system, a similar public-private distinction should be made.

7.1 Financial Cost Benefit Analysis

The attractiveness of a project to an individual investor depends on the financial profitability of this project, therefore a F-CBA is conducted to determine whether the introduction of Constructed Wetlands is feasible from a financial point of view. The bottom line is that investors want to make more money on their investment than they would have received if they had put their money in the bank. For both cases the Net Present Value (NPV) and the Real Internal Rate of Return (RIRR) are calculated.

Since Constructed Wetlands are a sustainable technology and hardly suffer from aging, the duration of the projects is set to 10 years (*t*). Assuming that a CW will last for 20 years, the rest value of the CW is set to half the value of year 0. The average expected inflation rate in Tanzania is 8.7%[12], the interest on a commercial loan, (for a period over 5 years), is 15.7%[13]. The real interest rate (*r*) can now be calculated with the following formula:

$$r = (1+i)/(1+p) - 1$$

r = the real discount rate
i = interest rate commercial loan
p = average expected rate of inflation

The real discount rate for the Constructed Wetland projects is 6.44%.
The discount factor can now be calculated for each year:

$$D = (1/1+r)^t$$

D = discount factor
r = real discount factor
t = year of the project

The outflows of non-financial operations of a project consist of all the initial expenses for a project, in this case:

- The design costs of the Constructed Wetland;
- The building materials;
- The construction costs and;
- Operation and Maintenance costs of the Constructed Wetland

The cash inflows of non-financial operations of a project consist of all direct and indirect cash inflows from the project, in this case:

- The operational sanitation cost reduction caused by the Constructed Wetland

[12] www.Bloomberg.com date 3/25/2008
[13] Tanzanian Budget 2008, http://www.pkfea.com/publications/Economyhighlights_tz.pdf

Net Present Value

$$NPV = \sum \frac{X^t}{(1+r)^t}$$

NPV is the sum of all terms

t = the time when the cash flow occurs
r = the real discount rate (the rate of return that could be earned on an investment in the financial markets with similar risk.)
X_t = the net cash flow (the amount of cash, inflow minus outflow) at time t

Table 13 presents the NPV in various situations:

NVP	Profitability	Conclusion
> 0	project would add value to the investor	The project may be accepted
< 0	The project would subtract value from the investor	The project should be rejected, from a financial point of view
= 0	the project would neither gain nor lose value for investor	This project adds no monetary value. Decision should be based on other criteria, e.g. strategic positioning or other factors not explicitly included in the calculation.

Table 13 NVP values and how they should be interpreted

Real Internal Rate of Return

$$\sum_{t=0}^{t=n} \frac{X^t}{(1+IRR)^t} = 0$$

The Internal Rate of Return, often used in capital budgeting, makes the Net Present Value of all cash flows from a particular project equal to zero. Generally speaking, the higher a project's Internal Rate of Return, the more desirable it is to undertake the project.

7.1.1 Constructed Wetland project at MUWASA, wastewater treatment plant

There are no financial benefits for the Constructed Wetland project at MUWASA, because the project did not realize a cost reduction nor did it create any other direct financial benefits to MUWASA. The quality of the effluent did improve but the benefits of this improvement are societal, and will be discussed at the Societal CBA. The financial and non-financial cash flows of this project are represented in table 14. The cash outflows are in year 0 the construction costs which where TSh.24,000,000 (~$ 19,260). The additional Operation and Maintenance costs (O&M) made by MUWASA are TSh. 300,000 every 5 years for desludging the Wetland; there are no additional yearly O&M costs since day to day maintenance is performed by the current staff. D is the discount factor for each year. The DCF after 10 years is TSh. 6,671,785.

year	inflow rest value	outflow construction	desludging	totaal CF	D	DCF
0		-24,000,000		-24,000,000	1.000	-24,000,000
1		0		0	0.939	0
2		0		0	0.883	0
3		0		0	0.829	0
4		0	-300,000	-300,000	0.779	-233,723
5		0		0	0.732	0
6		0		0	0.688	0
7		0		0	0.646	0
8		0		0	0.607	0
9	12,000,000	0	-300,000	11,700,000	0.570	6,671,785

Table 14 Non-financial cash flows for MUWASA CW project

The discounted cash flows are the input for the NPV calculation which is TSh. -17,561,938 for a project of nine operational years. This indicates that from a financial point of view the adoption of CW technology in addition to WSP will subtract value from the investors. The IRR is not calculated since NVP<0. One can conclude that from a strict financial point of view investors will not be interested to invest in this project.

7.1.2 Constructed Wetland project at Ruaha secondary school, Iringa

The Constructed Wetland project at the Ruaha School is from a socio-technical point of view a success. The initial costs of the project were completely covered by both, the embassy of Luxembourg and the embassy of the United States. The total construction costs for the Wetland were relatively low, because the UDSM did not charge for the design of the Wetland, and it was built by students and employees of the school. This resulted in a total amount of TSh. 3,121,250 ($ 2500), which was invested in year 0 of the project. Operation and Maintenance of the CW is TSh. 35,000 a month, which adds up to TSh 420,000 a year. The introduction of the CW reduced the cleaning cost of the septic tank: instead of emptying it 4 times a month it is now emptied once a year. Emptying costs TSh. 25,000; hence (4*12-1)* 25,000, which adds up to TSh. 1,175,000.

The avoided cash outflows for emptying the septic tank are represented in table 15. The cash outflows are in year 0 the construction costs and in the following years the Operation and Maintenance costs (O&M). The rest value of the Constructed Wetland is assumed to remain at half the building cost of year 0, in year nine. D is the discount factor for each year. The discounted cash flow becomes positive in year 1 and in year 9, the DCF is TSh. 1,320,458 (~ $974).

year	inflow avoided costs	rest value	outflow construction	O&M	totaal CF	D	DCF
0			-3,121,250		-3,121,250	1.000	-3,121,250
1	1,175,000		0	-420,000	755,000	0.939	709,320
2	1,175,000		0	-420,000	755,000	0.883	666,403
3	1,175,000		0	-420,000	755,000	0.829	626,084
4	1,175,000		0	-420,000	755,000	0.779	588,203
5	1,175,000		0	-420,000	755,000	0.732	552,615
6	1,175,000		0	-420,000	755,000	0.688	519,180
7	1,175,000		0	-420,000	755,000	0.646	487,768
8	1,175,000		0	-420,000	755,000	0.607	458,256
9	1,175,000	1,560,625	0	-420,000	2,315,625	0.570	1,320,458

Table 15 Non-financial cash flows for Ruaha CW project

The discounted cash flows are the input for the NPV calculation which is TSh. 2,807,036 when the project would run for 10 years. The corresponding real Internal Rate of Return is calculated with MS Excel and has a value of 21.98%, which is significantly more (15.54%) than the real discount rate of 6.44%.

The NPV value is higher than 0, and rIRR is higher than the real discount rate. This makes the project feasible from a financial point of view, even if the initial construction costs were made by the Ruaha School itself. The self-help basis on which this project is based kept these initial construction costs low, this in contrast to the construction and initial site cleaning costs of the CW at the Kleruu Teacher's College which were at TSh. 18,716,947, six times as expensive.

The CBA analysis shows that the funding of the project by the governments of Luxembourg and the United States was not necessary to make this project successful; the initial investment costs could have been made by the Ruaha School itself, and be earned back within one year.

In addition to this a sensitivity analysis has been made for several levels of construction costs, (actual costs, +25%, +50%, +75%, +100%) and minimal avoided costs to make this project financial feasible, hence in case in which NPV equals zero. These costs are calculated in MS Excel, and presented in table 16.

construction costs	minimum yearly avoided costs
3,121,250	754,365
3,901,563	837,956
4,681,875	921,547
5,462,188	1,005,138
6,242,500	1,176,071

Table 16 construction costs and minimal avoided cost for a feasible CW project

One can conclude that in similar cases as the Ruaha Secondary School; cases in which the actual sanitation costs are made by the school, Constructed Wetland projects are financial feasible up to the initial construction costs of TSh. 6,242,500 (~ $4,604). At actual costs the project is already financial feasible at TSh. 754,365 (~ $556) avoided annual costs.

7.2 Societal Cost Benefit Analysis

For the Societal CBA of the Constructed Wetland the public benefits of the implementation of this technology have to be quantified. Therefore this section focuses on the health benefits to society.

Health benefits

Knowledge of the health benefits of the implementation of Constructed Wetland technology is important for a Cost Benefit Analysis because some of the economic benefits depend on estimates of health effects. Over recent decades, compelling evidence has been gathered that significant and beneficial health impacts are associated with improving sanitation facilities[lxxxi]. Infectious diarrhea causes the main burden resulting from poor sanitation. Other diseases caused by poor sanitation such as the spread of cholera are not included in this paper because of lack of figures. In this analysis the health impact of the improvement of the sanitation system, by the addition of a Constructed Wetland, is calculated by the following two indicators:

- Reduction in diarrhea incidence rates (number of cases reduced per year)

- Reduction in mortality rates caused by diarrhea (number of deaths avoided per year)

The reduction in diarrhea incidence rates is calculated based on the average diarrhea incidence rates for children presented in the Tanzanian household survey 2004-2005, namely 12.6% of the children under 5 years of age, because, for this population group the consequences of diarrheal diseases are particularly dangerous.

The diarrhea-specific mortality for children under 5 years of age in Africa has been estimated at about 10.6 per 1,000[lxxxii]. UNICEF states that 17,6%[lxxxiii] of the Tanzanian population is under five years of age.

The reduction realized in both health related rates is estimated for three cases: a low case, a most likely case and a high case. The reduction in incidences caused by the implementation of Constructed Wetland technology is arbitrary for both regimes I and II set to 10, 20 and 30 percent because these effects are not directly measured. Hill et al. found a median reduction of diarrheal disease of 26%[lxxxiv] caused by improved sanitation; this is inline with the 3 suggested cases.

For the MUWASA project 17,6% of the Moshi population is estimated to be affected, since the Constructed Wetland is built at the community wastewater treatment plant which discharges its effluent in the city's river which is used for washing clothes, bathing and recreational purposes. Table 17 summarizes the health effects for the Moshi population under 5 years of age, caused the implementation of CW technology at the MUWASA wastewater treatment plant.

	Population under 5	low case	Reduction medium case	high case
Moshi	25,344	10%	20%	30%
Diarrheal incidences	3193	319	639	958
Diarrheal mortality	269	27	54	81

Table 17 Annual health effects caused by the implementation of CW technology at MUWASA

In all three cases lives are saved, 27 in the low case, to 81 in the high case. The diarrheal incidences drop in the low case with 319 and in the high cases with 958 incidents a year.

For the Ruaha School project the student population at the school is the target population. This school is a secondary school and there are no children under five which are most likely to die of diarrheal diseases, therefore the mortality rate is not calculated. Due to the lack of exact figures on diarrheal incidents at the age group between 12 and 18 the same percentage as for the population group under 5 years of age, 12.6%, is used. The total population at the Ruaha Secondary School is 750. Table 18 summarizes the health impacts caused by the CW addition. The CW technology prevents in the low case 9 and in the high case 28 diarrheal incidents.

	Population	low case	Reduction medium case	high case
Ruaha School	750	10%	20%	30%
Diarrheal incidences	95	9	19	28

Table 18 Annual health effects caused by the implementation of CW technology

Assuming an average of three days off school per case of diarrhea there are 27 to 84 days of school attending gained.

In the next section these health benefits are transformed to economic benefits.

Economic benefits of CW implementation

There are several potential economic benefits associated with the improvement of sanitation systems, ranging from the easily identifiable and quantifiable to the intangible and difficult to measure. Benefits include both: reductions in costs and additional benefits resulting from the introduction of CW's. Limited by data availability, the aim of this analysis is not to include all the benefits, but to capture the most tangible and measurable ones, and identify who the beneficiaries are.

The calculation of the total societal economic benefit of CW implementation is the sum of:

- Patient expenses avoided due to avoided illness;
- Value of deaths avoided;
- Value of child days gained of those with avoided illness.

Patient expenses avoided due to avoided illness

The avoided costs of treatment of ill children involve the cost of medicine (ORS). The average cost of diarrhea treatment per child, in Sub Sahara Africa is TSh. 7,200 ($5.50)[14]. Table 19 represents the involved annual savings on illness treatment for Moshi. These savings are TSh 4.6 million for the medium case.

	Diarrheal incidences	low case	Reduction medium case	high case
Moshi		10%	20%	30%
Reduction treatment costs [TSh]	3,193	2,296,800	4,600,800	6,897,600

Table 19 estimated annual savings on diarrhea treatment costs Moshi

Table 20 represents the saving on the parent's expenses on illness treatment of their ill children at the Ruaha School, ranking from TSh. 68K in the low case to TSh. 204K in the high case.

	Diarrheal incidences	low case	Reduction treatment costs [TSh] Medium case	high case
Ruaha School		10%	20%	30%
Reduction treatment costs [TSh]	95	68,040	136,080	204,120

Table 20 estimated annual savings on diarrhea treatment costs Ruaha School

Value days gained with avoided illness

When a child is ill at least one of the parents has to stay at home to take care of the child, assuming that this parent is usually working this would lead to income losses.

The value of avoided illness can be calculated: the number of illness cases avoided multiplied by 3 days of illness and then multiplied by avoided income losses of the parents. The average daily wage of one parent is set to TSh.4000 a day. For the MUWASA case, represented in table 20, the savings on income losses are presented in table 21. The avoided income losses are ranging from TSh 3.8 million for the low case to TSh 11 million for the high case.

	Diarrheal incidences	low case	medium case	high case
Moshi		10%	20%	30%
Avoided income losses	3,193	3,828,000	7,668,000	11,496,000

Table 21 avoided annual income losses Moshi

Table 22 shows the avoided parental income losses for the Ruaha Secondary School for each of the cases.

[14] www.ncbi.nlm.nih.gov/books/bv.fcgi?rid=dcp2.table.2558

	Diarrheal incidences	low case	medium case	high case
Ruaha School	95	10%	20%	30%
Avoided income losses		113,400	226,800	340,200

Table 22 avoided annual income losses

Value of avoided deaths

It is extremely difficult and arguably morally reprehensible to put a financial value to life and avoided death. However it can be useful for decision makers to gain insight in the financial consequences of premature decease, although these consequences are beyond the project lifetime of 10 years. For this reason this thesis aims to estimate the income losses caused by premature loss of life. Based on the number of deaths avoided, the value of avoiding these deaths is calculated using the future earnings of people whose lives are saved. The value of these avoided deaths for the MUWASA case is presented in Table 23. Assumed is that the children when they grow up work for 45 years, earning on average TSh. 1,000,000 (~ $764) a year.

	Diarrheal mortality	low case	medium case	high case
Moshi		10%	20%	30%
	269	27	54	81
benefits reduction mortality		1,208,908,800	2,417,817,600	3,626,726,400

Table 23 Value of yearly avoided deaths (based on predicted future earnings)

Calculated over a total period of 45 years, the CW at Moshi, each year creates a potential value of TSh. 1,208,908,800 ($846,236) in the low case to TSh 3,626,726,400 ($2,538,703) in the high case.

Total economic benefits for the MUWASA Constructed Wetland

From a strict financial CBA analysis the Constructed Wetland at MUWASA was not a feasible project; however, broadening the Cost Benefit Analysis to an economic CBA reveals the economic benefits as represented in table 24. Note that the value of premature death and the misery of illness are not represented in these figures.

	low case	medium case	high case
Moshi	10%	20%	30%
Reduction treatment costs [TSh]	2,296,800	4,600,800	6,897,600
Avoided income losses [TSh]	3,828,000	7,668,000	11,496,000
Total annual saving [TSh]	6,124,800	12,268,800	18,393,600

Table 24 Total economic benefits of MUWASA Constructed Wetland

The societal Cost Benefit Analysis for the Constructed Wetland Project at MUWASA can now be calculated with the figures from table 24. The societal Accounting Rate of Interest can be calculated based on the long term Tanzania state bond interest rate. This interest on a long term state bond is 11.25%[15]. The ARI calculated with this bond rate is 1.59%. For the Societal CBA the actual costs for the design of the Constructed Wetland arealso needed, usually these costs are 10%[16] of the building costs, therefore in this case TSh. 2,400,000.

year	society		Inflow		Outflow		total	D	Discounted cash flows
0				-	Construction and design	26,400,000	-26,400,000	1.000	-26,400,000
1	annual saving	12,268,800		-	O&M	-	-14,131,200	0.984	-13,910,031
2	annual saving	12,268,800		-	O&M	-	-1,862,400	0.969	-1,804,559
3	annual saving	12,268,800		-	O&M	-	10,406,400	0.954	9,925,391
4	annual saving	12,268,800		-	O&M	300,000	22,375,200	0.939	21,006,954
5	annual saving	12,268,800		-	O&M	-	34,644,000	0.924	32,016,454
6	annual saving	12,268,800		-	O&M	-	46,912,800	0.910	42,676,185
7	annual saving	12,268,800		-	O&M	-	59,181,600	0.895	52,994,400
8	annual saving	12,268,800		-	O&M	-	71,450,400	0.881	62,979,177
9	annual saving	12,268,800	Rest value CW	12,000,000	O&M	300,000	83,150,400	0.868	72,144,911

Table 25 econimic CBA MUWASA Wetland project

The economic CBA for MUWASA in the medium case is much more positive than the financial CBA, see table 25. The DCF is positive in the third operational year. In year 9 the NPV is TSh 251,628,883 and the rIRR 37.36%. Therefore, looking from a total societal point of view, the MUWASA Constructed Wetland project is, feasible and creates value for the entire society.

The sensitivity analysis for several levels of construction costs, (actual costs, +25%, +50%, +75%, +100%) and minimal societal benefits required to make this project societal feasible are calculated in MS Excel, and presented in table 26. This analysis teaches us that the total project at the same initial costs is still feasible even at a low economic benefit of TSh. 5,958,949 a year. This is less than the lowest estimated societal benefits, indicating the value of proper sanitation facilities to the society.

Construction costs	minimum yearly societal benefits
2,400,000	5,958,949
3,000,000	7,436,866
3,600,000	8,914,783
4,200,000	10,392,701
4,800,000	11,870,618

Table 26 Construction costs and minimal societal benefits for economic feasible CW projects

[15] http://af.reuters.com/article/tanzaniaNews

[16] Value based on interview with Mr. Kayombo

7.3 Findings Cost Benefit Analysis

Methodological findings
A Cost Benefit Analysis can be carried out to identify the beneficiaries and the (potential) financers of development projects such as a Constructed wetland project; however CBA does not provide answers to the question of who should pay. If all costs and benefits are included in a cost-benefit analysis, then a full analysis can be made of financing options. One of the problems associated with identifying beneficiaries in order to identify those willing to pay for the costs is that the main beneficiaries do not always understand the full benefits until well after the investment. Also, most costs are incurred in the first year of the intervention, while benefits accrue over time, these factors together lead to market failure, and imply that many private consumers cannot be expected to finance the initial investment costs up-front for improved sanitation.

On the other hand, sanitation improvements may result in a lower annual cost than the current option. This means that certain groups (e.g. schools) could be convinced that the addition of a CW could be cheaper in the long term, and therefore persuade them to finance sanitation system improvements privately.

The implication of these arguments is that there should be a variety of financing mechanisms for meeting the costs of sanitation improvements, depending on the income, the availability of credit, the economic benefits perceived by the various stakeholders, and the presence of NGOs and other aid organizations such as UN agencies and bilateral donors to promote and finance sanitation improvements.

Financing Constructed Wetlands

- The Constructed Wetland at the Ruaha School is already feasible from a financial point of view, even though there are much more benefits to society from this project. Financing of this type of projects by the technology users should therefore not be a problem. The initial construction costs are the main cost of a Constructed Wetland system; therefore, building on a self help base will further enhance the financial feasibility of these projects.

- Constructed Wetland at schools and similar governmental buildings are especially feasible for those institutions which are already paying the (high) price for the pollution they create and will save on their expenses. Institutions which are less concerned about the environment will only see their expenses on sanitation rise, without any cost reduction.

- The project at MUWASA is from financial point of view not feasible, because the addition of a Constructed Wetland did not create any cost reduction. Therefore an economic Cost Benefit Analysis was necessary to reveal the societal benefit of this improved wastewater treatment technology. NGO's, and other aid organizations the local population and the Tanzanian government could be persuaded by the figures from the economic CBA to invest in the Constructed Wetland project.

- Not only can this improved wastewater treatment avoid illness and premature death, it also creates economic benefits to society.

8 Conclusions and Recommendations

This chapter is divided in three sections; section 1 answers the research questions. The second part is the methodological reflection on the SNM theory combined with the CBA-analysis, and the third part gives recommendations for further research and policy recommendations.

8.1 Research conclusions

This section answers the research questions as stated in chapter 1. The first research question was stated as follows:

Which factor(s) are hindering successful dissemination of Constructed Wetlands in Tanzania?

This apparently simple question has a rather complex answer, which can be divided according to the SNM theory, into landscape, regime and niche factors. In addition to this the Cost Benefit Analysis reveals the financial constrains. In the projects the investments for the construction, maintenance and operation where made by the technology adopters at the Niche level, whereas the benefits of these projects are for the entire Tanzanian society. The current (malfunction) wastewater treatment regimes in Tanzania are environmental and economic unsustainable and the costs of water pollution is often not covered by the polluter; hence the addition of a CW is in that case an additional expense. The financial landscape constrains the dissemination because the societal benefits of adoption of CW technology are unclear, without the insights of the CBA analysis.

Landscape factors which hinder dissemination

- Sanitation is an unpopular subject to discuss and worldwide it receives little attention;
- More than half of the Tanzanian population (51%) lives on less than US$1/day, which makes it virtually impossible for this part of the population to pay for proper sanitation technologies;
- In Tanzania 6 to 6.5 million people currently live in unplanned peri-urban areas which have no or little connection to community services, such as water and electricity: without water supply Constructed Wetland cannot operate;
- Tanzanian policies rather focus on water supply than on sanitation;
- In Tanzania people have gotten used to and do accept malfunction of social services;
- Tanzanian W&S policy is heavily linked to international priorities in water governance, which causes the national policy to change frequently.
- Limited policy implementation capacity: Tanzania is still trying to implement policies and institutional changes which should have been done years ago. And just when they seem to catch up with this implementation the donor community changes policy again.

Regime factors which hinder dissemination

- The Constructed Wetland technology requires a basic level of technology in the current regime before it can enter this regime. The Wetlands do need water to function properly, and should be connected to a water born sanitation system. This implies unfortunately that the two regimes which cause the greatest direct health hazard, and are used by about 80% of the population (regime III and IV) are unsuitable for implementation of Constructed Wetland technology. The lack of infrastructure at sanitation regime III and IV cannot be directly solved by Constructed Wetlands. These regimes might be improved with other technologies and services or completely replaced by other systems. Therefore about 20% of the Tanzanian population can be directly seen as potential adopters of the Constructed Wetland technology; however this technology has an impact on the entire Tanzanian society.

Niche factors which hinder dissemination

- Lack of a clear **vision** on the niche project and the results of this project is important for failure of this project. The visions on sanitation and responsibility for the environment have been crucial factors. In the less successful cases, the Kleruu Teacher's collage and KIBO paper mill the reason for adopting Constructed Wetland technology was driven by complaints from the environment, instead of own environmental concerns; hence the enthusiasm and commitment to the Constructed Wetland project was not optimal and led to failure of the projects.

- **External pressure** of adopting the Constructed Wetland technology, **without complete commitment**, and consciousness of importance of the technology adopting party, lead to failure of these projects because after the construction phase, maintenance and proper operation is required. By neglecting this, the Wetlands will malfunction, and the project will fail in the long term.

- **No monitoring**; due to lack of financial means monitoring of the ongoing projects is not frequently done. Frequent evaluation and monitoring of the project could have benefited the less successful projects.

- **No knowledge absorption:** lack of knowledge absorption from the technology proveider leads to failure in the less successful niches at the Kleruu Teacher's collage and the KIBO paper factory.

- **Lack of socio-technological embedding**: In the less successful project there has been no technological embedding, and the CW has not become a part of "daily life".

- **No Network formation**: until now there has been no knowledge network formation; this hinders the dissemination of the Constructed Wetland technology because potential technology adopters do not know about the technology.

Cost Benefit Analysis

- Lack of financial feasibility, especially due to the great discrepancy between limited private and large societal net benefits of the adoption of Constructed Wetland technology hinders the dissemination of Constructed Wetlands.

The inventory of factors which are hindering successful dissemination leads to conclusions regarding the arrangements that UDSM will have to make in order to enhance the transfer of Constructed Wetland technology. Hence the second research question can be answered:

What arrangements (within UDSM) are necessary for effective transfer of this technology?

Potential technology adopters
The current sanitation situation in Tanzania is unsustainable which possibly creates opportunities for novel niche technologies to enter the current regimes. The niche technology of Constructed Wetlands might solve some of the sustainability problems in these current regimes, but it cannot become an independent new technological regime, hence the UDSM should do research to identify specific potential technology adopters for whom the technology is suitable. These adopters can be found in two regimes:

The centrally wastewater treatment plants which can be upgraded by CW technology because

- The currently used Wastewater Stabilization Ponds have large still water surfaces, which create an ideal breeding place for mosquitoes. CW's do not have surface water, and replacement of these ponds with CW'S would tackle this problem.

- The WSP's can spread an awful stench, which makes the surroundings very unattractive to live; Constructed Wetlands are odor less, replacement of the WSP with CW's makes the environment surrounding the wastewater treatment plant more attractive to live;

- The effluent of WSP's, if not sufficient cleaned, can be a source of bacterial contamination since it is discharged in local rivers; addition of a CW to the WSP's can improve the quality of the effluent

Secondly the septic tanks at the governmental buildings such as schools and hospitals, which are not connected to the piped sewage system, can be improved by Constructed Wetland technology.

- The frequent emptying of septic tanks is costly and overflowing tanks create a health hazard of bacterial contamination for the direct environment.

- A Constructed Wetland can be directly connected to the septic tank (because schools and hospitals have in general some spare land) and clean the overflowing water, making it suitable for reuse.

- The addition of a Constructed Wetland can reduce the cleaning costs and save water because it will be reused.

Marketing

- UDSM needs to contact schools, governmental institutions and UWASA's to search for these potential adopters. Once these potential adopters are found a further research needs to be done after site specific circumstances such as current sanitation system malfunctioning, financial means, and dedication to environmental issues.
- UDSM needs to create an information brochure in which the added value and maintenance requirements of the technology adopters are clearly explained.

Financial motivation

- The Constructed Wetland at private institutions such as schools can be already feasible from a financial point of view, even though there are much more benefits to society from this project. Financing of this type of projects should therefore not be a problem, nevertheless UDSM should promote the financial feasibility to these potential adopters and create awareness to this fact.
- The CW projects at domestic wastewater treatment plants are not feasible from a financial point of view. Therefore a societal-economic Cost Benefit Analysis is necessary to reveal the societal benefit of this improved wastewater treatment technology. NGO's, international aid donors, the local population and the Tanzanian government could be persuaded by the figures from the economic CBA to invest in such public Constructed Wetland projects.

8.2 Methodological reflection

This section reflects on the research theory and how this theory has been used in this research.

Strategic Niche Management

The SNM theory uses the three levels of landscape, regime and niche to describe the situation of technological innovation processes. This separation in three different levels has been very useful to describe the situation for the Constructed Wetland technology projects and in broader perspective the sanitation situation in Tanzania. The landscape level revealed the factors which are hindering or driving innovation at a national and international level, and can be used to explain why the current unsustainable sanitation situation has evolved. At the regime level the different dominant technologies and their performance are discussed, this has been valuable to identify weaknesses and opportunities for improvement of the performance of these technologies by means of Constructed Wetland technology. The third level, the niche level has, with the three niche processes, learning, visioning and network building has been a good methodology to analyze the pilot projects. However the niche processes and the elaborated description of these processes as described in chapter 2 are not always found to be appropriate to the underlying case. For instance, the findings from this research suggest that network building is not always necessary for a successful pilot project; however network building can be useful for the broader dissemination of the technology beyond the niche phase.

Interviews
The data for this research was gathered by secondary sources and interviews see appendix IV for the questionnaire. The questionnaire, which consists of question on all the theoretic niche processes, has proven to be not very useful for this type of research in Tanzania. People were intimidated by the list of questions, and their perception of sanitation and the pilot project did not match the questions or the questions were not completely understood. In addition to this people tend to give the desired answers, instead of providing insights into the real situation. A good example of this is the interview at IRUWASA. To the question on how often the wastewater effluent was measured the answer was: "every week". After the interview, in a more informal setting, the real situation was explained: due to lack of chemicals the effluent was never appropriate measured. For these reasons the questionnaire was not directly used to interview actors, but a more informal interview style was used and found to be more appropriate to reveal the real situation and important experiences of the actors. This experience with desired answers, instead of facts is the main difference between SNM research in the developed world and less developed countries.

Management tool
SNM has until now never been used to design experiments ex-ante with the goal of maximizing the success of niche projects. This research has altered the use of the theory by combining the landscape and regime analysis into a window of opportunity before analyzing the niche processes. In doing this the research has shown that the SNM theory can be used as a management tool to ex-ante predict in which situations the novel technology can (and cannot) be adopted. This research confirms this method, although this is not a guarantee for success of the pilot projects. Therefore one needs the combination of the window of opportunity and the niche processes, which can only be evolved after the implementation of some pilot projects. The results of the pilot projects can certainly be used as a management tool. In this research, it served to answer the research question on what UDSM should do to disseminate the Constructed Wetland technology.

Cost benefit analysis
In this research the SNM theory has been expanded with a Cost Benefit Analysis, because SNM lacks attention for the financial and societal-economic feasibility of niche projects. The addition of a CBA has proven to be very useful to reveal the beneficiaries of the introduction of Constructed Wetland technology. Even for projects which at first glance will extract money the benefits can be made visible, and these societal benefits can be much higher than the private cost. Therefore the combination of SNM theory with a CBA extends the use of the SNM theory as a management tool. The combined theories can be used to investigate where the new technology can be introduced and funds can be gathered by the analyses of the beneficiaries.

SMN in developing countries
The research experiences with SNM theory are mostly with high-tech state of the art technology in the developed world. There is less experience with the SNM theory in the developing countries, such as Tanzania. This thesis has found the SMN theory combined with a CBA very useful for the analysis of the Constructed Wetland projects. The analysis of the regime and niche processes might be different from the analysis of these processes in the developed world because of the high rate of malfunction technology, and economic unsustainable dominant regimes. For instance the availability of a tap does not necessary mean that there is water available 24

hours a day. In addition to this, in a LDC setting it is important to approach the SNM theory more informal to gain the required information.

8.3 Recommendations

Dissemination project
The University of Dar es Salaam has many different educational directions, e.g. technical, economy and marketing, healthcare and law. Many of the graduated students find it hard to find a job in Tanzania, which forces them to go abroad, resulting in a knowledge loss for Tanzania. UDSM could prevent this knowledge loss by creating job opportunities for these graduates by using the Constructed Wetland technology in a multi disciplinary dissemination project. This project could identify potential technology adopters, create awareness among government communities, and help them in fund raising and design of the CW's.

Monitoring current projects
The effluent of the Constructed Wetlands in the current pilot project is not frequently measured, so that effective performance monitoring is not possible. Frequent measuring of these effluents will teach if Constructed Wetlands remain efficient over time.

Constructed Wetlands in other Less Developed Countries
The CW technology dissemination to other LDC could be possible, but more research of performance of Wetlands in these countries would be required.

Aid organizations
The vision of aid organizations in Tanzania, such as UNICEF is too narrow. Their main concern is with official statistics showing the numbers of sanitation projects they have implemented, regardless of whether those systems are functioning properly. They are also not interested in exploring the potential of non-conventional sanitation technologies. Moreover, organizations expect the potential sanitation users to take initiative and self-organize. They do not see their role as being one of pro-active awareness raising and community mobilization. A broader view on sanitation would show that CW technology could be a good technological alternative when initiatives are undertaken to raise people's awareness about its benefits, and to impart proper training to look after their wetland.

Governmental policy
The Tanzanian government should produce a clear sanitation policy and create an institution which can enforce this policy. The principle that the polluter pays for his pollution reveals the real costs of improper sanitation to the economy. The awareness of the socio-economic benefits of Constructed Wetland technology will then facilitate the dissemination of this technology.

Appendix I interviewed persons and institutions

UNICEF	**Mr. Mussa Uwesu** Project officer waste
WaterAid	**Wilhelmina A. Malima, Mr. B. Taylor** Program manager
NETWAS	**Mr. Ryubha Megesa** Managing director
EEPCO	**Mr. Edmund** Environmental engineer
Dutch embassy	**Mr. J. Wiersma** Second secretary
World Bank	**Mr. Ato Brown** Senior sanitation engineer Tanzania
TEMEKE DAR	**Mr. ikagonji** Heath officer
MOSHI municipal	**Mrs. Vivian Kombi** Heath engineer
Temeke municipal	**Mr. Thomas Lyimo** Head of Waste Management Section
IRINGA municipal	**Mr. Moshi Kinyogoly** Health officer
National environment Council	**Mrs. Melama Sangeu** Environmental officer
DAWASA	**Mrs. Kasiga** Technical manager
IRUWASA	**Mr. Joohana Biganda** Sewage technician
MUWASA	**Eng. Ramadhan Y. Mng'agl** Technical manager
Ministry of health	**Mr. Honests Anicetus** Environment health officer
Ministry of water	**Mr. Gabriel Lwakabare** Project manager water & sanitation
UDSM	**dr. Sixtus Kayombo** Constructed Wetland &WSP research group
ICAT university Lisbon	**Mrs. C. Rebelo** PhD. student Constructed Wetland technology
RUAHA secondary school	**Mr. Dermot Mc Hugh** Projects coordinator
KLERUU teachers college	**Mr. J.M. Sekulu** Vice-principle
KIBO paper mill	**Mr. B. Chiwanza,** Pulp and paper mill manager

Appendix II the evolution of Tanzanian W&S policy

The international donor community: Water Supply and Sanitation

This section will elaborate the evolution of W&S policy development during the post World War II period. The focus will be on key issues in the W&S sector and the interventions which were considered to be appropriate at a particular time. The influence of these international donor community policies are reflected in the Tanzanian policies. This historical overview is made because in many low income countries the evolution of urban water supply and sanitation has been subject to strong foreign influence.[lxxxv] The initial water supply systems were usually established during colonial times and were planned and Constructed by the colonial administration. W&S became an important subject for international donor assistance and therefore foreign influence continued after independency. Water sector priorities have changed considerably over time, since donor activities started out on a larger scale in the 1960´s.

The initial phase of W&S donor activities (1948-1972)

The World Health Organization (WHO) was the first international body to provide a global perspective on the need for W&S sector services in developing countries.[lxxxvi] Since its foundation in 1948, water and sanitation are at the core of WHO's activities. Therefore, the WHO is considered the leading agency with expert knowledge of the sector in the initial phase of donor assistance to W&S. Health aspects of improved W&S services were also an important issue during this the initial phase of W&S donor activities.[lxxxvii] The World Bank granted the first water supply and sanitation loan in 1961 to the republic of China for the Taipei water system. In that same year the Inter American Development Bank was founded and granted its first loan for a water development project in Peru. The African Development Bank gave its first loan to a water sector project in Uganda in 1966 and the Asian Development Bank to Malaysia in 1968.[lxxxvi] According to Grover and Howarth, this early development assistance to the water sector was fragmented in terms of project coordination and knowledge sharing between countries and donor agencies.

International assistance and cooperation on W&S issues on a larger scale developed in the 1970´s.[lxxxvii] By the time of the first UN Conference on Human Environment in Stockholm in 1972 there was already a large number of donor agencies working on water sector related projects. The Stockholm conference had put environmental issues on the global agenda and an immediate outcome was the establishment of a separate UN body responsible for environmental concerns. This UN subdivision is called: the United Nations Environmental Program (UNEP) and has it's headquarter in Nairobi. In Stockholm several aspects of environmental problems related to water management were addressed on a very general level. It was recommended that higher priority had to be given to water issues although little was said on how this should be done. In general it was the WHO or the Food and Agriculture Organization (FAO) that were responsible for natural resources protection, pollution control or research and development. W&S issues were more specifically addressed at a separate conference on Human Settlements in Vancouver in 1976. In Vancouver, the increasing demand for water in rapidly growing urban areas was addressed. As migration from the country side into the cities increased, the need for adequate water and sewerage facilities was becoming urgent because of the emerging urban crises in the developing world. In Vancouver all participating governments made a commitment to: ***"adopt programs with realistic standards for quality and quantity to provide water for urban and rural areas by 1990 if possible."***

It was also mentioned that efforts to improve sanitation had to be accelerated but no specific targets for implementation were mentioned in relation to sanitation. This reflects the concentration to water supply during this time period while sanitation considerably lagged behind.[lxxxvi] During this period, World Bank lending to W&S concentrated on urban water supply projects rather than rural water, with the motivation that as migration from the countryside increases, the need for water services increases more rapidly in urban areas than in rural areas. The World Bank also reasons: ***"....if a choice must be made, concentrating on urban areas benefits the largest number of people per a given amount of investment."***[lxxxviii]

Whereas international development banks initially concentrated on urban water supply projects, **UNICEF** focused on rural water and hand pumps technology. Bilateral agencies concentrated on small scale individual projects in their respective areas whereas NGO´s were mostly working independently on small scale rural water projects during this time period.[lxxxvi]

The **WB** report from 1972 emphasizes the public health justification for investing in W&S. It argues that earlier project evaluations and studies have tended to underestimate the public health benefits of W&S sector investments compared to for instance the benefits of medical services.[lxxxviii] Especially sewerage systems are often under prioritized, despite of its public health benefits, since the immediate individual benefits might not be as apparent as for example for water supply. Interesting to note in this context is the fact that the World Bank paper from 1972 promotes water borne sewerage as ***".....the only satisfactory way of removal of human wastes."***

In the sector study from 1972, the **World Bank** noted that even though water and sewerage have many common features with other public utilities, it also has a much stronger character of a "social service" in the minds of the people than has for example power and telecommunications. Charging for water is recognized as a political sensitive question since ***"....the idea of paying the full price for water is not yet accepted in many developing countries".***

The World Bank (1972) also states that previous experiences from lending in the sector show that institutional improvement is much more difficult to achieve than technological improvements.

The Water Decade for Action (1981-1990)

The first **UN** World Water Conference took place in Mar del Plata, Argentina in 1977. This meeting was a landmark for international cooperation on water supply and sanitation issues and contributed to increase the focus on W&S activities within the international donor community.[lxxxix] Previous efforts had not delivered the expected results and therefore new and radical approaches to improve international assistance to water supply and sanitation were required. Apart from standard arguments such as the need for more resources to the sector and the promotion for water issues on the global development agenda, the Mar del Plata action plan emphasizes the need for water assessment activities, the role of research, scientific knowledge and technical cooperation between countries. The finding of **appropriate technologies**

was seen as crucial to solving the water crises; hence the knowledge provided by hydrologists and engineers was put at the forefront.[xc] **"Pricing and other economic incentives should be used to promote the efficient and equitable use of water."**[xc]

Still nothing explicit is said about water as an economic good or of the possibilities of the private sector to bring more efficiency into the sector. It is merely declared that the right incentives have to be created to increase efficiency within the sector, that cost recovery prices have to be introduced and that an end has to be put to the tradition of subsidizing water rates.

A concrete outcome of the Mar del Plata conference was the launching of an **International Drinking Water Supply and Sanitation Decade** (IDW&SD) from 1981-1990. An agreement was made, that national water strategies had to be prepared by all developing countries with set targets for implementation. The decade should be devoted to implementing these national plans for drinking water supply and sanitation. In Mar del Plata there was not enough support for the creation of a separate UN body on water,[xci] however the launch of the water decade brought a partnership program: the UNDP-WB **Water and Sanitation program** (WSP) which was an applied research project to support collaboration between international agencies during the drinking water supply and sanitation decade (1981-1990). Focusing on serving the poor, the WSP embodied the idea of concentrating on basic needs rather than waiting for macro economic growth to trickle down to the poor. This new direction is also reflected in a World Bank document from 1978. Here it is stated that whereas previous lending in the sector has been focused on providing the basic infrastructure required by other directly productive sectors, ***"...emphasis is now being placed on lending which will provide access to public services to a larger proportion of the population, particularly the low income groups."*** [xcii]

The International Drinking Water Supply and Sanitation Decade aimed at the ambitious goal of **giving all people access to clean drinking water supply and basic sanitation services by 1990.** Efforts accelerated during the decade and although many people were reached by the decade activities the goals remained far from met when the decade approached its end. In 1990, still one out of three persons in the developing world did not have a reliable supply of safe drinking water and even more people lacked access to sanitation.[lxxxvi]

In a UN report from 1989, an attempt was made to evaluate the actions of the decade and to identify the shortfalls and the **major constraints** during the decade. The report states, that besides **financial constraints**; i.e. the failure of attracting sufficient capital for sector development, **institutional and legal constraints** must be considered as being equally responsible for the inability to reach the decade goals. Lessons from the decade had alerted the donor community on the **importance of legal regulations** which were often underestimated in favor of the engineering approach to water and sanitation issues. It was recognized that sanctions and enforcements of legal regulations often failed because of the lack of governmental institutions in developing countries. This was considered a serious institutional constraint to the development of W&S services due to the fact that developing countries tended to have large state owned sectors.[xciii] In addition, the UN report (1989) recognizes that managerial skills were often downgraded, while new construction was favored. Therefore it is claimed that: ***"The organization of water and sanitation agencies should reflect that drinking water supply and***

sanitation are not purely engineering endeavors, but that they should integrate modern managerial methods." The shift in emphasis from engineering to managerial skills as key to W&S development goes together with the insight that efforts had to be put into using existing resources more efficiently rather than investing in new ones.

In terms of institutional constraints, the **UN** report (1989) also find that too many ministries with overlapping responsibilities were involved in water and sanitation activities and that coordination within the sector was poor. Therefore an **institutional reorganization of the water sector was needed**. The report further claims that in the past the sector has relied too much on central governments, local administrations and community participation for W&S service provision. This focus, it is claimed, have eliminated the role and capabilities of the private sector in W&S service provision. The problem of getting prices right is also emphasized as a large constraint to W&S sectors in the developing world. It is seen as a problem that water tariffs were set on a "political basis" rather than reflecting the real costs of production. User participation and public awareness were other issues addressed in the UN 1989 evaluation report. Especially the role of women was emphasized as they carry the main responsibilities for family health and sanitation but are nevertheless seldom included in the planning of water supply systems. To facilitate active user participation in sector planning the report also suggest that all agencies should have offices to deal with users and customers.

Contrary to what had previously been promoted in the WB (1972) document, centrally managed water borne sewerage systems were no longer seen as the sole solution but rather as a problem to the development of W&S systems in developing countries. The UN report concludes that: ***"Developing countries tend to adopt the standards of water supply and sanitation systems used in more developed areas. Since their economic capability is much lower than in the model countries the uncritical adoption of alien practices may result in over design of systems and under utilization of scarce capital. A related effect is that a majority of people do not benefit from high cost, centrally operated systems. In fact, high connection cost may prevent more widespread use of public systems, since in many cases the average user cannot afford the connection cost".***[xciii] This is also emphasized in WB report from 1989, which underline the need for low cost technologies in the sector.[xciv]

Since conventional water and sewerage systems, the standard western model, were only affordable for an elite minority it was emphasized that investments for other types of W&S projects also had to be made available. In order to extend services to the urban and rural poor alternative technologies have to be developed and applied. In this context the **role of women**, the **private sector** and the **involvement of communities** is put at the forefront. In line with the UN report the WB also states that more emphasis has to be put on optimizing the use of existing assets instead of pouring capital into developing new systems.

In 1990, the final year of the international drinking water and sanitation decade the ***"Global Consultation on Safe Water and Sanitation for the 1990´s"*** was held in New Delhi. Many of the previously mentioned issues from the Water and Sanitation Decade Report were addressed. In addition to that the huge funding gaps which the W&S sector in developing countries were facing was discussed and it was stated that ***"If costs were halved and financial resources at least doubled, universal coverage of water supply could be in range at the end of the***

century"[xcv] In this context the importance of better organization and clear sector strategies was emphasized in order to make the sector more attractive for external financial support.

Human resources development and education was further emphasized in this Global Consultation as keys to the new approach, both at university and community level. It was stated that **multidisciplinary approaches** have to be encouraged within academic education. Project management, for instance, was considered a compulsory component in the education in sanitary and environmental engineering. Regarding community education, participatory approaches which would empower and equip communities to own and control their systems was emphasized. This applied to rural communities as well as poor urban settlements.

To improve the general management situation, the New Delhi, conference also promoted a **new role for government** in W&S services: ***"from being that of a provider to that of promoter and facilitator"***, which should enable local public, private and community institutions to deliver better services.

The post water decade evaluations showed frustration over the lack of achievements, which paved the way for radical shifts in views on who should be the provider and for what reasons.

Sustainable water management (1990-2000)
In the 1990's a new approach was adopted which strived to create regulatory capacity in the W&S sector and to encourage private sector participation. In this context the international Conference on Water and the Environment held in Dublin Ireland, in 1992 is often pointed to as a landmark. The Dublin conference, which was held as a preparatory meeting for the Rio Summit later the same year, was attended by five hundred participants, including experts from a hundred countries and representatives of eighty international, intergovernmental and non governmental organizations.[xcvi]

In the Dublin statement is declared that the water crisis is not coming but it is already here. Therefore it is urgent to ***"...reverse the present trends of over consumption, pollution and rising threats from floods and droughts"*** and to find new ways to cope with the water challenge. The Dublin statement states that the challenge is about **managing scarcity**. The problems addressed in the Dublin principles in 1992 and the proposed strategies to cope with these problems are confirmed by a World Bank Study which was published the same year and summarized the Banks experiences from lending in the sector for 20 years. The report indicates **pricing** as a key to achieve efficiency within the sector and highlights the **lack of overall water sector policies**.[xcvii] It is also mentioned that projects are often initiated without any established sector policies or studies of sector contexts. Further on it is pointed to the fact that many projects address only immediate local problems, such as how to best get water supplies quickly into a major cities regardless of other demands for water in the country. Therefore it raises the need of **holistic approaches**, which take different uses of water as well as long term integrated planning into account. WB experience show a clear need for better organization and management of national water sectors, for water sector surveys, and for well planned water supply and sanitation strategies.

The Rio top Summit in Brazil in 1992 was the first Global UN forum on environmental issues held since Stockholm in 1972. At the Rio top summit, a further effort was made to encourage more integrated provision of environmental infrastructure for ***"water, sanitation, drainage and solid waste management"*** [xcviii]

The basic assumption behind **Integrated Water Resources Management** (IWRM) strategies is that water crises is mainly is a crises of governance, because good governance balances the needs of different uses of water i.e. domestic, industrial, agricultural and environmental needs. In order to take all different aspects into account the water resources of the world have to be holistically managed. In addition IWRM stresses that to use water efficiently it has to be treated as an economic good. In addition it aims to encourage a new management paradigm which is not based on traditional top-down governance models which used to put emphasis on technical solutions. Instead cross sectoral, participation approaches with a holistic perspective are encouraged as a means for sustainable water management. This includes for instance wider geographical areas, different uses of water and the integration of stakeholders at different levels in society in the decision making process.

Major policy redirections during the early 1990´s, such as the interpretation of water a an economic good, seemed to have opened the doors for Private Sector Participation (PSP) within W&S services provision and during the 1990´s many developing countries also entered on PSP programs for the W&S sector.

Water supply and sanitation 2000 onwards
At the UN millennium summit in New York the overall goals for the development work known as the Millennium Development Goals (MDGs) were set out. The MDGs for water fall under Goal number 7. ***"To secure an environmentally sustainable development", which also sets out to halve the proportion of people without access to clean drinking water until 2015.*** [xcix]

At the Bonn conference, named "Dublin + 10" held in December 2001, a strong effort was made to push for sanitation issues. The Water Supply and Sanitation Collaborative Council and UN Habitat launched **WASH** (Water, Sanitation and Hygiene for all) as a global advocacy campaign which aimed to raise awareness on the importance of sanitation issues and to put sanitation on top of the Johannesburg agenda.[c] The Bonn keys[ci] declare that: ***"It is time now to build on the national and international commitment on drinking water with the determination also to halve the number of those who do not have access to sanitation".***

Looking back at the 1990's, the World Bank notes that it has been more difficult to introduce the PSP paradigm in W&S than in other infrastructure sectors. This is largely related to a widespread resistance to raising tariffs to cost recovering levels. This makes the water sector a high risk investment for long term investments in assets. In addition, since the responsibilities for water and sanitation are often delegated to local governments, the lack of experience in PSP among these agencies has also been a major constraint.[cii]

Summary of findings
This section has emphasized conceptual changes and shifts in international water policies. The WHO was in the beginning an influential actor in the water sector, but now, the World Bank is catching up and is becoming a forerunner in policy formulation. This is reflected in the fact that WB documents often address questions much earlier than they appear in international development forums. One example is the argument for increased focus on sanitation, which already appears in 1972.

Secondly, the discussion on whether water can be considered as economic good is addressed in the WB study in 1972, while it appears as an issue to the wider public in the 1990's, manifested at the Dublin principles.

Donor awareness of the problems of poor W&S services in less developed countries rose because of increasing urbanization in these LDC's. Although the link between adequate W&S services and economic productivity was recognized, the public health motive for investment in the W&S sector is recognized. This can be related to the fact that WHO was considered the leading agency within the sector during this the early period.

The W&S matter has grown more complex over time and adequate water services are recognized not only as essential for health and nutrition, but also for economic productivity and poverty alleviation on a larger scale. The focus of the water challenge has shifted from a public health issue, to an emphasis on overall impact on poverty reduction.
Early development assistance to the W&S sector tended to emphasize hardware solutions i.e. investments and expansions in infrastructure. This technological top-down approach has moved towards an approach where policy formulation and capacity building are important components of water sector development. Within the W&S sector institution-building, human resources development and management have become key issues. While the initial problem focused on "finding the appropriate technologies" focus have shifted towards governance issues.
Early donor assistance to the water sector tended to focus on water supply whereas sanitation considerably lagged behind. Gradually the need for integrated approaches to urban water systems where new and used water were seen as part of the same system gained ground. The increased focus on sanitation is an example of the W&S problem is becoming more complex new experiences are gained and new knowledge is taken into consideration.
The W&S issue is increasingly being considered as part of the wider challenge of environmental sustainability. With the Rio Declaration from 1992 environmental concerns became a standard component of W&S policy debate. The new focus on sustainability and on ecosystems perspectives rubbed off on the W&S sector as holistic approaches were gradually promoted and integrated into W&S policies. In Rio, important steps were taken towards establishing policies for sustainable use of water resources through the formulation of IWRM strategies.

Appendix III Tanzanian wastewater effluent standards

NORPLAN

Appendix 1

Ministry of Water, River Basin Management

Water Resources Management Review
Effluent Treatment and Water Quality Standards

Effluent standards in Tanzania

Effluent standards as they are given in Water Utilization Act and in a proposal from National Environmental Management Council as well as general guidelines given in Pollution Prevention and Abatement Handbook 1998, from the World Bank, are given in the table below.

Substance	Maximum permissible value, Water Utilization Act, Amendment 1981		NEMC, proposal 1997	World Bank, general guidelines, 1998
	Direct discharge into receiving waters	*Indirect discharge, via municipal sewage treatment plant*		
Suspended solids	Not to form sludge or scum in the receiving water	-	-	-
Colour	Not to cause any change in the natural colour	100 Pt-Co	-	-
Taste and odour	Not to cause any change in the natural taste or odour		-	-
Temperature	Not to cause any increase of the water by more than 5°C	35°C or not more than 5°C above ambient temp. of the supplied water	-	Max. 3°C above ambient temperature of receiving water
Total dissolved	3000 mg/l; no restrictions for discharge to the sea	7500	-	-
Total suspended solids	-	-	100 mg/l	50 mg/l
pH	6.5 – 8.5		6.5 – 8.5	6-9
BOD, 5 days, 20°C	30 mg/l		30 mg/l	50 mg/l (BOD)
BOD, 5 days, 25°C	34 mg/l	No limit	-	
BOD, 5 days, 30°C	37 mg/l	No limit	-	
BOD, 5 days, 35°C	40 mg/l	No limit	-	
COD	-	-	60 mg/l dichromate	250 mg/l
Permanganate value	80 mg/l	No limit	-	-
Total Kjeldahl nitrogen	-	-	15 mg/l as N	-
Ammonia	10 mg/l	No limit	-	10 mg/l
Nitrates	50 mg/l	80 mg/l	-	-
Nitrite	1.0 mg/l	10 mg/l	-	-
Total phosphorous	6.0 mg/l	-	6 mg/l	2 mg/l
Fluoride	-	-	-	20 mg/l
Chloride	800 mg/l	800 mg/l	-	-
Chlorine, total residual	1.0 mg/l	5 mg/l	-	0.2 mg/l
Sulphate	600 mg/l	800 mg/l	-	-
Sulphide	0.5 mg/l	1.0 mg/l	-	1.0 mg/l
Cyanide, free	-	-	-	0.1 mg/l
Cyanide, total	0.1mg/l	0.2mg/l	-	1.0 mg/l
Aluminium	2.0 mg/l	5.0 mg/l	2.0 mg/l	-
Arsenic	0.1 mg/l	0.1 mg/l	0.2 mg/l	0.1 mg/l
Barium	1.5 mg/l	3.0 mg/l	1.5 mg/l	-
Cadmium	0.1 mg/l	0.1 mg/l	0.1 mg/l	0.1 mg/l
Chromium (VI)	-	-	0.1 mg/l	0.1 mg/l
Total chromium	-	-	1.0 mg/l	0.5 mg/l
Cobalt	1.0 mg/l	1.0mg/l	1.0 mg/l	-
Copper	1.0mg/l	1.0 mg/l	2.0 mg/l	0.5 mg/l
Iron	3.0mg/l	5.0 mg/l	-	3.5 mg/l
Lead	0.2 mg/l	0.2 mg/l	0.1 mg/l	0.1 mg/l

Appendix IV questionnaire

Introduction

I am conducting this interview to learn about your views and ideas concerning the possibilities of Constructed Wetlands to improve sanitation in peri-urban areas. I will be asking you some questions about the current used technologies and methods used for sanitation projects and your opinion of these.

Current Sanitation Project

Why was the current wastewater carried out, what was the initial problem?

How did you learn about the technology of Constructed Wetlands?

Why did you choose the Constructed Wetlands technology?

Did you look at other alternative technologies?

What were the activities of these project?

Does the current sanitation project also provide sanitation education?

Who are involved, & who is / are the leading actor(s)? (groups, persons, institutions).

Where there NGO's involved?

Experiences

Who is responsible for the CW?

What has been the performance of the Constructed wetland?

How much maintenance does the CW require?

Did you encounter problems operational problems like clogging and overflowing?

Did you need any outside assistance by these problems, if yes from whom and how was the quality of this assistance?

What are the operating costs of the Constructed wetland?

Does anyone monitor the performance of the Constructed wetland, regarding BOD_5 and pathogens?

Does the government check your waste water effluent?

Economic

Who funded the CW project?

Did you get financial help from the government, if yes was this sufficient?

Is it difficult to raise enough funds for projects like this?

Are the entrepreneurs involved?

Has the Tanzania government sufficient budget to fund these projects?

Will the created sanitation project be self sustainable?

Do you get any benefits of the CW? Such as water re-use?

Actors

Were there other actors involved during the lifetime of the project? (Maybe some disappeared -> if, so pl. indicate why they left or some entered at a later point in time)

Could you describe the actors involved as being part of a network?

Do you still miss some important actors?

How did the network between the actors develop?

Are the same actors involved at different projects?

How are communities involved?

Did they know each other before entering this project?

Barriers

What kind of barriers do you mostly encounter with the CW project?
For example:
- problems with technology
- problems with technological knowledge
-
- financing problems
-
- labour problems
-
- Social -cultural problems
-
- planning and organizing

How do the communities react regarding these CW project?

Did you notice a resistance, or critical questions from persons or groups?

Lessons

What are the most important lessons so far?

In technical areas

On infrastructure/ logistics

On social impact

On policies

Organisational & institutional issues in the project itself (incl. networking)

On how to develop a demand for sanitation

Expectations

Do the expectations you had at the beginning of the project come out right? Or where they changed (slightly) during the process? If so, were actions taken to improve things or change project activities?

Did your project generate a discussion, are more people talking about it? And will the project create a spin-off?

Do you think the Constructed wetland technology should be recommended to other institutions, like schools and governmental buildings, settlements?

How do you think the future for sanitation projects in Tanzania will develop? And how do you see the role played by the government project in this?

What do you think UDSM should do to disseminate the CW technology?

LITERATURE

[i] http://www.unwater.org/

[ii] Faechem, R. G. and Cairncross, S., "*Small Excreta Disposal Systems*", The ROSS Institute of Tropical Hygiene, London, U.K., pp. 1-30.

[iii] Parkinson, J. and Tayler, K. (2003), "*Decentralized wastewater management in peri-urban areas in low-income countries*", Environment & Urbanization Vol. 15 No

[iv] Chaggu, E. J., Mgana, S., et al.(1993), "*Groundwater Pollution: Majumbasita, Dar es Salaam*", Final Research Report, Ardhi Institute, Tanzania, pp. 1-38.

[v] Denny, P. (1997), "*Implementation of Constructed Wetlands in developing countries*", Water Science and Technology Vol 35, No 5, pages 27–34.

[vi] Mashauri D.,. Mulungu D and Abdulhussein B. (2000), "*Constructed Wetlands at the university of Dar es Salaam*", Elsevier Science Ltd, London

[vii] July (2005) est. Worldfactbook, https://www.cia.gov/cia/publications/factbook/geos/tz.html

[viii] (2002) est. Worldfactbook, http://www.cia.gov/cia/publications/factbook/geos/tz.html

[ix] Data from October (2004), "*Tanzania National Profile Data in Brief*", National Bureau of Statistics Tanzania.

[x] WUP - Water Utilities Partnership Project No. 5 (April 2000) Workshop Papers. DAWASA: Dar es Salaam.

[xi] WHO/UNICEF (2005)," *Meeting the MDG Drinking Water and Sanitation Target: A Midterm Assessment of Progress*". Geneva: The World Health Organization and the United Nations Children's Fund.

[xii] United Nations (2006). UN Statistical Division. "*Progress towards the Millennium Development Goal*", 1990-2005, New York: The United Nations.

[xiii] Tanzania Demographic and Health Survey, 2004-2005. Preliminary report. http://www.popline.org/docs/1695/294994.html

[xiv] Mulligan, J., Fox-Rushby, J., Adam, T., Johns, B. & Mills A. (2005) "*Unit costs of health care inputs in low and middle- income regions. Disease Control Priorities Project Working Paper No. 9*", September (2003), revised June, (2005). Geneva: The World Health Organization

[xv] Hoogema R., Kemp R., Schot J. and Truffer B. (2002), "*Experimenting for sustainable transport, The approach of Strategic Niche Management*", Spon Press, London

[xvi] Geels, F.W. (2004) *"From sectoral systems of innovations to socio-technical systems: insights about dynamics and change from sociology and institutional theory"*, *Research Policy* 33: 897-920

[xvii] Raven, R. (2005b) *"Strategic Niche Management for Biomass, a Comparative Study on the Experimental Introduction of Bio energy Technologies in the Netherlands and Denmark"*. Eindhoven: Technische Universiteit Eindhoven

[xviii] Roep, D., (2002). *"Managing technical-institutional design processes: some strategic lessons from environmental co-operatives in the Netherlands"*, Michigan Technological University

[xix] Schot, J. (1998) *"The usefulness of evolutionary models for explaining innovation. The case of the Netherlands in the 19th Century', History and Technology"*, 14: 173-200.

[xx] Rotmans, J., Kemp R., van Asselt M., (2001), *"More evolution that revolution, transition management in public policy"*, foresight vol.03, no.01, feb.01

[xxi] Dosi, G., Freeman, C., Nelson, R., Silverberg, G. and L. Soete (1988) *"Technical change and economic theory"*, London: Pinter.

[xxii] Rip, A. and Kemp R (1998) *"Technological change' in Rayner, S. and E.L. Malone Human Choices and Climate Change Volume 2"*- Resources and Technology, Columbus, Ohio, Battelle.

[xxiii] Levinthal, D.A., (1998). *"The slow pace of rapid technological change: gradualism and punctuation in technological change. Industrial and Corporate Change (7)"*, 217-247.

[xxiv] Kemp, R., Schot, J. and Hoogma, R (1998) *"Regime shifts to sustainability through processes of niche formation: the approach of Strategic Niche Management"'*, Technology Analysis and Strategic Management, 10, 2: 175-195.

[xxv] Weber, M., Hoogma, R, Lane B & Schot, S (1998). *"Experimenting with Sustainable Transport Innovations: a Workbook for Strategic Niche Management"*. Twente University, Enschede, 68 pp.

[xxvi] Geels, F.W. and Kemp, R (2000) *"Transities vanuit een socio-technisch perspectief', one of three reports on transition research by Rothmans"*, ICIS-MERIT, Maastricht Economic Research Institute on Innovation and Technology, Maastricht

[xxvii] van der Laak, Raven, R. en Verbong, G (2007) *"Strategic Niche Management for biofuels: Analyasing past experiments for developing new biofuel policies"*, Energy Policy vol 35, no 6, pp 3213-3225

[xxviii] Verbong and Geels, (2007), *"The ongoing energy transition: Lessons from a socio- technical, multi-level analysis of the Dutch electricity system"* (1960–2004),

[xxix] Schot, J.W., Hoogma, R., Elzen, B., (1994) *"Strategies for shifting technological systems"*. Futures 10, 1060-1076

[xxx] Institute of Marine Sciences (2002), *"Cost–benefit analysis case studies in eastern Africa for the GPA strategic action plan on sewage"*, university of Dar es Salaam, Tanzania

[xxxi] Hutton, G. And Haller, L., (2004) *"Evaluation of the Costs and Benefits of Water and Sanitation Improvements at the Global Level"*, World Health Organization,Geneva,

[xxxii] Hutton, G. (2001) *"Economic evaluation and priority setting in water and sanitation interventions, in Water Quality: Guidelines, Standards and Health"*. Risk assessment and management for water-related infectious disease

[xxxiii] Drummond, M.F., O'Brien, B., Stoddart, G.L., and Torrance, G.W. *"Methods for the economic evaluation of health care programmes"*. Second ed. 1997: Oxford University Press.

[xxxiv] Prüss, A., Kay, D., Fewtrell, L., and Bartram, J. *"Estimating the global burden of disease from water, sanitation, and hygiene at the global leve"l.* Environmental Health Perspectives (2002). 110(5): p. 537-542

[xxxv] Gold, M.R., Siegel, J.E., Russell, L.B., and Weinstein, M.C. *"Cost-effectiveness in health and medicine"*. (1996) Oxford University Press.

[xxxvi] Hammer, D.A (1992). *"Creating freshwater Wetlands. Lewis publishers, Boca Raton. Wetlands and water quality enhancement"*. Mondi Wetlands project.

[xxxvii] Kadlec, R.H. and Knight, R.L (1996) *"Treatment Wetlands"*. Lewis Publishers, New York.

[xxxviii] Lorion, R. (2001). *"Constructed Wetlands: Passive Systems for Wastewater Treatment"*. Prepared for the US EPA Technology Innovation Office

[xxxix] Hammer, D.A and Bastian, R.K (1989). *"Wetland ecosystems: Natural water purifiers?"* Chapter 2, pp 5-10. In: Hammer, D.A (Ed), *"Constructed Wetlands for wastewater treatment: Municipal, industrial and Agricultural"*. Chelsea, MI: Lewis publishers.

[xl] Denny, P. (1997), *"Implementation of Constructed Wetlands in developing countries"*, Water Science and Technology Vol 35, No 5, pages 27–34.

[xli] Brix, H. (1993). *"Macrophyte – Mediated oxygen transfer in Wetlands: Transport mechanisms and rates"*. In: Moshiri, G.A. (ed.), Constructed Wetlands for Water Quality Improvement, Lewis Publishers, Boca Raton, Florida, USA. pp. 391-399.

[xlii] Bavor, H.J. and. Adcock, P.W (1994) *"Relating Phosphorous Distribution Within Wetlands to Their Long Term Performance. Proceedings, 2nd Annual Conference, Soil and Water Management for Urban Development"* – Creative Stormwater Management, Sydney, Australia, September 1994.

[xliii] Mitchell, C. (1996). "*Essential Wastewater Microbiology. Course Notes for IWES '96*", International Winter Environmental School, Gold Coast, Africa, July 1996

[xliv] Mitchell, C. (1996). "*Pollutant Removal Mechanisms in Artificial Wetland. Course Notes for IWES '96*", International Winter Environmental School, Gold Coast, Africa.

[xlv] Broderick, S.J., Cullen, P and Maher, W (1988). "*Denitrification in a natural wetland receiving a secondary treated effluent. Water Resources*", 22(4), 431-439

[xlvi] Reed, S.C. and Brown, D. (1995). "*Subsurface flow Wetlands - A performance evaluation*". Wat. Env. Res., 67, 244-248

[xlvii] White, K.D. (1995). "*Enhancement of nitrogen removal in subsurface flow Constructed Wetlands employing a 2-stage configuration, an unsaturated zone, and recirculation*". Water Science and Technology, 32, 59-67

[xlviii] ESRF – Economic and Social Research Foundation (April 2000) "*Overcoming Constraints on Tanzanian Growth: Policy Challenges Facing the Third Phase Government*". ESRF: Dar es Salaam.

[xlix] http://hdrstats.undp.org/countries/country_fact_sheets/cty_fs_TZA.html

[l] UNDP (2000), "*Tanzania Human Development report, The State of Progress in Human Resource Development (1999)*", Dar-es-Salaam, Tanzania, pp. 65.

[li] National Bureau of Statistics, Household budget Survey (2000/01), July (2002) Dar es Salaam, Tanzania

[lii] De Waal, D. "*national water sector assessment Tanzania", (2005)* WaterAid UK

[liii] United Nations (2001), "*Population, Environment and Development: The Concise Report. Chapter VI: Population, Environment and Development in Urban Settings, ST/ESA/SER.A/ 202*", United Nations Population Division, Department of Economic and Social Affairs, New York.

[liv] United Nations (1999), "*World urbanization prospects: the 1999 revision. Chapter VI: population growth in cities*", Working Paper No 161, Population Division of the Department of Economic and Social Affairs, United Nations Secretariat, New York.

[lv] Birley, M. and Lock K. (1999), "*Health Impacts of Peri-urban Natural Resource Development*", Cromwell Press, Trowbridge, UK.

[lvi] Birley, M. and Lock, K. (1998), "*Health and peri-urban natural resource production*", Environment and Urbanization Vol 10, No 1, April, pages 89–106.

[lvii] Mato , R. (2001), "*Groundwater Pollution in Urban Dar es Salaam*", Tanzania, technical university Eindhoven.

lviii Vice President's Office (1999), *"Poverty and Welfare Monitoring Indicators"*, The GovernmentPrinter Dar es Salaam, Tanzania, 18-35, pp. 66.

lix Black, M., Sanitation: "crearting *a stink about the world's wastewater"*, the guardian august 20, (2008)

lx Plumb, L., *"Dignity and the decent facility"y,* New Internationalist august (2008).

lxi Chaggu, E.J., (2003) *"Sustainable Environmental Protection Using Modified Pit-Latrines"*, Wageningen, the Netherlands, pp. 1-36.

lxii World Bank (1997) Tanzania: *"Water Sector Study, Water, Urban and Energy 1"*, Eastern and Southern Africa, Africa Region.

lxiii Grosh and Forgy (1996). *"Tanzania Social Sector Review": Water and Sanitation.* World Bank, Washington, pp 160-179

lxiv Kleemeier, L. (1995) *"From Supply-Driven to Demand-Driven Provision of Rural Drinking Water: A Tanzanian Case Study of the Arguments for a Transition"*, Copenhagen, Centre for Development Research.

lxv F.Z. Njau, Principal Executive Engineer, *"Tanzania's Water Sector Review Process"*, in Hirji and Patorni, (1994)

lxvi Ponte, S., (1999). *"Trading images: Discourse and statistical evidence on agricultural adjustment in Tanzania"*, (1986-95). In: Forster, P.G.,Maghimbi, S. (Eds.), *"Agrarian Economy, State and Society in Contemporary Tanzania"*. Ashgate, Aldershot.

lxvii Scott, J., (1998). *"Seeing Like a State: How Certain Schemes to Improve the Human Condition Have Failed"*. Yale University Press, London.

lxviii McGinnis, M., (1999). *"Polycentric Governance and Development: Readings from the Workshop in Political Theory and Policy Analysis"*. Michigan University Press, Michigan.

lxix Mato R. (1997), Kassenga G.R., "A *study on problems of management of medical solid wastes in Dar es Salaam and their remedial measures, Resources"*, Conservation and Recycling, Volume 21, Number 1, September (1997) , pp. 1-16

lxx Mandara, M. P. and Mhalu, F. S. (1981), *"Cholera Control in an Inaccessible District in Tanzania:Importance of Temporary Rural Centres"*, Medical Journal of Zambia, (1980/81), 15, pp. 10-13.

lxxi Kilama, W. L.,Mandara, P. M., Murru, M. and Macpherson, C. N. L. eds. (1991), *"Health and Disease in Tanzania"*, HarperCollinsAcademic, USA, pp. 116-129.

lxxii Tanzanian government (2001). *"Tanzania state of the coast 2001:People and the environment"*, Tanzanian coastal management partnership.

[lxxiii] Collignon, B.Vézina, M. (2000) *"Independent Water and Sanitation Providers in African Cities"*, World bank

[lxxiv] Marshall. J. (2002), *"Water and Sanitation in Tanzania"*, Watsan

[lxxv] Lugalla, J. L. P. (1990). *"Socialist Construction and Urbanization Process: An analysis of Urban Poverty and Politics in Tanzania"*. In Kironde, J. M. L. (1994). The Governance of Urban Development in Tanzania,

[lxxvi] Edmund, J. (2002) *The pilot of ecological sanitation project in Majumbasita, Dar es Salaam, Tanzania,EEPCO,* Tanzania

[lxxvii] Ruijsink, S.(2004) *"Urban upgrading needs in an informal settlement in Dar es Salaam, Tanzania"*, Eindhoven University of Technology, the Netherlands

[lxxviii] W&SCFS (Water Supply and Sanitation Fact Sheets) http://www.tzonline.org/pdf/watersupplyandsanitation.pdf

[lxxix] Mashauri, D.A., Mulungu D.M., and B. S. Abdulhussein,(1990) *"Constructed wetland at the University o Dar es Salaam"*, Elsevier science Londen

[lxxx] World Health Organization, United Nations Children's Fund, and Water Supply and Sanitation Collaborative Council, *"Global Water Supply and Sanitation Assessment 2000", Report*. (2000).

[lxxxi] Hutton G. (2004) " *Evaluation of the Costs and Benefits of Water and Sanitation Improvements at the Global Leve"l*, World Heatlh Organization

[lxxxii] Snyder, S. D., and Merson, M.H (1982). *"The magnitude of the global problem of acute diarrhoeal disease. A review of active surveillance data"*. Bull. W. H. O. 66:605-613.

[lxxxiii] http://www.unicef.org/infobycountry/tanzania_statistics.html#47

[lxxxiv] Hill Z, B Kirkwood, and Edmond, K (2001), *"Family and Community Practices that Promote Child Survival, Growth, and Development: A review of the Evidence"*, Public Health Intervention Research Unit, Department of Epidemiology & Population Health, London School of Hygiene

[lxxxv] Bohman, *A (2006), "Framing the water challenge Multilateral donor policies for water supply and sanitation"*, Umeå University, Umeå, Sweden

[lxxxvi] Grover, B, Howarth D (1991) *"Evolving International Collaborative arrangements for Water Supply and Sanitation"*, Water International 16, pp 145 - 152

[lxxxvii] Seppelää Osmo T. *"Effective water and sanitation policy reform implementation: need for systematic approach and stakeholder participation Water Policy 4"* (2002) pp 367-388

[lxxxviii] World Bank (1992) *"OED Précis "Urban Water Supply and Sanitation"* Operations and Evaluations Department, June 1992 [lxxxix] Black M., (2003) *"1978 – 1998 Learning what works – a twenty year retrospective View on International Water and Sanitation Cooperation"* UNDP – World Bank Water and Sanitation Program

[xc] UN (1977) *"Report of the United Nations Water Conference"*, Mar del Plata 14 – 25 March (1977), United Nations, New York

[xci] Grover B, (1998) *"Twenty five years of international cooperation in water related development assistance"*, 1972 – 1997, Water Policy 1, (1998), pp 29 – 43.

[xcii] World Bank (1978) *"Operational Manual Statement – Energy, Water Supply and Sanitation and Telecommunications (EWT)"*, No.3.72 Issued: September (1978)

[xciii] UN (1989) *"Legal and Institutional Factors affecting the implementation of the International Drinking Water Supply and Sanitation Decade, Natural Resources/Water series"*, United nations , New York (1989)

[xciv] World Bank (1989) "General *Operational Overview - Overview of Water and Sanitation Activities FY89"*, Water and Sanitation Division December (1989)

[xcv] UN (1990) *"Report of the Global Consultation on Safe Water and Sanitation for the 1990´s"*, 10 – 14 September (1990)

[xcvi] UN (1992) *"A International Conference on Water and the Environment, Development Issues for the 21st century"*, 26 – 31 January (1992), Dublin Ireland

[xcvii] World Bank (1992) "OED *Précis "Urban Water Supply and Sanitation"* Operations and Evaluations Department, June (1992)

[xcviii] UN (1992) "b *Earth Summit – Agenda 21 – Chapter 18 in UNDP (1994)* " Statements and Recommendations from major international meetings on water supply and sanitation" UNDP, New York

[xcix] http://www.developmentgoals.org

[c] http://www.africanwater.org/bonn.htm#wash

[ci] Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, Federal Ministry for Economic Co – operation and Development (2001) *"Water – a key to Sustainable Development - International Conference on Freshwater Bonn (2001), 3 – 7December"* Lemmens Verlags & Mediengesellschaft mb

[cii] World Bank (2003) A Report No. 26443 *"Efficient sustainable services for all? An OED Review of the World Bank's Assistance to Water Supply and Sanitation"*, Operations Evaluations Department

M. Sc. Theses In Technology and Development Studies: 2006

06.01 Rik Luiten: Power Supply Performance: Tanzanian Manufacturing Sector Aim.

06.02 Janske van Eijck: Transition towards Jatropha Biofuels in Tanzania? An Analysis with Strategic Niche Management.

06.03 Arend Driest: The role of entrepreneurs in the innovation process in Ghana's timber exporting sector.

06.04 Martine Teeselink: The Vietnamese Software Industry: Export Success or Domestic Strenght?

06.05 Jeanet Eggengoor: Exploring the feasibility of minimizing the waste product. Fly ash from the Indonesian Textile Industry by co-processing in the Indonesian Cement Industry.

M. Sc. Theses In Technology and Development Studies: 2007

07.01 Hans van Dijkhuizen: Overcoming bottlenecks with implementation of new technologies. African aviation system.

07.02 Ina de Visser: Design and implementation of biomass energy systems in rural India.

07.03 Robert ten Hagen: Firm Performance in a changing policy environment. The case of TAMECO knife factory. Tanzania.

07.04 Maarten Louwerse: Prospects for ICT service sector growth in the Indian state of Kerala.

07.05 Edwin Vriens/Jan van Diesen: The implementation of an innovation for sustainable economic development in rural areas. The case of solar fruit & vegetable drying in rural Tanzania.

07.06 Raphaël Dasselaar: Diffusion of innovation in disaster areas. The post tsunami reconstruction effort in Aceh, Indonesia.

07.07 Miguel Alvares: Design of Assessment Method for Sustainable Micro-Hydro Projects in Suriname.

07.08 Bob Boogaart: Road Capital Stock and Economic Growth. measurement and Analysis in Mozambique.

07.09 Hijmen van de Twillert: Waste Management in the Costa Rican Construction Sector.

07.10 Annemiek Daamen: The Development of Cooperation: Enhancing the role of technology in Dutch development cooperation policy.

07.11 Frank Bus: A decision support model for the design of innovative public spaces. Port of Rotterdam/Harbour of Dar es Salaam, Tanzania.

07.12 Winnie Versol: Artisanal gold mining in Suriname. Overcoming barriers to the development and adoption of sustainable technologies.

07.13 Jeroen Brouwer: Design of a sustainable refurbishment policy for Multi Family buildings in Post Slovakia, in order to meet new housing standards.

M. Sc. Theses In Technology and Development Studies: 2008

08.01 Frank Ermers: Biomass gasifiers in rural India: Past experiences and future plans reviewed

08.02 Robbert Jobse: Migration and Urban Infrastructure Services. The Impact of Internal Migration and Urban Growth on Infrastucture Services in Trujillo, Peru.

08.03 Willem Christiaens: Development of Biomass Gasification Technology in India: An analysis with Strategic Niche Management.

08.04 Vicky Lammens: Managing technology and innovation for the Base of Pyramid. The impact of trust and capabilities on BoP innovation. Ghana.

If you would like to receive a copy of one of the above indicated M.Sc. theses, please contact:

Department of Technology and Development Studies
Eindhoven University of Technology
Secretariat Technology and Development Studies (TDS):
Pav. Q 1.01
Tel.: 040 247 2242/247 2246
PO Box 513
5600 MB Eindhoven
The Netherlands