Sanitation in Informal Settlements of Nairobi and Kisumu, Kenya

Understanding of Environmental, Technical and Socio-Cultural Aspects

Master Thesis, submitted for the achievement of the academic grade of

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Civil Engineering Sciences, Environment and Transportation

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Sandra WAGENDORFER

Preface

GERMAN

Die gegenwärtigen Entwicklungen im Bevölkerungswachstum seit der industriellen Revolution stellt die Menschheit vor große Herausforderungen im Bereich von Wirtschafts-, Sozial- und Umweltfragen. Zusätzlich soll der ständige wachsenden der Stadtbevölkerung im Zuge der fortschreitenden Urbanisierung die notwendige Infrastruktur wie Straßen, Wasser- und Energieversorgung bereitgestellt werden. Die Versorgung mit Trinkwasser und Hygieneanlagen sind zwei von mehreren weltweit implementierten Zielen die nicht nur zur Verbesserung der Lebensqualität des Menschen dienen, sondern auch ein nachhaltiges Zusammenspiel zwischen Mensch und Umwelt ermöglichen sollen. Diese Masterarbeit beschäftigt sich in erster Linien mit der Frage der Siedlungshygiene in den sogenannten Informal Settlements und nimmt sich in Kenia die Städte Nairobi und Kisumu zum Beispiel. Das Ziel ist die Herausarbeitung der dort angewandten Sanitärsysteme und deren Eignung für dieses Anwendungsgebiet zu bestimmen. Außerdem werden die zusammenspielenden sozialen und ökologischen Faktoren von der eine erfolgreiche Implementierung eines Sanitärprojektes abhängig ist besprochen. Diese Masterarbeit wurde in Zusammenarbeit mit der Jomo Kenyatta University of Agriculture and Technology und den Einwohnern der fünf untersuchten Informal Settlements durchgeführt.

Keywords: Siedlungshygiene, Toilettentechnologien, Wasserversorgung, Kisumu, Nairobi, Gender, Armut

ENGLISH

The increase of the world's population and the global developments since the industrial revolution cause various stresses for humanity in economic, social and environmental field. Additionally the increasing rate of depopulation from rural areas to the cities requires elevated attention in the provision of urban infrastructures. To face the ongoing urbanisation and the increasing population rate, the provision of safe water supply and sanitation are two of various globally established goals to be achieved in the near future to allow a sustainable and healthy development. This master thesis mainly deals with the provision of sanitation in the urban informal settlements and uses the case examples of Nairobi and Kisumu, both cities in Kenya, to assess the current sanitation situation in technological, environmental and social matters. The aim is to work out which types of sanitation facilities are available and feasible for these areas and additionally determinate the factors that have to be considered for a successful execution of a sanitation project. Since there is an undeniable connection between water supply and sanitation, the related aspects of water supply to sanitation provision are discussed as well. The work was executed in cooperation with the Jomo Kenyatta University of Agriculture and Technology in Nairobi and the residents of the five investigated informal settlements in Nairobi and Kisumu.

Keywords: Sanitation, Sanitation Technologies, Water Supply, Kisumu, Nairobi, Gender, Poverty

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List of Abbreviations and Acronyms

CBD	- City Business District
COHRE	- Centre on Housing Rights and Evictions (Switzerland)
DHS	- The United States Department of Homeland Security
Ecosan	- Ecological sanitation
IBID	- latin, short for ibidem, meaning “the same place”, used to provide a reference or source that was before cited in the same section
IFAT	- Internationale Fachmesse für Wasser, Abwasser, Abfall und Recycling [engl.: International trade fair for water, wastewater, waste and recycling]
GIZ	- Deutsche Gesellschaft für Internationale Zusammenarbeit (former Deutsche Gesellschaft für Internationale Zusammenarbeit GTZ)
HIV/AIDS	- Human Immunodeficiency Virus /Acquired Immune Deficiency Syndrome
IRIN	- Humanitarian news and analysis, a service of the UN Office for the Coordination of Humanitarian Affairs
IWRM	- Integrated Water Resource Management
KIWASO	- Kisumu Water and Sewage Company
KSh	- Kenyan Shilling
MDG	- Millennium Development Goal
NWRMS	- National Water Resource Management Strategy
NCWSC	- Nairobi City Water and Sewerage Company
NGO	- Non-Governmental Organisation
O&M	- Operation and Maintenance
SDI	- Slum Dwellers International
UDDT	- Urine Diversion Dry Toilet
UN	- United Nations
UNDP	- United Nations Development Programme
UNEP	- United Nations Environment Programme
UNESCO	- United Nations Educational, Scientific and Cultural Organization
UN-HABITAT	- United Nations Human Settlement Programme

UNICEF	- United Nations Children's Fund
UNSD	- United Nations Statistics Division
US $	- United States of America Dollar
WHO	- World Health Organization
WSP	- Water and Sanitation Program

Exchange Rates

US $ 1	is equivalent to	ksh 83.78000	(16.04.2011)
ksh 1	is equivalent to	US $ 0.01194	(16.04.2011)

(Source: http://investing.money.msn.com/investments/currency-exchange-rates/?symbol=%2fKESUS)

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1 Introduction

Be curious, not judgmental.

Walt Whitman

1.1 Why Undertake this Research?

These days we exploit the resources that nature offers us and in return we dump our wastes in all sorts of physical conditions back into our environment. The air that surrounds us carries various kinds of toxic compounds, the water bodies and soils are polluted with solid and liquid wastes and what cannot be buried is simply thrown away or even left behind in Earth's orbit. "Out of sight, out of mind" was enough for us for a long time, and today we pay for this attitude. Vast changes in the climatic conditions and the repeated occurrences of extreme environmental states, such as droughts and floods, pose some major challenges. The impact of our actions has plunged the global economy into a crisis. As a result the already existing poverty rises, bringing with it rural depopulation, pour health, malnutrition, unemployment, and finally to close the circle an even faster growing amount of people who live with income way below the poverty line.

But all this was not the reason why I got interested in these issues. When I was twelve years old, my parents took me to Indonesia and China for the first time. Ever since then we have travelled to lots of countries that are considered to be Developing Countries and face those issues. After a while I was able to understand why some people live the way they live and understood the correlations between economics, environment and the living condition of these people. At the same time I began to think about the impact of those humanitarian disasters on the planet's flora and fauna. I understood that with our actions we harm not only ourselves, but we take nature down with us. This is the point that is the reason for me to become active in developing issues. To allow people a sustainable lifestyle by establishing resource oriented facilities to satisfy the daily needs, might allow our nature and our ecological environment to regenerate.

The ultimate personal aim of this research is to collect sanitation systems that are feasible for utilization in the informal settlements, as well as the evaluation of the current situation in the informal settlements on the case example of Nairobi and Kisumu in Kenya. The surveyed informal settlements were picked in a way so that as many different social, technical and environmental situations are observable. The criteria that are vital for the establishment and operation for a sanitation facility are resulting from this research.

1.2 Statement of the Problem

Worldwide about 2.5 billion people are living without access to safe sanitation which leads to about 200 million tonnes of untreated human excreta annually (UNICEF, 2008). Lack of proper sanitation facilities causes poor health to the urban as well as the rural poor and often leads to diseases such as diarrhoea. As a result about 5.000 children die each day caused by water-borne diseases of which they suffer due to a combination of unsafe water and sanitation (COHRE et. al., 2008). Granting access to safe sanitation plays a vital part in the improvement of the quality of life by helping to avoid water-borne illnesses (ibid). To meet these issues it is necessary to establish appropriate legal frameworks and educate the affected residents about their rights and duties (UNEVOC, 2006). The establishment of frameworks must go hand in hand with transparency of governance and the guarantee of freedom of speech and especially with the appreciation of differences between cultures and sexes (UNEVOC, 2006).

1.3 Objectives of this Research

The aim of this research is to assess the socio-cultural and ecological perspectives of the sanitation issues in the developing world by using the case studies of informal settlements in Nairobi and Kisumu, both cities in Kenya. Particular attention is laid on social and gender aspects in sanitation, since traditional constructions in society and households are inseparably connected with the social sex, or so-called gender. Further on the understanding of the differences between sanitation in the developed world and sanitation in the developing world is targeted. As a result the reader of this master thesis should be able to understand alternative sanitation systems as well as the issues that come with them in informal settlements. The basic question behind this research is to understand which reasons and issues are relevant and vital for the success or failure in the implementation of sanitation facilities in informal settlements.

The specific objectives of this research are:

I. To investigate the current socio-cultural status of water and sanitation in the informal settlements.
II. To examine the legal framework for sanitation in the informal settlement.
III. To examine the applicable sanitation systems in the informal settlements.
IV. To examine the factors which are vital for the success of a sanitation project in the informal settlement.

1.4 Research Questions

The above objectives are attended to by the following questions, which were applied to the investigated informal settlements:

Objective I

a. What are the sources of water supply in the informal settlements?
b. What are the influences on the pricing mechanism in the informal settlements?
c. What uses is the water put to in the informal settlements?
d. What is the environmental quality in the informal settlements?
e. What types of sanitation facilities are available in the informal settlements?
f. What are the management structures for water and sanitation in the informal settlements?
g. What are the socio-cultural influences affecting water and sanitation?
h. What are the influences on the life times on sanitation systems in the informal settlements?

Objective II

a. What are the international guiding principles in regards to provision of sanitation?
b. What are the national legal frameworks governing provision of sanitation in Kenya?
c. What is the main legal issue in informal settlements?

Objective III

a. What is the new paradigm shift in sanitation provision in the informal settlements?
b. What strategies are employed by residents in ensuring adequate and safe sanitation services?

Objective IV

a. What are the requirements for an adequate sanitation system in the informal settlement?

1.5 Premises

Though the main objective of this research is the analysis of the sanitation situation in the informal settlements of a developing country, cities in Kenya, the factor of water in general and specifically water supply cannot be excluded. All environmental compartments are linked with each other and therefore an impact on one system influences the other connected environmental systems.

1.6 Outline of the Research

1 – Introduction

This chapter describes the motivations of the author in the choice of the topic, states the present problems of sanitation in informal settlements and defines the objectives of the research.

2 – Theories and Principles in Sanitation Management

This chapter discusses some of the theories that describe the ecological state of our environment and principles that were established to guide in the decision making processes towards sustainable solutions in sanitation management. Further on this section describes the issues that concern gender and poverty.

3 – Sanitation Systems

One of the objectives of this work is to collect a range of different sanitation systems that are in use in the developing world and introduce their functioning to the reader. Most of the cities in developed countries have a centralized sanitation system that is not sustainable, for it only extracts nutrients from the environment without returning them properly. The sanitation systems that are subject to this work are supposedly self-sustaining and resource-oriented systems. Additionally this chapter is used to define key terms that were used in the research as well as the premises that had to be made.

4 – Legal Framework in Sanitation

This section gives an outline of the legal frameworks that concern sanitation in informal settlements on the national level concerning Kenya, as well as the international level.

5 – Methodology

The primary and secondary sources as well as the research instruments that were used and the target population that were considered in this research are described in this section. Further on the process of data analysis and presentation of the data is explained. Additional results of the fieldwork such as experiences and challenges are mentioned.

6 – Study Area

This chapter gives a definition for informal settlements, and continues with describing the natural, socio-economical and sanitation conditions in Kenya's informal settlements. This then leads to the description of the locality of the three informal settlements that were visited in Nairobi and the two that were visited in Kisumu.

7 – Results and Analysis

The results of the interviews in the informal settlements are displayed in this section and evaluated under the consideration of water supply and sanitation, with their economical, ecological and socio-cultural aspects and their correlations.

8 – Summary, Conclusion and Recommendations

This section summarizes the research objectives and provides answers to the research questions given in chapter 1.4. Further on conclusions resulting from the research questions and the undertaken

theoretical and practical investigations are presented and recommendations are offered in this chapter.

1.7 Definitions of Key Terms

Adaptation to Climate Change

The IPCC defines adaptation as an "*adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities*" (Joint Liasion Group of the Rio Conventions, 2004).

Biogas

"*Gas, especially methane (CH_4), that is produced when bacteria cause plant to decay. It can be used as fuel*." (Macmillan Dictionary).

Carrying Capacity

The capacity of ecosystems to support continued growth in population numbers, resource consumption, and waste production (UNESCO-UNEVOC, 2006).

Climate Change

"*The changes that are thought to be affecting the world's weather so that it is becoming warmer*" (Macmillan Dictionary).

Dry Toilet System

Dry toilet systems work without the input of water, therefore no flushing mechanisms are necessary to dispose of the excreta (Tilley, et. al., 2008).

EcoHumus / Compost

"*A mixture of decaying plants and vegetables that is added to soil to improve its quality*" (Macmillan Dictionary).

Ecological Footprint Assessment

The area of land and water needed to support the total flow of energy and materials consumed by a person, household, community or workplace (UNESCO-UNEVOC, 2006).

Flying Toilet

"*The flying toilet is a toilet solution whose name derives from Kibera in Nairobi. It means that one uses a conventional plastic bag as a toilet, which after use, is thrown outside the home into the street or on a pile. The name "flying toilet" comes from the practice of throwing the bag as far as possible*." (www.peepoople.com)

Global Warming

"*The slow increase in the temperature of the Earth caused partly by the greenhouse effect increasing the amount of carbon dioxide in the atmosphere*" (Macmillan Dictionary).

Gender,

The report of the Water for Asian Cities Programme (UN-HABITAT, 2006b) describes gender as "*the array of socially constructed roles and relationships, personality traits, attitudes, behaviours, values, relative power and influence that society ascribes to the two sexes on a different basis. Gender is thus an acquired identity that is learned, which changes over time, and varies widely within and across cultures*."

Gender Equality

"*Gender equality means that the different behaviours, aspirations and needs of women and men are considered, valued and favoured equally*" (UN-HABITAT, 2006b).

Gender Equity

"*Gender equity means fairness in the treatment for women and men, according to their respective needs. This may therefore include equal treatment or treatment that is different but which is considered equivalent in terms of rights, benefits, obligations and opportunities*" (UN-HABITAT, 2006b).

Hotel

In informal settlements the term hotel refers to a restaurant or a bar.

Humanure

Human excrements and eventually dry cleansing material that are composted for e.g. agricultural purposes (Tilley, et. al., 2008).

Lacto-fermentation

"*The lacto-fermentation process (also lactic acid fermentation) is a biological anaerobic degradation process (similar to silage production process in agriculture), but without gas formation*" (Conradin, et. al., 2010).

Sanitation

As defined by the World Health Organization (WHO, 2011) sanitation refers to the provision of methods to safely dispose of human urine and excreta, for it is known that improved sanitation has a positive impact on health in households and whole communities.

Sustainable Development

"*Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs. It contains within it two key concepts:*

- *the concept of 'needs', in particular the essential needs of the world's poor, to which overriding priority should be given; and*
- *the idea of limitations imposed by the state of technology and social organization on the environment's ability to meet present and future needs*." (United Nations, 1987)

Superstructure

The superstructure describes the housing of a sanitation facility, and depending on the construction material and the type of sanitation system it can be either fixed or portable (Tilley, et. al., 2008).

Urine Diversion

Urine diversion refers to the applicable option of separating the urine from the feaces by using affiliated user interfaces (Tilley, et. al., 2008).

Vermi-composting

"*Vermicomposting is the process of using earthworms to break down organic wastee in order to create a faster than normal composting. The worm population is self regulating and will increase to the point where available food and space constrain further expansion*" (Conradin, et. al., 2010).

Wet Toilet System

Wet toilets are toilet structures that work with the addition of water for the flushing of excreta (Tilley, et. al., 2008).

2 Theories and Principles in Sustainable Development

2.0 Introduction

This section describes the ideas behind the concept of sustainable development and its necessity to provide a safe and healthy environment for future generations. This chapter includes consideration of socio-cultural, environmental and economic values and perspectives of sustainable development. The challenges to a sustainable development in the future such as human population growth and the consumption oriented lifestyle, presented through the theories of carrying capacity and ecological footprint, are discussed with a focus on the impact that sanitation has on the subject. Further on the issues that gender and poverty place in today's world, with focus on sanitation and its connection with both subjects, are presented.

2.1 Sustainable Development

The United Nations Conference on Environment and Development (UNCED), also known as the Earth Summit, was held in Rio de Janeiro, Brazil, in June 1992. The ultimate result of this conference was the Agenda 21, a framework for global actions to achieve future sustainable development. Whereas sustainable development is a process by which the needs of present generations can be satisfied without compromising the ability of future generations to satisfy their needs (UNESCO-UNEVOC, 2006).

In understanding the meaning of sustainable development it is helpful to consider the issues concerning overpopulation, carrying capacity and the assessment of the ecological footprint (discussed later in the chapter 2.2). It is a concept that aims to balance social and economic progresses involve cultural differences, adapts to local as well as global needs and respects ecological values and limits (UNESCO-UNEVOC, 2006). This approach does not lock up the concept into a fixed framework. It rather tries to figure out a dynamic balance between the different dimensions of sustainable development. The different dimensions of sustainable development include ecological (environmental), socio-cultural and economic challenges and values (UNESCO-UNEVOC, 2006).

2.1.1 Socio-Cultural Values

Education on sustainable development means to improve living conditions and enable people to defend their universal human rights. Therefore they must be informed on policies at all levels to prevent themselves from renouncement of those rights and hereby create an environment of peace and security

as a vital basis for sustainable development (UNESCO-UNEVOC, 2006). Not to redeem peace and freedom results in human tragedies of various kinds. This can only be avoided by promoting transparent governance, freedom of speech and a say in policy formulations (UNESCO-UNEVOC, 2006). Another valuable factor is the respect of gender equality. But not only the respect of the other gender, rather the understanding and respect of the needs and differences of each member of the society and culture is vital to fully develop each individual's potentials. The combination of cultural diversity and associated intercultural understanding creates many opportunities for sustainable development and education (ibid). Subsequently not only a safe environment but also a healthy population is a condition for sustainable development.

2.1.2 Environmental Values

Overpopulation and overexploitation of natural resources in combination with global warming and rural transformation are obstacles for a sustainable development of humanity and Earth's ecosystem. The increase in population rates naturally leads to higher demands in resources. Uncoordinated exploitation of resources and inadequate land use simply led to waste of resources as well as uneven distribution of vital resources. Further the industrial revolution, once raised us into a level of higher efficiency, now turns out to be our greatest challenge. The conduction of massive monocultures, urbanization and the pollution of various compartments of Earth's environment changed the conditions of the natural evolution of the climate. Societies now suffer under natural disasters like desertification and flooding. Once again, education can enable people to populate the land sustainably and learn how to prevent natural disasters.

The introduction of safe sanitation systems that would decrease the pollution and contamination of our environment play a vital part in the establishment of a sustainable and healthy lifestyle. Figure 1 shows an example for successful intervention in overall mortality and diarrhoea mortality by improving sanitation and water supply in Stockholm from 1878 to 1925 (Burström, B., et. al., 2005).

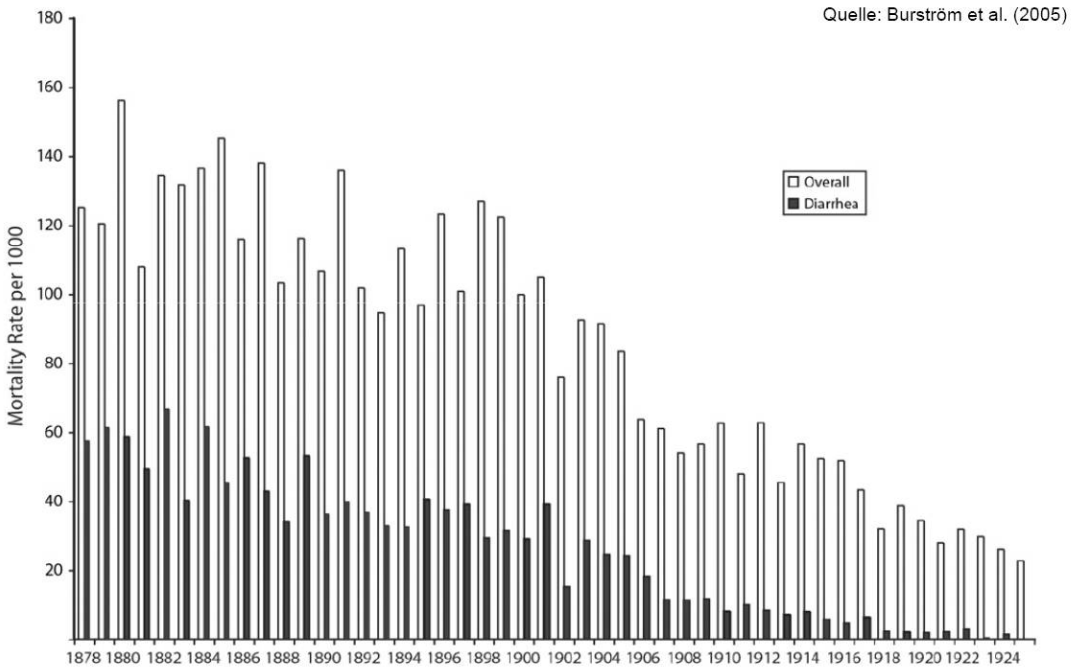

Figure 1. Overall mortality and diarrhoea mortality among children aged younger than 2 years: Stockholm, 1878 to 1925
(Source: Burström, et. al., 2005)

2.1.3 Economic Values

Globalization, which is a result of the industrial revolution, is now a huge network of communication, trade and transportation with all sorts of means. Since the evolution of globalization took place swiftly within times of political outrage, proper communication and logistics were not able to be established consistently. As a result unequal distribution of resources as well as unequal governance among other obstacles led in many regions to a huge gap between rich and poor. The market economy does not efficiently support equality in the world's population and hardly puts effort in environmental protection. Therefore corporate responsibility and reduction of poverty are the economic key factors to sustainable development.

As any other country it is Kenya's responsibility to alter the economic values to achieve social, environmental and economical sustainability. President Kibaki addressed the 26th session of the UNEP Governing Council and Global Ministerial Forum at Gigiri UN Complex offices, held from 21st to 24th of February 2011, stating that large scale investments have been made in renewable energy production such as geothermal and wind energy to secure low-carbon emissions in the future.

New sanitation systems that are build to run self sustained play a vital role in the lives of low income communities. Such sanitation facilities yield income through the collection of human wastes as well as through the transformation of those wastes into marketable products.

2.2 Challenges to Sustainable Development

2.2.1 Human Population Growth

Within the past decades humanity has experienced an extraordinary growth of population. To be more exact, the period of growth took a brief start in the 1950s, only to continue even more rapid in the 1960s and 1970s (UN-DESA, 2004). In numbers this means that around 1950 the earth was populated by about 2.5 billion people and only 50 years later by the year 2000 we already passed the 6 billion mark (Figure 2) (ibid).

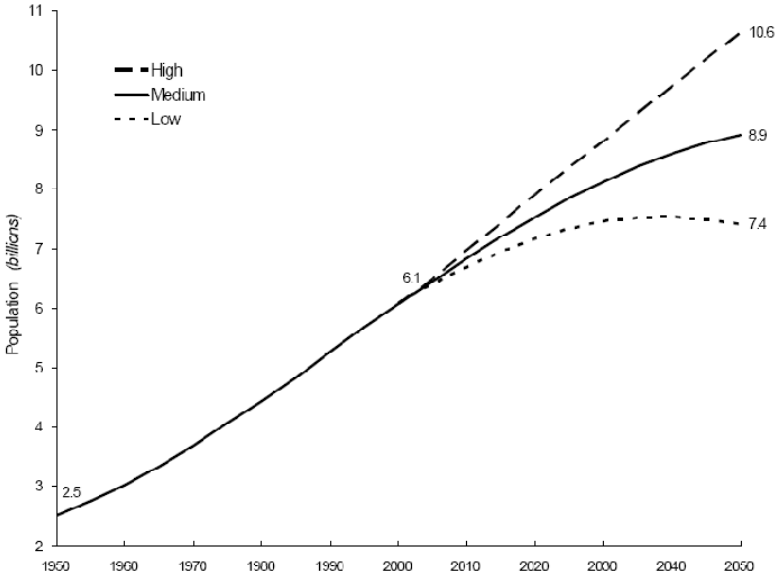

Figure 2. Estimated human world population, 1950-2000, and projections: 2000-2050
(Source: UN – Department of Economic and Social Affairs, 2004)

Assessments on the future development of human population growth vary extremely. In 2004 the United Nation carried out an assessment on this matter up to the year 2300 (UN – DESA, 2004). The report states that already by 2050 we could possibly reach 10.6 billion individuals, but alternative assumptions also suggest a possible population of 8.9 or 7.4 billion people. Due to the enormous rate of uncertainties any demographic projections after 2050 cannot be much more than guesses. Most often we can use the development of the past to project the trends for the future, but the sudden increase in human population aggravates guesses. In addition the developments are not uniform across the whole planet. Some countries such as Japan showed a decline in the birth rate, some others show an increase in life expectancy and further on society determines the size of a family. In developing countries the family size increases with sereneness of the state of poverty. Nowadays an incredible amount of people in the developing world are surviving with less than US $ 1.25 per day (World Bank, 2011). This fact leads to

malnutrition and poor health conditions. At the same time these circumstances come with unsafe sanitation.

In the last decades poverty drove an increasing number of the rural poor to move into the city in expectation to find a better job there and receive more income. For most of this people this dream of improved living conditions does not come true, on the contrary they fall even deeper into poverty, and as a result they spend their days in informal settlements of the cities, sharing a minimum of space, money and resources with an ever growing amount of other slum dwellers.

2.2.2 Carrying Capacity and Ecological Footprint

There are some scientific methods to describe the situation of balance or possible imbalance of biomass and life cycles. One of these methods is described by biologists as the carrying capacity (Santa-Barbara Family Foundation, 2003). It is defined as the maximum population of a given species that can survive indefinitely in a given environment. Therefore the carrying capacity shows the balance between the species consumption needs and the given resources. From this perspective many studies on the development of animal species have been carried out, resulting in two quite different patterns, which describe how various species reach the carrying capacity. One course of development is known as the sigmoid phenomenon (ibid), where a low population level starts to increase rapidly as long as the resources are abundant and then slow down as regulatory factors become relevant. At the point where the environment is able to sustain the population, the growth rate remains on a stable level. This pattern is also known as the K-selection species (ibid). Those species produce a low amount of offspring with a high chance of survival. Secondly, the r-selection species, describes the other pattern of reaching the carrying capacity which is similar in the beginning, but continues to rise, not responding to the same regulatory factors (ibid). As a result the population requires far more resources than the environment can provide. Finally mortality becomes the primary regulatory factor and the population collapses. These strategies of colonisation of a habitat can simply be described as quantity and quality orientated strategies. Figure 3 shows the graphical schema of the development of the two given types of species.

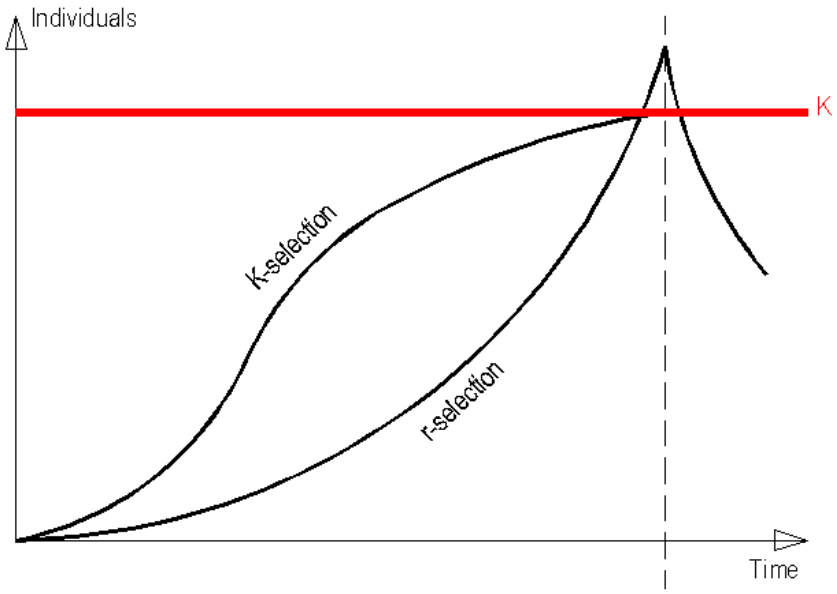

Figure 3. Graphical schema of the theory on carrying capacity
(adapted from Source: Santa-Barbara Family Foundation, 2003)

In terms of the human species it is obviously quite hard to assign such a pattern. If one considers the development of humanity as described in chapter 2.2.1, we follow the phenomenon of the r-selection species. But what tells us apart is the possibility to take a certain amount of control over our development. We are able to adapt and adjust our environment, causing advantageous as well as adverse effects for our environment as well as ourselves. We are able to learn from past actions and reactions by observation. Therefore we can readjust our lifestyle to regain the sustainability of our species. However, the more and more individuals come into being, uneducated on the effects of our current, consumption-orientated lifestyle, the harder it will get to turn the tide.

Similarly as the carrying capacity, the ecological footprint method compares the amount of consumed resources and generated waste to the nature's capability to decompose our waste and generate new resources in a certain time frame. Figure 4 shows the influences and correlations of the ecological footprint assessment (Global Footprint Network, 2010a).

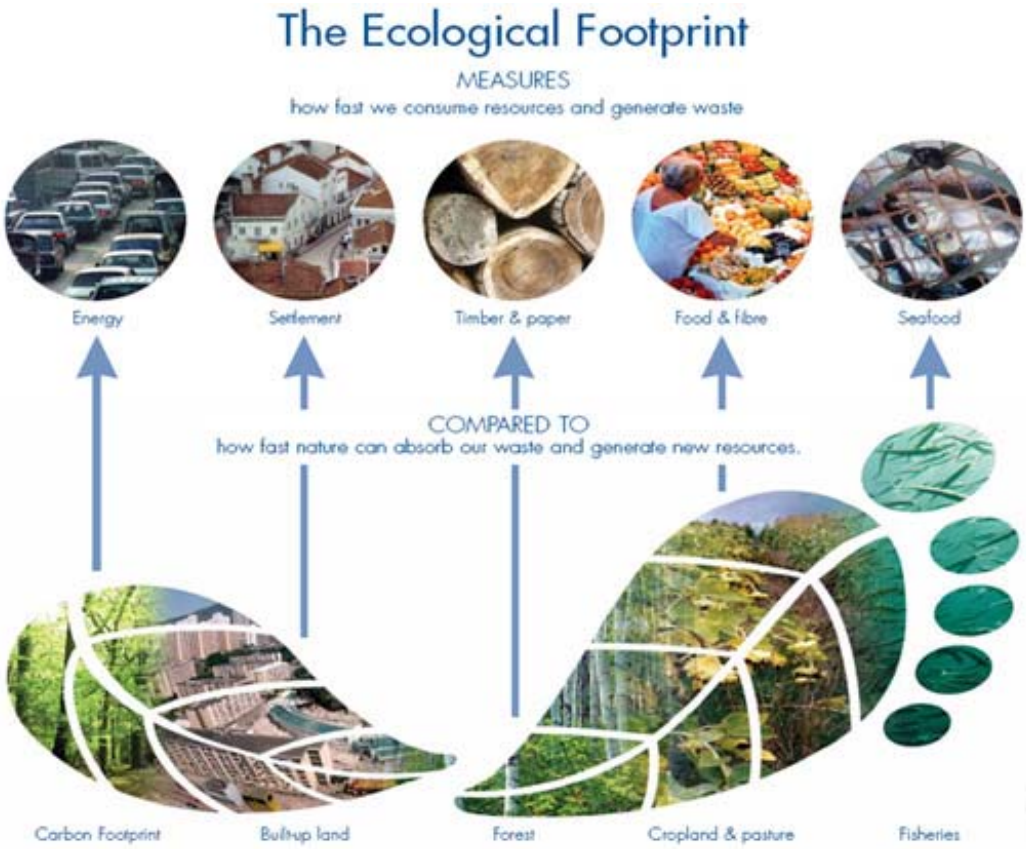

Figure 4. Influential factors of the ecological footprint assessment
(Source: Global Footprint Network, 2010a)

The assumption of the ecological footprint can be undertaken for a single human being, as well as for a community, a company or all of humanity. However, the assessment becomes more difficult the more extensive the system and the correlated factors become. The assessment describes the pressure that we put on our planet by the combination of overpopulation and consumption orientated lifestyle. Current estimates published by the Global Footprint Network (2010b) state that humanity uses the equivalent of 1.5 planets Earth, which means that it takes our planet 1.5 years to regenerate the resources that we claim within only one year. Based on the development of vast overshoot of consumption since the 1970s the United Nations conclude that by the 2030 we will extend our demand up to the equivalent of two Earths, which can be seen as quite a threat since we only have one.

One possible method to restore some of the used resources is to adapt sanitation technologies. Humans consume energy in form of nutrients and extract them after digestion. Sanitation systems in the developed world are usually centralized systems in which the nutrients that are still bound when the excreta get treated. In the treatment process most of the nutrients are extracted from the nutrient cycle. The aim is, to design sanitation technologies that collect the excreta and prepare them so that the nutrients are feasible to be returned into the nutrient cycle, and perhaps even yield other resources from the digestion of excreta such as biogas.

2.3 Global Frameworks to Sustainable Development

Legal frameworks and guidelines provide the necessities for uniform and standardized handling of all sorts of issues such as governmental decision making and construction works. However this chapter reveals legal frameworks for the sanitation and water supply sector on the international as well as the national level concerning Kenya. Additionally a comparison between the presented frameworks and the current situation in the two visited cities and the five visited informal settlements is presented and conclusions are drawn.

2.3.1 Agenda 21 and Rio Declaration

The United Nations Conference on Environment and Development (UNCED), which was held in Rio de Janeiro, Brazil, in 1992 delivered the Agenda 21 action plan related to sustainable development. 178 governments voted to adopt the program into their national legislation (United Nations, 2009). The action plan is divided into four main sections:

Section I: Social and Economic Dimensions

This section of the Agenda 21 by the United Nations (2009) aims to promote sustainability through trade, which should lead to the optimum use of recourses and distribution of goods in consonance with the ideals of sustainable development. Therefore consumptions patterns must be changed by identifying unsustainable production and consumption patterns. Further on trade and environment should be in accordance and support each other and therefore economic policies shall always include the principles of sustainable development. Also the poor must be enabled to achieve sustainable livelihoods, whilst demographic dynamics and differences must be considered and human health must be protected. Since the population of humans grew largely within the last centuries, sustainable settlements must be developed to stop further increase of the exploitation of the planets resources.

Section II: Conservation and Management of Resources for Development

The second section of Agenda 21 (United Nations, 2009) deals with the protection of the atmosphere and the environment to maintain the fragile ecosystem. The action plan includes the prevention of further deforestation, sustainable agriculture and rural development, conservation of biological diversity and protection of all environmental compartments of negative, unsustainable influences and their adverse effects.

Section III: Strengthening the Role of Major Groups

There shall be a global action to lead women and children of all cultures towards sustainability and

provide a legitimate environment for both genders (United Nations, 2009). Non-Governmental Organizations should become the ultimate partners in sustainable development and support local authorities in the establishment of Agenda 21 in their governance (ibid).

Section IV: Means of Implementation

Financial recourses and mechanisms, science, public awareness, education and training, national mechanisms and international co-operations for capacity building as well as international legal instruments and mechanisms, and information for decision making, are the key words and topics of this section (UNEP, 2009).

The result of this United Nations Conference on Environment and Development was the **Rio Declaration on Environment and Development**, which states the content of Agenda 21 in 27 principles.

Quite a number of these principles are applicable to the implementation of safe and sustainable sanitation systems. Particularly **principle 1**, which states that "*Human beings are at the centre of concerns for sustainable development. They are entitled to a healthy and productive life in harmony with nature.*" (UNEP, 1992) plays a considerable part in sustainable sanitation management. Some of the major health problems such as diarrhoea that occur in the developing world are related to unsafe sanitation and hygiene patterns. Therefore the human being that is living under such conditions cannot lead a healthy and productive life.

Further on the **third principle** indicates the right to development to "*meet environmental needs for the present and the future*" and therefore concerns the health and protection of ourselves, our children as well as our environment (UNEP, 1992).

The **fifth principle** refers to the eradication of poverty (UNEP, 1992). In developing countries poverty and poor sanitation go hand in hand. To improve hygienic conditions means to improve the health situation, whilst this results in an increase of labour force and reduction of poverty.

The general idea of a global partnership must also mean a global exchange of information and technologies as regarded to in **principle nine** (UNEP, 1992). Hence successfully implemented sanitation systems that had positive impacts on the lives of the poor must be accessible to everyone.

Additionally although the inclusion of all concerned people in the exchange of information a higher level of participatory work force can be gained and a more sustainable result achieved (**principle 10**) (UNEP, 1992).

Along goes the enacting of proper environmental legislation, that are reflect the priorities in environmental protection of each country and therefore amongst others build a legal framework for sanitation possibilities (principle 11) (UNEP, 1992).

The principles 17 and 23 of the Rio Declaration (UNEP, 1992) come into account when major decisions on the choice of sanitation systems are at hand. Natural limitations in resources and the impact of a sanitation system on those resources can be surveyed by undertaking an environmental impact assessment to avoid exploitation of valuable resources.

Due to their experiences and motivations the youth (principle 21) as well as indigenous people (principle 22) play a vital role when it comes to sustainable development and the successful establishment and maintenance of a sanitation system (UNEP, 1992).

Finally, principle 27 of the Rio Declaration (UNEP, 1992) reports that states and people must cooperate. Communities especially those in low income areas that lack the support of their legal authorities might not be able to lead sustainable healthy lives and naturally will not be able to maintain any facility whatsoever.

2.3.2 The Millennium Development Goals (MDG)

The United Nations Summit in 2000 released eight Millennium Development Goals to be globally achieved until 2015. The following sections list these eight goals and indicate some contents of the recent United Nations Millennium Development Goals Report 2010 that are closely related to the contents of this thesis.

GOAL 1 - ERADICATE EXTREME POVERTY AND HUNGER

Targets

1. Halve, between 1990 and 2015, the proportion of people whose income is less than US $ 1 a day (United Nations, 2010)
2. Achieve full and productive employment and decent work for all, including women and young people (United Nations, 2010)
3. Halve, between 1990 and 2015, the proportion of people who suffer from hunger (United Nations, 2010)

The Millennium Development Goals Report of 2010 by the United Nations states that in 2008 the World Bank adjusted the international poverty line up to US $ 1.25 per day per capita. Despite this adjustment, it was possible to decrease the poverty rate in developing countries from 46 per cent in

1990 to 27 per cent in 2005 (United Nations, 2010). But still the report states that it is expected that by 2015 about 920 million people would still live under the international poverty line. Additional the economic crisis has driven more workers into either unsecure employment or even unemployment. The report also mentions that the minimization of malnutrition of children under five years in sub-Saharan Africa and Northern Africa is now not only declining in urban areas but also even more rapidly in rural areas.

GOAL 2 - ACHIEVE UNIVERSAL PRIMARY EDUCATION

Target

1. Ensure that, by 2015, children everywhere, boys and girls alike, will be able to complete a full course of primary schooling (United Nations, 2010)

The proceedings of the United Nations (2010) state that the enrolment in facilities for primary education in the developing world has risen 7 per cent from 82 per cent in 2000 to 89 per cent in 2008. Nevertheless the global distributions of the national and regional percentages presented in the report are uneven, and results in an enrolment status of 90 per cent worldwide (ibid).

GOAL 3 - PROMOTE GENDER EQUALITY AND EMPOWER WOMEN

Target

1. Eliminate gender disparity in primary and secondary education, preferably by 2005, and in all levels of education, no later than 2015 (United Nations, 2010)

The gender gap presented in the ratio between male and female enrolment in educational facilities increases with the height of the education level. In 2008 in sub-Saharan Africa 91 girls per 100 boys enrolled in primary school, 79 girls per 100 boys in enrolled in secondary school and only 67 girls per 100 boys enrolled in tertiary school (United Nations, 2010).

Another gender gap is that women are overrepresented in some tertiary education studies such as social sciences, and underrepresented in other tertiary education studies such as engineering (United Nations, 2010). Income generating activities outside of the agricultural sector show a similar picture, where in sub-Saharan Africa only one women in three paid employees occupies a job apart from farming (ibid).

GOAL 4 - REDUCE CHILD MORTALITY

Target

1. Reduce by two thirds, between 1990 and 2015, the mortality rate of children under five (United Nations, 2010)

The main conclusion of the United Nations report on the Millennium Development Goals of 2010 is that child mortality is falling, but still not quick enough to meet the 2015 target. In 1990 sub-Saharan Africa 184 out of 1000 children died before they reached the age of five years, compared to 144 out of 1000 children that died in 2008 before their fifth birthday (United Nations, 2010). The United Nations MDG target for this region would be that not more than 61 children will have to face this fate in 2015 which requires a strong increase of preventive actions. The report also mentions that four major diseases, which are pneumonia, diarrhea, malaria and HIV/AIDS, are responsible for 43 per cent of all child deaths under five years of age worldwide in 2008. Therefore the United Nations (2010) advises a refocus on these diseases as well as ensuring proper nutrition to decrease the risk of death.

GOAL 5 - IMPROVE MATERNAL HEALTH

Targets

1. Reduce by three quarters, between 1990 and 2015, the maternal mortality ration (United Nations, 2010)
2. Achieve, by 2015, universal access to reproductive health (ibid)

The decrease of hunger plays an important role in the increase of maternal health. The United Nations (2010) report that giving birth is risky especially in Southern Asia and sub-Saharan Africa due to the lack of skilled care. Untreated diseases, abortions, obstruct labour and complications during pregnancy and childbirth are mentioned in the report to be the causes of maternal mortality. The report does not state any numbers concerning maternal mortality, and reasons with systematic underreporting and misreporting as causes for the challenges in the measuring. However, it presents numbers concerning the proportion of deliveries that are supported by skilled health personnel. In sub-Saharan Africa the proportion of 41 per cent such supported deliveries in 1990 rose up to 46 per cent in 2008. Additionally the inequality of health care between rich and poor is striking (ibid).

GOAL 6 - COMBAT HIV/AIDS, MALARIA AND OTHER DISEASES

Targets

1. Halt and begin to reverse, by 2015, the spread of HIV/AIDS (United Nations, 2010)
2. Achieve, by 2010, universal access to treatment for HIV/AIDS for all those who need it (ibid)
3. Halt and begin to reverse, by 2015, the incidence of malaria and other major diseases (ibid)

The United Nations (2010) report that the spreading of HIV/AIDS peaked in 1996 with about 3.5 million newly infected and the mortality rate caused by HIV/AIDS peaked in 2004 with about 2.2 million deaths. Nevertheless, the report also states that the number of people living with the virus is still increasing since medical support allows increasing life expectancy. The report also mentions that in 2008 out of a

global total of about 33.4 million people about 22.4 million lived with HIV/AIDS in sub-Saharan Africa.

According to the United Nations (2010) knowledge and understanding of HIV amongst young people is still lacking, and especially in sub-Saharan Africa the knowledge on the subject is depending on the wealth, which is reconfirmed by the disparities between rich and poor in condom use. However the report also indicates that amongst women aged 15 to 24 the acceptance of condoms as tool against the spreading of diseases has increased in Kenya from 25 per cent in 2000 to 40 per cent in 2007.

Sub-Saharan Africa was able to increase the access to treatment for HIV from 14 per cent in 2005 up to 43 per cent in 2008 (United Nations, 2010). In 2008 about 2.9 million people in this area received antiretroviral therapy, an increase of 39 per cent compared to the 2.1 million people with access to proper medication in 2007 (ibid).

Concerning the third target, the reduction of the spreading of malaria is accomplished by the increased production of mosquito nets. In Kenya in 2008 only 3 per cent of the population used insecticide-treated bed nets and not more than a year later already the percentage of users rose up to 46 per cent (United Nations, 2010). Still poverty is a limiting factor concerning the use of mosquito nets and malaria treatment.

GOAL 7 - ENSURE ENVIRONMENTAL SUSTAINABILITY

Targets

1. Integrate the principles of sustainable development into country policies and programs and reverse the loss of environmental resources (United Nations, 2010)
2. Reduce biodiversity loss, achieving, by 2010, a significant reduction in the rate of loss (ibid)
3. Halve, by 2015, the proportion of the population without sustainable access to safe drinking water and basic sanitation (ibid)
4. Achieve, by 2020, a significant improvement in the lives of at least 1000 million slum dwellers (ibid)

The drinking water target is about to be met until 2015, as stated by the United Nations (2010). The report states that in sub-Saharan Africa the percentage of population with access to safe drinking water increased from 49 per cent in 1990 up to 60 per cent in 2008. However another 13 per cent increase within the seven years until 2015 is necessary to meet the MDG target. Further on the report shows that only 47 per cent of the rural population compared to 92 per cent in urban areas of sub-Saharan Africa have access to safe drinking water.

The situation concerning sanitation in sub-Saharan Africa is presented by the report as far worse than the water supply situation. About 24 per cent of the rural population and 44 per cent of the urban

population has access to adequate and safe sanitation (United Nations, 2010).

GOAL 8 - DEVELOP A GLOBAL PARTNERSHIP FOR DEVELOPMENT

Targets

1. Develop further an open, rule-based, predictable, non-discriminatory trading and financial system (United Nations, 2010)
2. Address the special needs of least developed countries, landlocked countries and small island developing states (ibid)
3. Deal comprehensively with developing countries' debt (ibid)
4. In cooperation with pharmaceutical companies, provide access to affordable, essential drugs in developing countries (ibid)
5. In cooperation with the private sector, make available benefits of new technologies, especially ICTs (ibid)

The report (United Nations, 2010) reveals that even though the financial crises struck many of the globes economies, international aid is increasing. Still the report also mentions that only five donor countries managed to reach the UN target for official aid.

2.3.2.1 Connection between the Millennium Development Goals and Sanitation

Except for the goals two and eight, all those given objectives are obviously connected to the issue of water management and therefore clearly relevant to this thesis. But if we come back to systems thinking, all those goals are linked in some way. Diseases, gender inequality, poverty and hunger, education, environmental sustainability and child health are all issues with many separate influences but they also influence each other. For example the second goal that aims to guarantee a full course of primary schooling to all children by 2015 might on the first look not be connected to sanitation and water management. But a child, that has no access to safe drinking water and sanitation, or has to starve because of malnutrition, will less likely be able to succeed in acquiring any knowledge. Additionally education represents the tool to safe sanitation and water supply and ultimately to sustainable development (DSW, 2009). Proper education for women enables them to ensure their personal health as well as their children's well being. Further on the report states that higher education increases the knowledge on sexuality and prevention, which results in educated women conceiving halve as many children as uneducated women (DSW, 2009). For instance in Uganda a women with a higher education level had in average 4.4 children compared to a woman without any education who conceived on average 7.7 children (ibid).

2.3.3 Bellagio Principles

The Bellagio Principles deal with sustainability and sustainable development in sanitation and wastewater management in order to achieve the Millennium Development Goals, by proposing changes to sanitation practices and policies in four principles as follows (UNESCO, 2006):

Principle 1

Human dignity, quality of life and environmental security should be at the centre of the new approach, which should be responsive and accountable to needs and demands in the local setting:

- *Solutions should be tailored to the full spectrum of social, economic, health and environmental concerns.*
- *The household and community environment should be protected.*
- *The economic opportunities of waste recovery and use should be harnessed.*

Principle 2

In line with good governance principles decision-making should involve participation of all stakeholders, especially the consumers and providers of services.

- *Decision-making at all levels should be based on informed choices.*
- *Incentives for provision and consumption of services and facilities should be consistent with the overall goal and objective.*
- *Rights of consumers and providers should be balanced by responsibilities to the wider human community and environment.*

Principle 3

Waste should be considered a resource, and its management should be holistic and form part of integrated water resource, nutrient flow and waste management processes.

- *Inputs should be reduced so as to promote efficiency, as well as water and environmental security.*
- *Exports of waste should be minimized to promote efficiency and reduce the spread of pollution.*
- *Wastewater should be recycled and added to the water budget.*

Principle 4

The domain in which environmental sanitation problems are resolved should be kept to the minimum practicable size (household, community, town, district, catchment, city) and wastes diluted as little as possible.

- *Waste should be managed as close as possible to its source.*
- *Water should be minimally used to transport waste.*
- *Additional technologies for waste sanitisation and reuse should be developed.*

2.4 Gender

Socio-cultural aspects are a vital part in all considerations for sustainable development. In the matter of sanitation and water supply the gender aspects are of special importance, since it is mostly the women who are responsible for the provision of water. The term gender mainstreaming describes the attempt to make women's perspectives the same necessity in all concerns such as in political, social and economic spheres as men's (UN-HABITAT, 2006b). This was the result of the United Nations Third World Conference on Women in 1985 in Nairobi, Kenya.

2.4.1 Gender and the Millennium Development Goals

Women and girls are the primary responsible for the provision of water in their homes. This is why they feel the impact of inadequate water supply the most. At the same time men are seen as the managers and planers in the public domain, therefore the perspectives of women are not proportionally represented (UN-HABITAT, 2006b). Recognizing the needs, experiences and contributions of women is an extremely important part to achieve a pro-poor governance as stated in the UN-HABITAT (2006b) report. The basic ideology of gender mainstreaming is to achieve equity between the genders in all levels of society. In the water sector this demands a balance to access of information, the amount of physical work and financial contributions as well as access and control over the resources and benefits from them.

United Nations, *The Millennium Development Goals Report 2010*, 2010:

The third Millennium Development Goal aims to promote gender equality and the empowerment of women and targets to eliminate gender disparity in primary and secondary education until 2005 and in all levels of education no later than 2015. Though UN statistics from the school year 2007/2008 show that the development countries all together are approaching the goal of equal quota between girls and boys, still the fulfilment of the 2005 target has not been accomplished even yet (United Nations, 2010). Figure 5 and Figure 6 display the number of enrolled girls for every 100 boy for the primary and secondary education level as a comparison between the school years 1998/1999 and 2007/2008 (modified from United Nations, 2010).

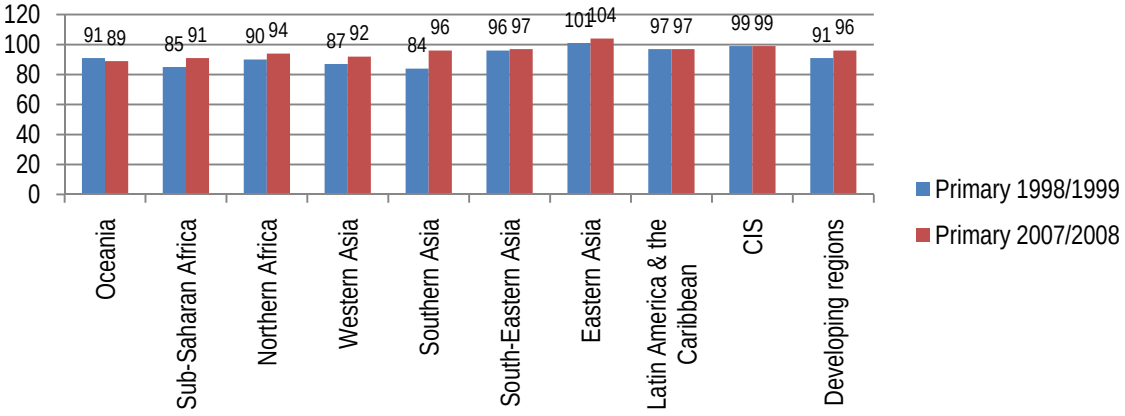

Figure 5. Number of girls enrolled in primary schools for every 100 boy in 1998/1999 and 2007/2008 (modified from Source: United Nations, 2010)

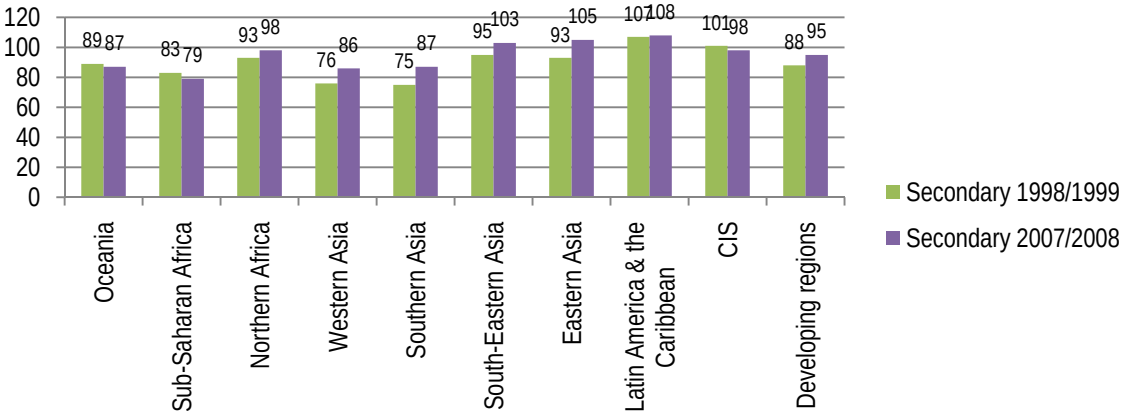

Figure 6. Number of girls enrolled in secondary schools for every 100 boy in 1998/1999 and 2007/2008 (modified from Source: United Nations, 2010)

The first and the second Millennium Development Goal are directly linked with each other, for poverty is the major reason for families to keep girls at home. This happens not only because of the costs for education, but also because of the lower status of women in society. Women and girls are responsible for the household and therefore also for the provision of water, which often becomes a very time consuming process. Improved water provision, meaning not only quality wise, but also concerning the walking distance would enable and encourage slum dwellers to allow their girls access to education. It is critical that governments invest in pro-poor and gender sensitive approaches when it comes to water and sanitation (UN-HABITAT, 2006b; UN-HABITAT, 2006c).

2.5 Poverty

Poverty is a term that is not only to be bound to monetary perspectives. It also resembles the lack of satisfaction of human needs, such as clean and fresh water in sufficient quantity as well as nutrition and education.

Poverty is not only affecting humanity. Our ecological system suffers poverty when it comes to natural diversity of the flora and fauna. In the last few decades many species had been extinguished, whilst the population of others had increased enormously.

Poverty can also be approached in a comparative way. The income of a group of people can be relatively low compared to the income of another group of people. In economics poverty is defined by the global poverty line, which also defines absolute poverty. The first case of relative poverty is very distinct in developing countries. The gap between the rich and the poor is extremely high. In extreme cases a person can suffer absolute poverty, but no relative poverty, for most of the country's population is poor.

The first Millennium Development Goal demands to eradicate extreme poverty and hunger, for at least halve the proportion of people who earn less than US $ 1.00 per day between 1990 and 2015 (United Nations, 2010). The latest report by the United Nations (2010) on the progress concerning the achievement of the Millennium Development Goals indicates a reduction in advance in poverty reduction due to the global economic crisis. Nevertheless the report also states that the target can still be met until 2015 and releases the percentage of people living with less than US $ 1.25 per day (Figure 7) as a comparison between the initial state in 1990 when the MDG were established, and the state in 2005. However to reach the target, the employment rate must raise, in fact this first MDG presses to provide decent work for all (ibid).

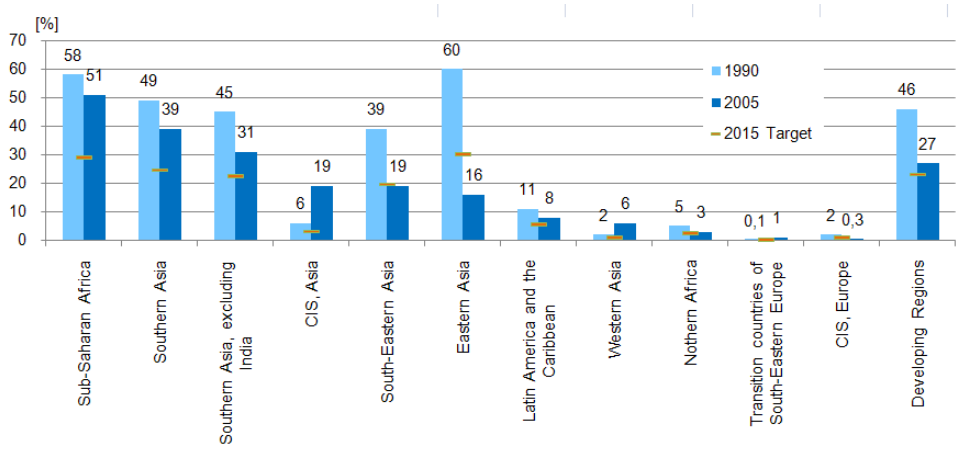

Figure 7. Proportion of people living with less than US $ 1.25 per day
(modified from Source: United Nations, 2010)

Some people live in poverty because of unawareness about their rights. For example, a person might get financial support by the government, but does never apply for it because he or she was never educated about the financial possibilities. Other people on the contrary choose to live in poverty. This decision can be related to religious or philosophical living adjustment.

There are many more different reasons for poverty and for its spreading. But fact is that poor sanitation is an issue that comes along with poverty. Water, soap, cleansing material, all these things have to be purchased and therefore require a certain amount of possessions. A person who can hardly afford to buy food and water will not think of spending money for any hygiene article. After some time, poverty and poor hygiene are followed by disease. And as the personal situation worsens, the possibility to find a job decreases and the person falls deeper into poverty. This cycle can only be broken by influences from outside. The establishment of sanitation facilities in informal settlements is one way to break this cycle and create new hope and opportunities.

3 Adaptive Sanitation in the Face of Sustainable Sanitation Management

3.1 Introduction

Climate change and global warming, which for instance result in increase of severity and frequency of floods and droughts, are presenting an environmental challenge to humanity. This chapter refers to the impact of global warming on Earth's ecosystem and resources. Further on alternative sanitation systems and the contributions that these sanitation systems can make to sustainable development and to a reduction of the exploitation of resources are presented.

3.2 Effects of Global Warming

Scientists do still not represent a united opinion on the questions of climate change and global warming and their existence. Nevertheless, if existing or not, it is part of the concept of sustainable development as well as an economic strategy to create systems to be adaptable and therefore resistant to changes in the conditions of operation. The next chapters describe the possible effects of a resource crisis and the adaptations in the sanitation sector that are possible to meet this resource crisis.

3.2.1 Resource Crisis

Global warming alters the proportions held in different water storages, but not its total volume. Nevertheless, it became harder and harder to predict water flows in their occurrence and their quantity (WHO, 2009). Therefore, sanitation that should be adaptable to the effects of climate change should be as independent as possible of water supply. In developed countries the disposal of human excreta normally requires an excessive amount of water due to the extensive implementation of centralized water-borne sanitation systems especially in the cities. Additionally it is the purpose of the concept of Integrated Water Resource Management (IWRM) to not only dispose of excreta, but put it to use again for the production of further biomass. Another challenge resource management in combination with population growth brings along is an increasing demand for energy but the decreasing availability of common resources to do so. In this point of view, the awareness of the effects of climate change, and global warming in specific, can be seen as an opportunity to adapt our technologies to these circumstances, where the readjustment of sanitation systems is amongst these opportunities, and develop more sustainable technologies. The key questions to be asked in sustainable sanitation

management are:

- What are the effects of climate change, and especially global warming, on water supply and sanitation, and how and where do they occur?
- How can technologies be optimized to adapt to climatic alterations and the shifting of resources and their availability?

3.3 Resource-Oriented Sanitation

3.3.1 Terms and Defintions on Sanitation

As defined by the World Health Organization (2011) sanitation refers to the provision of methods to safely dispose of human urine and excreta, for it is known by experience that improved sanitation has a positive impact on health in households and whole communities. Insufficient sanitation is a major cause of the breakout and spreading of diseases. To preserve a once accomplished hygienic condition, maintenance of the sanitation facilities is necessary. Further basic sanitation, according to the definition established at the UN World Summit on Sustainable Development (WSSD) in 2002, consists of the following key principles:

- *"Develop and implement efficient household sanitation systems;*
- *Improve sanitation in public institutions, especially schools;*
- *Promote safe hygiene practices;*
- *Promote education and outreach focused on children, as agents of behavioural change;*
- *Promote affordable and socially and culturally acceptable technologies and practices;*
- *Develop innovative financing and partnership mechanisms;*
- *Integrate sanitation into water resources management strategies"* (UN World Summit on Sustainable Development, 2002).

Poor sanitation habits are a serious threat to the cleanliness of the environment and have a significant impact on the cleanliness of the water bodies that supply us with fresh water. The fact that water scarcity might become an issue at some point is known for several decades, but only nowadays, when the threat became obvious this knowledge became common to people. Back in the year 1966 U.S. Representative Jim Wright claimed in his book "*The Coming Water Famine*"

> *"The crisis of our diminishing water resources is just as severe (if less obviously immediate) as any wartime crisis we have ever faced. Our survival is just as much at stake as it was at the time of Pearl Harbor, or the Argonne, or Gettysburg, or Saratoga."*
>
> (Wright, J., 1966)

In the same year U.S. Senator Edmund S. Muskie indicates in a speech that *"high quality water, in the right quantity at the right place at the right time, is essential to health, recreation, and economic growth"* (Muskie, 1966). Safe sanitation plays a vital role in the preservation of good water quality. Centralized, water-borne, sewer based sanitation systems are generally less resource recovery oriented sanitation systems than those presented in chapter 3.4.1, that can even pose threats to water bodies and fresh water sources.

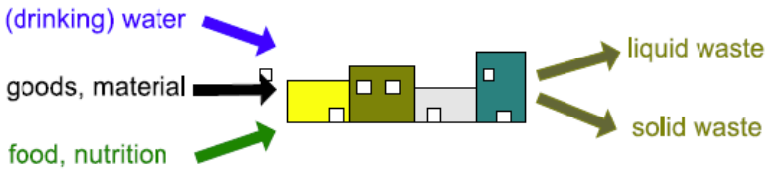

Figure 8. Linear flows in a conventional sanitation system
(Source: Langergraber, et. al., 2004)

Sanitation is a multi-stepped process that concerns the management of wastes and other products from the point of generation to the point of disposal or even better until the point of (re-)use. Figure 8 shows the input and output flows of conventional centralized sanitation systems (Langergraber, et. al., 2004). Products that can arise at the household level are listed and explained by Tilley et. al. (2008) as follows:

> Urine or Yellowwater is excreted from the body in liquid form and is in this context to be understood as pure of faeces or water. A human adult discharges about 500 Litres urine within a year, which might, depending on the diet, contain about 2 to 4 kg of nitrogen.
>
> Faeces are to be understood as semi-solid excrement without urine or water. Within a year a human produces about 50 Litres per year.
>
> Brownwater comprises of faeces and flushwater. It is generated by urine diverting flush toilets.
>
> Greywater is the total of water which is generated when washing food, clothes and dish ware, as well as bathing.
>
> Blackwater is a mixture of urine, faeces, flushwater, anal cleansing water (if anal cleansing is practiced) and dry cleansing material, such as toilet paper.

3.3.2 The Concept of Resource-Oriented Sanitation

As a result of the precedent developments described in chapter 3.2, a resource-oriented approach is favoured. Therefore waste water must be seen as a resource and not simply as waste, which is also demanded by the third Bellagio Principle. Human excreta are the result of nutrition ingestion and digestion and they remain in the water, nutrient, material and energy cycles (Mutua, 2008), which

makes it possible to recover some of the nutrient and energy from the waste water. Figure 9 shows the nutrient and water flows as a loop between different sections of use within a human settlement according to the concept of sustainability in sanitation and water management (Conradin, et. al., 2010).

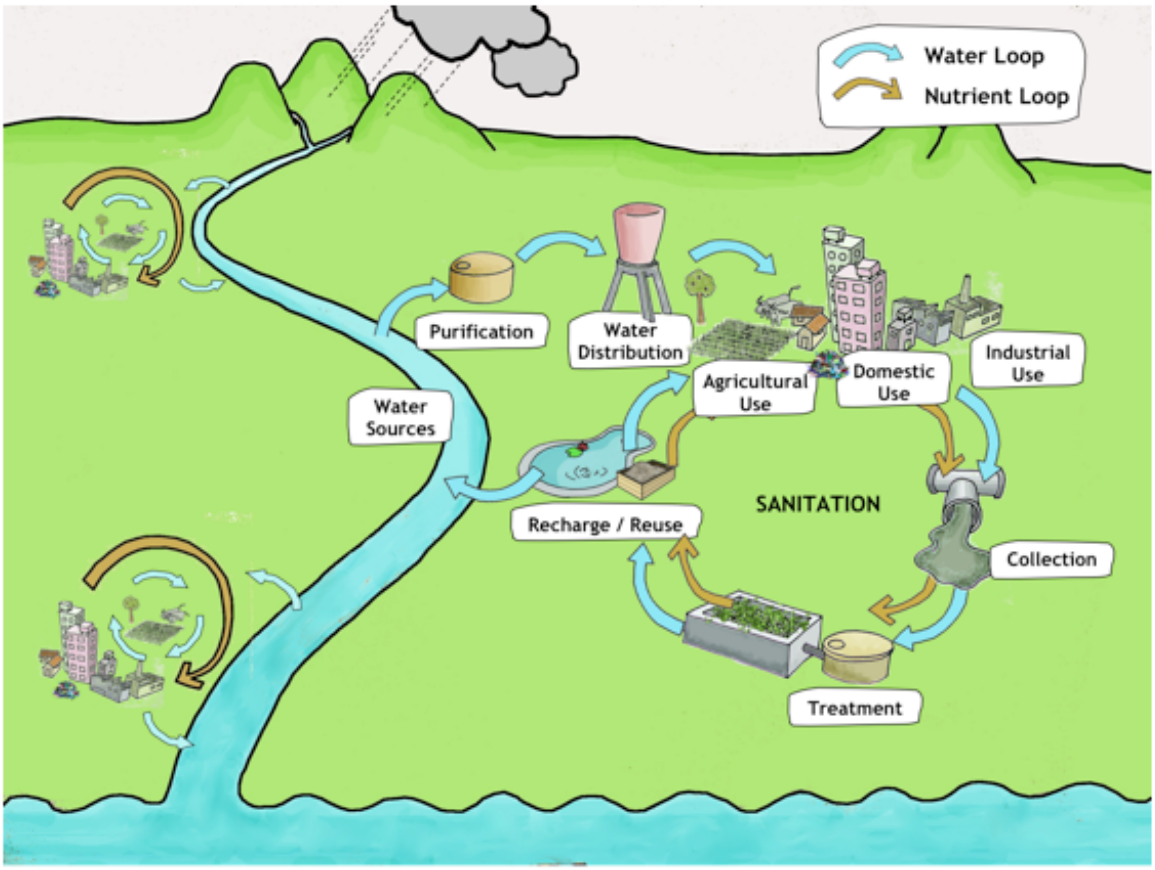

Figure 9. Sustainable sanitation and water management loop
(Source: Conradin, et. al., 2010)

The loop described in Figure 9 shows the stages of a water cycle in an urban settlement. The given loop includes a centralized sewerage system with waste water treatment. The aim that is presented in this research is to recover as many resources and to be as energy neutral as possible for which reason a centralized waste water treatment is not considered an option, since the treatment process requires a lot of energy and additionally leads to a loss of nutrients and therefore to a loss of resources.

A resource oriented approach to sanitation can deliver liquid for irrigation in the form of urine, fertilizer in the form of degenerated faeces and biogas for cooking and heating as well as the generation of electricity by the collection methane gas which is a product of faecal degeneration. In all the informal settlements that are subject to this research at least one of those resources is scarce.

To understand the concept of resource-oriented sanitation it is helpful to understand the products that are part of the sanitary flow stream in their chemical and physical characteristics (Table 1).

Table 1. Characteristics of flow streams
(United Nations Educational Scientific and Cultural Organization, 2006)

Fraction	General characteristics
Faeces	- Hygienically critical, potentially containing a series/array of pathogens, leading to water-borne diseases (e.g. bacteria, viruses, protozoa, nematodes, worm eggs) - Consists of organics, nutrients and trace elements - Improves soil quality and increases its water retention capacity - Average production ca. 50 kg/cap/a - Consists mainly of organics submitted to decomposition processes and a minor proportion of nutrients
Urine	- Hygienically uncritical - Contains the largest proportion of nutrients available to plants - May contain hormones or medical residues - Average production ca. 500 l/cap/a - Consists mainly of nutrients available to plants and very little organics, therefore no need for stabilisation
Grey water	- Usually no major hygienic concern - Volumetrically the largest portion of waste water - Contains usually almost no nutrients (simplified treatment) - May contain a vast range of various substances - Average production 25 – 100 m^3/cap/a

3.4 Sanitation Technologies

In the following section the current state of technology of sustainable sanitation technologies are catalogued to deliver an overview of the possibilities in management of human excreta and the management of the reuse or disposal those wastes. There are a couple of methods to differentiate toilet systems. One of the first differentiations can be made between waterless systems such as the dry toilet (dry systems), and toilets that include the input of water (wet systems). Another differentiation can be made between single pit and double pit toilets as well as toilets that do not require a pit at all. The content of Table 2 shows a differentiation of the toilet systems by the amount of pits used and gives some examples for each type.

Table 2. Toilet differentiation by number of pits
(adapted from Source: Conradin, et. al., 2010)

Without Pit	Single Pit	Double Pit
Urine Diverting Dry Toilet	Arborloo	Fossa Alterna
Terra Preta Toilet	Ventilated Improved Pit Toilet (Single VIP)	Ventilated Improved Pit Toilet (Double VIP)
Composting Toilet		
PeePoo Bag		

Further on these toilet systems can be alternated depending on the choice of user interface such as described by Tilley et al (2008):

- Simple Concrete Slap
- Pour Flush Toilet
- Low-Flush Toilet
- Flush Toilet
- Urinal
- Waterless Urinal
- Urine Diversion Dry Toilet
- Urine Diversion Flush Toilet
- Vacuum Toilet

The choice of sanitation system depends on various factors, such as technical and environmental factors, as well as institutional and community factors. The content of Table 3 indicates those four factors and some the considerations that have to be made beforehand to the establishment of a new sanitation facility (Muthoni Kagiri E., 2008).

Table 3. Guideline for the implementation of sanitation technologies
(Source: Muthoni Kagiri, 2008)

Factors of general relevance	Factors specifically relevant to Operation and Maintenance
Technical Factors	
- Design preference (substructure, floor slab, squatting or raised seat, superstructure) - Technical standards and expected lifetime of the technology - Availability of construction materials - Cost of construction	- Operation and management requirements - ease of access - use of decomposed waste - Pit-emptying technique.
Environmental Factors	
- Soil texture, stability, permeability - Groundwater level contamination - Control of environmental pollution - Availability of water - Possibility of flooding	- Operation and management implications for environmental protection - protection against groundwater - protection from flooding
Institutional Factors	
- Existing national/local strategies - Roles and responsibilities of actors implied - Training capacity - Availability of subsidies and loans - Availability of masons, carpenters, plumbers, sanitary workers, pit-emptiers and pit-diggers	- pit-emptying services (municipal/private) - sewerage maintenance capacity - potential involvement of the private sector - national budget allocations for sanitation - training and awareness education - monitoring
Community Factors	
- Socio-cultural aspects: taboos, traditional habits, religious rules and regulations, cleansing material, preferred posture, attitude to human faeces, gender-specific requirements - Motivational aspects: convenience, comfort, accessibility, privacy, status and prestige, health - Discouraging factors: darkness, fear of falling in the hole, or of the pit collapsing, or of being seen from outside, smells; insect nuisance - Social organization factors: role of traditional leadership, religious leaders, schoolteachers, community-based health workers - Other factors: population densities, limited	- Operation and management costs - Operation and management training and awareness for sanitation - health awareness and perception of benefits - presence of environmental sanitation committee - women's groups - social mobilization on hygiene and sanitation - environmental cleanliness, ownership; behaviour

The following two sections list and describe sanitation technologies that can be used as dry toilets without a pit, single or double pit, and others that are used as wet sanitation systems.

3.4.1 Dry Toilet

According to Tilley et. al. (2008) the input in the dry toilet includes urine, faeces and anal cleansing water. The dry toilet generally works without water, though the input of anal cleansing water can be accepted (ibid). This system requires to a device on which the user can either sit or squat on and where the excretions (urine and faeces) fall into a hole. In case this device is used for an alternating double pit system, the toilet slap must be designed to be portable from one pit to the other. To avoid overflow it is important that storm water shall not get into the pit. Depending on the input material the following sanitation systems can be arranged as dry toilets:

- Urine Diverting Dry Toilet (ecosan system)
- PeePoo Bag
- Single Pit Toilet
    - Arborloo
    - Single Ventilated Improved Pit Toilet
- Doubled Pit Toilet
    - Fossa Alterna
    - Double Ventilated Improved Pit Toilet

According to the Compendium of Sanitation Systems and Technologies by Tilley et. al. (2008) the use or disposal of the waste products depend on the actual toilet system that has been chosen. The report states that for instance in the case of Arborloos, which is basically a special form of the single pit toilet, after the pit is almost completely filled with excreta the rest of the pit will be filled and covered with soil and then abandoned. Further on the report mentions the fossa alterna where the faecal sludge (blackwater) is undertaking a treatment process while the second pit is in use. After the second pit is filled the treated sludge of the first pit can be used for agricultural purposes. The report also states that the same counts for the urine diverting dry toilet, where urine can be used as irrigation liquid and the treated faeces serve as fertilizer.

A problem with dry toilet systems is that they demand a certain discipline in terms of behaviour in use than wet systems if they are to fulfil all of their purposes. For this reason it is necessary that the user is able to understand what is expected of him and what kind of benefits the system can offer if used correctly (Water and Sanitation Program-South Asia, et. al., 2008).

A special form of dry sanitation is promoted as ecological sanitation, also known as ecosan (Water and Sanitation Program-South Asia, et. al., 2008). This sanitation system involves the separation of faeces and urine at source and therefore allows the reuse of excreta for soil improvement and urine as fertilizer for agricultural irrigation (ibid). Another advantage is the reduced amount of water demand for flushing and as a result a reduction of wastewater. Nevertheless the most important advantage of this system is the improved recycling of nutrients that are otherwise lost in other sanitation technologies such as conventional centralized sanitation technologies.

Table 4 shows the output of ecosan systems and the required treatment processes to achieve almost complete recovery of nutrients, energy and trace elements, as well as the possible usages of these recovered resources (United Nations Educational Scientific and Cultural Organization, 2006).

Table 4. Separation of substances and examples of possible ecosan elements (GTZ)
(Source: United Nations Educational Scientific and Cultural Organization, 2006)

Substances	Urine (yellow water)	Faeces (brown water)	Greywater	rainwater	Organic waste
Treatment	Hygienization by storage or drying	Anaerobic digestion, Drying, Composting	Constructed wetlands, gardening, wastewater ponds, biological treatment, membrane-technology	Filtration, Biological treatment	Composting, Anaerobic digestion
Utilization	Liquid or dry fertilizer	Biogas, Soil improvement	Irrigation, groundwater recharge, Direct reuse	Water supply, Groundwater recharge	Soil improvement, biogas

3.4.1.1 Sanitation Systems without Pits

Sanitation systems that are constructed without pits have the advantage that contamination of groundwater is less likely than for sanitation systems with pits (Conradin et. al., 2010). Therefore possible high groundwater tables do not necessarily limit the volume of the excreta storage. In conventional systems with vaults the removal of excreta is assuaged since the vaults are not reaching several meters below ground level and are not as deep as a pit. Nevertheless, conventional vault systems may require an increased surface area compared to pit toilets to create a reasonable storage volume. Additionally the elevation above ground level requires stairs to bridge the high difference, which

makes it difficult to reach for children, disabled and elderly people. An exception is presented by the PeePoo bag, which is simply supported by a plastic bottle, but has the disadvantage of transport of not yet hygienized excreta to a separate storage site (www.peepoople.com).

Further on sanitation systems with urine separation are especially useful in areas where fertilizers and soil improvement is required as it is in rural areas or for urban agriculture (Conradin et. al., 2010). Anyhow, the end products of composting can be collected and sold and therefore represent an opportunity for income generation.

3.4.1.1.1 Urine Diverting Dry Toilet

Additionally to the casual dry toilet system, the urine diverting dry toilet is designed to separate urine and faeces which makes it part of the ecosan practices (UNESCO, 2006). It is highly important that the faeces remain dry therefore also anal cleansing water must be separated from the faeces (Tilley et. al., 2008). The report by WaterAid (2008) identifies two different types of urine diverting dry toilets, the single- and the double-vault UDDT. For both systems the report states that the single- or double-vault for the faeces is constructed as a watertight chamber and a jerry can serves as storage tank for urine. To enable the removal of the compost the vaults need to have openings (WaterAid, 2008). Conradin et. al. (2010) propose to support the drying process of the faeces by constructing the cover flap of the openings with metal sheets which will heat up due to absorption of sunlight. Figure 10 shows a sketch of the urine diverting dry toilet system.

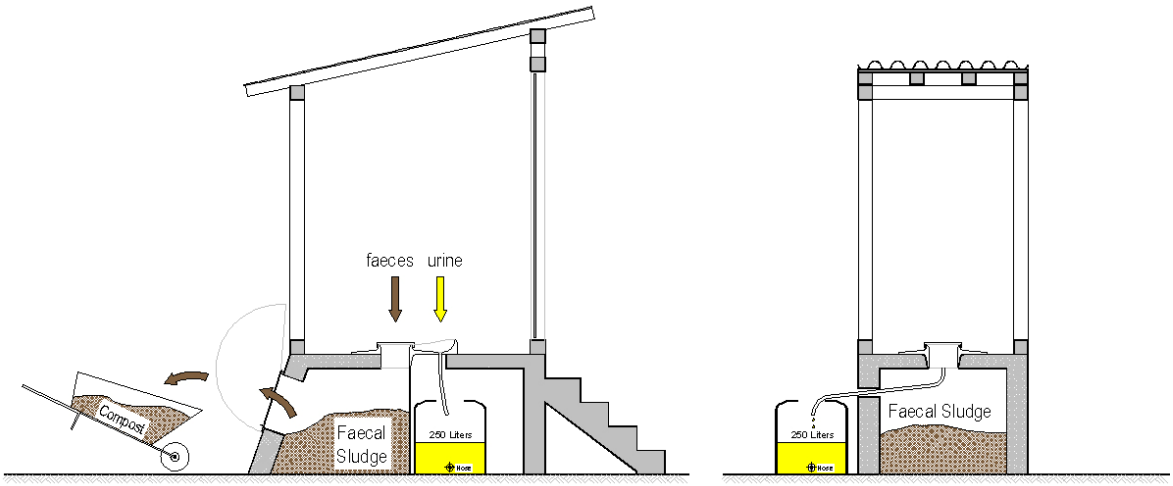

Figure 10. Urine Diverting Dry Toilet
(adapted from Source: Conradin, et. al., 2010)

3.4.1.1.2 Terra Preta Toilet

According to the SSWM Toolbox (Conradin et. al., 2010) this dry toilet system aims to produce fertile soil close to the properties of Terra Preta. In this toolbox it is also mentioned that this sanitation system

is based on urine diversion, lacto-fermentation, vermi-composting and the addition of charcoal. It is also reported that the most important criteria for the storage tank as well as the toilet seat is air-thickness to allow anaerobic conditions for the lacto-fermentation. However, the opening and closing of the toilet cover will allow for some air to enter the system. The addition of charcoal after every use reduces the development of odour and delivers stable organic matter for the soil production (Conradin et. al., 2010). To support the lacto-fermentation the addition of lacto-bacilli can be added (ibid). In order to provide feasible living conditions for the earthworms and microorganisms oxygen is require for which reason the vermi-composting process is an aerobic decomposition process that is undertaken by earthworms and microorganisms (Dickerson, 2001). Figure 11 shows the structure of a Terra Preta toilet including the input and output, as well as the processes necessary to put the excreta into use.

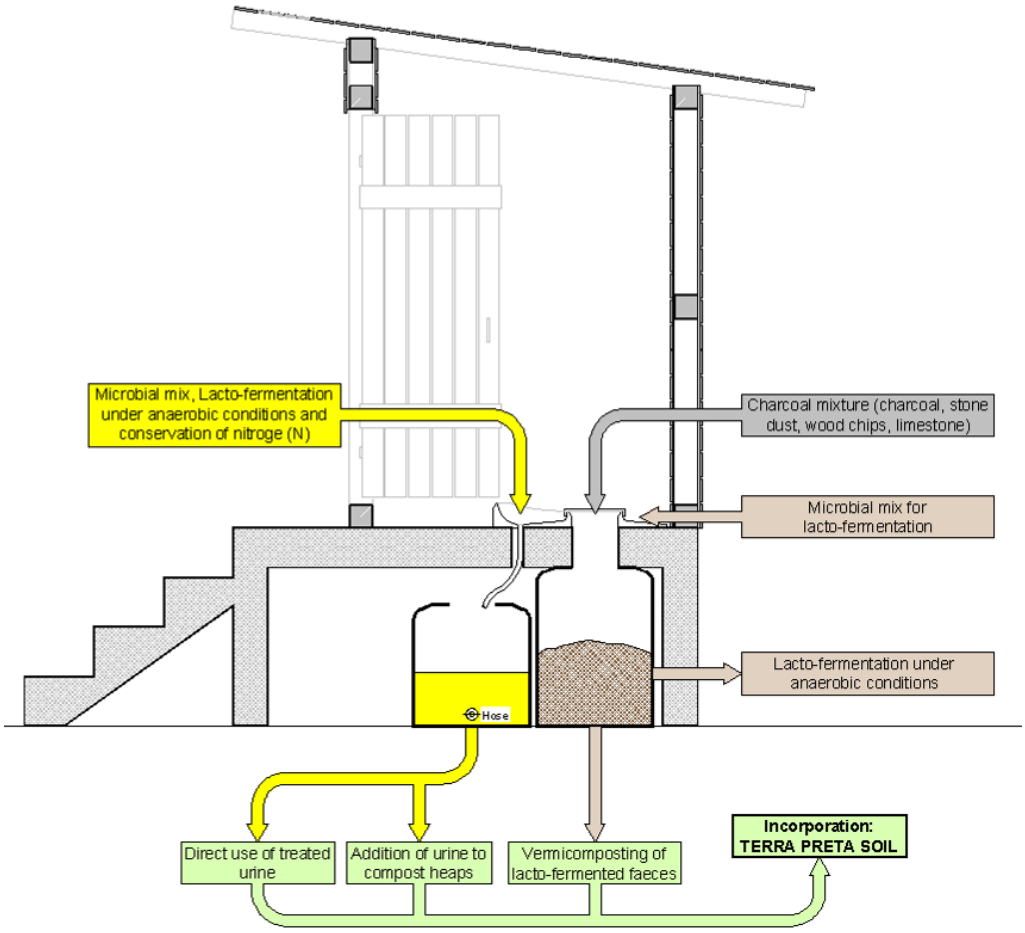

Figure 11. Input, output and processes of a Terra Preta toilet
(adapted from Source: Conradin, et. al., 2010)

This sanitation facility requires qualified user participation to create the end product that is aspired. In community-shared sanitation blocks with a variety of users, education activities are necessary to allow the system to be successful, but the highest responsibility lies with the caretaker of the facility to ensure that the required materials for composting are added and that the required anaerobic conditions remain.

3.4.1.1.3 Composting Toilet

Faeces are collected in a composting chamber, anal cleansing materials and organic household wastes can also be added (Conradin et. al., 2010). Since urine and anal cleansing water as well as the moisture of the organic wastes soak the excreta material, it is important to add dry organic materials such as sawdust to adjust the moisture of the material and therefore reduce the development of odour and the attraction of insects (Conradin et. al., 2010). The end product of the aerobic thermophilic composting process is humus-like soil which is useful to improve the fertility and structure of the soil (ibid). Additionally Conradin et. al. (2010) mentions that urine can be diverted, which decreases the humidity of the compost, and used separately.

3.4.1.1.4 PeePoo Bag

On the Peepoople Homepage (www.peepoople.com) it is reported that the PeePoo bag is a slim bag for single use and represents a safer option to the flying toilet. The bag is filled with urea powder, which is a non-hazardous chemical that together with enzymes in the faeces undertakes a breakdown of the excreta into ammonia and carbonate. Depending on the surrounding temperature the bacteria that are responsible for diseases are inactivated within two to four weeks. The bag itself is a degradable bioplastic and breaks down into carbon dioxide, water and bio-mass. The end product of the degeneration of the excreta can be used as a fertilizer.

Figure 12 a - e. Usage instructions: a) and b) Bring out and develop the protecting gauze, c) Place in a cut PET-bottle or a small bucket, d) close the gauze after use, e) secure the bag with a knot
(Source: http://www.peepoople.com)

The bag can be held with the hands and used sitting, squatting or standing, and the gauze prevents contact with the excreta. Apart from that, the bag also fits into cut plastic bottles and small buckets. Figure 12 shows the steps of handling of the PeePoo bag before and after use as shown on the PeePoople Homepage.

3.4.1.2 Single Pit Toilet

This system can be used with water or as a dry toilet, depending on the local water availability and habits (Tilley et. al., 2008). It is used to collect and store excreta. Depending on the choice of user interface, the inputs to the system can be urine, faeces, anal cleansing water, flush water and dry cleansing material (ibid).

The single pit toilet basically consists of a pit, the latrine superstructure and a slap with a hole and is therefore very cheap in construction. The pit should be deep enough to last as long as possible, where as a design life of about 25 to 30 years is reasonable (Conradin et. al., 2010). According to Conradin et. al. (2010) the depth should be at least two meters, but the groundwater table is a natural limit that must be considered to avoid contamination of potable water.

According to Tilley et. al. (2008) dry anal cleansing is advantageous to minimize water content. To prevent people from falling into the pit and increase convenience and reduce odour, a slab with a hole should be used to cover the pit, additionally a toilet seat can be installed over the slab. As the pit fills, two processes limit the rate of accumulation, which are leaching of the liquid input and degradation of the solid organic input (ibid).

3.4.1.2.1 Arborloo

The Arborloo is a single pit or single ventilated improved toilet that will simply be filled and covered with soil, if it cannot be emptied (Tilley et. al., 2008). This does not deliver any benefits in resources, nevertheless as stated by Tilley et. al. (2008) this action bans health risks.

To build an Arborloo basically means that the concrete slap and the superstructure must be build in a way so that they can be continuously moved from one site to the next. According to Tilley et. al. (2008) the concept of the Arborloo includes that after the pit is filled a tree is planted on the site. Tilley et. al. (2008) proposes that the pit is usually dug about 1 meter deep and not lined, so that the tree can grow properly. After defecation a cup of soil or ash should be put into the pit to cover the excreta and prevent the diversion of odour and therefore avoid the attraction of flies. The addition of soil and ashes also helps the faecal sludge to compost faster than without it. Figure 13 shows the sections of a Arborloo in the use and after filling of the pit.

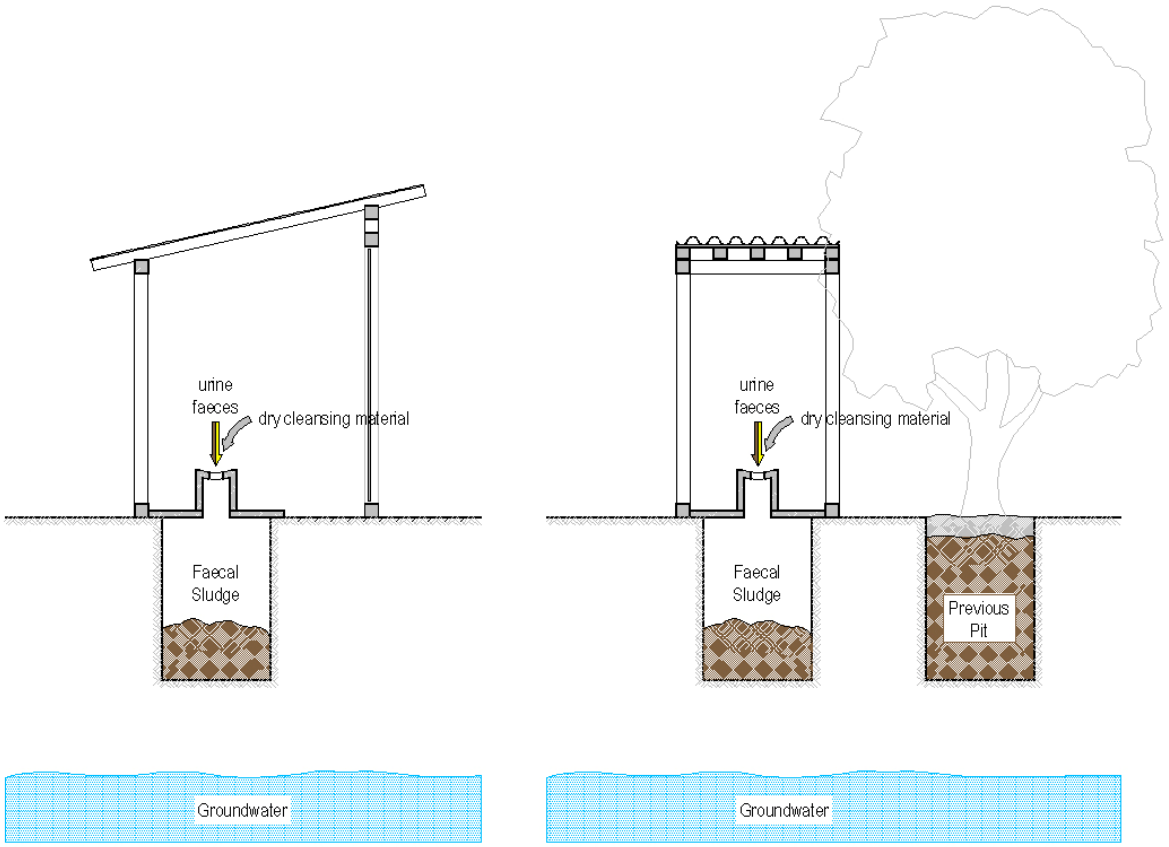

Figure 13. The Arborloo principle
(adapted from source: Tilley, et. al., 2008)

In the Compendium of Sanitation Systems and Technologies (Tilley et. al., 2008) it is mentioned that the constant reconstruction of the single pit toilet on a new location is more labour intensive than cost intensive, but still a lot of space is required. Also the necessity that the groundwater table is deep enough so that no danger of contamination occurs is mentioned in the report. An advantage stated in the report is the possibility for income generating activities, since the location of a previously used pit is due to the compost very fertile for which reason fruits and vegetables can be grown and sold.

3.4.1.2.2 Single Ventilated Improved Pit Toilet

Using a ventilation pipe the single ventilated improved pit toilets can be completely free of disturbing smells. Flies that get into the pit try to escape through the ventilation pipe and get trapped in the fly-screen and die (Tilley et. al., 2008). The ventilation works best in windy areas, but by painting the pipe black a greater heat difference between pit and pipe will create an updraft that pulls air up the pipe (ibid). Figure 14 shows two sections of a single ventilated improved pit toilet.

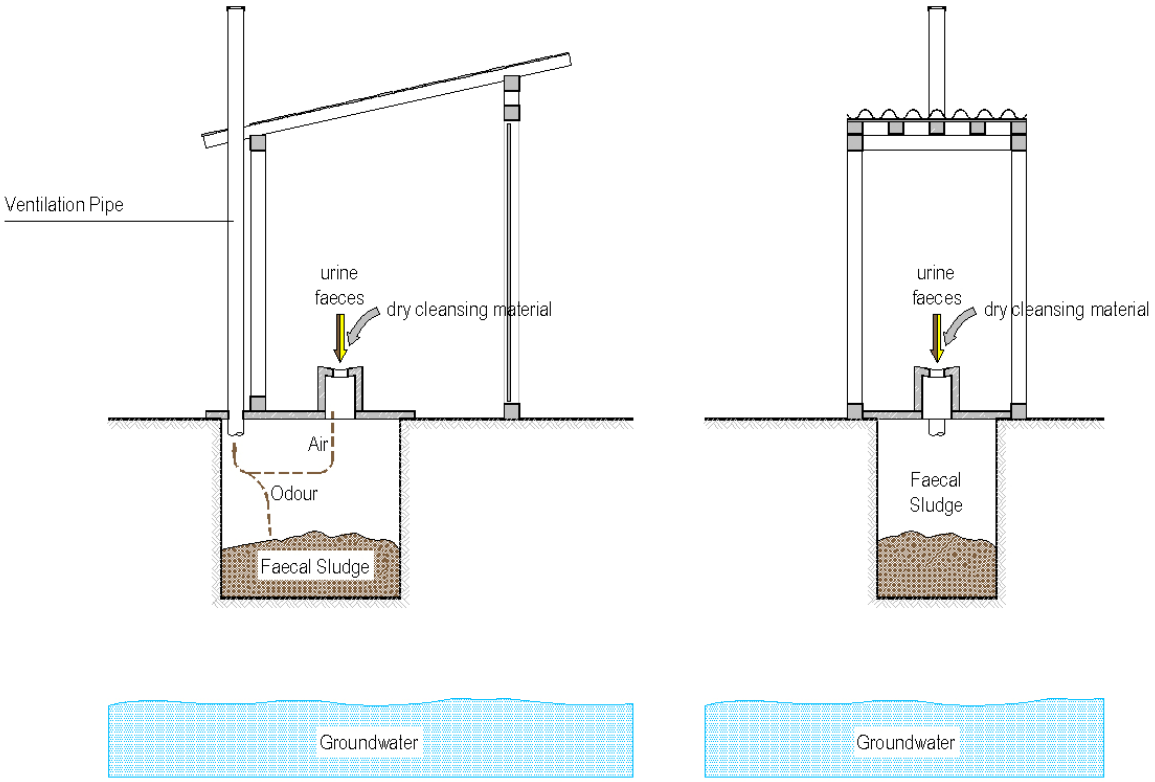

Figure 14 Single Ventilated Improved Pit Toilet
(adapted from source: Tilley, et. al., 2008)

The pit should have a diameter between 1 and 1.5 meters and a depth of at least 3 meters (Tilley et. al., 2008). The concrete slap and the superstructure do not have to be removable, for the pit is designed to last up to 20 years or even more, depending on its depth (ibid). The Compendium of Sanitation Systems and Technologies (Tilley et. al., 2008) mentions that effluents from the faecal sludge leaches from the pit into unsaturated soils and transports faecal organisms that are removed along the way. In addition the report states that the necessary distance for the removal of faecal organisms depends on the soil type, moisture, degree of pollution of the effluent and so on. It might be difficult to decide the necessary distance to a water source on site, but in the report it is proposed that a minimum distance of 30 meters should be kept.

The single VIP can be upgraded to a double VIP or a urine diverting dry toilet (UDDT), as well as a pour flush toilet, where as the first two improvements are based on the dry toilet system and the third system is water-based (Tilley, et. al., 2008).

3.4.1.3 Double Pit Toilet

3.4.1.3.1 Fossa Alterna

The Compendium of Sanitation Systems and Technologies (Tilley et. al., 2008) describes the fossa alterna as a dry toilet system, with alternating pits, in which only one pit is used at a time as to be seen

in Figure 15. The system is designed to produce compost, which is a hygienized earth-like material, rich in nutrients and organic matter, for safe use in agriculture (ibid).

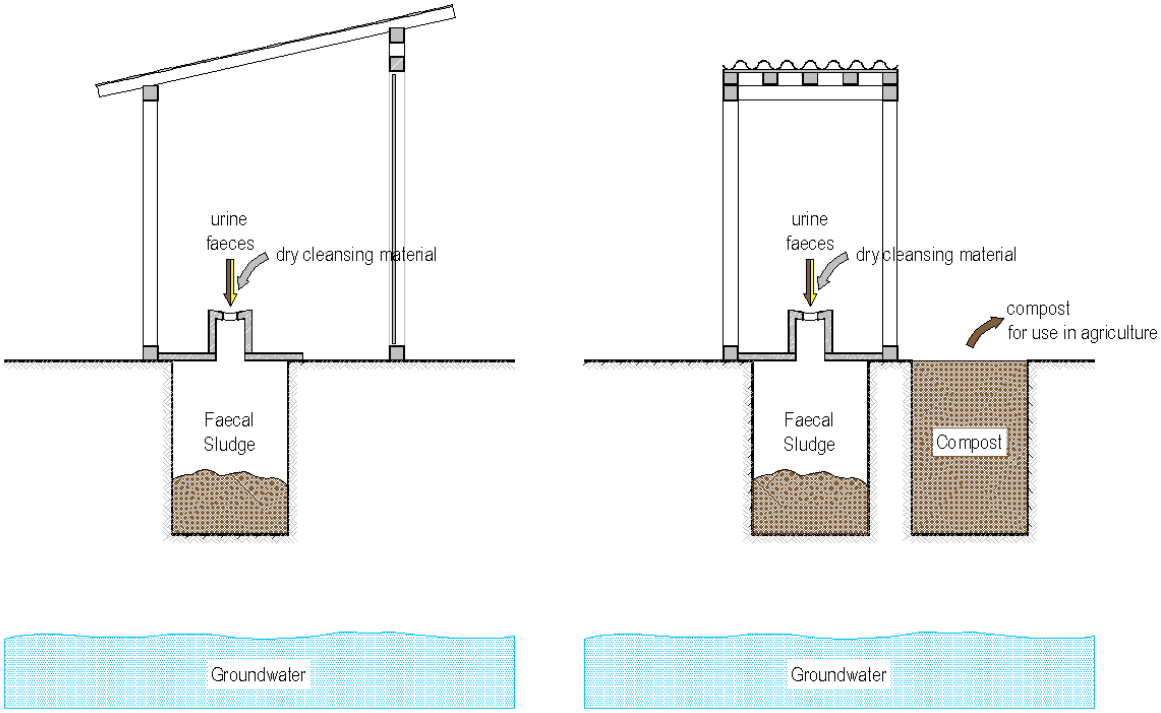

Figure 15. Fossa Alterna
(adapted from source: Tilley, et. al., 2008)

In order to prepare the earth to take up the liquid input, leaves should be placed on the ground of the pit. The input in the fossa alterna consists of urine, faeces, and dry cleansing material, as well as soil, ash and leaves after defecation, but not after urination (Tilley et. al., 2008). With the adding of soil and leaves pore space is increased, which allows anaerobic conditions, additionally a great variety of organisms are applied with the material, which help in the degradation process (ibid). The ash reduces odours and therefore keeps insects away. Water should not be added for it encourages the development of pathogens, and at the same time it would fill the pore space required for anaerobic degradation (Tilley et. al., 2008).

After the first pit is filled, usually within 12 to 24 months as stated by Tilley et. al., (2008), depending on its volume and the amount of users, the superstructure and the concrete slap are moved to the second pit. Within the time the second pit is in use, the material in the first pit can degrade to compost, and as soon as the second pit is filled, the first pit, now filled with compost can be emptied and reused, whilst in the second pit the faecal sludge is left for degradation (ibid).

3.4.1.3.2 Double Ventilated Improved Pit Toilet

The double VIP works the same way as the Fossa Alterna in combination with the advantages of the single VIP. Again the second pit can be used after the first pit is filled. Until the second pit gets filled up,

the material in the first pit can rest and degrade where as the resting time should be at least one year to sanitize the material (Tilley et. al., 2008). The result should be humus-like, on the contrary to the compost produced in the Fossa Alterna. Within the time a pit is not used, it should be locked, to prevent it from pollution and to avoid animals and humans to fall into the pit (ibid). Figure 16 shows the principle of functioning of the double ventilated improved pit toilet.

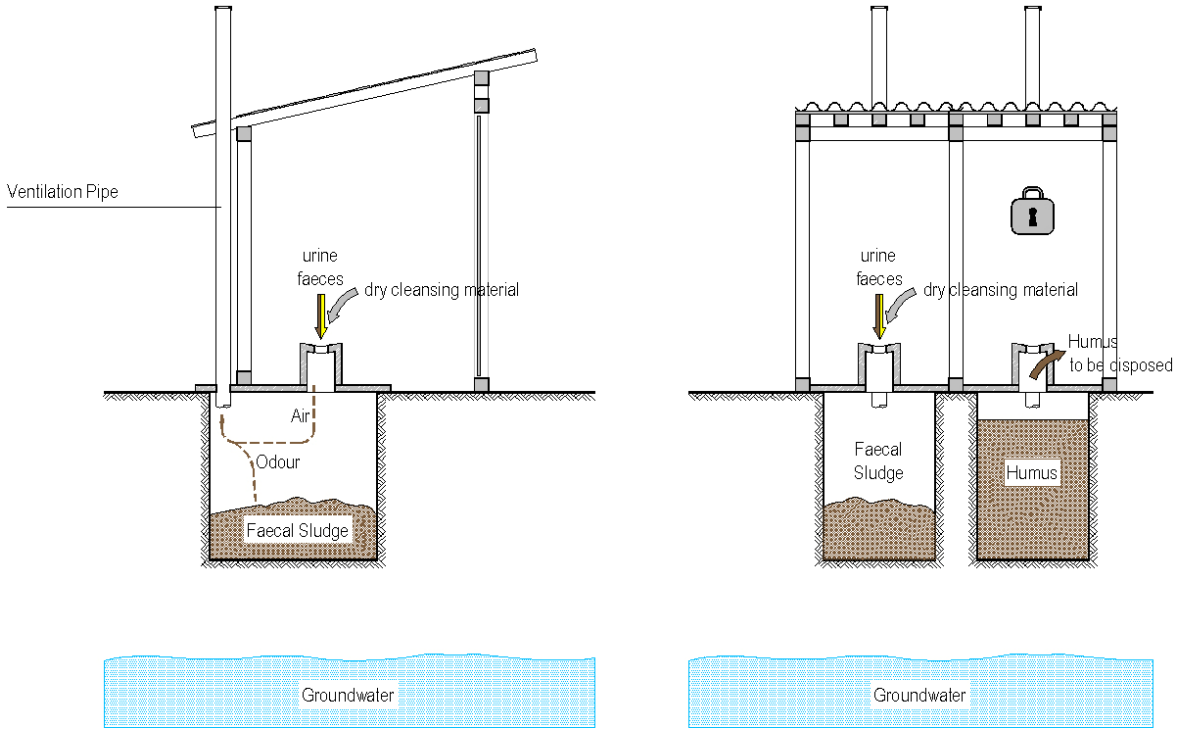

Figure 16. Double Ventilated Improved Pit
(adapted from source: Tilley, et. al., 2008)

3.4.2 Wet Systems

The experiences during the fieldwork revealed only a moderate implementation of flush toilets in the informal settlements. This is due to the fact that water is a scarce resource. Adaptive sanitation systems as described in the previous sections are aiming to consume as few resources as possible or even restore resources from human wastes. However, for the reason of completeness three wet toilet systems are described in the following two sections.

3.4.2.1 Pour Flush Toilet

The pour flush toilet (Figure 17) can be a double pit system or a sanitation facility with a septic tank or a biogas reactor (Tilley et. al., 2008). The Compendium of Sanitation Systems and Technologies (Tilley et. al., 2008) suggests that the input in the pour flush toilet includes faeces, urine, flush water and eventually anal cleansing water. The report also explains the necessity of a water seal which

prevents odour and insects from escaping the toilet through the pipe. The amount of water that is required to flush the excreta is given by the report as 2 to 3 litres to create enough force to move the excreta over the curved seal.

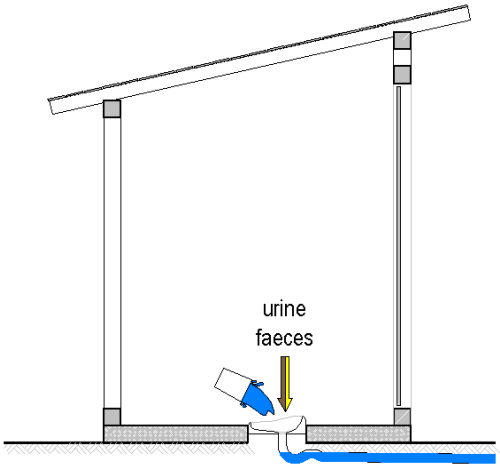

Figure 17. Pour Flush Toilet
(adapted from source: Tilley, et. al., 2008)

3.4.2.2 Urine Diverting Flush Toilet and Conventional Flush Toilet

The cistern flush toilet (Figure 18 a), which consists of a water tank and a section for excreta, and the urine diverting flush toilet (Figure 18 b) with separate sections for urine and faeces are both flush sanitation systems (Conradin et. al., 2010). As mentioned by Conradin et. al. (2010) the urine diversion flush toilet is designed for high income countries, since the user interface for urine separation is similar in its appearance to the conventional flush toilet and therefore is manufactured from ceramics. The installation of such a toilet system requires higher investments than the adaptive dry sanitation systems mentioned in chapter 3.4.1.

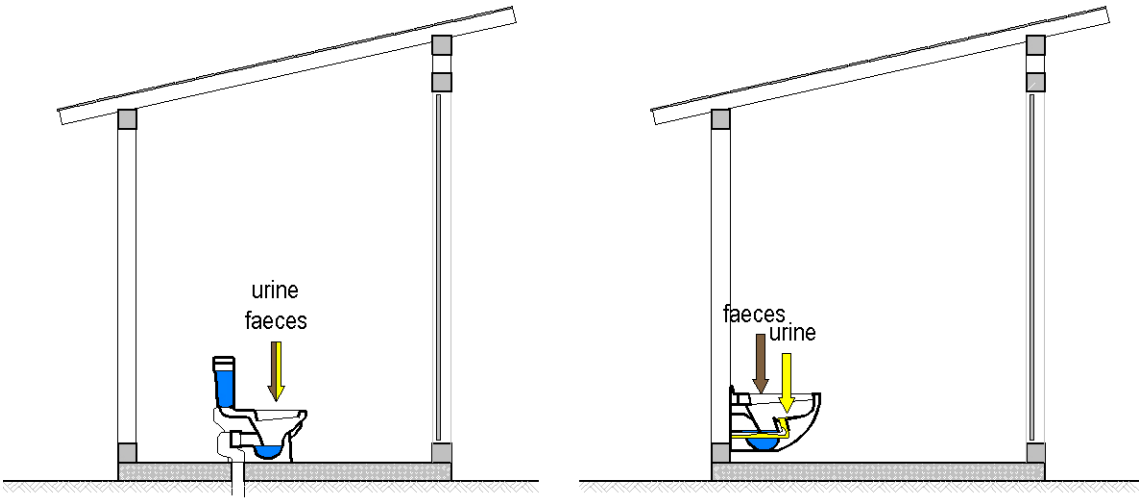

Figure 18 a, b. Conventional Flush Toilet [a)], Urine Diverting Flush Toilet [b)]
(adapted from source: Tilley, et. al., 2008)

3.5 Application in Kenya

3.5.1 IkoToilet

The technology implemented in the IkoToilet is based on the idea of resource recovery by collecting and re-using biogas (methane gas) (Tilley et al, 2008). However this system is not a dry toilet system, but works with the input of water. The IkoToilet represents an implementation of this sanitation system in Kenya, and is a system that is highly suitable for schools and public places, because there the waste yield is high enough to produce the destined output in a reasonable time and amount. The fermentation of organic matter delivers methane gas, which can be used for the production of electricity (Tilley et al, 2008). Apart from the production of biogas, the anaerobic digestion of biomass also produces nutrient rich faecal sludge, which can be used as soil amendment (Tilley et al, 2008). The Sanitation Series Magazine indicates in the December 2010 issue "*In turn this leads to enhanced agricultural productivity in addition to the fact that subjecting organic matter to digestion for gas production results in the following:*

- *Reduction of odour and smell*
- *Higher content of ammonium-nitrogen*
- *Higher fertilizing value*
- *Reduction of pathogens: e.g. coliform, e-coli and salmonella by 99% to 99.9%*
- *Reduction of viscosity, homogenizing, liquidizing, thus better application*
- *Production of enzymes improving plant health*"

Underground concrete tanks are used to collect and store the excreta. As a pre-treatment process the sludge is mixed with water, and further on solid material will be separated from the sludge by sifting (Ecotact Limited, 2010, pp. 4). In the collection tank gas is produced through fermentation which then rises to the top of the dome from where it is collected for usage (Tilley et. al., 2008). According to the information given in the December 2010 issue of the Sanitation Series Magazine the digester has a volume of about 32 m^3 and allows a biogas production of approximately 7 to 10 m^3 per day. Under these conditions, the report assumes the supply of 20 homesteads and a school with electricity for eight hours daily, considering the operation of a 12 kW generator and a hourly consumption of around 900 litres of gas. Figure 19 shows the technical description of the digester plant of an IkoToilet.

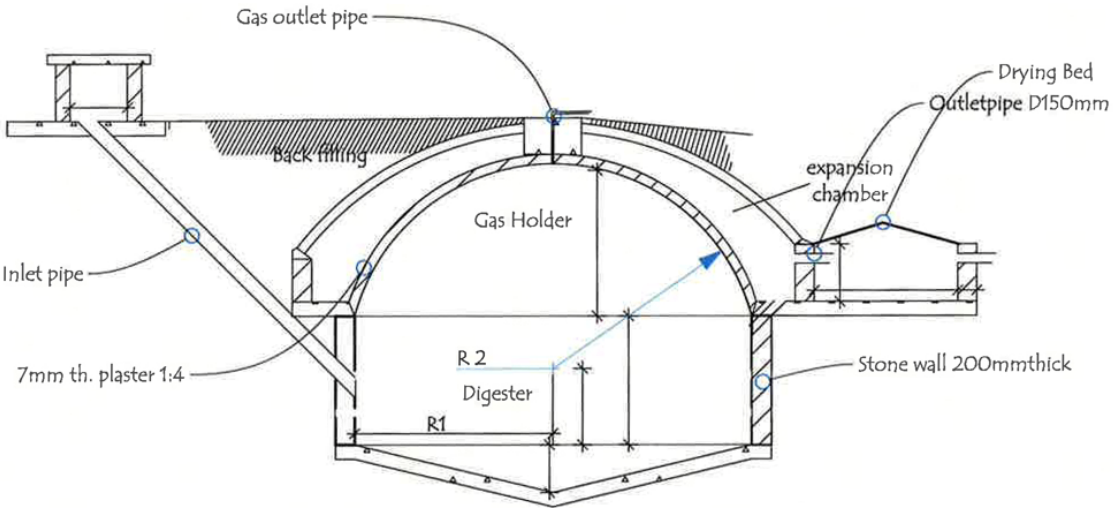

Figure 19. Techical desciption of the construction of the digester plant
(Source: Ecotact Limited, 2010)

3.5.2 Bio-Centre

The technical principle of the bio-centres is the same as that of the IkoToilets. A big underground concrete dome collects and digests the wastes. The aim is to collect the generated methane gas and to put it to use. Additionally the composted wastes can be used as fertilizer. The facility is designed to serve around 600 users daily who are not only offered toilet facilities but also showers (Achieng, 2007). The structure of the bio-centres always includes toilet and shower facilities, business and office space, multi-purpose space as well as biogas fuelled cooking, drinking water and fertilizer from the digester (ibid). As described in chapter 3.4.1 there is a constant generation of biogas, which increases the pressure on the concrete structure. This pressure can be used to transport the gas through pipes to surrounding households. Figure 20 a - d shows the interior of a bio-centre in Gatwekera, a village of Kibera, that is fully operating.

Figure 20 a - d. Interior of a bio-centre [a)] shower, [b)] flush toilet, [c)] and [d)] cooking device fueled by biogas
(Source: Author)

According to the information given in the December 2010 issue of the Sanitation Series Magazine the digester volume for the implementation of the system in rural areas can be lower, since the daily consumption period is about 4 hours. Under the conditions given in the previous chapter, the report states that about 3.6 m^3 of gas are utilized for energy generation and the remaining 2.4 m^3 can be used

for about 8 hours of cooking purposes. Figure 21 a to b show the construction of a bio-centre by a community in an informal settlement in Kisumu and Figure 23 a to b show the ground floor and section of a bio-centre.

Figure 21 a - b. Working process in the construction of a bio-centre
(Source: The Buckminster Fuller Challenge)

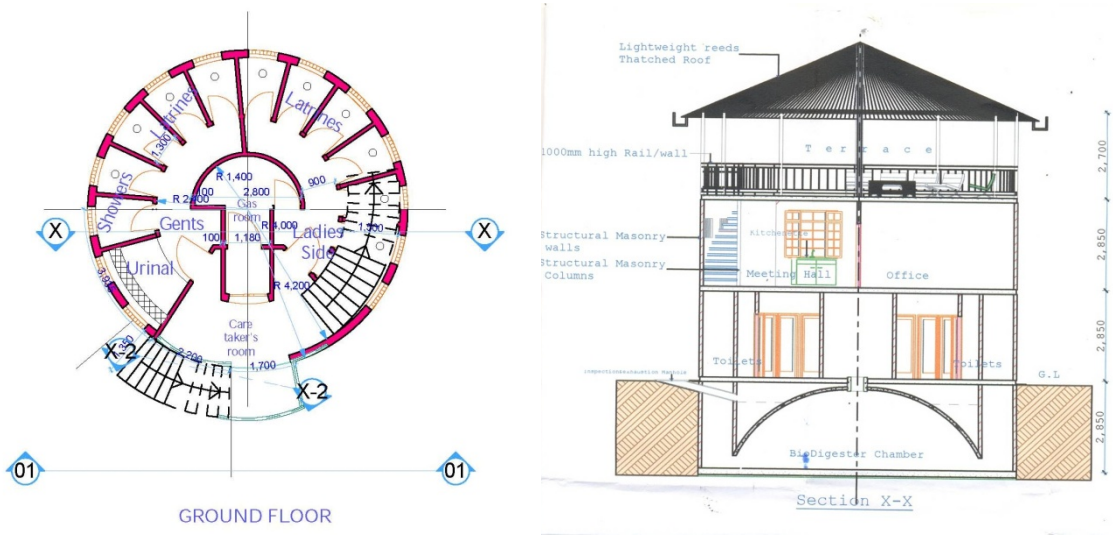

Figure 22 a - b. Ground floor and section of a bio-centre
(Source: The Buckminster Fuller Challenge)

3.5.3 Cost Aspects of Adaptive Sanitation in the Informal Settlements

The construction, maintenance, rehabilitation and operation of any sanitation system do not only cause **internal costs** for labour and material but also causes external costs. The internal costs of maintenance, rehabilitation and operation of any sanitation system do not only cause internal costs for labour and material, but also causes external costs. Apart from the mentioned internal costs of a conventional water borne sanitation system also produce costs when it comes to the treatment and disposal of wastewaters. **External costs** of such a system occur on the social and environmental level. Loss of habitat, eventual reduction of the quality of water bodies due to release of pollutants such as medical residues, as well as loss of nutrients and impoverishment of soils are some of them. Additional costs for awareness raising activities are external costs of system that is based on adaptive sanitation.

Both systems improve the health situation of the users (internal benefit). Adaptive sanitation however has the advantage to the conventional system to cause external benefits such as reduction of effluent discharge to potential drinking water sources and therefore securing of drinking water supplies, increasing access to fertilizer, reduction of nutrient loss, as well as potential for energy production.

Table 5 shows a detailed comparison of the internal costs and benefits as well as the external costs and benefits of conventional water borne sanitation systems and adaptive systems (adapted and modified from UNESCO et. al., 2006).

Table 5. Comparison of internal costs and benefits as well as external costs and benefits of conventional water borne sanitation and adaptive systems
(adapted and modified from UNESCO et. al., 2006)

INTERNAL COSTS	
Conventional water borne sanitation systems	**Adaptive systems**
• Disposing of treated wastewater to a surface water body • Construction, maintenance and operation of the infrastructure	• Construction, maintenance and operation of the sanitation facility
EXTERNAL COSTS	
Conventional water borne sanitation systems	**Adaptive systems**
• Social loss of recreational area • Possible effects of subsequent drinking water treatment • Loss of natural habitats and effects on coastal areas • Effects of medical residues (hormones, antibiotics etc.) • Eventual rehabilitation costs • Impoverishment of soils as a result of nutrient loss • Costs of using high quality drinking water to flush the system	• Transformation costs to adapt existing sanitary infrastructure • Additional awareness raising activities • Need for continued research and development of different parts of the system
INTERNAL BENEFITS	
Conventional water borne sanitation systems	**Adaptive systems**
• Improved health situation	• Improved health situation
EXTERNAL BENEFITS	
Conventional water borne sanitation systems	**Adaptive systems**
	• Securing drinking water supply • Reducing the discharge of effluent to potential drinking water sources • Improvement of soil structure and fertility • Increased access to fertilizing agents • Reduced energy consumption in the treatment works • Nutrient and resource conservation • Potential for energy production

On the household level the individual suffers higher costs of initial financing for an adaptive system than for conventional water borne systems. Centralized systems such as the conventional water borne system need the financing of the user interface, the pipes and their connection to the sewer system. The sewerage infrastructure, treatment plants etc. are expenditures that are carried by the public. The instalment of decentralized systems such as the adaptive toilets is reasonably cheaper than the construction of more infrastructure intensive centralized sanitation systems. Nevertheless they require the financing of the construction of the entire sanitation facility by the users. Residents of informal settlements, which generally generate low income, cannot afford high investment costs. Apart from their contribution of labour force they have the option to apply for micro loans. However, any other investment including technical labour comes from NGOs which are sponsored by external investors. Additionally adaptive projects like bio-centres require investments in awareness raising activities and skill training. Those costs cannot be directly projected on the sanitation structure for they are no necessity for its construction. Therefore the development of financing mechanisms for pro-poor sanitation is necessary and a challenge to researchers (UNESCO et. al., 2006).

4 Legal Frameworks in Sanitation

4.1 Introduction

Adequate legislations, both at the national and the international level, for sanitation exist. These legislations are strongly encouraging the establishment of partnerships in the public as well as in the private sector. Due to the recent developments, caused amongst others by overpopulation of the planet and global warming, a resource oriented lifestyle and therefore also resource recovery in sanitation is encouraged.

The legal situation in informal settlements is very difficult. The land that is occupied by the settlements is property of the government. However landlords use this land illegally to build housing structures and rent them to the slum dwellers. The challenges of this uncontrolled construction of structures in informal settlements and their still ongoing expansion create conflicts with urban development strategies as well as agricultural uses of land. Referring to the Bellagio Principles described in chapter 2.3.3 the first three Bellagio Principles are in conflict with the legal situation in the informal settlements. The first principle demands human dignity, quality of life and environmental security, a state which is clearly not observable in these areas. The residents live in these informal settlements with few or even without legal support (SDI, 2011). They are hardly connected to any official infrastructure such as energy and water supply. Further on the third Bellagio Principle states that waste should be considered a resource. In order to reuse waste it must be collected and treated, a service that is also not applied in the informal settlements. Some of the residents receive a minimum of education which makes them hardly able to follow the second principles aim to participate in decision making. Only the fourth principle, which demands that environmental sanitation problems are to be resolved in a minimum practicable size is on the way of implementation which can be seen on the examples of the decentralized adaptive sanitation projects such as the bio-centre.

4.2 National Level – Kenya

4.2.1 Water Act 2002

The Community Guide to the Water Act 2002 describes that in 1974 the Kenyan Government established a National Water Master Plan with the aim to supply all Kenyans with safe drinking water by the year 2000. Between 1975 and 1992 studies on the subject were carried out, first with the assistance of the Governments of Sweden and later the Japanese Government. These studies showed that Kenya

was not able to provide the necessary budget and also lacked the institutional capacities to achieve this aim. A major problem indicated in the Community Guide to the Water Act 2002 was that the main mandate of the Kenyan Ministry of Water Development was to develop water supply systems, and did not care for the actual water resources, which leads to massive degradation in quality and quantity of many water bodies.

In March 2003 the new Water Act Nr. 8 of 2002 became effective as the legal framework for the Kenyan water supply and sanitation sector. In this framework a clear separation between conservation of water resources and provision of water and sewerage services was established. In this new Water Act the role of the community in water provision as well as quality standards for potable water were more clearly defined. Table 6 describes the new institutional framework that is defined by the Water Act 2002.

Table 6. Institutional Framework under the Water Act 2002
(Source: Munala, 2009)

Institution		Roles and responsibilities
1.	Ministry of Water and Irrigation (MWI)	- Development of legislation, policy and strategy formulation, sector coordination and guidance, and monitoring and evaluation - Overall sector investments planning and resource mobilization
2.	Water Services Regulatory Board (WASREB)	- Regulation and monitoring of service provision (Water Services Boards and Providers) - Issuing of licenses to Water Services Boards - Setting standards for provision of water services - Developing guidelines (water tariffs etc.)
3.	Water Services Boards (WSBs)	- Efficient and economical provision of water services - Developing water and sewer facilities, investment planning and implementation - Rehabilitation and replacement of infrastructure - Applying regulations on water services and tariffs - Procuring and leasing water and sewerage facilities - Contracting Water Service Providers (WSPs)
4.	Water Service Providers (WSPs)	- Provision of water and sanitation services, ensuring good customer relation and sensitization, adequate maintenance of assets and reaching a performance level set by regulation
5.	Water Services Trust Fund (WSTF)	- Financing provision of water and sanitation to disadvantaged groups (pro-poor) as water poverty fund
6.	The Water Appeals Board (WAB)	- Arbitration of water related disputes and conflicts between institutions and organizations

The Water Act 2002 consists of six parts

- Part One states the full name and the purpose of the Act as well as the date on which the President signed it and the date on which it became effective
- Part Two deals with the ownership and control of water bodies in Kenya
- Part Three explains principles of water resource management
- Part Four deals with water supply and waste water
- Part Five is on financial issues and provisions
- Part Six is about issues and supplements

According to Munala (2009) the National Water Resource Management Strategy (NWRMS) of Kenya supports the implementation of the Water Act 2002. The Water Service Trust Fund (2011) states on its homepage that this strategy paper has the following objectives "*with respect to water resource management as stated in the NWRMS [...]:*

- *To conserve the water catchments;*
- *To manage the resources properly;*
- *To increase the availability of water resources (through conserving flood water and improving water quality);*
- *To increase the usage of the water for economic and social improvements;*
- *To develop sustainable and responsive institutions;*"

4.2.2 The Millennium Development Goals and Kenya

The United Nation Millennium Development Goals, their eight goals and their twenty targets have been listed in chapter 2.3.2, and with reference to the United Nation Millennium Development Report 2010 the most recent evaluation of achievements in sub-Saharan Africa have been presented. In the following section a more specific evaluation for the national level of Kenya, made available by the United Nations Statistics Division, is presented.

Table 7 shows the Kenyan statistics concerning the achievement of the Millennium Development Goals with a focus on poverty rates, as well as water supply and sanitation differentiated between total, rural and urban sections. And further on the change of human population size between 1990 and 2008 is presented. The statistics in Table 7 are only an excerpt of all the statistics given by the United Nations Statistics Division on their webpage (UNSD, 2010).

Concerning the increase of the international poverty rate, which is now marked at US $ 1.25 per capita per day, according to the data shown in Table 7 Kenya has managed to decrease the poverty rate by

18.7 per cent between 1992 and 2005. In the given table the term “national poverty line” is used to reflect a country’s economic and social circumstances. Therefore the global and the national poverty lines cannot be used for comparison. The percentage of population below the national poverty line in the urban area decreased 14.6 per cent between 1997 and 2006, compared to a decrease of 3.3 per cent in the rural area (UNSD, 2010). If this trend continues, in 2015 still 43 per cent of the rural population and 19.8 per cent of the urban population will be living below the national poverty line.

Considering water supply the total percentage of the Kenyan population using improved drinking water sources increased 16 per cent from 1990 to 2010. Considering rural and urban areas separately, Table 7 reveals that the improvement is mainly due to a 20 per cent improvement of the water supply situation in the rural areas between 1990 and 2010. The urban areas however show a decrease of 8 per cent of population that has access to improved drinking water sources. This situation reflects the still on-going rural depopulation with addition of high birth rates in developing countries. Therefore in the rural area, where population is decreasing, the drinking water situation has improved where as in it has been made worse in the urban areas. Additionally to the data given in Table 7, Figure 23 shows the comparison of the use of drinking-water in Kenya in 1990 and 2008 for urban and rural areas as well as for the total population of Kenya (WHO/UNICEF, 2010a). The data given in Figure 23 leads to the same conclusion in improved drinking water supply as in Table 7. In 1990 about 61 per cent of the rural population had access to improved drinking water sources, whereas the number increased in 2008 up to about 70 per cent. At the same time in 1990 around 39 per cent of the urban population had safe access to drinking water, and in 2008 the number decreased to about 31 per cent.

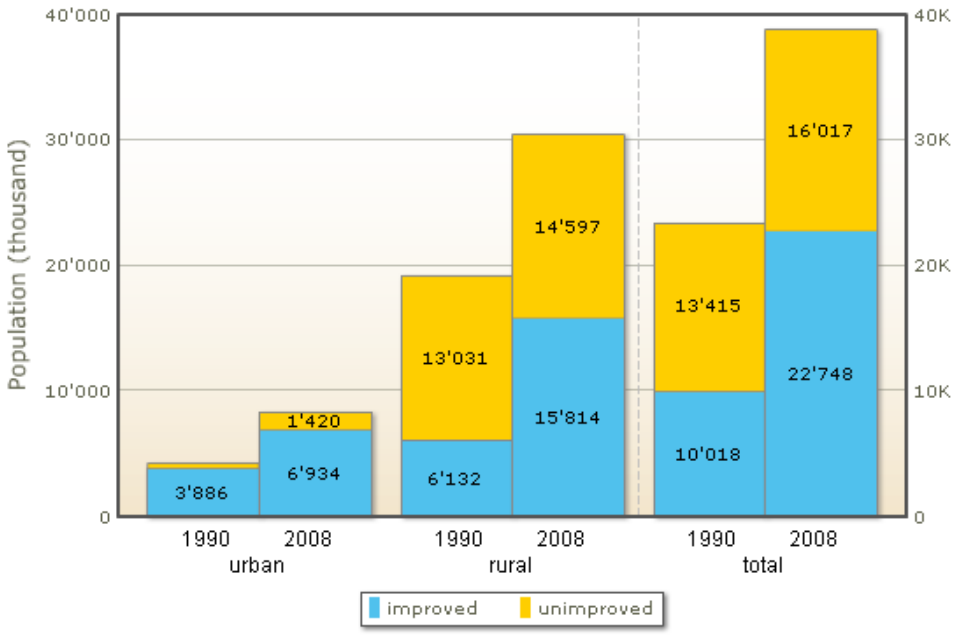

Figure 23. Use of drinking-water in Kenya
(Source: WHO/UNICEF, 2010a)

The WHO/UNICED Joint Monitoring Programme for Water Supply and Sanitation defines improved sanitation facilities as such facilities that "*facilities include flush/pour flush toilets or latrines connected to a sewer, -septic tank, or -pit, ventilated improved pit latrines, pit latrines with a slab or platform of any material which covers the pit entirely, except for the drop hole and composting toilets/latrines*" (UNSD, 2010). Table 7 reveals that the sanitation situation has improved only slightly between 1990 and 2010. In 1990 about 26 per cent of the total population had access to improved sanitation facilities, and in 2010 about 31 per cent of the Kenyan population has the possibility to use improved sanitation facilities. Considering only the urban population an increase from 24 per cent in 1990 to 27 per cent in 2010 was accomplished. Whereas in the rural areas an increase of 5 per cent from 27 per cent in 1990 to 32 per cent in 2010 was achieved. Additionally to the data given in Table 7, the Figure 24 shows the use of improved and other sanitation facilities in Kenya for the population in rural and urban areas as well as for the total population.

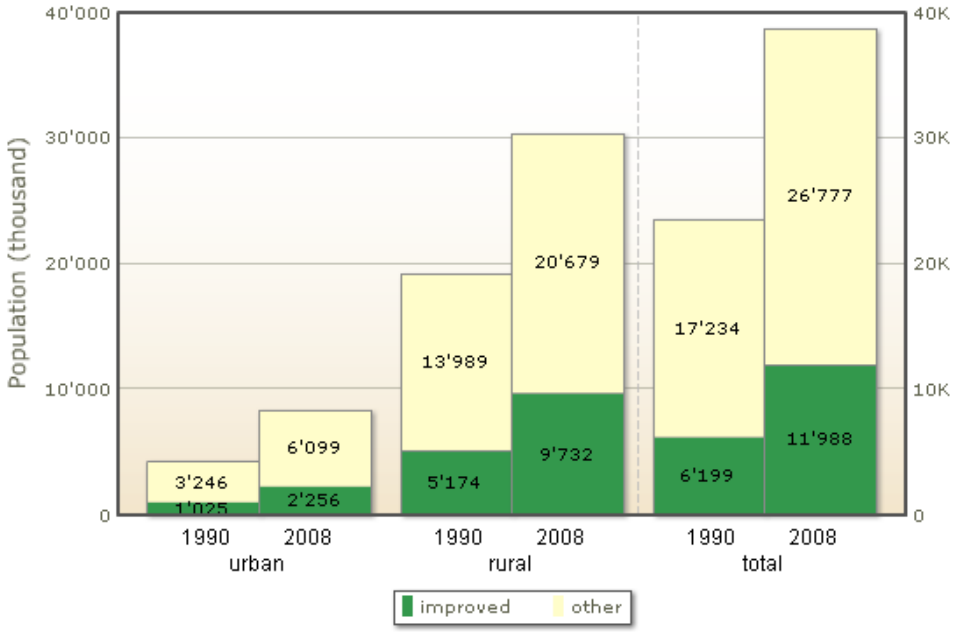

Figure 24. Use sanitation in Kenya
(Source: WHO/UNICEF, 2010a)

Figure 24 reveals an increase of access to safe sanitation in the urban regions as well as in the rural region and shows the same percentage development as given in Table 7. The following two pages show in Table 7 the excerpt of the statistics of the United Nations Statistics Division that has been referred to before.

Table 7. Statistics concerning the Millennium Development Goals and their achievement in Kenya (adapted and modified from Source: UNSD, 2010)

1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Population below US $ 1.00 per day, percentage (latest update: 23.06.2010)																		
		38,4 [31,32,35]		28,6 [31,36]			19,6 [31,37]								19,7 [31,33,34]			
Population below national poverty line, urban, percentage (latest update: 23.06.2010)																		
				40			52									46,6		
Population below national poverty line, rural, percentage (latest update: 23.06.2010)																		
				29			49									34,4		
Proportion of the population using improved drinking water sources, total (latest update: 23.06.2010)																		
				47			53									49,7		
Proportion of the population using improved drinking water sources, urban (latest update: 23.06.2010)																		
43					48					52								59
Proportion of the population using improved drinking water sources, rural (latest update: 23.06.2010)																		
91					89					87								83
Proportion of the population using improved sanitation facilities, total (latest update: 23.06.2010)																		
32					38					43								52
Proportion of the population using improved sanitation facilities, urban (latest update: 23.06.2010)																		
26					27					29								31
Proportion of the population using improved sanitation facilities, rural (latest update: 23.06.2010)																		
24					25					26					27			27
27					28					30					31			32
54,9 [70]					54,8 [70]					54,8 [70]					54,8 [10, 71, 72]			54,8 [71, 72]
2.344.776 [70]					2.847.731					3.379.459					4.044.152 [71, 72]			4.370.412

Global monitoring data ... The figure is regularly produced by the designated agency for the global monitoring, based on country data. However, there is no corresponding figure at the country level, because the indicator is defined for international monitoring only (example: population below 1$ a day)

Country Adjusted ... The figure is the one produced and provided by the country, but adjusted by the international agency for international comparability—that is to comply with internationally agreed standards, definitions and classifications (age group, ISCED, etc)

Estimated ... The figure is estimated by the international agency, when corresponding country data on a specific year or set of years are not available, or when multiple sources exist, or there are issues of data quality. Estimates are based on national data, such as surveys or administrative records, or other sources but on the same variable being estimated.

Footnotes:

10 The decrease in the percentage of slum dwellers is mostly due to a change in the definition of adequate sanitation. In 2005, only a proportion of households using pit latrines were considered slum households, whereas in 1990 and 2001 all households using pit latrines were counted as slum households.

31 Expenditure base.

32 Data are for 1992-93.

33 Data are for 2005-06.

34 Estimated from Kenya Integrated Household Budget Survey; 2005-06; National coverage.

35 Estimated from Welfare Monitoring Survey I; 11/1992 - 12/1992; National coverage.

36 Estimated from Welfare Monitoring Survey II; 1994; National coverage.

37 Estimated from Welfare Monitoring Survey III; 1997; National coverage.

70 DHS 1988, 1993, 1998

71 DHS 1993, 1998, 2003

72 Trend analysis was used to estimate the percenatage [!] of slum

5 Methodology

5.1 Introduction

This chapter describes the design of the research as well as the used source of data and the instruments that were utilized for the undertaking of the research. The chosen methods of research as well as the research questions are based on the principles of the PESTLE analysis, which is described in the appendix. Additionally it deals with the issues of the choice of the target population for the fieldwork, the data analysis and presentation as well as the experiences and challenges of the fieldwork in the five visited informal settlements.

5.2 Research Design

The research consists of three parts. The first part is the preparatory phase before the fieldwork, which is dominated by literature research and the definition of the actual research field and topic, which includes the definition of the research aim. One of the main aims of the literature review was to collect sanitation systems that are in use in the developing world as well as the collection of socio-cultural and gender related issues in the matter. Based on the preparatory research the questionnaires for the fieldwork were prepared. The second part of the research is the fieldwork itself. Various household members and managers of sanitation and water points were questioned randomly in five different informal settlements, three of them in Nairobi and two in Kisumu. Additional literature review was necessary to describe the current status of sanitation and water supply in the considered informal settlements. Thirdly, during the post fieldwork phase the results of the collected questionnaires were recorded in an excel-file and prepared for analysis. The data that was collected in a notebook during conversations with residents and community leaders on the field were included in the findings (chapter 7) and evaluated. The on field examined sanitation systems and their applicability was compared with the sanitation systems collected during the literature research and their applicability evaluated. The last part of this third phase was the presentation of the research.

Further on the research can be parted into exploratory and descriptive research, whereas the exploratory research includes the walk-through in the informal settlements and the fieldwork in which the questionnaires were filled. The descriptive research includes the literature studies and the analysis of the collected fieldwork data. The research was undertaken during March 2011.

5.3 Source of Data

This research benefits from two main sources of data: primary and secondary sources of data.

5.3.1 Primary Source of Data

The most important source of data for this research is the direct conversation with the population of the informal settlements that were subject to this research and the conversations with people who were willing to share their experiences on not only the subject of research but also many other related topics. A walk-through and direct observation of the conditions on housing, sanitation, water supply and social standards led to a greater understanding of the issues that people in informal settlements face every day.

Photographs were taken on the site during the fieldwork to support the information gathered during the interviews.

5.3.2 Secondary Source of Data

The most basic start to this research as to any other research was a very long and, in this case travel-intensive study of literature which started in the main library of Tampere University of Technology in Finland and continued in Austria, went further on at the UN-Water stand at the IFAT – Entsorga 2010 trade fair in Munich to finally end up in Nairobi and Kisumu, Kenya. In the beginning this literature research was not more than the simple will to get more familiar with technical principles and issues of water supply and sanitation in the developing world as well as the frameworks concerning those topics.

Other sources of secondary data, apart from the research in the library, are the internet, reports and publications of NGOs and governmental documents.

5.4 Research Instruments

As the objective of this study is to collect data in the field of mainly sanitation related topics in informal settlements with consideration of socio-cultural, technical and gender issues, the questionnaires were designed to produce a comparison between different settlements including their differences in population density and cultures, the differences in their background and their development as well as their possible similarities. However the interviewees were not picked based on statistical assumptions or a certain pattern, as the informal settlements are not arranged in any particular order to facilitate organised sampling. To achieve these aims three different questionnaires

were designed:

- Questionnaire for households,
- Questionnaire for water points and
- Questionnaire for sanitation points (Appendix II).

Table 8 shows the five different informal settlements that were visited in Nairobi and Kisumu and the amount of questionnaires that were collected in households, as well as at water and sanitation points. Additionally the amount of collected questionnaires was differentiated according to the gender of the interviewee, in which M stands for male and F for female. There is only one exception to this differentiation, which occurs when the interviewee is member of a management group at a water or a sanitation point. These groups are indicated as G for group in the table. In the informal settlement Obunga in Kisumu the gender of the respondents to the questionnaires at households and sanitation points were unfortunately not recorded.

Table 8. Amount of questionnaires collected in each informal settlement
(Source: Author)

Informal Settlement	Household		Sanitation Point		Water Point		Total	
NAIROBI								
Kibera	M	7	M	2	M	1	M	10
	F	23	F	1	F	1	F	25
Mukuru kwa Njenga	M	10	M	5	M	3	M	18
	F	15	F	5	F	7	F	27
		1		-				1
Kibagare	M	8	M	4	M	2	M	14
	F	21	F	3	F	5	F	29
			G	3	G	3	G	6
KISUMU								
Obunga		32		5	M	5		47
					F	5		
Bandani	M	16	M	8	M	6	M	30
	F	21	F	2	F	5	F	28
TOTAL		154		38		43		235

Table 8 shows that a total of 235 questionnaires were collected during the fieldwork, of which 154 are questionnaires to household members, 38 were filled at sanitation points and another 43 respondents were questioned at water points.

5.4.1 Questionnaire for Households

The interviews that were undertaken with members of a household consist of three parts:

- Water Provision in the informal settlement,
- Cultural behaviour in the protection of water sources and
- Sanitation technology interface and cultural behaviour.

The aim of the first part of the questionnaire is to figure out who carries the responsibility for water collection within the household. This question considers the fact that due to traditions in society, in most households the female family members are responsible for the provision of water as a household duty. Another important point is the time effort that the person who is responsible for the water provision has to make per trip to the water source, especially when queuing becomes an additional issue. Further on the respondent is questioned about the price of the fetched water as well as the stability of this price. Additionally colour and odour were used as indicators for the quality of the water.

The second part of this questionnaire considers the impression of the questioned residents of holding “everybody else” and “climate change” responsible for the increasing lack of potable water. Therefore the first few questions are about the sufficiency of water supply and how the inhabitants deal with water scarcity in the household level. Additionally they were asked to make remarks on the situation and make suggestions on possibilities to change their current predicament. And the final question on how the inhabitants dispose of their waste water alluded to their habits of waste disposal as a contributor to water contamination.

The last part of the household questionnaire deals with the sanitation issues of the communities. The aim is to figure out what kinds of sanitation facilities are in use, if there are sanitation facilities available at all, how much the managers of the facilities charge for their service and if it is affordable to the respondent. The question of comfort of the used sanitation facility was approached from three different targets. Firstly the amount of users of the facility has considerable impact on the cleanliness and hygiene of the facility. Secondly the question of security for women and children due to experiences in criminal behaviour of the slum dwellers were discussed. And thirdly the comfort of use for elderly people is an issue due to their possibly reduced physical capabilities. The knowledge of the importance of personal hygiene was questioned by asking the respondent on the use of hand washing facilities. In some informal settlements private or plot-shared pit latrines are in common use. Therefore the last question tries to figure out how people deal with those facilities and their waste output.

5.4.2 Questionnaire for Water Points

An important part of the questionnaires at water points as well as sanitation points is to figure out the gender balance in the management of those facilities in case they are managed by a group rather than an individual. Type of water source, water prices, colour and odour as indicators of the water quality are part of this questionnaire.

An important point that is strongly connected to the questions on protection of the water sources in the household questionnaire is repeatedly asked here. The respondent is to indicate if there is a sanitation facility close by, additionally the type of sanitation facility as well as the distance of this facility to the considered water source. This relates to the problem of water contamination due to faecal sludge that percolates through the soil into the groundwater.

5.4.3 Questionnaire for Sanitation Points

This questionnaire includes questions on the type of sanitation facility and the input material, such as anal cleansing water and / or dry cleansing material. Often the rising amount of users leads to distresses when it comes to the cleanliness of the visible structure of the facility, but also when it comes to the purity of the output material. Therefore littering and problems in maintenance as well as means and frequency of extraction of the output are indicators of the sustainability of the facility. And finally the availability of hand washing possibilities should give information on the awareness of hygiene issues.

The questionnaires on the sanitation situation were carried out with several owners of sanitation facilities as well as household members in the surveyed locations since the settlements reveal a mix of plot-shared and community-shared toilets. Basically, people have the choice between public single pit toilets, household shared single pit toilets and bio-centres.

5.4.4 Photographs

Additionally to the notes and interviews, photographs were taken to support the written explanations and analyses. Further, photos offer a constant reminder to the reader of the environmental situation in the informal settlement.

5.5 Target Population and Focus of the Study

As it is the aim of this research to gather a wide range of information the target population of the

survey are all residents in the informal settlement. Depending on the spreading of a settlement the survey is undertaken in a range as wide as possible within the schedules of this work. A special focus was laid on social, religious and gender diversity in the respondents. But nevertheless the choice of respondents was limited to social patterns that only allowed the questioning of acquaintances of the respective contact persons in the field.

5.6 Data Analysis and Presentation

During the field work the surveyed data was collected on the prepared questionnaires as well as in a notebook. To ease the analysis of the questionnaires as well as to preserve the collected data, all responses were recorded in an excel-file immediately after the fieldwork. To have the answers of each type of questionnaire in one file made it easier to keep track over the results of all 235 questionnaires as well as the results and their correlations.

During the analysis of the questionnaires the key issues that form the basis of the subsequent discussions stand out. These include:

- Water provision in the informal settlements:
    - Water availability and use in informal settlements,
    - Pricing in water supply in informal settlements,
    - Water sufficiency, reliability and adequacy.
- Sanitation in the informal settlements.
    - Types of sanitation facilities,
    - Use, acceptance and maintenance of sanitation facilities in the informal settlements,
    - Technical and performance aspects of adaptive sanitation in the informal settlements,
    - Dependencies and Influences in the Implementing Sanitation in the informal settlements
    - Cost aspects of adaptive sanitation in the informal settlements.
- Environmental quality.
- Management and gender issues in the informal settlements.

After defining these key questions, the excel-file was rearranged to fit into this order and to compare the questionnaires and their results of all five visited informal settlements with each other. Again, having the answers to a given question in one row and every settlement next to each other eased the evaluation of the data. The calculated results of the interviews can be observed more closely in Appendix III.

5.7 Fieldwork Experiences and Challenges

5.7.1 Entering an Informal Settlement

One cannot easily enter an informal settlement without proper guidance, especially when contact to the inhabitants and individual interviews are necessary. It is, due to their situation, easily understandable that the inhabitants do not trust everybody. Therefore, to establish personal contact and to start a conversation, a contact person who is already known to the inhabitants is essential. This often is also necessary when entering a part or a village within the settlement that is mainly occupied by members of other cultures, tribes or religions.

5.7.2 Challenges

The interviewers themselves experienced linguistic problems during the fieldwork. The majority of interviewees in the informal settlements were not able to speak English, some did not even speak Swahili, but only the native language of their tribes. Also a lot of people in the informal settlements that were visited in Kisumu area are illiterates and therefore were not able to fill the forms themselves. Apart from illiteracy, the definitions and meanings of some terms like “sanitation” were not perfectly clear to the respondents.

Another problem with the interviewees was that they expected an immediate benefit of the interviews, which basically means that they wanted to be paid and often had to be convinced to support this research. In the two informal settlements in Kisumu that were subject to this research, people often indicated that they already have filled the form because another group of interviewers was there at the same time, and the respondents could not distinguish the two different questionnaires, nor did they want to be questioned twice a day. Especially male respondents often confronted the interviewers with hostility. However, these minor incidences did not affect the study and the results, more over they are a reflection of the situation and conditions of the informal settlements during the time of the survey.

6 Study Area

6.1 Introduction

The study was undertaken with the support of the NGO Umande Trust in a sample of informal settlements in Nairobi and Kisumu, Kenya. The following section starts by giving an explanation of what an informal settlement in the context of this research is. It then describes the visited locations in terms of their natural and socio-economic situation, as well as the sanitation and environmental conditions of the surveyed locations.

6.2 What is an Informal Settlement?

Informal Settlements, also known as “Shanty Towns” and “Slums”, are accumulations of improvised dwellings of impoverished people, mostly built from scrap material, lacking standard living conditions and basic infrastructure like water supply, sanitation, sewerage, public transportation and educational facilities (UN-HABITAT, 2006a). These settlements are often characterized by high population density and unplanned urban layout (ibid).

The genesis of the sudden increase in informal settlements in Kenyan towns can be traced back to the 1960s (Fashoyin, T., 2001). During the 1960s and 1970s Kenya experienced a GDP growth of an average of 6.6 per cent per year. Due to high inflation, economic disasters such as oil shocks and an immense growth of population the newly formed republic was not able to maintain this growth (ibid). As a natural follow-up a low employment rate and increasing poverty was the result that is lasting until this day.

The poor population of the rural areas flees towards the cities in search for new job opportunities and better payment (People's Daily Online, 2005; UN-HABITAT, 2006). This population movement turned out to be another shock for Kenya’s economy since the cities could not provide employment for all those immigrants, whilst the agricultural sector was losing work force (Fashoyin, 2001). The results of this development are the ever-growing informal settlements in the cities. Within these settlements poverty, hunger, poor health and high crime rates are the major issues that are continuously worsen by constant growth of population. Additionally the outbreak of the HIV/AIDS pandemic has played a major role in addition to the already existing poverty levels in these areas (Fashoyin, 2001).

6.2.1 Sanitation Conditions in the Informal Settlements

Sanitation conditions vary widely in the informal settlements. Nairobi has numerous informal settlements in which the ownership of property is a major problem for the establishment of sanitation facilities (SDI, et. al., 2010). In some locations within the informal settlements there is simply no space to build a public toilet, whilst in others there might be enough room, but the land is property of the city council, which is not always willing to give away the land. At the same time, in other settlements plots that house a few families share their own pit latrine. The problem that occurs here is the improper use of this facility. Occasionally people dispose of other wastes in the latrine and therefore encourage the development of odour and parasites. As a result, when the pit is full, the content will not be removed or perhaps even reused, instead the toilet will be abandoned.

Even though the situation of sanitary conditions is improving as revealed in chapter 4.2.2, still some of the sanitation projects are only a short-term relief to the slum dwellers due to the mentioned misuse of the facilities. Additionally Schouten et. al. (2010) mentions that community-shared toilets are only operating during daytime due to the insecurity at night in slums. Further on the report states that lack of space as well as unfitting soil quality as well as the unsystematic layout and high population density of the informal settlements pose limitations for the erecting of additional sanitation sites.

6.2.2 Living and Housing in the Informal Settlements

The shelters in the informal settlements are mainly consisting of one room which host an entire family. Corrugated iron is the most visibly used construction material. Some of the shelters are co-joined to a plot, and the narrow pathways between the ‘shacks’ are filled with wastes and sewerage from the inhabitants.

Parallel to the unemployment rate the crime rates in informal settlements is high, and poses an extreme risk to their inhabitants. The occasional development of cartels in the electricity and water supply sector make life for the slum dwellers even more difficult. Due to this lifestyle, concerning the water and waste management as well as the lack of education, infectious diseases and the spreading of HIV/AIDS are on the daily agenda.

6.2.3 Environmental Challenges

Kenya basically has two rainy seasons throughout the year, which feed the water bodies with fresh water. At the end of a dry season, the need for fresh water starts to become imminent. If the start of

a rainy season is delayed, water becomes scarce. This lack of fresh water means a rise of the charges for water in the informal settlements. As a result of the price increase, residents are forced to fetch water from other alternatives like rivers and springs that might be heavily contaminated with wastes from the city and the informal settlements.

A long dry season followed by a heavy long lasting rainfall might cause the contrary to the previous drought. Due to the composition of the soil, which happens to be red clay, the drought can dry out the ground completely, so that it is not able to absorb the water that the heavy rainfall brings along. As a result the affected areas are flooded.

6.3 Case Study in Informal Settlements in Nairobi

Figure 25 shows the three informal settlements in Nairobi that were visited during this survey. These three informal settlements are Kibera, Mukuru kwa Njenga and Kibagare.

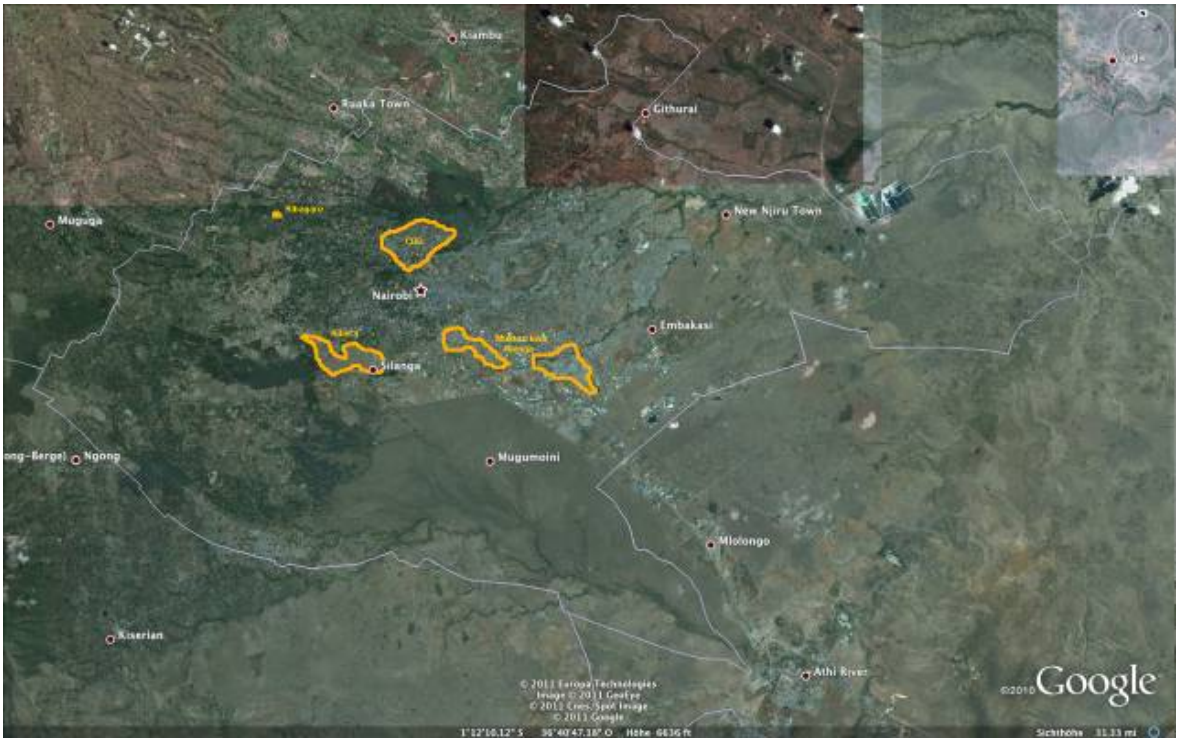

Figure 25. Location of Kibera, Mukuru kwa Njenga and Kibagare in context to Nairobi City Centre (Modified from source: Google Earth)

Table 9 shows the population and the size of the three visited informal settlements in Nairobi and compares their population densities.

Table 9. Size, population and population density of Kibera, Mukuru kwa Njenga and Kibagare
(Source: Karanja, M., 2010; Umande Trust)

Informal Settlements	Population [capita]	Size [km²]	Population Density [capita/km²]
Kibera	170,070 (Karanja, M., 2010)	2.54 (Umande Trust, Nairobi)	66,957
Mukuru kwa Njenga	130,402 (Karanja, M., 2010)	0.32 (Amnesty International, 2010)	41,729
Kibagare	15,000 (Karanja, M., 2010)	0.016 (SDI, et. al., 2010)	240

6.3.1 Kibera

Kibera is the biggest and probably most famous informal settlement in Kenya, located about 7 km away from the city centre in the southwest of Nairobi (Schouten, 2010). Reports on the population of the informal settlement vary enormously. A report of the Kenyan newspaper Daily Nation states that the 2009 Kenya Population and Housing Census indicates a total population of the about 170.070 inhabitants, whereas other sources such as Karanja (2010) and Langergraber, et. al. (2004) speak of half a million people or even more.

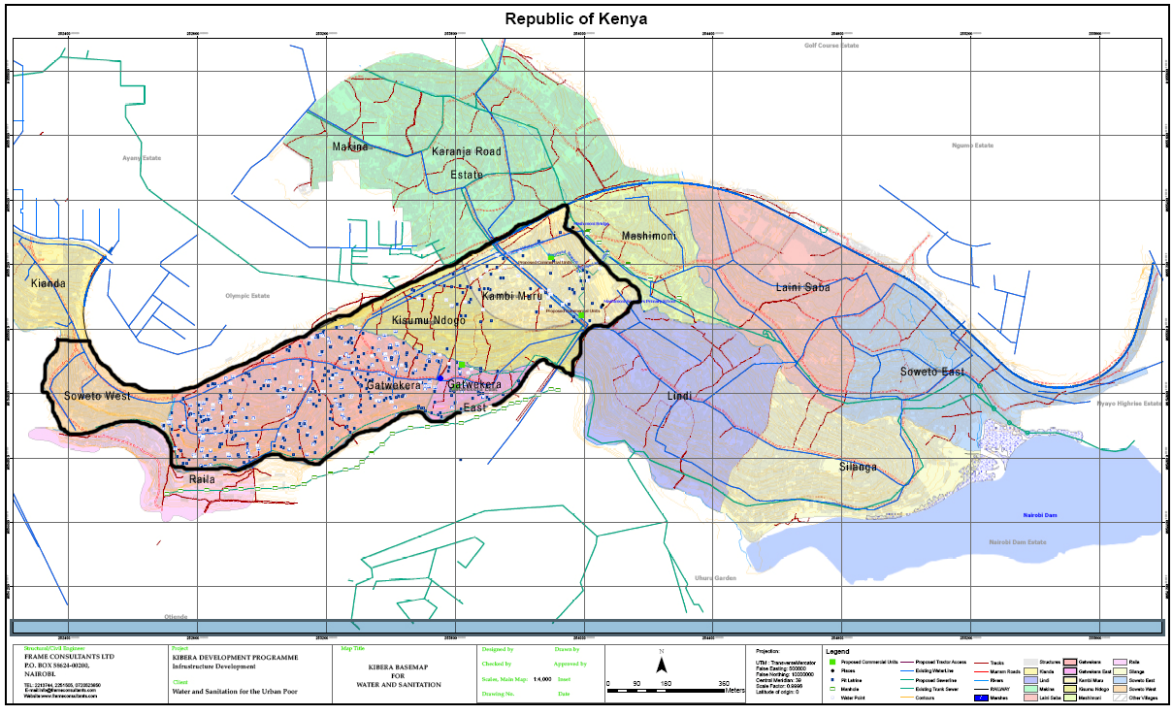

Figure 26. Map of Kibera
(Source: Umande Trust, Nairobi)

The informal settlement itself is parted into 14 villages, whereas each village is dominated by a different tribe. Figure 26 shows the entire Kibera informal settlement and its villages, whereas the fat black borderline marks those villages that were visited during the fieldwork. The 14 villages of Kibera are: Kianda, Raila, Soweto East and West, Gatwekera and Gatwekera East, Kisumu Ndogo, Kambi Muru, Mashimoni, Laini Saba, Lindi, Silanga, Makina and Karanja Road Estate.

The tracks of the train connection from Mombasa to Kisumu are either bordering or crossing right through the informal settlement. The photographs shown in Figure 27 a – c were taken from the train tracks towards Kibera.

Figure 27 a - c. Kibera arranged along the train tracks between Mombasa and Kisumu
(Source: Author)

Those villages of the Kibera informal settlements in which the questionnaires were undertaken are described shortly in the following sub-sections.

Gatwekera

The Nairobi slum inventory report by Karanja et. al. (2009) describes Gatwekera as the biggest village within Kibera with about 40 acres (0.16 km²) land size and a population of about 70,000 people. Additionally the report also states that it is located near the railway line and the river Kyahiti. Further on they report that there are about 70 water points within the village which belong either to individuals or management groups. The pipes lie close to the surface and are surrounded by mud and waste, since there is no sewer but approximately 230 latrines within the village (ibid). The water from leaking pipes gets into contact with disposed waste water on the ground surface. According to the residents the main tribes present in Gatwekera are the Luo, Luhya, Kamba and Maasai.

Kisumu Ndogo

The settlement is mainly populated by members of the Luo tribe. Since the first settlers of this area were Luos, coming from Kisumu, these people decided to name the place Kisumu Ndogo, Swaheli for “small Kisumu” (Karanja et. al., 2009). The Nairobi slum inventory report by Karanja et. al. (2009) indicates a land size of about 30 acres (0.12 km²) which is shared by approximately 35,000

residents. Further the report states that there is piped water within the village that serves 35 water points, which are owned either by individuals or small groups. Furthermore the report firstly mentions the existence of about 120 latrines that are owned by landlords, and secondly the lack of trenches within the settlement.

Soweto West

The Nairobi slum inventory report by Karanja et. al. (2009) states that the first settlers, of this approximately 40 acres (0.16 km²) area of land, were people of the Kikuyu tribe. The report mentions that the current populations is about 40,000 people who share 56 water points, which are owned either by individuals, churches or small groups. Further the report states that there are about 200 latrines, but no sewer in the village.

Kambi Muru

According to the Nairobi slum inventory report by Karanja et. al. (2009) the population of Kambi Muru is approximately 40,000 people, which share a land size of about 8 acres (0.03 km²) that is under governmental ownership. Further on the report states that there are five water points within the village as well as some individual connections to NCWSC. The sanitation situation is rather poor, since only those who share a toilet facility on a plot have free access to a toilet, the others either have to use their neighbour's toilet or find other solutions (ibid).

6.3.2 Mukuru kwa Njenga

According to Karanja et. al. (2009) Mukuru kwa Njenga is one of Nairobi's biggest informal settlements with an approximate land size of 5 acres (0.02 km²), however Amnesty International (2010) indicates a land size of about 0.32 km². The land is located in Nairobi's industrial area, which makes the location especially interesting to industrial workers and their families. The population count is very variable, due to occasional immigration from rural areas to find jobs in the industrial zone, but Karanja et. al. (2009) indicates a population of 86,697 people (1999 census) in Mukuru kwa Njenga. After several years people migrate to other regions and are replaced by new immigrants (ipid).

The conversation with the residents revealed that the crime rate was judged as very high, which is understandable due to the situation at hand. They also mention that many families live below the international poverty line of US $ 1.25, cannot find employment and further more cannot afford to send their children to school. Very often, this leads to alcoholism and criminal behaviour, such as

burglary and eventually sexual misbehaviour.

Mukuru kwa Njenga is also an exceptional example for the formation of cartels in the water and electricity sector. The inhabitants report that neither any water nor any connections to electricity supplies are legally engaged.

6.3.3 Kibagare

Kibagare is one of the smaller informal settlements in the Westlands Division of Nairobi, located west of Nairobi's city centre, with about 15,000 inhabitants and approximately 3,000 households (SDI, et. al., 2010). It was established in 1972 and is directly adjacent to the wealthy Loresho Estate (SDI, et. al., 2010), but separated from it by a wall and a secured gate. Basically the entire village is located alongside of one street. According to Karanja et. al. (2009) the property lies on a Railway and Road Reserve, which makes it a public utility land under the trusteeship of the Nairobi City Council. Karanja et. al. (2009) also states that there is a mixture of tenants and private owners, of whom most rent the shelters to the inhabitants of the settlement.

The visible ground layer is composed of red clay soil. Walking through the village, it is easy to see, that the rather small amount of inhabitants, compared to other visited informal settlements, and the therefore smaller amount of sewage water can easily percolate into the ground. Also the fact that many people seem to dispose of their wastewater into a nearby stream, helps not to overstress the soils capacity as a reservoir.

The village is located in a hillside situation, with the alluded road situated alongside of the hill. Uphill the settlement is bordered by Nairobi School on one side and on the other side by the Nairobi City Water and Sewerage Company depot. The border of downhill side of the settlement has changed quite often throughout the years. Much of the lower area of the land has been claimed by their potential owners and forced the slum dwellers to give up their homes. The main road between the uphill and downhill area is owned by the government and is therefore to be kept free of any buildings.

As already mentioned Kibagare is located very closely to the Nairobi City Water and Sewerage Company depot and therefore has a rather good water connection, possibly the best of all informal settlements around Nairobi. This fact and the lesser amount of inhabitants have an enormous impact on the water supply and sanitation situation.

6.4 Case Study in Informal Settlements in Kisumu

Kisumu is Kenya's third largest city, it is the capital of the Nyanza province and an administrative, commercial and industrial centre of the Lake Victoria Basin (UN-Habitat, 2006a). The city is located in the Western Highlands, directly at the shore of Lake Victoria and was founded in 1898 as Port Florence (UN-Habitat, 2005). Figure 18 shows the central business district of Kisumu as well as the surrounding formal and informal settlements.

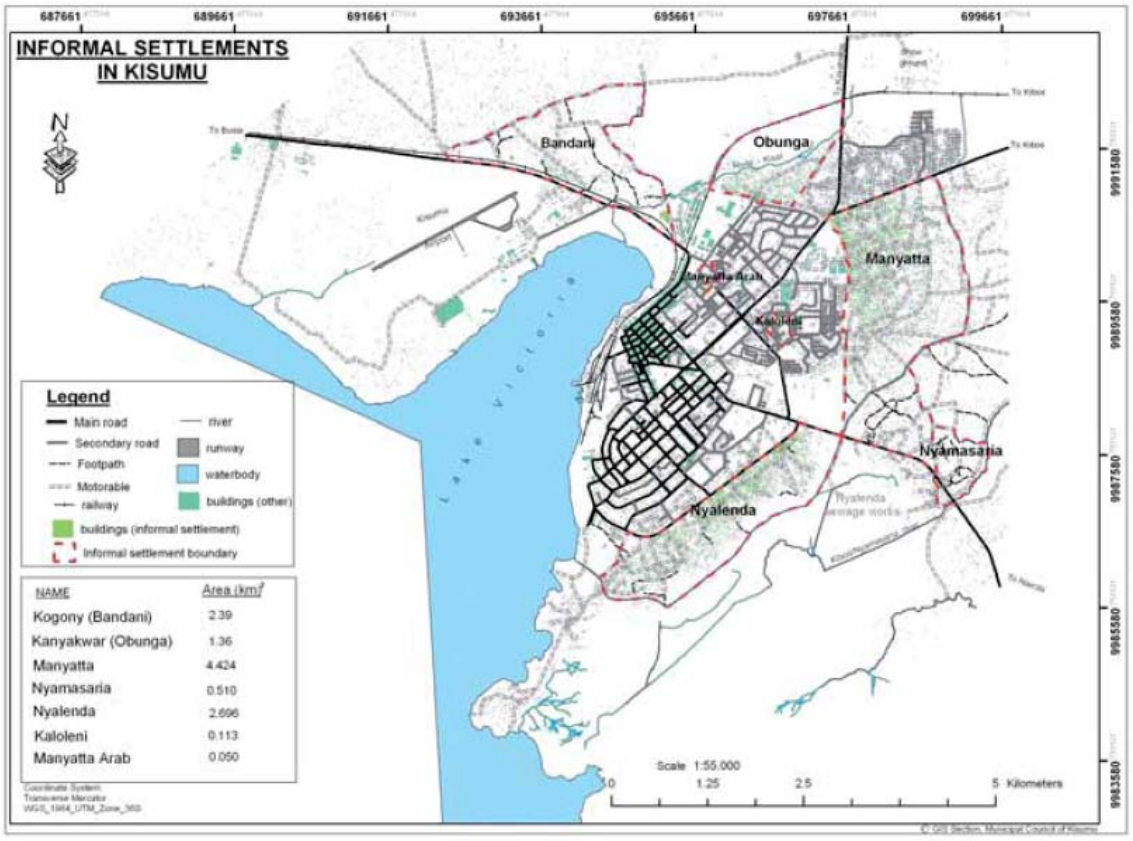

Figure 28. Context of informal settlements within the larger Kisumu area
(Source: UN-HABITAT, 2005)

The central business district of Kisumu is surrounded by eight informal settlements, which are namely: Bandani, Obunga, Manyatta A and B, Nyamasaria, Nyalenda A and B and Kibos (UN-Habitat, 2005). The Kisumu Urban City Profile report by UN-Habitat (2006a) reveals that about 60 per cent of Kisumu's approximately 500,000 inhabitants are living in informal settlements. Further on another UN-Habitat (1999) report indicates that another 60 per cent have no access to safe drinking water. The lack of sewerage services in the informal settlements, leads to unsafe sanitation habits, which include defecation and disposal of their wastes in open space (Munala, 2009). The population and size as well as the population density of the two informal settlements in Kisumu, Obunga and Bandani that were subject to this research, are shown in Table 10.

Table 10. Population, size and population density of Obunga and Bandani
(Source: modified from Munala, 2009)

Informal Settlements	Population [pp]	Size [km^2]	Approx. population Density [pp/km^2]
Obunga	8,576 (1)	1.39 (2)	6,200
Bandani	13,961 (1)	2.42 (2)	5,800
(1) Source: UN-HABITAT, 2005 (2) Source: UN-HABITAT, 2005 (maps, size of informal settlements determined with AutoCad)			

6.4.1 Obunga

The informal settlement of Obunga is situated adjacent to Kisumu's industrial area. The slum itself can be parted in three different areas: Sega Sega, Obunga central and Kasarani (Munala, 2009). For its closeness to the industrial area the informal settlement provides housing for casual workers working in the nearby industries (UN-Habitat, 2005). A report by UN-Habitat (2005) states that the road infrastructure in Obunga and Bandani is the worst of Kisumu area. The report also mentions that roads are impassable due to poor drainage and inadequate spacing between the shacks.

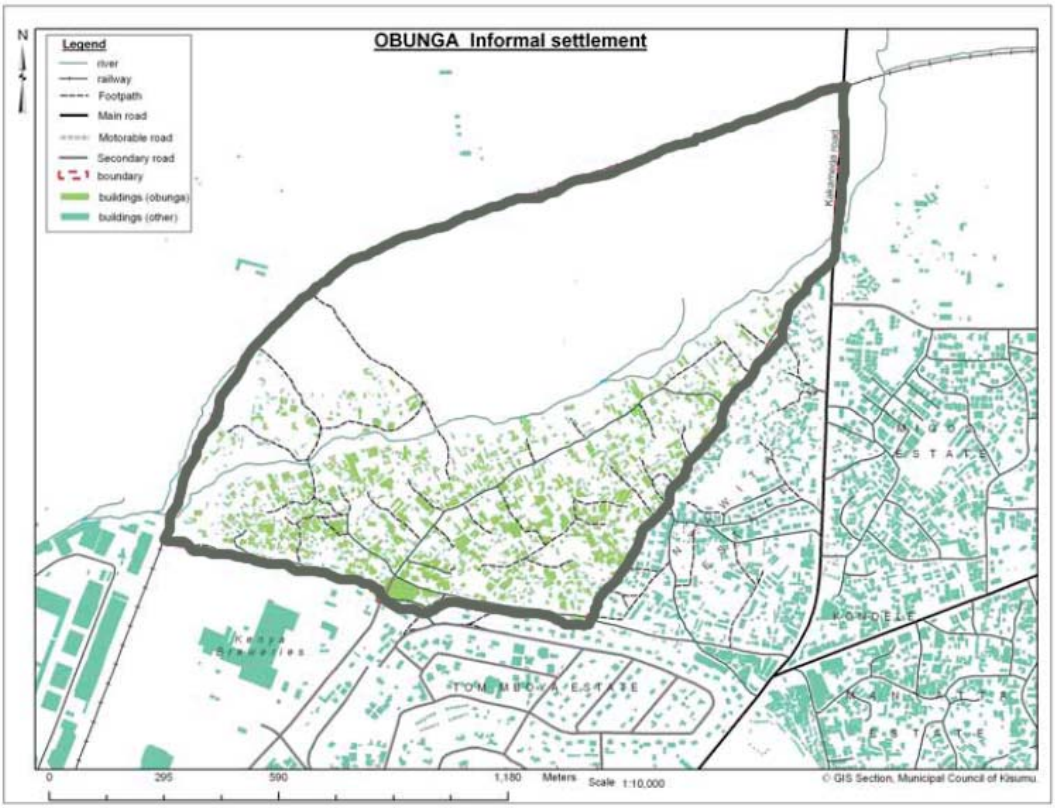

Figure 29. Map of Obunga
(Source: UN-HABITAT, 2005)

Obunga is provided with water supply infrastructure and water is supplied by the Kisumu Water and

Sewerage Company through the community organisations and also has access to shallow-wells. Nevertheless water supply is a major problem especially during times of water shortages. The situation is not much different when it comes to sanitation facilities. Most of the facilities are unevenly distributed due to the geographical profile of the region, and therefore force people to either queue and spend a long time or relieve themselves in the surrounding area. The lack of land for public facilities such as a community shared toilet or community centers in both Obunga and Bandani worsen the already poor health and sanitation situation (UN-Habitat, 2005).

6.4.2 Bandani

Bandani is another informal settlement that gives the impression of being more a rural village with poor inhabitants, than what a European would picture when thinking of a slum. Same as in Obunga the infrastructure is poor. The workers of Bandani and Obunga usually walk to reach their workplace and have to cross the railway line to Butere, which causes a serious threat to life (UN-Habitat, 2005). The water supply and sanitation system faces the same obstacles as in Obunga. Bandani is one of Kisumu's informal settlements that suffer from severe lack of water supply services (Munala, 2009). Also the provision of sanitation facilities is far off of being sufficient (UN-Habitat, 2005).

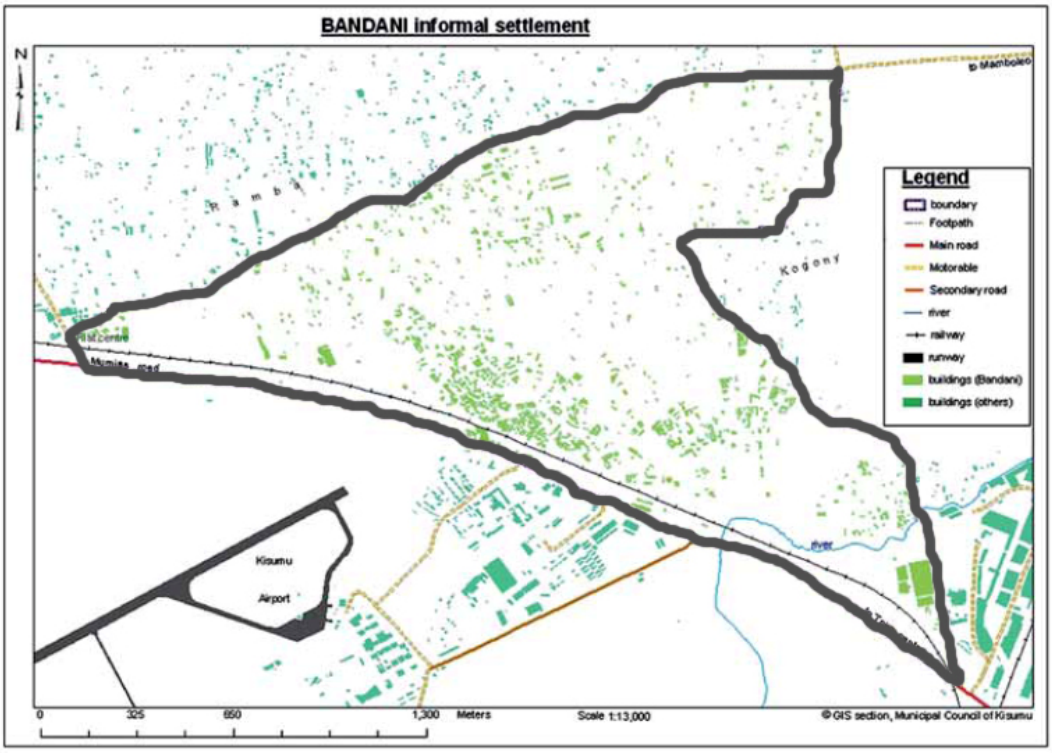

Figure 30. Map of Bandani
(Source: Munala, 2009)

Neither Bandani nor Obunga have their own health care facilities. Most of the slum dwellers cannot afford to pay for public transportation to get to their work place, and poor living conditions often cause immense health problems that cannot be met due to the rather far distance to the nearest health facilities (UN-Habitat, 2005).

When the well is dry, we know the worth of water.

Benjamin Franklin, Poor Richards Almanac, 1746

7 Investigation and Results of the Fieldwork

7.0 Introduction

The following sections present the results of the fieldwork parted in the key issues that were described in chapter 5.6. The first part deals with the water provision in the informal settlements concerning the availability and use, the water sufficiency and adequacy as well as pricing of water. The second part considers different types of sanitation technologies that are applied in the informal settlements and their use and maintenance. Thirdly the management of groups and organisations is discussed with a special focus on gender distribution within the management groups. The fourth section considers the environmental quality of water and sanitation services in informal settlements and the influences on each other. The fifth section deals with the socio-cultural influences in the water and sanitation sector. And finally the adaptative capacities of informal settlements concerning sustainability and sustainable development are discussed.

7.1 Water Provision in the Informal Settlements

As mentioned in chapter 1.5 there is a certain connection between sanitation and the use of water, for which the centralized sewer-based sanitation systems are the best example. The aim of the following chapter is to show the difference between the water supply system that we in the developed world are used to and the accessability of fresh water in the informal settlements. By doing so it will become easier to understand why the dry toilet systems as described in chapter 3.4.1 are more feasible than centralized water-borne systems.

7.1.1 Water Availability and Use in the Informal Settlements

The three visited informal settlements in Nairobi are connected to the water supply by Nairobi City Water and Sewerage Company (NCWSC). The connectivity varies in the level of legality involved. For instance in Kibera and Kibagare the connections are legal and have metering systems. But in Mukuru kwa Njenga on the other hand all connections are made illegally with no official metering system. The community sources the water from NCWSC but the distribution within the settlement is controlled by water cartels. In Bandani informal settlement in Kisumu, water is sourced from a variety of sources that include springs, rivers and Kisumu Water and Sewerage Company meter points.

Figure 31 a to c show different types of water points in the visited informal settlements.

Figure 31 a - c. [a)] Water point in Mukuru, [b)] protected spring in Bandani, [c)] piped water in Kibagare (Source: Author)

The usage of water does not vary widely between the five visited informal settlements, nor does the use fully depend on any cultural inclinations. The major variation in water usage are due to the differences in the social status and the income generating activities of the household members. Women are the ones who are responsible for the household and therefore require most of the water for cooking, cleaning and washing. Another big contributer to water usage is the undertaking of private businesses such as grocery shops and hotels. The average water use in all five informal settlements, calculated from the responses of the questionnaires, lies between 100 and 300 litres per household per day. Figure 32 a to c shows various occasions for the use of water in everyday life in the informal settlements.

Figure 32 a - c. [a)] Grocery shop in Kibera, [b)] washing area in Kibagare, [c)] cleaning ritual infront of mosque in Kibagare (Source: Author)

During the dry season the water availability decreases and is reducing further until water becomes a scarce resource that is hard to get especially in the informal settlements. The water rationing strategies of the water suppliers cause additional stress to the slum dwellers. In this time not only the usual water prices can rise up tremindously, but also the time which people spend in queues increases.

7.1.2 Pricing in Water Supply in the Informal Settlements

The usual price for the filling of a 20 litre jerry can with potable water ranges between ksh 2 and

ksh 5. However, due to the legal situation in Mukuru kwa Njenga, water is sold for between ksh 5 and ksh 10 per 20 litre jerry can. Figure 34 shows the five visited informal settlements and the prices that the questioned households pay daily for 20 litres of water under usual circumstances. The interviewees reported that during water scarcity the prices rise up to ksh 20 per 20 litres of water. Figure 33 and Figure 34 show the five visited informal settlements and the different water prices for 20 litres of water in connection with the amount of water points and households who sell / purchase water for the indicated charges.

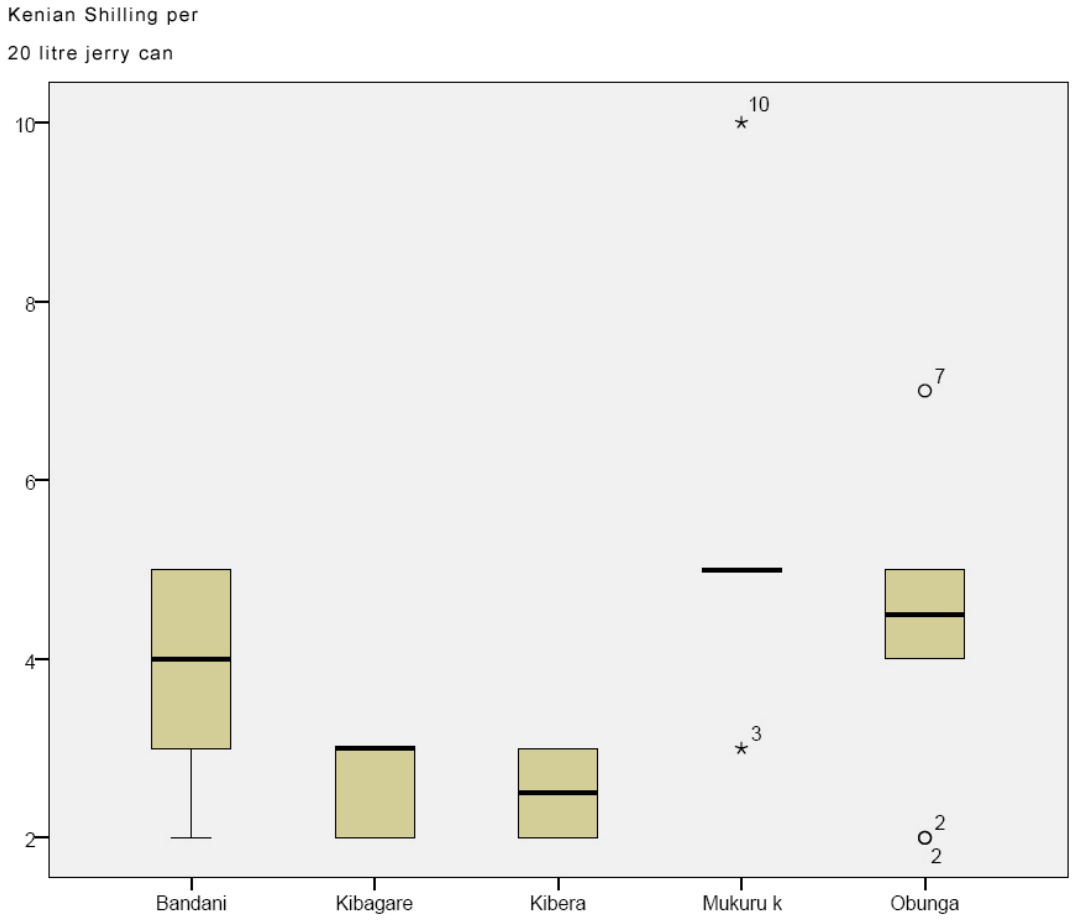

Figure 33. Water prices and amount of water points (sellers) per settlement
(Source: Author)

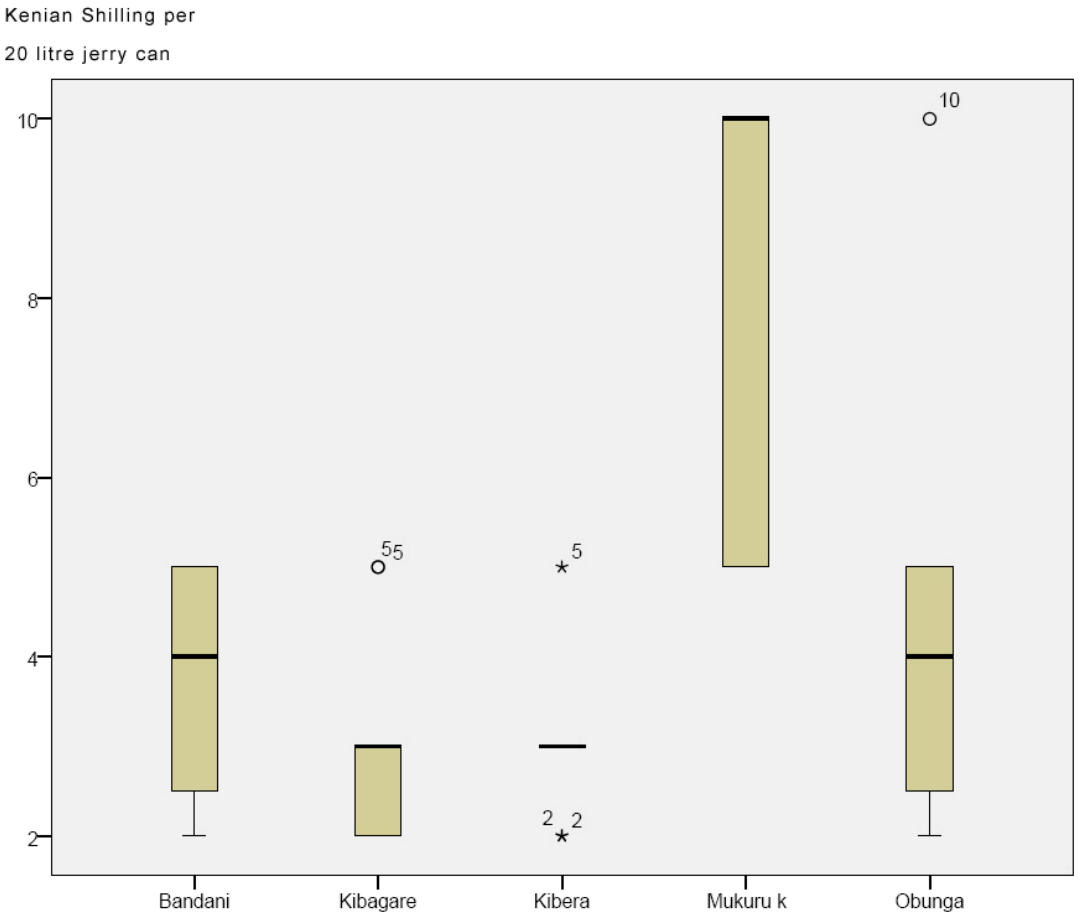

Figure 34. Water prices and amount of clients (households) per settlement
(Source: Author)

Figure 33 shows that the water price in Mukuru kwa Njenga and Obunga is higher than in the other three settlements. Whereas Figure 34 shows that in Mukuru more people pay ksh 10 per 20 litre jerry can than those who pay ksh 5 / 20 litre jerry can. The average price for water is the highest in Mukuru kwa Njenga which is calculated with the results of the household questionnaires to be around ksh 9 per 20 litres of water. The four other informal settlements sell their water for about ksh 3 per 20 litres on average.

In 1997 the absolute poverty line for Kenya for rural households was established at ksh 1,239 per month and for urban households ksh 2,648 per month (Thornton, et. al., 2002). The conversion from ksh per month to ksh per day sets the national poverty line in the urban sector at ksh 87.1 per day. Considering the income generation compared to the national poverty line, Figure 35 shows that 28 out of 40 water vendors can exceed the national poverty line with the generated income. On the international level the situation is mildly worse, since 24 out of 40 water vendors earn more than US $ 1.25 daily.

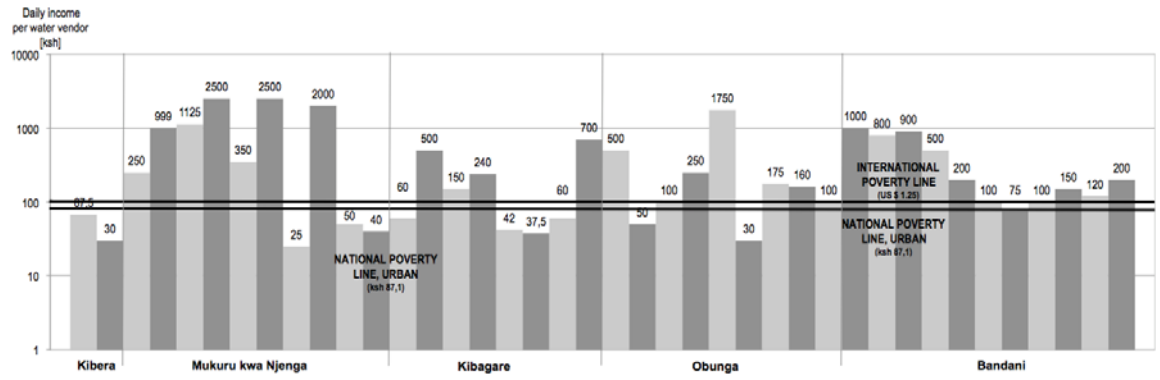

Figure 35. Gross daily income of water vendors in comparison with national (urban) and international poverty level
(Source: Author)

However, even if the gross earning is above the national or rather international poverty line, the net income can still fall below, since charges from the water company or the water cartels reduce the income. For instance in Nairobi the average tariff is approximately ksh 25 per m³ (Biesinger et. al, 2007) which converts to about ksh 0.5 per 20 litre jerry can. Of the 20 interviewed water vendors in Nairobi's informal settlements 11 water vendors were able to exceed the international poverty line with their gross income, and still the net income of 10 water vendors can exceed the international poverty line (Figure 36).

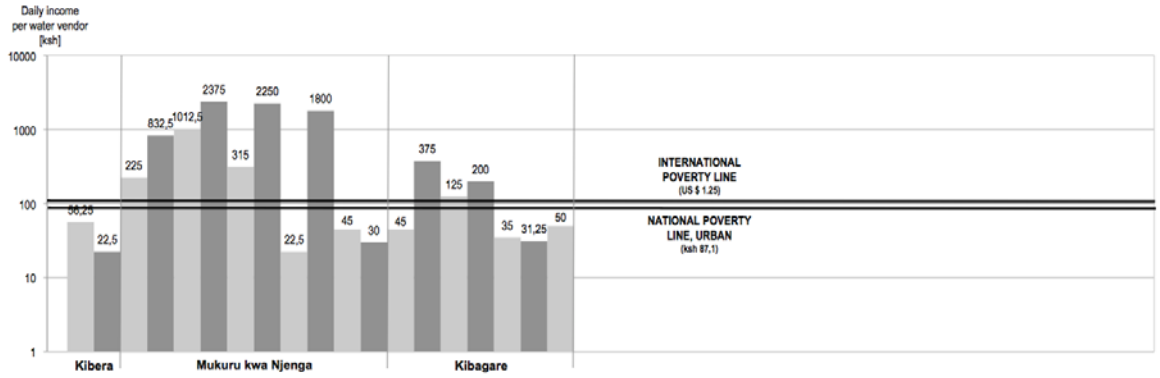

Figure 36. Net daily income of water vendors in comparison with national (urban) and international poverty level
(Source: Author)

7.1.3 Water Sufficiency, Reliability and Adequacy

The responsibility for the collection of water for the family falls to about 65 per cent to the female household members. The remaining 35 per cent do not only represent the male community members, but also employees who are send to fetch water, water vendors who deliver water to their clients and other family relations. Members of single households have to go and fetch water far more rarely than others. One respondent even mentioned to make only one trip for potable water in three days.

There are significant differences to the means of transportation of water. Men are usually, when they are in good health, able to carry more than a single 20 litre jerry can. Additionally it was observed that they often use a carriage to transport twelve 20 litre jerry cans or more. Women on the other hand usually walk with a single 20 litre jerry can. Depending on the tribe to which the woman belongs, the ways to carry the jerry can varies as shown in Figure 37 a to c.

Figure 37 a - c. Three different means of transportation of water
(Source: Author)

This difference in transportation is one of the influences that have an impact on the time requirement and at the same time the amount of daily trips that are necessary to fetch the water. This survey reveals that on average four to six trips per day are undertaken per household per day to meet the need for potable water. Figure 38 shows for each visited informal settlement a list of the amount of trips, and combines this list with the number of people who undertake a certain amount of trips per day.

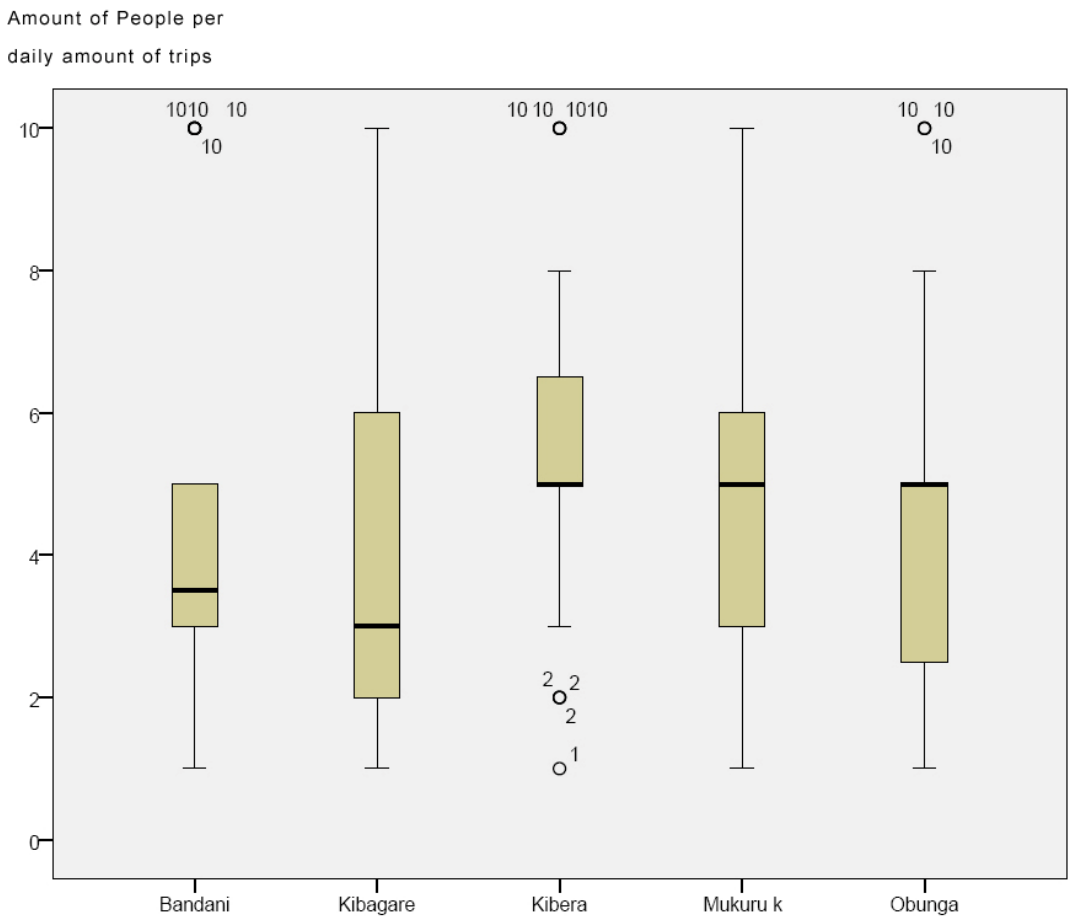

Figure 38. Amount of people per daily amount of trips (for the five visited informal settlements) (Source: Author)

Figure 39 shows separately for the five considered informal settlements the number of trips that people undertake within a certain timeframe. This graph reveals that only in Kibera and Kibagare the distances to the water source are short enough so that a single trip under normal circumstances does not exceed a timeframe of 30 minutes (apart from one exception in both settlements). Bandani on the other hand obviously has serious problems when it comes to the time consumption per surveyed trip. About 54 per cent of the undertaken trips take longer than one hour, including the queuing at the water point.

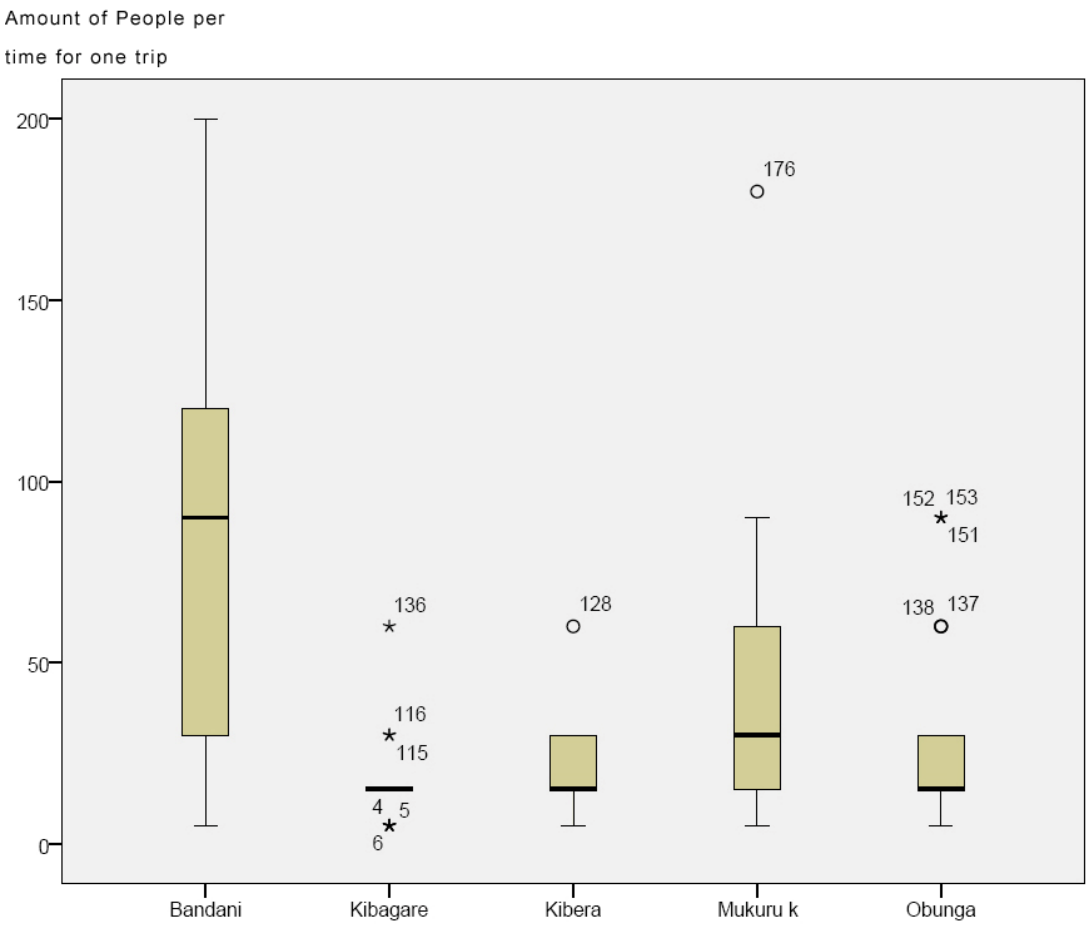

Figure 39. Amount of people per time for one trip (for the five visited informal settlements)
(Source: Author)

As mentioned droughts and water rationing by the water supply companies can result in major problems such as extended queuing time at the water source, as shown in Figure 40 a to c, and water scarcity. Around 20 per cent of Kibera's, 69 per cent of Mukuru's, 34 per cent of Kibagare's, 25 per cent of Obunga's and 54 per cent of Bandani's residents report to not have sufficient water supply throughout the year. The slum dwellers try to overcome this periods of water scarcity with with water storage and minimization of usage.

Figure 40 a - c. Queue at a water point served by KIWASCO
(Source: Author)

The respondents to the household and water point questionnaires were asked about their opinion on

the water quality characterized by the indicators of colouration and odour. Figure 41 shows the results of the survey on the household level. The yellowish columns represent acceptability of the colouration, the blueish columns represent the results on the questions about the odour of the water. In Kibera, Obunga and Bandani the majority, which is represented by more than 88 per cent of the respondents, considers the colouration of the potable water agreeable. In Mukuru kwa Njenga and Kibagare the colour of the water is still judged as acceptable by at least 65 per cent of the respondents. The odour of the water is judged as agreeable by at least 78 per cent in Kibera, Mukuru kwa Njenga, Obunga and Bandani. Only 46 per cent of Mukuru's residents do not complain about the water's odour.

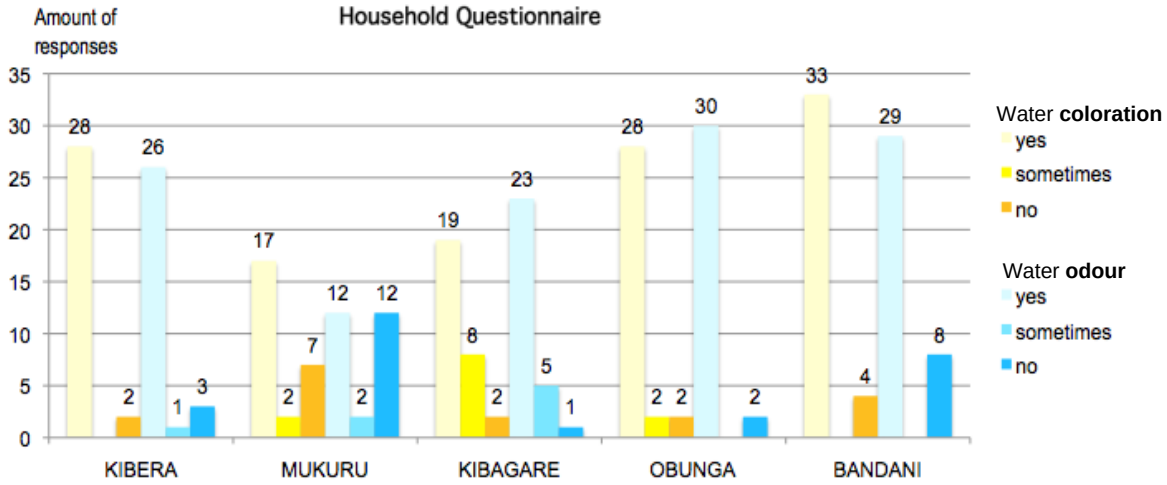

Figure 41. Acceptability of the coloration and the odour of the water on the household level (for the five visited informal settlements)
(Source: Author)

The perspective of the water vendors are basically the same. In all five visited informal settlements more than 80 per cent of the respondents judged the colouration of the water acceptable. The odour of the water was found to be agreeable by more than 90 per cent of the interviewed water vendors in Kibera, Kibagare, Obunga and Bandani. Only in Mukuru kwa Njenga 60 per cent of the water vendors do complain about the smell of the water (Figure 42).

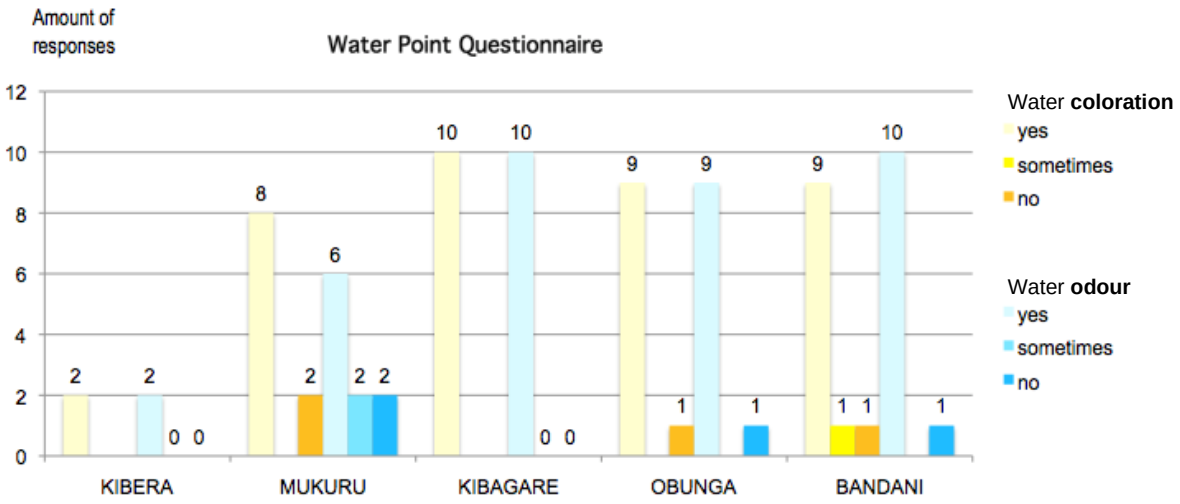

Figure 42. Acceptability of the coloration and the odour of the water on the vendor level (for the five visited informal settlements)
(Source: Author)

The study reveals that a majority of the slum dwellers in the considered informal settlements do not have too many complaints about the colour and odour of the water, nevertheless the people treat their water before use, either by boiling it or adding of chemicals such as chlorine (Figure 43) or water guard. This is a contradiction to the responses given during the interviews, as this indicates a sub-conscious acceptance that their water is not safe. Figure 43 shows a chlorine dispenser funded by Umande Trust, beside a protected spring in Bandani.

Figure 43. Chlorine dispenser in Bandani, funded by Umande Trust
(Source: Author)

Apart from the discussion on the quality of the water, the given issues on access and reliability of water, which depend not only on the income but also on seasonal patterns and the water supply companies clearly show that a additional expenditure of valuable fresh water in water-based sanitation system is an expenditure too much, considering the fact that it can be avoided by using dry toilets.

7.2 Sanitation in the Informal Settlements

7.2.1 Types of Sanitation Facilities

The usage of community shared pit latrine facilities is widely spread, especially in Kibera, Obunga and Bandani, as to be seen in Figure 44. Fourteen respondents in Mukuru kwa Njenga and nine more in Kibagare mention that they use a plot-shared pit latrine facility. The usage of bio-centres is not yet widely spread. In Mukuru kwa Njenga as well as in Obunga and Bandani, the bio-centres are either under construction or in the beginning phase of operation. However, Schouten et. al. (2010) reports of a study undertaken by Jenkins and Curtis in 2005 on user satisfaction concerning biogas toilet facilities. According to the report the study reveals that the users are discontented with the smell that is to be associated with the technology.

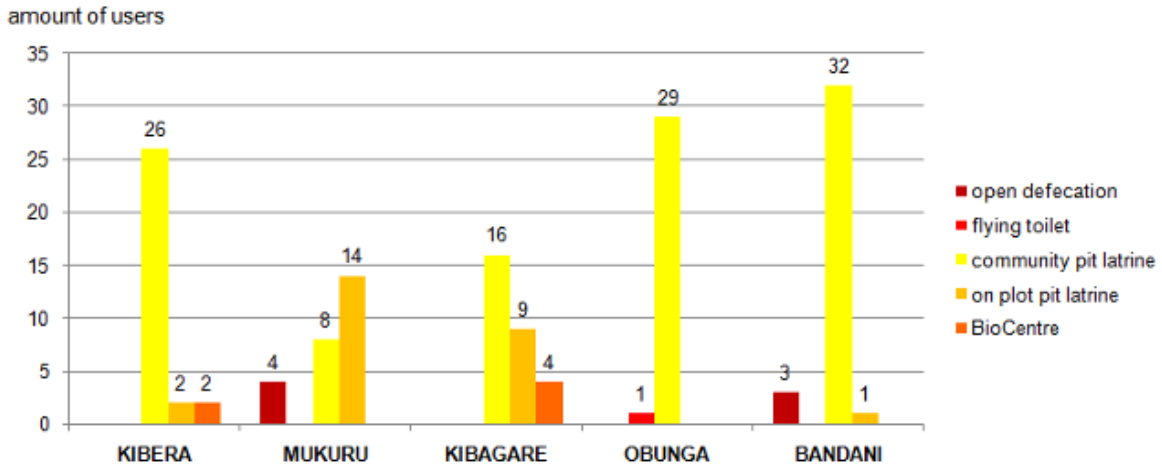

Figure 44. Amount of people using the various sanitation options (primary choice)
(Source: Author)

Nevertheless, lack of money changes the picture. Especially in Bandani people defecate in the open or use flying toilets when they can not afford to use the community toilet or their on-plot toilets are filled (Figure 45). The residents in Mukuru kwa Njenga and Kibagare who usually use on-plot pit latrines abandon those that are filled and use the community shared facilities instead.

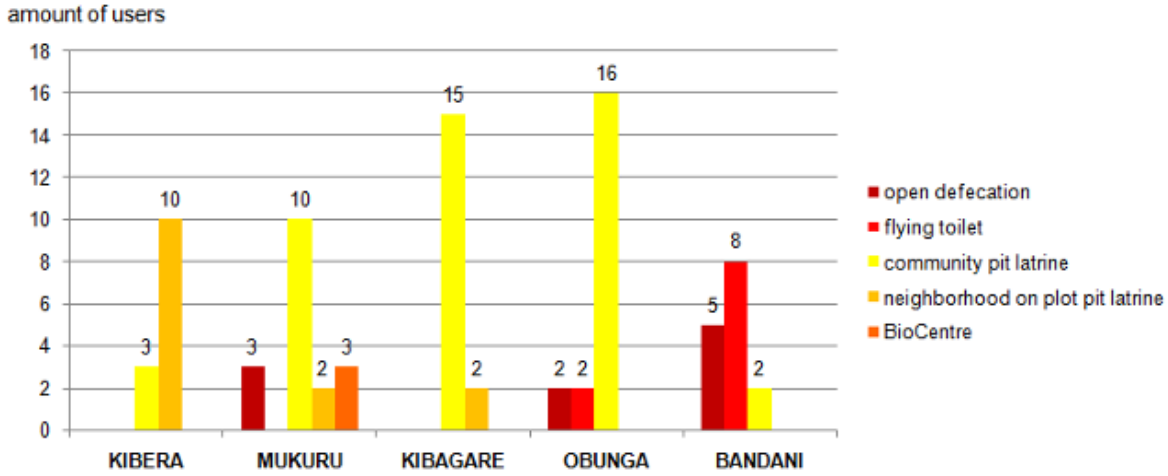

Figure 45. Amount of people using the various sanitation options (secondary choice)
(Source: Author)

Comparing the five visited informal settlements the sanitation situation is the poorest in Bandani. Even though this survey revealed that 88 per cent of the respondents have the opportunity to use community shared facilities, 13 of the 37 respondents indicated that they are forced to relieve themselves in the open, five of them e.g. in the bushes and eight use flying toilets.

Figure 46 a - d. [a)] Plot-shared single pit toilet, [b)] community-shared single pit toilet with shower, [c)] bio-centre, [d)] inside a plot-shared single pit toilet
(Source: Author)

As Figure 46 a to d reveal that most of the sanitation facilities encountered during the fieldwork were either community shared or plot share single pit latrines. The single pit toilet and its correct use and handling is described in chapter 3.4.1.2. A most vital part is the application of leaves or similar material after ever defecation to loosen up the material and provide the best possible conditions for degradation. Additionally this practises reduce the odour and therefore the facility attracts less insects. Of all those plot shared pit latrines not a single one was maintained this way and therefore was in extremely dirty and unhygienic state. Also the construction of the facilities themselves where not designed for such a handling. As to be seen in Figure 46 a,b and d most of those toilets have a rectangular concrete slap that is not transportable and therefore excludes the application of the arborloo system. As a result these toilets are either emptied by the users themselves or by a contracted company, or the users simply abandon the toilet with its superstructure which results in a

loss of already scarce space.

7.2.2 Use and Acceptance of Sanitation Facilities in the Informal Settlements

The usage and comfort of a sanitation facility varies between the different users. In the field survey in the five visited informal settlements the respondents were questioned about the comfortability of use of the sanitation facilities for women, children and elderly people. There are many problems that lead to these unagreeable circumstances. Women and children are usually the major target groups for crime especially when the toilet facility is not very close to the homestead, whereas the elders may have problems using the facilities due to lack of physical capability. Other reasons for discomfort include for example the state in Mukuru kwa Njenga where around 90 per cent of the interviewees report to share their toilet facilities with more than fifty people which reportedly has an impact on the cleanliness of the facility. The fear that children might fall into the hole in the concrete slap or become victims to crimes and also the fact that they lack the money to pay for the facility are other reasons given for the negative responses for acceptability of use for children. Low acceptance of the facilities for elder people is due to the fact that the pit latrines only consist of a slap. Therefore the people have to squat over the hole which is considerably more difficult for elderly people. Those who do not use any sanitation facility at all either do not have the opportunity to use one or lack the money to pay for the service. The price for the use of the toilet is ksh 5 and ksh 10 for the use of the shower.

Table 11. Percentage of acceptance of various toilet systems in relation to questioned respondents (Source: Author)

	KIBERA		MUKURU		KIBAGARE		OBUNGA		BANDANI		TOTAL	
	Users	Acceptance [%]	Users	Acceptance [%]	Users	Acceptance [%]	Users	Acceptance [%]	Users	Acceptance [%]	Users	Acceptance [%]
open defecation												
women			4	-100%					4	-100%	8	-100%
children			4	-100%					4	75%	8	38%
elder			4	-100%					4	-100%	8	-100%
flying toilet												
women							2	50%			2	50%
children							2	50%			2	50%
elder							2	-100%			2	-100%
community pit latrine												
women	26	85%	7	14%	16	69%	29	59%	32	44%	110	59%
children	26	88%	7	14%	16	63%	29	72%	32	19%	110	55%
elder	26	88%	7	14%	16	69%	29	59%	32	41%	110	59%
on plot pit latrine												
women	2	100%	14	64%	9	22%			1	-100%	26	50%
children	2	100%	14	43%	9	22%			1	-100%	26	38%
elder	2	100%	14	64%	9	22%			1	-100%	26	50%
BioCentre												
women	2	100%			3	100%					5	100%
children	2	100%			3	100%					5	100%
elder	2	100%			3	100%					5	100%

The comparison of indicated usage of toilet facility and the acceptability of this facility for women, children and elderly is shown inTable 11. It must be considered that the questioned household member provides evaluations on acceptability of the facility for women, children and elderly at the same time. The results are described in per cent and differentiated between the five informal settlements. Additionally the user acceptance over the five settlements as a total in combination with the total of questioned user per facility are shown in Table 11 as well as in Figure 47.

The research area in Kibera includes the villages of Soweto West, Gatwekera and Gatwekera East, Kisumu Ndogo and Kambi Muru. There are five bio-centres within Gatwekera and Gatwekera East area, namely the Nyaharwa bio-centre, the Jasho Letu bio-centre, the Kidiyot bio-centre, the Multi Vision bio-centre and the Tosha II bio-centre. Additionally Karanja et. al. (2009) states that there are about 550 latrines within the given research area in Kibera. The high population

density in Kibera of about 66,957 capita per square kilometre and the size of the research area of about 0.68 square kilometres explains the rather small amount of two respondents that indicate to use the bio-centre and the higher amount of 26 clients to community-shared pit toilets.

The results in Table 11 clearly show the unacceptance of open defecation as a toileting method. However 75 per cent of the respondents in Bandani find open defecation for less problematic than for women and elderly due to their less developed sense of shame. However security is a problem that affects all in toileting in the open especially during the night time. Table 11 also shows a 100 per cent inacceptance of the on-plot pit latrine in Bandani, but only one of 37 interviewees is using this toilet system.

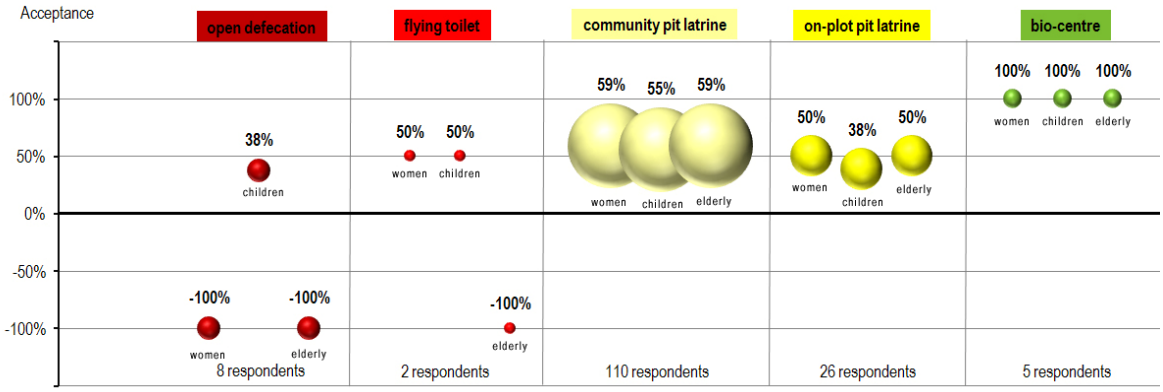

Figure 47. Percentage of acceptance of toilet systems in relation to questioned respondents (Source: Author)

Figure 47 shows the percentage of acceptance of five different sanitation facilities as a total of all household questionnaire responses. Additionally the amount of respondents using a certain type of sanitation facility is catagorized by the size of the spheres since the amount of users has a weightning effect on the percentage of acceptance. For instance, the survey revealed that the bio-centre enjoys a 100 per cent user satisfaction, however only 3 per cent of the interviewees use the bio-centre. On the other hand the community pit latrine of enjoys 55 to 59 per cent user satisfaction that is represented by 73 per cent of the interviewees. Therefore one must consider the proportion of users per facility when evaluating the user acceptance of the certain facility. An additional consideration must be made on the availability of sanitation facilities for the users.

The awareness on the importance of hygiene lead to the fact that sanitation facilities offer an opportunity for handwashing. See for instance a wash basin with a small tank at the Gatwekera bio-centre (Figure 48). Around 79 per cent of the interviewees in the five informal settlements indicate to wash their hands after every use of the toilet, whereas in Kibagare the rate is the highest with about 93 per cent and the lowest in Bandani with 62 per cent of the respondents claiming to wash their

hands after the use of the toilet.

Figure 48. Interviewee using a hand washing device at BioCentre, Kibera
(Source: Author)

7.2.3 Maintenance of Sanitation Facilities in the Informal Settlements

About 60 per cent of the questioned managers of sanitation facilities complain about problems concerning the maintenance of the facilities, mainly because of the human excreta on the concrete slap, small space to proceed with the cleaning process and the lack of water. Only about eight per cent of the questioned managers extract the wastes in the pit themselves. For instance, four of the considered facilities drain their wastes through a pipeline into the bio-centre, the rest of the respondents pay specialists to exhaust the wastes and dispose of them. In Kibera two of three interviewees extract the waste themselves, of which one uses it for urban agriculture and the other one disposes of it in the open sewer. The duration between subsequent extraction varies between two weeks and three years, depending on the type of facility, the amount of users and the size of the pit.

7.2.4 Technical and Performance Aspects of Adaptive Sanitation in the Informal Settlements

According to UNESCO (2006), to define the technical and performance aspects of a sanitation facility a system thinking approach is useful to not only determine the functionality of a single technical asset but also the influences that one asset has on another or on the entire system. The following aspects for assessment of functionality are suggested:

- *Collection, treatment, transport and use of wastes* (UNESCO, 2006)
- *Resource and energy efficiency during operation* (UNESCO, 2006)
- Availability of technical labour
- Life expectancy

Bio-centres are permanent structures, built of concrete and brick. The collection and treatment of the human wastes is undertaken in an underground concrete dome, therefore extraction and transportation of the waste to a treatment facility is not necessary. The maintenance operations at the bio-centre are more time and labour consuming for the facility consists of a set of toilets and showers as well as a cooking device. Additionally the extraction of the fertilizer and the handling of the collected biogas is part of the operation of the facility. After the on-site treatment the wastes are put into use as fertilizer. The biogas that is developed during the treatment process is put into use for cooking and the production of electricity. Therefore the resource and energy efficiency during the operation is high. The Figure 49 a to c show the inside of a bio-center in its construction phase.

Figure 49 a - c. Construction of a bio-centre [a)] hole in the concrete slap and the dome, [b)] toilet, [c)] showers (Source: Author)

Pit latrines are temporary structures where the wastes are collected in a pit. As described in chapter 3.4.1.2 the pit latrine offers ways for waste treatment. Nevertheless the study revealed that 75 per cent of the surveyed pit latrines are not emptied for reuse, instead the residents abandon them. However the wastes of the remaining 25 per cent are exhausted from the pits and disposed of. Therefore the wastes have to be transported by exhaustion trucks. The resource efficiency as well as the energy efficiency is very low. The wastes could be composted on-site and used as fertilizer. Additional energy is necessary to exhaust the wastes and to dispose of them. Furthermore due to improper use of the pit latrines the maintenance, which consists of frequent cleaning of the toilet, is a burden to the users caused by the development of odour and attraction of insects.

The idea of having bio-centres was developing a sanitation system that would be adaptable in the informal settlements. However the use of standardized Asian-type squatting toilets defeats this purpose. This makes its use difficult for the elderly and dangerous for children.

The availability of technical labour within the informal settlements is very limited due to the low level of education. Therefore all technical support has to come from the outside and is provided to the residents of the informal settlements by NGOs. Adaptive sanitation systems such as the bio-centres need require detailed knowledge on various technical aspects since these facilities are not a

simple structure because apart from their function as shower and toilet facility they are designed to produce fertilizer and biogas.

Pit latrines are temporary structures made of a pit, covered by a concrete slap with a hole and a superstructure that is build of wood and metal. The depth of the pit limits the life expectancy of the pit latrines. When the pit is full the users either empty the pits or abandon the toilet. Bio-centres are built of concrete and brick. The depth of the pit does not limit the timeframe for their operation, since the dome that collects the wastes is emptied continuously as stated by the management teams. Therefore the life expectancy of these buildings is limited by the life expectancy of the construction material.

The improper handling of the pit latrines leaves a certain ecological footprint. Its size depends on the environmental background in which the toilet facility is located. Abandoned pit latrines require space even though they are unused, and their effluents have a certain potential to contaminate water bodies and therefore also drinking water. Since this system is an open loop system the loss of valuable resources and nutrients in the pit contribute is a great economical as well as ecological loss. Adaptive toilet systems aim to close the loop and reduce those losses and adverse effects.

7.2.5 Dependencies and Influences in the Implementation of a Sanitation Facility in the Informal Settlements

To ease the understanding of the understanding of the society approach to sanitation, Santosh et. al. (2007) names three cultural aspects that have to be considered, which are psychological deterrents of handling human wastes, social aspects such as gender issues and religious influences. Additionally economic well being of either the individual or the society has an impact on the approach of a sanitation system.

During the fieldwork personal observations clearly revealed the interconnections between cultural and religious believes, societal status as well as the natural environment and legislative boundaries when it comes to the construction and use of a sanitation facility. Figure 50 tries to explain the correlation of four subsections that influence each other in consideration of a community approach to the sanitation system (Santosh et. al., 2007). The subsection human settlement considers the differences of availability of space between urban and rural settlements. Further on the choice of sanitation system strongly depends on the natural background such as the natural terrain and landscape. The society aspect considers the differences in the choice or even availability of sanitation systems. For instance, in the developed world a household within a city will naturally connect the sanitation to the public sewerage since the infrastructure is in existence, and additionally

legislation often demands the procedure. Religious differences in sanitation can be encountered with members of Islamic religion, since they consider cleaning as a part of the purification rituals, of which reason the households demand water in their toilets and latrines. These given influences on the community approach to a sanitation facility go along with the responses from the interviewees to the household questionnaires. Santosh et. al. (2007) also reports of Muslim communities minding that the direction of the toilet facilities must never face towards or directly away from Mecca. Also the Koran states that the use of excreta for agriculture is allowed if the excreta are free of impurities. He also states that the Bible only mentions concerns on *sexual morality, personal hygiene and the burial of human excreta*, but nothing about the use of excreta for agriculture.

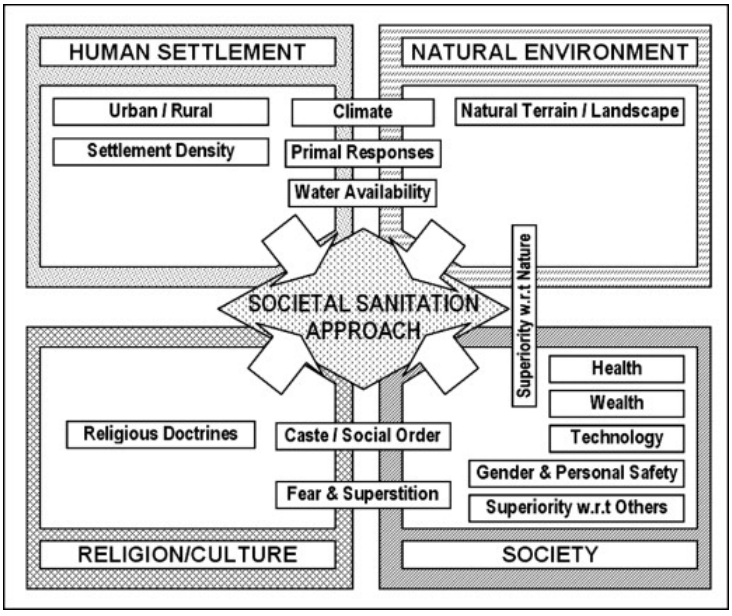

Figure 50. Detailed system structure/model of societal sanitation approach
(Source: Santosh et. al., 2007)

Another approach to be considered in the community aspects of sanitation is given by the United Nations Educational Scientific and Cultural Organization and the International Hydrological Programme of UNESCO (2006). They report that the promotion of sanitation can be approached from two points of view. The institutional point of view promotes sanitation as an important factor to improve hygiene and health. At the same time they report that this argument does not motivate low-income households to invest into sanitation facilities. They rather propose factors such as privacy, safety, dignity and social status as the household point of view of motivation. This is strongly reflected by the answers given to the household questionnaires. The interviewees in this research indicated their wishes for safety and for the cleanliness of the facility, which is a reference to the natural wish for personal dignity.

7.3 Environmental Quality in the Informal Settlements

The quality and safety of water depends strongly on the correct handling of sanitation facilities, especially in informal settlements where the pit latrine is a common toilet system. The survey revealed that about 37 per cent of the considered water points have a sanitation facility less than 50 meters away. Of those 56 per cent are pit latrines, which are possible hazards to the water points. Three of those possibly endangered water points are boreholes, which can suffer contamination by the effluents of the pit latrines. A borehole that had to be abandoned due to contamination by a nearby pit latrine can be observed in Figure 51 a and b.

Figure 51 a, b. Abandoned borehole due to contamination by a nearby pit latrine
(Source: Author)

The residents of the settlements pour their domestic waste water into the open sewerage channels, trenches and riverflows along with their domestic solid wastes. The effluents of these distributions either perlocate into the groundwater or contaminate the rivers directly.

Figure 52 a - d. [a)] Water pipe and polluted river, [b) and c)] water pipes in sewerage, [d)] solid wastes on unoccupied land
(Source: Author)

Figure 52 a to d show the expanse of pollution in the informal settlements by the examples of water pipes in contaminated sewers and rivers as well as the massive amount of disposed solid wastes on land that is not yet occupied by any form of construction.

7.4 Management and Gender Issues in Sanitation Management in the Informal Settlements

A report by Achieng (2007) mentions that the first bio-centre in Nairobi was erected in 2007 in Gatwekera, one of Kibera's fourteen villages. Further on she states that this bio-centre was handed over to a business management committee that consist of five male and five female members of the community. The report also indicates that this group received training in business management beforehand to be prepared to deal with all activities concerning the bio-centre, which include toilet and shower facilities, business and office space, multi-purpose space as well as biogas fuelled cooking, drinking water and fertilizer from the digester.

During the fieldwork within the five visited informal settlements investigations on the gender distribution in the management groups of the sanitation and water points were undertaken. Table 12 shows the gender distribution in management groups of sanitation and water supply points in Kibera, Kibagare and Bandani informal settlements. Even though 60 per cent of the water and sanitation points shown in Table 12 are led by a male gender chairperson, an average of 57 per cent of the considered group members are female.

Table 12. Gender distribution in management groups of sanitation and water supply points in Kibera, Kibagare and Bandani
(Source: Author and Umande Trust)

	KIBERA						KIBAGARE	BANDANI		
	Water Point	Sanitation Point	Water & Sanitation Point	Water & Sanitation Point	Water & Sanitation Point	Water & Sanitation Point	Sanitation Point	Water Point	Water Point	Water & Sanitation Point
Name of the Management Group	Bidii yetu group	MUVI gorofani	TOSHA-2	KIDYOT	Lindi Usafi group	JASHO LETU	Haki Zetu	-	-	-
Amount of Members of the Group	33	52	80	66	20	70	42	7	9	10
Amount of Female Group Members	12	10	80	25	13	45	22	3	5	5
Percentage of Female Group Members	36%	19%	100%	38%	65%	64%	52%	43%	56%	50%
Gender of the Chairperson	male	male	female	male	male	male	female	female	female	male

The role of women in the water supply and sanitation sector gets more and more attention, which is represented in the results in Table 12 as well as in various reports on gender mainstreaming, such

as the UN-HABITAT report Mainstreaming Gender - Water and Sanitation (2006b) and the Interagency Task Force on Gender and Water report A Gender Perspective on Water Resources and Sanitation (2004).

8 Answers to the Research Questions, Conclusions and Recommendations

8.1 Introduction

The following chapters present the summary of the fieldwork through answering the research questions given in chapter 1.4. Further on the conclusions that can be drawn from the observations and the fieldwork are discussed and recommendations for further development in sanitation projects in the informal settlements are presented. The last subsection suggests topics for further considerations as a result of this master thesis.

8.2 Answers to the Research Questions

Objective I - To investigate the current socio-cultural status of water and sanitation in the informal settlements.

a. What are the sources of water supply in the informal settlements?

In general there is a great variety in sources of water supply in the informal settlements, which e.g. include protected springs, boreholes, shallow wells and water tanks. With 47 per cent occurrence in this research the water tank is the most common source of water encountered in this research.

b. What are the influences on the pricing mechanism in the informal settlements?

The water price is influenced by environmental matters such as the dry seasons during the year and the correlated water scarcity as well as anthropological reasons such as pollution and illegal connections and development of water cartels in the informal settlements.

c. What uses is the water put to in the informal settlements?

The residents of the informal settlements use the water for all sorts of domestic purposes, such as cooking, washing and drinking. In case a resident undertakes a business such as a small shop or a hotel the water is also used for occupational purposes.

d. What is the environmental quality in the informal settlements?

Trenches and drainages along the streets and narrow pathways are filled with garbage. These trenches also act as lining for the water supply pipes. Solid wastes pollute most of the streets and pathways as well as unoccupied spaces between the shacks and therefore occasionally pose a certain threat to fresh water sources.

e. What types of sanitation facilities are available in the informal settlements?

The most common sanitation facility that was encountered in the visited informal settlements is the pit latrine, either in the form of a plot-shared or a community-shared facility. Apart from that open defecation still remains a problem to several areas in the considered informal settlements.

f. What are the management structures for water and sanitation in the informal settlements?

As the results of this study given in Table 12. Gender distribution in management groups of sanitation and water supply points in Kibera, Kibagare and Bandani reveal, female participation in management structures in the water and sanitation sector is significant. The lowest amount of female management participation is recorded at a sanitation point in Kibera were 10 out of 52 group members (MUVI gorofani group) are women. At the same time, another management group (TOSHA-2 group) with a hundred per cent female participation is also recorded in Kibera.

g. What are the socio-cultural influences affecting water and sanitation?

It is observed that sanitation habits are influenced by the religion for Christians use toilet paper after toilet whereas Muslims refuse to use toilet paper and use water instead. In the water sector the way women carry the jerry cans depends on the tribe to which she belongs.

h. What are the influences on the life times on sanitation systems in the informal settlements?

The lifetime of a sanitation facility depends highly on the construction material as well as the proper use and maintenance. The lifetime of pit latrines is reduced due to misuse, for which reason they are abandoned after they are filled. Bio-centres are built of permanent structures such as concrete and brick. Their lifetime is not limited by the size of the pit because treated wastes are extracted continuously.

Objective II - To examine the legal framework for sanitation in the informal settlement.

a. What are the international guiding principles in regards to provision of sanitation?

Important guiding principles on the international level are the Agenda 21 on the implementation of sustainable development into national legislations, the eight Millennium Development Goals defined by the United Nations and the Bellagio Principles which deal with sustainable development in sanitation and waste water management in specific.

b. What are the national legal frameworks governing provision of sanitation in Kenya?

In 2002 the new Kenyan Water Act became effective, which defines a clear differentiation between water conservation of water resources and provision of water and sewerage services. Hand in hand the correlated responsibilities and duties for the water supply sector as well as the wastewater sector are described.

c. What is the main legal issue in informal settlements?

The major legal problem in informal settlements is the question of land ownership. Many informal settlements are established on government property, whilst the slum dwellers pay rental fees to private landlords. This legal handling leads to uncontrolled urbanization which poses management problems to the city councils. Therefore poor connection to infrastructure such as roads and public transportation, water supply and sewerage are resulting.

Objective III - To examine the applicable sanitation systems in the informal settlements.

a. What is the new paradigm shift in sanitation provision in the informal settlements?

The shift in paradigm is based on the fact that the demand for resources is increasing far more than can actually be met. Therefore newer sanitation projects are designed to recycle resources and complete cycles rather than wasting resources. The concept of the bio-centres follows these principles by introducing an adequate waste and resource management system.

b. What strategies are employed by residents in ensuring adequate and safe sanitation services?

Nowadays the residents take the opportunity of using sanitation facilities, rather than defecate in the open. This is already an improvement to stressed sanitation and hygiene situation. Multiple uses of facilities such as the bio-centre offers are adaptive systems that provide not only showers and toilets but also space for shops and community areas as well as resources such as biogas and fertilizer.

Objective IV - To examine the factors which are vital for the success of a sanitation project in the informal settlement

a. What are the adaptive requirements for an adequate sanitation system in the informal settlement?

To be considered adequate a sanitation system in the informal settlements must be resource oriented, easy to use and maintain and therefore also easy to understand in its functionality. It should provide benefits to the users and the managers of the facility.

8.3 Conclusions

8.3.1 Conclusions on Commonness of Sanitation Facilities

The **most common sanitation facility** in all five visited informal settlements is the pit latrine with 82 per cent of the respondents using it (Figure 53). Schouten et. al. (2010) describes the main reasons for its popularity as the independence of infrastructure such as a sewer line or electricity connection. However personal observations during the fieldwork lead to the conclusions that firstly for landlords who rent out shelters in plots literally do not want to waste more space for more improved toilet facilities. Secondly community-shared toilets obviously already exist for quite some time and the knowledge about the proper handling of any other more improved sanitation type than the single pit latrine is still not widely spread. These two facts simply explain the high percentage of users of the single pit latrine as given in Figure 53.

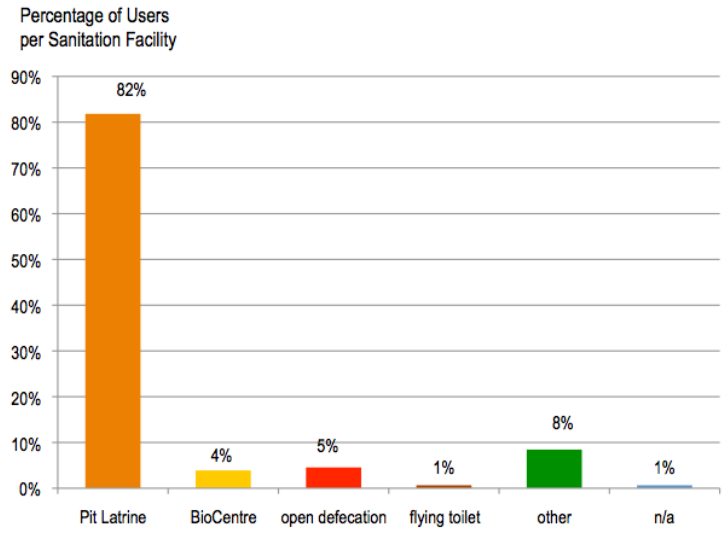

Figure 53. Percentage of users per sanitation type
(Source: Author)

The content of Figure 54 a by Schouten et. al. (2010) shows the **determinants for user satisfaction** on community-shared toilet facilities and the importance of each determinant to the user's satisfaction. The results displayed in Figure 54 a are based on a research that was undertaken in Kibera, whereas the results of Figure 54 b are based on research in the five informal settlements that are subject to the given research.

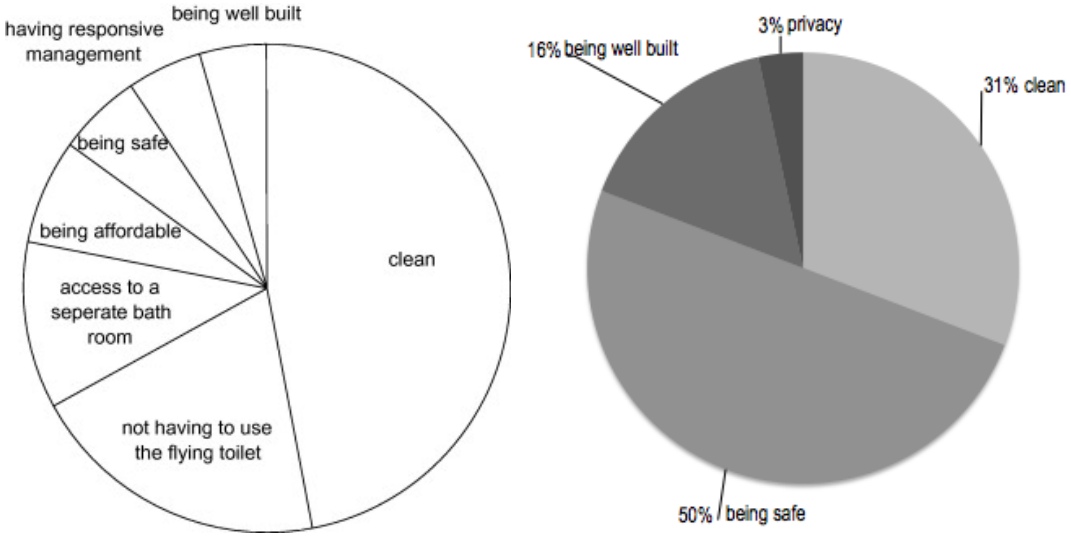

Figure 54 a, b. [a)] Most important determinant for satisfaction with communal sanitation facilities (Source: Schouten et. al., 2010), [b)] investigated satisfaction with communal sanitation facilities (Source: Author)

The figure by Schouten et. al. (2010) reveals that the cleanliness of the facility is the most important factor compared to the other six factors. Figure 54 b however reveals that the cleanliness of a communal sanitation facility is less significant to the users than its safety. Also the constructional factor shows more significance than in Figure 54 a. The factor of privacy includes the "access to a separate bath room" factor defined by Schouten et. al. (2010) as well as the general possibility of not having to defecate in the open. Affordability and the responsiveness of the management were apparently no issue to the respondents of this research. Additionally to the criteria given by Schouten et. al. (2010) the respondents added physical problems for the elderly people.

8.3.2 Conclusions on the Usage and Environmental Effects of Sanitation Facilities

Apart from open defecation, which is still a present issue, pit latrines, which are either plot-shared or community-shared, are as previously explained the most common sanitation facilities. There is still a considerable potential for improvement of plot-shared pit latrines simply by educating the households on the correct usage. Instead of providing the necessary conditions for the faeces to compost, the residents dispose of other solid wastes in the pits. Therefore the latrines either have to be emptied by a specialist or are abandoned. At community-shared latrines a caretaker prevents the disposal of solid wastes by constant control over the facility and the users. Still the waste in those latrines are not composting properly in the latrine since the users do not add leaves or ashes after each use. The bio-centres represent a remarkable improvement not only considering the sanitation situation but also considering resource issues. However, as reported by Schouten et. al. (2010), complains

about the smell of the biogas may become an obstacle for the bio-centres. Nevertheless the observations during the fieldwork do not correspond with this statement. Compared to Schouten et. al. (2010), who states that other criteria such as privacy, convenience, safety and accessibility scored well in the 2005 study of Jenkins and Cutis in Kibera, this research revealed that the users are mainly unsatisfied with the cleanliness and convenience of the toilets.

Concerning the environmental effects of a sanitation system especially to the water supply of the informal settlements it has been observed that occasionally the quality of the drinking water coming from a borehole is compromised by the improper technical execution and usage of nearby pit latrines.

8.4 Basics and Recommendations for the Successful Implementation of a Sanitation Facility

To increase the chance of a successful execution of a project in informal settlements, it is necessary to build upon the basics given by the researches and developments in the sanitation sector within the last decades as well as an elaborate local data collection and evaluation. In the following subsections the mentioned basics are summed up and a recommendation for future projects is presented. This chapter is fully based on the observations made during the fieldwork in Kenya and therefore aims to be utilized as a summary of information for orientation when starting on a sanitation project. It therefore represents my personal ultimate goal of this research, which is to build a simple knowledge base on sanitation and it dependencies for the implementation in the informal settlements.

8.4.1 Availability of Space for Sanitation Facilities

Depending on the natural and geographical environment the undertaking of a sanitation project in a rural informal settlement has the advantage of higher availability of free space than in an urban informal settlement due to a lower population density. Most of the water supply in rural informal settlement is undertaken locally with e.g. boreholes and shallow wells. This is the point where the correct choice of sanitation system is vital to the protection of the water source. Pit latrines may contaminate the groundwater and therefore the water source for consumption and use. Additionally a resource-oriented approach to the project may produce additional resources such as urine for irrigation as fertilizer and excreta as soil improvement. Sanitation projects in densely populated urban informal settlement are often limited in the availability of space due to the higher population. Resource oriented project such as the bio-centres or IkoToilet have to be designed in a certain size

to fulfil their purposes. The resources that might be of use in agricultural areas are of limited use within the cities and may be either sold elsewhere or disposed of. Instead of the production of fertilizer the production and collection of biogas is more valuable in these areas.

Further on, the challenges of uncontrolled construction of structures in informal settlements and their still ongoing expansion create conflicts with urban development strategies as well as agricultural uses of land area. In most of the visited informal settlements the sewer coverage is very low, if present at all. Pit latrines can show adverse effects on potable water as well as health in general. At the same time poor storm water drainage systems can lead to flooding and may result, often in combination with inadequate management of solid waste, in the contamination of water sources and nutriments.

8.4.2 Technical and Environmental Approach to Sanitation

The project based data collection must include the existing sanitation facilities as well as the existing water sources. As explained in the chapter 7.3 the environmental quality of the freshwater supply highly depends on the nearby sanitation facility. Possibly existing but abandoned sanitation facilities might not be useless and neither the nearby water source must be abandoned. A systematic, selective and purposeful technical approach to the local situation in combination with the technical basics and experiences is vital to prevent simple planning mistakes.

8.4.3 The Community Approach to Sanitation

The most basic predefinition is that those people who are concerned with a new sanitation project must have a need for it and therefore the motivation to participate in the successful undertaking of the project. Without their cooperation a facility cannot be designed to meet the interests and needs and will be abandoned sooner or later. Therefore the successful undertaking of a sanitation project and its future functioning is depending on the inclusion of all members of the community independent of their social status, religion, their age or sex. However if possible every group should be presented. Repeatedly, a toilet must be used by everyone and therefore must meet the needs of every user. Hence NGOs tend to involve the users and community members in the construction process, both to create a sense of responsibility for the facility amongst the users, as well as to save labour costs. However, Schouten et. al. (2010) reports that residents who received payment in the undertaking of earlier projects, tend to become somewhat spoilt and expect payment for their participation, which might become an obstacle to a future project that should be considered.

Also the proper use and maintenance of the facility requires the help of the entire community for which reason again the entire community must be educated about the functioning, the operational obstacles as well as the benefits of the sanitation facility. Some projects that were undertaken in the last decades failed due to the disgust that people feel towards their excreta and the improper handling of the toilets. Even the single pit latrine in the informal settlements can be more profitable if the users would add the in chapter 3.4.1.2 recommended ingredients to allow the wastes to degenerate into compost.

Discouraging factors like unclean facilities, the fear of falling into the pit, smell and attraction of insects and parasites must be reduced or even eliminated and replaced with motivational aspects such as comfort, privacy, improved health and hygiene as well as the possibility of financial benefits.

The economic capabilities of a community must also find way into the considerations and the planning process. As described in chapter 3.5.3 there are various costs and benefits that can arise in sanitation projects and the handling of those aspects must be in accordance with the capabilities and the motivations of the involved parties.

A good example for the successful execution of a new sanitation facility is the bio-centre in Kibagare, which is well accepted by the residents. Even though the construction of the building is not fully completed by now, it was still possible to engage the biogas production earlier than usual due to the fact that the sewerage of the surrounding sanitation facilities is drained to the new bio-centre. A less successful implementation of a bio-centre was observed in Nyalenda in Kisumu. Although this bio-centre is strategically well positioned adjacent to a school, hardly any of the residents and pupils of the school use the facility, possibly due to the fact that the benefits have not been promoted sufficiently and due to the presence of other options. Therefore the produced biogas is not yet enough to put it into use. Awareness rising amongst the residents about the functionality and benefits of the system and attraction of users is advisable. For example another bio-centre in Obunga that is currently in construction plans to attract their users by offering free use of the toilet facilities within the first month of operation. With this action the managers want to attract enough users so that the production of biogas can start as soon as possible. Additionally they offer pipe connections to the adjacent housings within 200 metres diameter to provide these houses with gas for a small fee.

8.4.4 Recommendation for the Handling of Projects in the Informal Settlements

Water supply and sanitation are both subjects that are common projects in the improvement of the

living standards in the informal settlements. The personal experience from the visitations in the informal settlements show that there is a immense waste problem in the informal settlements, that also affects the sanitation situation in terms of occasional waste disposal in sanitation facilities, and therefore waste management requires a higher priority in future considerations. A prior expurgation of extremely polluted areas will also have an effect on hygiene situation and the hygiene behaviour of the inhabitants of the informal settlements and it will show a positive effect on the health situation.

8.5 Areas for Future Research

Continuous observation and supervision of upcoming as well as ongoing projects in the informal settlements are a necessity to provide the basis for a successful undertaking of the project. For instance, the operation of the bio-centre in Nyalenda in Kisumu, which is as previously explained, hardly used, can be improved by observing the issues that lead to the current situation and recommendation of actions for improvement.

In a smaller but not less important level, a research concerning on-plot shared pit toilets could improve the sanitation situation for the slum dwellers. Education on the correct usage and function as well as the possible benefits of the pit latrines can result in better hygiene as well as in generation of income by the production of fertilizers, and a decrease in waste of land due to the re-use of the toilet facility.

Treatment of the water is most important to provide safe drinking water. Both of the water supply companies in the investigated informal settlements, KIWASCO and NCWSC, indicate to treat their water before distributing it to their clients. Around 76 per cent of the respondents to the household questionnaires report to find the odour and the coloration of the water agreeable. Nevertheless they also indicate to treat their potable water before use either by boiling it or by adding chemicals such as the “water guard”. This contradiction is probably caused by the fact that the also residents complain about leaking water supply pipes that are lined within the open sewerage. Anyways, the addition of “water guard” is not the universal solution to the problem of water quality, due to the fact that the addition of chemicals that consist of chlorine adversely affect the digestive system. But basically the provision of a safe infrastructure to transport water and wastewater will improve the water quality and even reduce the impression that home treatment of the water is necessary. Additionally the exploration of the use of other healthy options to disinfect water instead of boiling which consumes a lot of fuel resources or the use of water guard, which is cost intensive and contains chemicals can present a relief to the residents of informal settlements.

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Appendix I

PESTEL Analysis

Originally the PEST-analysis was introduced to list the factors of single categories which might have an influence on the considered unit (CIPD, 2011). The term PEST stands for Sociological, Technological, Economical and Political analysis. Later on analysts added Legal and Environmental factors and extended the analysis to PESTLE or PESTEL (ibid). Recently Education and Demographic Factors have been introduced to further expand it to STEEPLE and STEEPLED (ibid). The method itself, apart from all variations and extensions, is basis for strategic management decisions affected by the given factors of the macro-environment (Gillespie, 2007).

Macro-Environment

On the webpage BusinessDictionary.com the macro-environment is described by external factors which have an impact on the decision making of an organization, and at the same time are outside of the control of the organization. As a result of the analysis the performance and the undertaken strategies are adapted to the given factors.

Meso-Environment

This describes the environment in which an organization operates as well has limited influence (CIPD, 2011).

The general idea of this method is to analyze how the external environment affects the considered process. Therefore the PESTLE analysis can not only be used on organizations but also on projects.

Table 13. Components of PESTLE analysis
(Source: Marketing Minefield, 2007)

Factor	Often Comprised Of
Political	- Current taxation policy - Future taxation policy - The current and future political support - Grants, funding and initiatives - Trade bodies - Effect of wars or worsening relations with particular countries
Economic	- Overall economic situation - Strength of consumer spending - Current and future levels of government spending - Ease of access to loans - Current and future level of interest rates, inflation and unemployment - Specific taxation policies and trends - Exchange rates
Sociological	- Demographics - Lifestyle patterns and changes - Attitudes towards issues such as education, corporate responsibility and the environment - Social mobility - Media views and perceptions - Ethnic and religious differences
Technological	- Relevant current and future technology innovations - The level of research funding - The ways in which consumers make purchases - Intellectual property rights and copyright infringements - Global communication technological advances
Legal	- Legislation in areas such as employment, competition and health & safety - Future legislation changes - Changes in European law - Trading policies - Regulatory body
Environmental	- The level of pollution created by the product or service - Recycling considerations - Attitudes to the environment from the government, media and consumers - Current and future environmental legislative changes

Appendix II

Questionnaires

The following section contains the three questionnaires that were designed for the fieldwork in the informal settlements Kibera, Mukuru kwa Njenga, Kibagare in Nairobi as well as Obunga and Badani in Kisumu.

HOUSEHOLD QUESTIONNAIRE

This survey is part of an ongoing student research on gender and socio-cultural aspects regarding water and sanitation services in the informal settlements. It aims to understand the role gender and socio-cultural issues play in the way water and sanitation services are used and viewed in the formal settlements. The information acquired in this survey shall be treated confidentially and will be for academic purposes only. Your responses are highly appreciated.

Interviewee No: _____ Date: _____ Location: _____

Period of stay here: _____ Age: _____ Gender: _____

WATER PROVISION IN THE INFORMAL SETTLEMENT

1a	Where do you collect your water from?	
1b	Who owns the source?	
2	Who is responsible for the collection of water?	
3a	Are you always using the same source?	
3b	If not, why?	
4a	How much do you pay for water?	
4b	Is the price level stable at the source?	
5	What do you use the water for?	
6	How much do you collect per day?	
7	Who fetches the water if you are not able to go?	
8	How many trips do you go to collect water per day?	
9	How much do you carry per journey?	
10a	Is the color of water acceptable?	
10b	Is the smell of the water acceptable?	
11	Do you have to queue for water?	
12a	How long does it take you do walk to the water source and back again?	
12b	What would you like to do with the time that would be saved if the distance to the source is reduced?	

CULTURAL BEHAVIOR IN THE PROTECTION OF WATER SOURCES

1a	Is there always enough water for you and your family?	
1b	What do you do to assure that you always have water?	
2a	Why can't you get enough water all the time?	
2b	What do you think should be done about it?	
2c	What would you tell the officials / responsible / city council about it?	
3	How should the water be protected and who should do that?	
4	How do you ensure that the water you use is clean and protected?	
5	How do you dispose of waste water?	

SANITATION TECHNOLOGY INTERFACE AND CULTURAL BEHAVIOUR

1a	What type of sanitation system do you use?	
1b	Apart from the one you use, what other types of sanitation systems exist in your area?	
2	With how many people do you share the facilities?	
3a	Is the system comfortable for women?	
3b	If not, why?	
3c	Is the system comfortable for children?	
3d	If not, why?	
3e	Is the system comfortable for the elder?	
3f	If not, why?	
4a	Do you clean your hands after leaving the toilet?	
4b	What is the source of water for cleaning your hands?	
5	When the toilets are full, do you extract the waste output yourself?	

SANITATION POINT QUESTIONNAIRE

This survey is part of an ongoing student research on gender and socio-cultural aspects regarding water and sanitation services in the informal settlements. It aims to understand the role gender and socio-cultural issues play in the way water and sanitation services are used and viewed in the formal settlements. The information acquired in this survey shall be treated confidentially and will be for academic purposes only. Your responses are highly appreciated.

Interviewee No: _____ Date: _____ Location: _____

Period of stay here: _____ Age: _____ Gender: _____

SANITATION TECHNOLOGY INTERFACE AND CULTURAL BEHAVIOUR

1	Gender of the employee?	□ male □ female
2	Type of sanitation system?	
3	How many clients do you serve per day?	
4	What materials do you offer to your clients?	□ anal cleansing water □ dry cleansing material (toilet paper) Other:
5a	Do you have problems maintaining the facilities?	
5b	If yes, what kind of problems?	
6a	Do you extract the output/waste of the sanitation facility yourself?	
6b	If yes, what do you do with it?	
6c	If no, who extracts the material?	
7	How often do you have to empty the excreta storage?	
8	Do people expose of other wastes in the sanitation facility?	
9a	Do you provide a hand washing device?	
9b	If yes, of which type is the device?	
9c	What is the source of water for the hand washing device?	

WATER POINT QUESTIONNAIRE

This survey is part of an ongoing student research on gender and socio-cultural aspects regarding water and sanitation services in the informal settlements. It aims to understand the role gender and socio-cultural issues play in the way water and sanitation services are used and viewed in the formal settlements. The information acquired in this survey shall be treated confidentially and will be for academic purposes only. Your responses are highly appreciated.

Interviewee No: _____ Date: _____ Location: _____

Period of stay here: _____ Age: _____ Gender: _____

WATER PROVISION IN THE INFORMAL SETTLEMENT

Type of Water Source		□ Water Kiosk □ Borehole □ Private Well Other:
1	Gender of the owner:	□ Male □ Female
2	How much water do you sell per day?	
3	How much do you charge for water?	
4a	Is the color of the water acceptable?	
4b	Is the smell of the water acceptable?	
5a	Is your water source close to a sanitation facility?	
5b	What type of facility is it?	
5c	How far is it?	

Appendix III

Analysis of the Fieldwork Data

The following table shows the evaluation of the fieldwork data as an excerpt of those data sets that have been evaluated in percentage rates and used in chapter 7 for the presentation of the results and the analysis of this research.

			Kibera	Mukuru	Kibagare	Obunga	Bandani	Total
WATER PROVISION IN THE INFORMAL SETTLEMENTS								
	Water Source							
Household	1b	Who owns the source?						
		Male [%]	63	0	0	41	38	30
		Female [%]	20	0	0	28	19	14
		Group [%]	0	0	3	19	38	14
		Other [%]	17	100	34	13	5	31
		City Council [%]	0	0	62	0	0	12
	3a	Are you always using the same source?						
		Yes [%]	73	8	52	84	97	66
		No [%]	27	92	48	16	3	34
	Pricing							
Household	4a	How much do you pay for water?						
		Ksh 0 / 20 litres [%]	3	0	3	0	5	3
		Ksh 2 / 20 litres [%]	7	0	28	16	24	16
		Ksh 2,5 / 20 litres [%]	0	0	0	3	0	1
		Ksh 3 / 20 litres [%]	87	0	59	13	11	33
		Ksh 4 / 20 litres [%]	0	0	0	6	27	8
		Ksh 5 / 20 litres [%]	3	31	7	25	32	20
		Ksh 10 / 20 litres [%]	0	58	0	3	0	10
		Ksh 13,33 / 20 litres [%]	0	4	0	0	0	1
		Ksh 20 / 20 litres [%]	0	4	0	0	0	1
		n/a [%]	0	4	3	34	0	8
		Average [ksh / 20 litres]	2,9	8,9	2,8	2,8	3,5	4,2
Household	4b	Is the price level stable at the source?						
		Yes [%]	83	4	90	53	16	49
		No [%]	13	96	7	28	78	45
		n/a [%]	3	0	3	19	5	6

			Kibera	Mukuru	Kibagare	Obunga	Bandani	Total
Water Supply	2	How much water do you sell per day?						
		Average [litres]	22,5	4096	1281	1350	2746	-
	3	How much do you charge for water?						
		2 ksh / 20 litres [%]	1	0	3	2	1	-
		3 ksh / 20 litres [%]	1	1	5	0	2	-
		4 ksh / 20 litres [%]	0	0	0	3	2	-
		5 ksh / 20 litres [%]	0	7	0	4	3	-
		7 ksh / 20 litres [%]	0	0	0	1	0	-
		10 ksh / 20 litres [%]	0	1	0	0	0	-
		Average [ksh / 20 litres]	2,5	5,3	4,2	4,3	3,4	
	Water Use							
Household	5	What do you use the water for?						
		Everything [%]	83	88	97	88	100	92
		Household chores [%]	17	8	0	9	0	6
		Human consumption [%]	0	4	3	0	0	1
		n/a [%]	0	0	0	3	0	1
	Water Collection Responsibility							
Household	2	Who is responsible for the collection of water?						
		Male [%]	30	8	3	-	41	22
		Female [%]	63	64	83	-	54	65
		Together [%]	0	8	3	-	0	2
		Other [%]	7	20	10	-	5	10
	7	Who fetches the water if you are not able to go?						
		Family member [%]	70	77	90	53	78	73
		Other [%]	13	19	3	19	22	16
		Myself [%]	3	0	0	3	0	1
		Never happened [%]	10	0	0	0	0	2
		No one [%]	0	4	3	19	0	5
		n/a [%]	3	0	3	6	0	3

			Kibera	Mukuru	Kibagare	Obunga	Bandani	Total
	8	How many trips do you go to collect water per day?						
Household		< 1 trip [%]	7	0	0	0	0	1
		1 trip [%]	3	8	3	6	3	5
		2 trips [%]	13	12	24	16	19	17
		3 trips [%]	7	12	24	16	27	18
		4 trips [%]	0	8	10	3	19	8
		5 trips [%]	30	27	3	34	14	21
		6 trips [%]	17	15	17	0	0	9
		7 trips [%]	7	4	7	0	0	3
		8 trips [%]	3	4	0	3	0	2
		9 trips [%]	0	0	0	0	0	0
		10 trips [%]	13	4	10	9	16	11
		> 10 trips [%]	0	8	0	0	0	1
		n/a [%]	0	0	0	13	3	3
	9	How much do you carry per journey?						
Household		10 litres [%]	3	4	0	3	0	2
		20 litres [%]	87	65	83	66	70	74
		30 litres [%]	0	4	0	0	5	2
		40 litres [%]	7	8	14	16	22	14
		50 litres [%]	0	0	0	0	0	0
		60 litres [%]	0	4	0	0	3	1
		> 100 litres [%]	3	4	0	3	0	2
		n/a [%]	0	12	3	13	0	5
	11	Do you have to queue for water?						
Household		Yes [%]	67	96	79	47	86	75
		No [%]	33	4	21	53	14	25
	12a	How long does it take you do walk to the water source and back again?						
Household		< 5 minutes [%]	6	3	13	21	2	9
		5 – 15 minutes [%]	61	35	74	63	21	45
		15 – 30 minutes [%]	24	15	6	18	13	14
		30 – 60 minutes [%]	3	21	3	17	10	9
		60 – 90 minutes [%]	0	18	0	13	15	9
		90 – 120 minutes [%]	0	0	0	0	17	5
		120 – 150 minutes [%]	0	0	0	0	10	3
		150 - 180 minutes [%]	0	3	0	0	4	2
		> 180 minutes [%]	0	0	0	0	8	2
		n/a [%]	6	6	3	2	0	3

			Kibera	Mukuru	Kibagare	Obunga	Bandani	Total
	Water Quality							
Household	10a	Is the color of water acceptable?						
		Yes [%]	93	69	66	87,5	89	82
		No [%]	7	31	34	12,5	11	18
	10b	Is the smell of the water acceptable?						
		Yes [%]	87	54	79	94	78	79
		No [%]	13	46	21	6	22	21
Water Supply	4a	Is the color of the water acceptable?						
		Yes [%]	100	80	100	90	82	
		No [%]	0	20	0	10	8	
	4b	Is the smell of the water acceptable?						
		Yes [%]	100	60	100	90	91	
		No [%]	0	40	0	10	9	

			Kibera	Mukuru	Kibagare	Obunga	Bandani	Total
CULTURAL BEHAVIOUR IN THE PROTECTION OF WATER SOURCES								
	Water Sufficiency							
Household	1a	Is there always enough water for you and your family?						
		Yes [%]	80	31	66	75	46	60
		No [%]	20	69	34	25	54	40

			Kibera	Mukuru	Kibagare	Obunga	Bandani	Total
SANITATION TECHNOLOGY INTERFACE AND CULTURAL BEHAVIOUR								
	Sanitation Type							
Household	1a	What type of sanitation system do you use?						
		Pit Latrine [%]	93	77	72	72	92	82
		Bio-Centre [%]	7	0	14	0	0	4
		Open Defecation [%]	0	11,5	3	0	8	5
		Flying Toilet [%]	0	0	0	3	0	1
		Other [%]	0	11,5	10	22	0	8
		n/a [%]	0	0	0	3	0	1
	Use of Sanitation Facilities							
Household	3a	Is the system comfortable for women?						
		Yes [%]	87	38	55	56	38	55
		No [%]	13	62	45	44	62	45
	3c	Is the system comfortable for children?						
		Yes [%]	90	27	52	69	24	52
		No [%]	10	73	48	31	76	48
	3e	Is the system comfortable for the elder?						
		Yes [%]	90	38	55	56	35	55
		No [%]	10	62	45	44	65	45
Sanitation	4	What materials do you offer to your clients?						
		Dry cleansing material [%]	100	100	45	100	80	-
		Anal cleansing water [%]	0	0	0	0	10	-
		Both [%]	0	0	55	0	10	-
	Hygiene							
Household	4a	Do you clean your hands after leaving the toilet?						
		Yes [%]	83	69	93	87,5	62	79
		No [%]	17	31	7	12,5	38	21
Sanitation	9a	Do you provide a hand washing device?						
		Yes [%]	100	80	80	60	50	-
		No [%]	0	20	20	40	50	-

			Kibera	Mukuru	Kibagare	Obunga	Bandani	Total
	Extraction							
Household	5	When the toilets are full, do you extract the waste output yourself?						
		Yes [%]	7	23	0	16	0	8
		No [%]	93	77	100	84	100	92
	Management							
Water Supply	1	Gender of the owner:						
		Male [%]	0	27	33	50	36	-
		Female [%]	50	67	33	50	36	-
		Group [%]	50	7	33	0	27	-
Sanitation	1	Gender of the employee?						
		Male [%]	67	50	57	40	80	-
		Female [%]	0	50	43	60	20	-
		Group [%]	33	0	0	0	0	-
	Maintenance							
Sanitation	5a	Do you have problems maintaining the facilities?						
		Yes [%]	67	90	40	60	50	-
		No [%]	33	10	60	40	50	-
	6a	Do you extract the output/waste of the sanitation facility yourself?						
		Yes [%]	67	0	20	0	10	-
		No [%]	33	100	80	100	90	-
	Environmental Protection							
Sanitation	8	Do people expose of other wastes in the sanitation facility?						
		Yes [%]	67	100	0	20	30	-
		No [%]	33	0	100	80	70	-