


Diplomarbeit von
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Economic Effects of Sustainable Sanitation

Logistics of Human Excreta in Uganda

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Summary

The present thesis provides an introduction to the topic of sanitation and indicates its close links to slum settlements, malnutrition and public health. Furthermore, the issue of sustainable sanitation as an alternative to conventional and inadequate sanitation and its economic impact are considered. Sustainable sanitation, the underlying paradigm covered in this thesis, considers human excreta as valuable resource rather than waste, promoting the closure of nutrient cycles by reusing the excreta as fertiliser. At the same time sustainable sanitation provides effective alternatives for reducing sanitation induced diseases arising from inadequate sanitation practices. In a second step, taking into consideration the above mentioned findings, large scale scenarios for the logistics of sustainable sanitation in urban areas - an issue which has been identified as crucial for its successful implementation have been designed. The geographical focus of the thesis is Sub-Sahara Africa, particularly Kampala, the capital of Uganda. However, being based on field work conducted in this region, the findings of this thesis can well be adapted to other developing countries in the world.

The main findings of the thesis are summarised below: There are 2.6 billion people in the world that lack adequate access to improved sanitation (SuSanA, 2008, p. 1). The effects of this situation can among others be understood by taking a look at the number of people that are affected by diarrhoea, being considered as main burden of disease of poor water, sanitation and hygiene (cf. Prüss et al., 2002, cited in Hutton et al., 2007, p. 469). But not enough, also the issue of undernourishment and with it the suffering of close to one billion people is indirectly affected by sanitation due to the negative impact diarrhoea has on the nutrient uptake efficiency. Another aspect potentially affecting the nutritional status of people emerges when considering that common sanitation practices prevent nutrients present in human excreta from being reused for food production. Finally, this threatening image is intensified by considering trends of urbanisation and the dynamic emergence of slums that are per definition, places of inadequate water supply, sanitation and hygiene (UNHABITAT, 2003a, p. 12).

Considering the diversity and impact of the above mentioned numbers and links, inadequate sanitation can be seen as a trigger for a variety of problems, which can for instance be expressed as number of people dying from infectious diarrhoea, decreased productivity because of people being debilitated or forced to stay at home or environmental degradation. Another way of presenting those effects is by introducing an economic dimension by attributing monetary values to the individual effects, where applicable. This practice has two main advantages. Firstly, it allows calculating the average economic burden a person suffers from e.g. in terms of productive days lost. Secondly, it contrasts the burden that could be averted by investments in infrastructure improvements (e.g. sustainable sanitation facilities) with the costs of those investments by calculating benefit-cost ratios (BCR) (cf. chapter 3.2 and Hutton et al., p. 494). The results of the calculations in this thesis show that the annual

economic burden per person that could be averted by the implementation of sustainable sanitation adds up to 28.05 EUR, whereas the BCR of investments in sustainable sanitation infrastructure is 4.37.

Another important result of this thesis was the design of a system for large scale sustainable sanitation in slum areas considering the above mentioned issues and transforming them into a practicable proposal. Experiences from former projects implementing sustainable sanitation in urban areas showed a variety of problems that had to be considered: One important issue in connection of sustainable sanitation and urban areas is the aspect of the area for reusing the generated fertiliser. Agricultural production in urban areas is considered to be low due to spatial restrictions. In order to overcome this barrier and transport the excreta to places where they can be reused, former projects also implemented logistics systems. However, those systems were often characterised by unsuitable technical infrastructure (e.g. vehicles) or deficient economic sustainability, involving external funding. Another issue that was raised in this thesis is the question regarding the motivations of different stakeholders. A variety of reasons led to system designs, where the residents of the slum areas were involved in the logistics system, by delivering the human excreta to collection points. It was shown, that without means of external motivation such as incentives, this involvement could not be achieved.

The proposal of a logistics system as designed in this thesis involves three stakeholder groups: Slum residents, generating human excreta, a private company, handling the logistics and farmers outside of Kampala buying sanitised human excreta as fertiliser. The price was calculated based on the amount of nutrients which are delivered to the farms. Apart from defraying the logistics and yielding profit for the service provider, the price also had to cover the incentives paid to the residents. The calculations of the logistics system, which were conducted from the perspective of a private service provider, showed the profitability of the venture. The minimum size of the system in terms of people being served, is 66 659, the maximum size adds up to 429 999 people. The profit expressed as return on sales would range between 6.16% and 17.83%, respectively.

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Acronyms and Abbreviations

AfDB	African Development Bank
AMCOW	African Ministers' Council on Water
BCR	Benefit-cost ratio
CSR	Corporate Social Responsibility
DALY	Disability-Adjusted Life Year
DED	Deutscher Entwicklungsdienst (In 2011 changed to GIZ – Gesellschaft für Internationale Zusammenarbeit)
DWD	Directorate of Water Development
FAO	Food and Agricultural Organisation of the United Nations
GNI	Gross National Income
GTZ	Deutsche Gesellschaft für Technische Zusammenarbeit (In 2011 changed to GIZ – Gesellschaft für Internationale Zusammenarbeit)
ISWM	Integrated Sustainable Waste Management
IWA	International Water Association
JMP	Joint Monitoring Programme
K	Potassium
KCC	Kampala City Council
kg	Kilogramme
l	Litre
LAWA	Länderarbeitsgemeinschaft Wasser
MDER	Minimum Dietary Energy Requirement
MDG	Millennium Development Goal
N	Nitrogen
NEMA	National Environment Management Authority
NGO	Non-Governmental-Organisation
NPK	Synthetic fertiliser containing nitrogen (as N), phosphorous (as P_2O_5) and potassium (as K_2O)
NWSC	National Water and Sewerage Cooperation
O&M	Operation and maintenance
ODA	Official Development Assistance
P	Phosphorous
PEA	Private Emptiers Association (cesspool emptiers)

RUWASS	Reform of the Urban Water & Sanitation Sector Programme
SANDEC	Department of Water and Sanitation in Developing Countries
SEI	Stockholm Environment Institute
SSWARS	Sustainable Sanitation and Water Renewable Systems
SuSan Design	Sustainable Sanitation Design
SuSanA	Sustainable Sanitation Alliance
t	Metric ton
UBOS	Uganda Bureau of Statistics
UDDT	Urine-Diversion-Dehydrating-Toilet
UGX	Ugandan Shilling (exchange rate: 1 Euro = 2.807 UGX, dated: 10.04.2010)
UN	United Nations
UNEP	United Nations Environment Programme
UNHABITAT	United Nations Human Settlements Programme
UNHS	Uganda National Health Survey
UNICEF	United Nations Children's Fund
UOS	Uganda Organic Standard
VIP	Ventilated Improved Pit Latrine
WHO	World Health Organisation
WISA	Water Institute Southern Africa
WSA	Water Suppliers Association (fresh water tank trucks)
WSP	The World Bank Water and Sanitation Program
WSSCC	Water Supply and Sanitation Collaborative Council
WSSD	UN World Summit on Sustainable Development

1 Introduction

In the year 2006, 2.6 billion people had no access to improved sanitation on a global scale. More than 5.3 billion incidences of diarrhoea[1] were registered and every day more than 6000 people died because of sanitation-related diseases and poor hygienic conditions (WHO/UNICEF, 2008, p. 7; WHO, 2008, p. 28; SuSanA, 2008, p. 1). Little has changed.

But, the effects of infectious diarrhoea cannot be limited to rates of morbidity and mortality. A whole series of other effects among them health care costs, decreased productivity regarding school or job and deficient environmental health can be listed. A certain number of those effects can be connected with an economic dimension: for instance some incidences of infectious diarrhoea need treatment which leads to health care expenses whereas other, less serious incidences, lower the productivity of children or adults resulting in low rates of school attendance, inattention due to weakness or decreased income generation. Apart from that, also effects not connected with health issues show to have economic dimensions. The productive time lost due to bad access to facilities is one popular example for that. All in all the total costs that can be attributed to deficient sanitation, water supply and hygiene, including both health and non-health issues add up to more than 119 billion EUR per year on a global scale. This leads to an average per year and capita burden of 20 EUR (Hutton et al., 2007, p. 492). It has to be kept in mind that this number is calculated based on the global population, whereas the majority of people who suffer are found in developing countries with people often earning less than 2 EUR per day.

As a reaction to that, the Millennium Development Goal (MDG) 7: "Ensure environmental sustainability" - target C: "Halve, by 2015, the proportion of the population without sustainable access to safe drinking water and basic sanitation" was formulated in Johannesburg, in the year 2002, at the UN World Summit on Sustainable Development (WSSD)[2]. Being neglected when the MDGs were originally formulated in 2000, water supply and sanitation gained importance not only due to numbers such as the ones cited above. There are authors that even consider the MDG 7, target C as instrument for sustainable development, economic growth and poverty reduction, elevating a success of this goal as a crucial factor for the achievement of all other MDGs (Rosemarin, 2008, p. 2).

As mentioned above, there are 2.6 billion people globally, who do not have access to improved sanitation. In turn, there must have been around 4 billion[3] who had this opportunity. This deduction raises the question of how different sanitation practices are classified and what is considered improved- and what unimproved sanitation? According to the Joint Monitoring

[1] Including, cholera, salmonellosis, shigellosis, amoebiasis and other protozoal-, viral- and bacterial-intestinal diseases (Girard et al., 2006).

[2] When the MDGs were originally formulated in New York in the year 2000, „[...] water supply and sanitation services had not been included as one of the environmental targets" and had to be added later in 2002 (Rosemarin et al., 2008, p. 1).

[3] Total population 6.54 billion (World Bank, 2010)

Programme (JMP), sanitation can be categorised in two classes: unimproved sanitation including open defecation, the use of unsafe pit latrines and shared facilities; and improved sanitation including flush toilets, ventilated improved pit latrines or composting toilets (WHO/UNICEF, 2010, p. 12).

Whereas improved sanitation has been identified as an effective and efficient way of reducing infectious diarrhoea, its diverse negative health effects, societal, environmental and economic damages, another approach referred to as sustainable sanitation is successively emerging. It offers the same advantages as improved sanitation, but does furthermore provide a whole series of additional benefits. Sustainable sanitation cannot be limited to certain technology options – various technologies comply with the principles of sustainable sanitation (Rosemarin et al. 2008, p. 21). A sustainable sanitation system is rather defined by its ecosystem approach towards human excreta (Esrey et al. 2001, p. 1). Besides improving the environmental quality of the surroundings, reducing health risks, investment-, operation- and maintenance (O&M) costs as well as water consumption, sustainable sanitation also enables the reuse of nutrients from human excreta that are otherwise lost. Thereby it generates a valuable fertiliser for agricultural use. On a small scale, e.g. in rural areas this reuse ideally takes place on-site involving no or very limited infrastructure. However, implementation on a larger scale in order to bridge the gap between areas of nutrient generation (cities) and areas of nutrient demand (areas with agricultural production), calls for different, more efficient and new approaches[4]. Additionally, when considering the unplanned structure of slum settlements and the lack of financial resources both, from residents and local authorities, the need for developing alternatives to sophisticated and expensive sewer networks, commonly applied in industrial countries, preferably involving the private sector becomes obvious (UNHABITAT, 2003a, p. 11; Singeling et al., 2009, p. 7).

That is why this thesis investigates the implementability of a privately operated logistics system that collects, transports, sanitises and redistributes human excreta from slum settlements to farmers in peri-urban areas and the countryside. At the same time the system delivers sustainable sanitation to people living in slum settlements, who do not even have access to basic improved sanitation facilities, thereby contributing to the achievement of MDG 7, target C.

1.1 Objective and research questions

The present thesis considers the issue of sanitation in general and especially its connection to present developments regarding slum settlements, undernourishment and public health. Main objectives of this thesis are to introduce the concept of sustainable sanitation, present its benefits with a particular focus on the economic effects and its impact on the MDGs. Focussing on the economic effects is on the one hand, motivated by the fact that they are not

[4] Supported by Rosemarin et al., 2007, p. 39, by constituting that there is a lack of relevant publications.

obvious even though posing a considerable economic burden on the people most likely suffering under inadequate sanitation. On the other hand, investment decisions regarding (sustainable sanitation-) infrastructure improvements are just as any other type of investment based on economic parameters. Hence, when it comes to investments in sanitation infrastructure the easily available cost information are often highlighted, whereas the benefits are likely to be neglected, being represented by parameters that are not- or only indirectly measurable and transferable in monetary terms (Hutton et al. 2007, p. 498). Hence, putting emphasise on the neglected benefits is necessary to modify investment decisions from a purely input-based- to an input and result-based orientation, increasing the distribution of sanitation facilities (Hutton et al., 2007, p. 498).

Another objective of this thesis is to design and test the feasibility of a logistics system that delivers sustainable sanitation on a large scale to unplanned and resource scarce urban slum settlements. Thereby combining and transforming the above mentioned insights into a practicable proposal for the city of Kampala[5] and connecting urban areas of nutrient generation with agricultural areas of nutrient demand around the city. Apart from contributing to the above mentioned economic effects, the system also generates income for slum residents as well as the system operators.

The two research questions dealt with in the present thesis are:

1. *What are the economic effects of sustainable sanitation?*
2. *How can a system for the removal of human excreta from slum areas look like according to the principles of sustainable sanitation?*

The first question is going to be answered based on a literature review, the second by applying a mixture of literature review, qualitative research[6] applying semi-structured interviews and focus group discussions as well as a cost calculation for feasibility testing.

1.2 Structure

Excluding introduction (chapter 1) and conclusion (chapter 7), the structure of the thesis can roughly be separated into 5 sections:

- Sanitation: interrelationships and facts (chapter 2)
- Sustainable sanitation (chapter 3)
- Design backgrounds – The Integrated Sustainable Waste Management concept (chapter 4)
- Methods (chapter 4)
- Case study Kampala (chapter 6)

[5] Kampala is considered to be a representative example of a Sub-Saharan African city, with a large number of inhabitants living in slum settlements suffering under inadequate sanitation conditions.
[6] Conducted in Uganda during an internship with GTZ in 2009/2010.

The introduction gave an overview of sanitation and presented its impact on sustainable development. In chapter 2 the interrelationships between sanitation, urbanisation/slum-emergence, soil depletion/undernourishment and public health will be presented and discussed. Furthermore, an overview of past developments and future trends regarding the aforementioned issues will be given. The next chapter focuses on sustainable sanitation. After the concept is clarified and the aspect of source separation is introduced, a technological overview and a comparison of conventional- and sustainable sanitation are presented. Finally, the effects of sustainable sanitation among them health and non-health variations and the economic perspective towards those aspects will be brought into focus. Chapter 4 introduces the Integrated Sustainable Waste Management Approach (ISWM) which served as foundation for the design of the logistic systems presented in chapter 6. Insights about the methods used for the preparation of case study and logistics system will be given in Chapter 5. The methodology was based on a mix blending semi-structured interviews with focus group discussions and a cost calculation regarding the feasibility of the designed logistics system. Chapter 6 consists of a case study, where a large scale system for the logistics of human excreta, based on the information gathered in the preceding chapters will be presented. Finally, the conclusion summarises the results and considers them in the bigger picture of sustainable development. The thesis closes with an outlook regarding future research.

2 Sanitation: facts and interrelationships

Sanitation correlates with a whole series of issues especially people in developing countries are affected by. The first chapter (2.1) deals with sanitation and slums and draws a picture of their physical structure, global distribution and trends. The second chapter (2.2) gives an overview of the global situation regarding undernourishment. Additionally, its effects and the causes with a special focus on soil depletion are considered and conventional and alternative counter measures against soil depletion as one underlying cause of undernourishment are compared. Chapter 2.3 gives insights about public health and sanitation. Therefore it ranks different diseases, among them infectious diarrhoea according to their global impact and illustrates their transmission pathways, if applicable. Finally, chapter 2.4 presents the global sanitation situation and classifies the commonly applied sanitation systems according to their quality, costs and health benefits.

2.1 Slums

Describing slums or slum settlements, also known as squatter- or informal settlements by using adjectives such as "squalid, overcrowded and wretched" is a relatively simple task, considering their apparent physical, spatial and social features (UNHABITAT, 2003a, p. XXIX). However, defining them is much more sophisticated as the settlements can consist of simple shacks made from waste materials like pieces of corrugated iron sheets, wood and plastic sheets but also more permanent housing structures constructed of bricks and concrete. Even though the appearance might be diverse, all slums combine the following characteristics[7] to various extents (cf. UNHABITAT, 2003a, p. 12):

- inadequate access to safe water
- inadequate access to sanitation and other infrastructure
- poor structural quality of housing
- overcrowding
- insecure residential status

In the year 2003 *The Challenge of Slums: Global Report on Human Settlements 2003* referred to as "the first global assessment of slums, emphasising their problems and prospects" was published and stated that slums are home to about one billion people[8] (UNHABITAT, 2003a, p. V). According to that, one out of three urban dwellers lives in a slum on a global average (cf. UNHABITAT, 2003a, p. XXV). This amount increases by exclusively focusing on

[7] An UN Expert Group uses the listed characteristics to formulate an operational definition for slums.

[8] Despite seeming to be out-dated, comparing the number cited in „Global Report on Human Settlements 2003 – The Challenge of Slums" (UNHABITAT, 2003a, p. XXV) with the recently published number in the „Global Report on Human Settlements 2009 – Planning Sustainable Cities" (UNHABITAT, 2009, p. 13) does not reveal a difference.

developing countries: According to UNHABITAT (2003a, p. 246) some 43% of the combined urban population of all developing regions and 78% of the urban population of the least developed countries lived in slums in 2001. Considering Figure 1, it can be seen, that over the last decades the growth rate of people living in rural areas decreased and almost stagnated, whereas the number of urban residents and slum dwellers rose considerably. 2007 was the first year more people lived in urban than in rural areas and projections show that in 2050, 70% of the world population might be living in cities, thereby also increasing the number of slum dwellers living in poverty (cf. UNHABITAT, 2003a, p. 25; World Urbanisation Prospects, 2010).

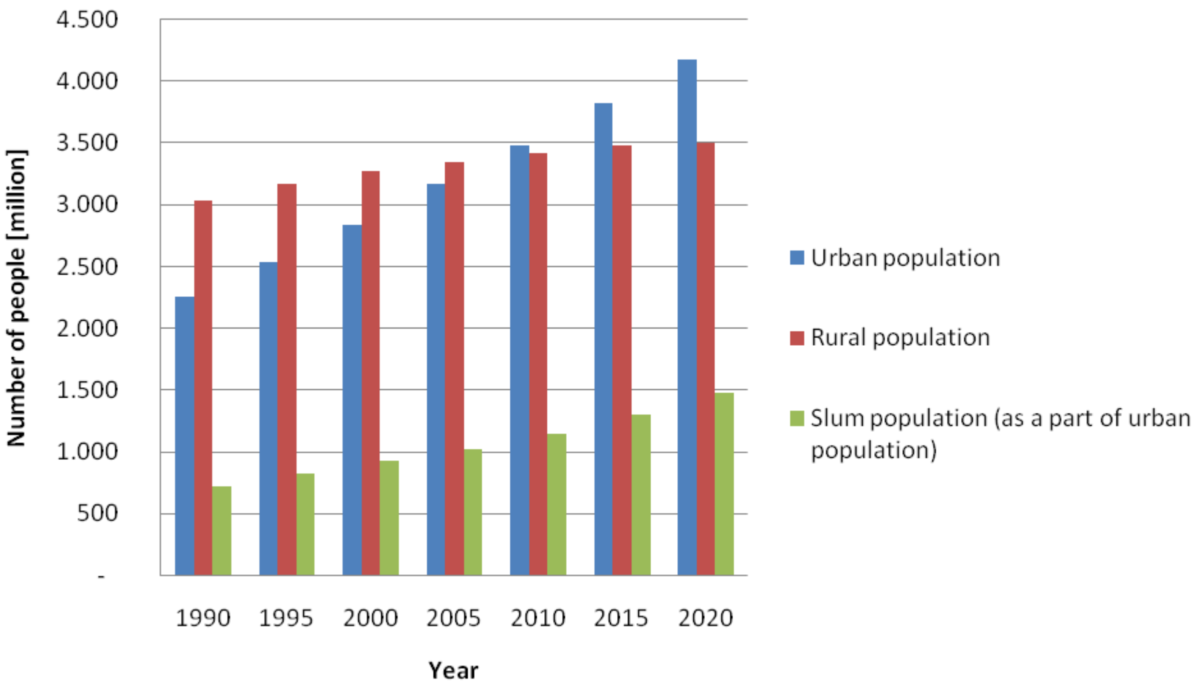

Figure 1: Development of the global urban-, rural- and slum- population from 1990 to 2020 (based on World Urbanisation Prospects, 2010, p. 29 and UNHABITAT, 2003b, p. 1)

Hence, keeping in mind the global dynamics of population growth and urbanisation, slums are likely to accommodate a growing number of people in the future. Already today slums are among others characterised by insufficient water supply, sanitation and hygiene. Thinking about alternatives that improve the present situation and at the same time are able to handle future population increase is urgently required.

2.2 Undernourishment

The Food and Agricultural Organisation of the United Nations (FAO) (2010, p. 8) describes *undernourishment* as the condition of the caloric intake being below the minimum dietary energy requirement (MDER[9]). According to FAO (2010), the total number of undernourished[10] people declined from more than one billion in 2009 to 925 million in 2010 representing a decrease from 15% to 13.5% on a global scale (cf. Figure 3) (FAO, 2010, p. 9). Although declining, the number is still alarming and reveals shocking results considering regional disparities. The largest number of undernourished people, 578 millions, lives in Asia and the Pacific, the biggest proportion of undernourished people can be found in Sub-Saharan Africa adding up to 30% in total (cf. Figure 2). In this region, the Democratic Republic of Congo shows the highest values with 75%, followed by Eritrea with 66%, and Burundi with 63% (OXFAM, 2010).

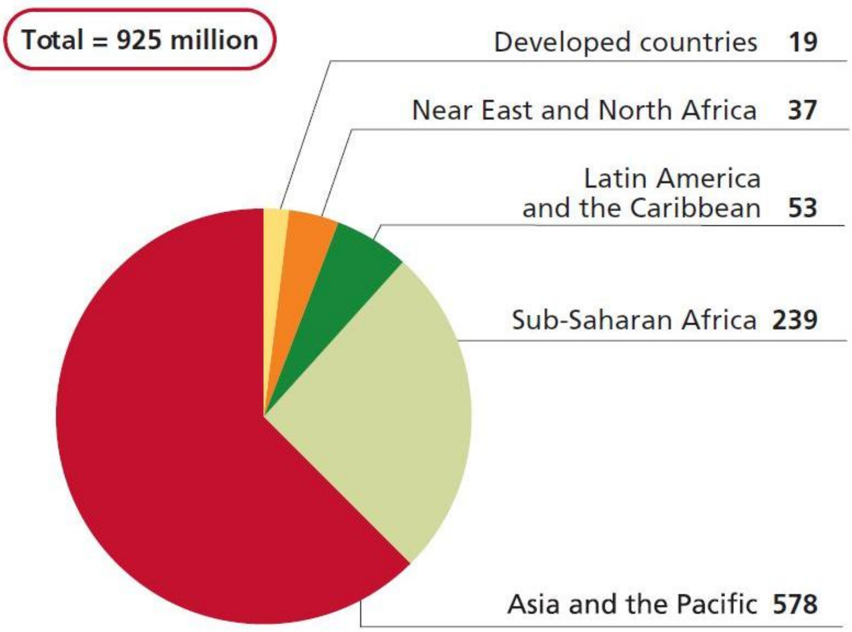

Figure 2: Number of undernourished people per region, in 2010 (FAO, 2010, p. 10).

The trigger of the recent decline can be seen as a consequence of the preceding maximum: the effects of the economic crisis of 2008/2009, contributing to high food prices, are said to decline and global economy is recovering (cf. Figure 3) (FAO, 2010, p. 8). But despite a recent decline, the level of undernourished people is still higher than before the crisis 2005-2007, where 848 million people suffered from undernourishment and is also higher than 40 years ago (cf. Figure 3) (FAO, 2010, p. 9). Not enough, also future prospects published e.g. by OXFAM (2010) consider the world being off-track of reaching the MDG 1, Target C: “Halve, between 1990 and 2015, the proportion of people who suffer from hunger” (cf. Figure 3).

[9] “The MDER is the amount of energy needed for light activity and to maintain a minimum acceptable weight for attained height. It varies by country and from year to year depending on the gender and age structure of the population“ (FAO, 2010, p. 8).

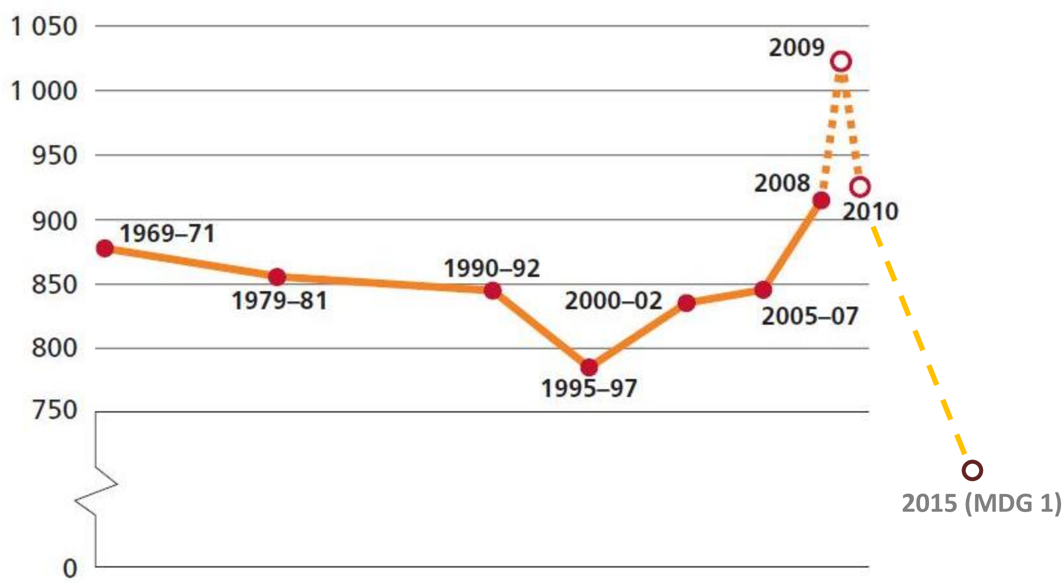

Figure 3: Number of undernourished people in the world, 1969 to 2015 (FAO, 2010, p. 9. Note: Figures for 2009 and 2010 are estimated by FAO with input from the United States Department of Agriculture, Economic Research Service. Extended by projections until 2015 based on MDG 1, Target C)

2.2.1 Effects of undernourishment

After getting insights about the extent of undernourishment above, the following section will deal with its effects. Adequate nutrition has various impacts on the human body. It is quite obvious that nutrition is essential for growth and a good health status but furthermore it contributes largely to the cognitive development of children and adolescents (FAO, 2010, p. 33). For instance, studies have shown that children suffering from insufficient nutrition by the age of two years will never develop the educational and productive potential they could have reached (FAO, 2010, p. 33).

Since undernourished people are more vulnerable to diseases they also show a higher morbidity and are more likely to die prematurely (FAO, 2010, p. 33). Bryce (2005, p. 1147) e.g. investigates that in the period of 2000-2003, 10.6 million children younger than five years died in the world. 73% of all these deaths were attributable to the following incidences: pneumonia (19%), diarrhoea (18%), malaria (8%), neonatal pneumonia or sepsis (10%), preterm delivery (10%), and asphyxia at birth (8%). The underlying cause of 53% of these deaths is undernutrition, adding up to more than 5 million children dying each year (Bryce, 2005, p. 1147). Finally, it has to be stressed, that nutrition is not only affected by insufficient food quality and quantity. It is also affected by diseases such as diarrhoea, limiting the nutrient uptake efficiency triggered by insufficient sanitation, water supply and the “unavailability of preventive health services” (FAO, 2010, p. 33; Ramalingaswami, 1996).

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[10] As of now, undernourishment, as defined above, will be considered as indicator of deficient food supply and extreme consequence of food insecurity.

2.2.2 Causes of undernourishment

While the connection of *poor health* and this thesis' topic *sanitation* has already been touched above when discussing the effect of water and sanitation induced illnesses on undernutrition, the connection of *environmental degradation,* especially soil depletion leading to low food production and *sanitation* will be investigated more thoroughly in the following paragraphs.

The productivity of a soil, i.e., the yield produced by growing plants on the same is influenced by a series of different soil characteristics. Among those characteristics are nutrient content, water-holding capacity and organic matter content but also soil reaction, expressed as acidity, salinity and topsoil depth (Scherr, 1999, p. 5). When decreases in soil productivity can be experienced, soil degradation exists. UNEP (2007, p. 96) rates nutrient depletion as the "most significant biophysical factor limiting crop production over large areas in the tropics, and especially in Sub-Saharan Africa".

In fact, nutrient depletion is a natural process which occurs as growing plants constantly remove nutrients from the soil they are grounded in, to incorporate them in their metabolism. However, current practices of intensive agriculture and one-way nutrient management altered the process becoming a severe problem (for information regarding nutrient flows, cf. Box 1) (Joensson, 2003, pp.1; Langergraber and Muellegger, 2004, p. 435; Esrey, 2001).

Nutrient flows

Linear nutrient flows

The current way of managing nutrients can be considered as a one-way or linear flow. The process of soil nutrient removal would occur as described above. The plants are harvested and subsequently transported to areas of consumption. On the one hand, the plants serve as food for human beings. On the other hand they are used as fodder crop for meat production. Both, plants and meat are finally consumed by human beings, digesting, thereby removing certain amounts of nutrients for metabolism and excreting the residues.

The excreta are transported using freshwater to some kind of treatment facility, if available, or are otherwise directed into a waterway or the surrounding environment without treatment, causing environmental and health problems (Langergraber and Muellegger, 2004, p. 435, Prüss-Üstün and Corvalán, 2006, p. 34 and Ujung and Henze, 2006). Irrespective their final destination, the nutrients are relocated from their origin, the piece of land where they were removed from the soil in order to enable plant growth (Langergraber and Muellegger, 2004; Rosemarin et al., 2008).

Circular nutrient flows

The nutrients in this approach start the same way as they would do according to the linear flow approach and they are also digested and excreted by human beings. However, unlike above, the nutrient carrying excreta are not transported and deposited at a place where they do not originate from. After having been transformed into a safe fertiliser, the nutrients are instead returned to the soil to enable further plant growth and assure future soil fertility (Langergraber and Muellegger, 2004, p. 435; Rosemarin et al., 2008, p. 21). The same is applicable to animal excreta and organic waste.

Box 1: Linear and circular nutrient flows (own contribution)

2.2.3 Conventional counter measures against soil depletion

In conventional agriculture the imbalance of nutrients left in the soil is compensated by the application of vast amounts of synthetic fertilisers of fossil origin, most commonly containing the plant macro-nutrients nitrogen (N), phosphorous (P) and potassium (K) (Vinneras, 2002 cited in Langergraber and Muellegger, 2004, p. 435; Joensson et al., 2004, p. 5). The production of nitrogen fertilisers consumes large amounts of energy mostly derived from fossil sources. The production of phosphate and potash fertilisers requires the exploitation of limited mineral deposits (Langergraber and Muellegger, 2004, pp. 435).

Hence, on the one hand this issue creates situations of dependence on imports for countries that cannot rely on own resources. One the other hand, recently published projections for peak -oil, -phosphorous and -potassium state that fossil fuel reserves are calculated to last for maximum 40 years, economically exploitable reserves of phosphorous are projected to cease after 50 to 100- and potassium reserves after 300 years (Langergraber and Muellegger, 2004 p. 436; Rosemarin et al., 2008, pp. 15; Gilbert, 2009, p. 717).

This knowledge, combined with the aforementioned current practices of linear nutrient management casts a different light on the situation and calls for more sustainable alternatives. Possible effects of this seemingly inevitable development can be conjectured by considering the food price increases in the past eight years (cf. Figure 4) where among others[11] increasing fuel- and fertiliser prices were identified as the main drivers (Rosemarin et al., 2008, p. 14).

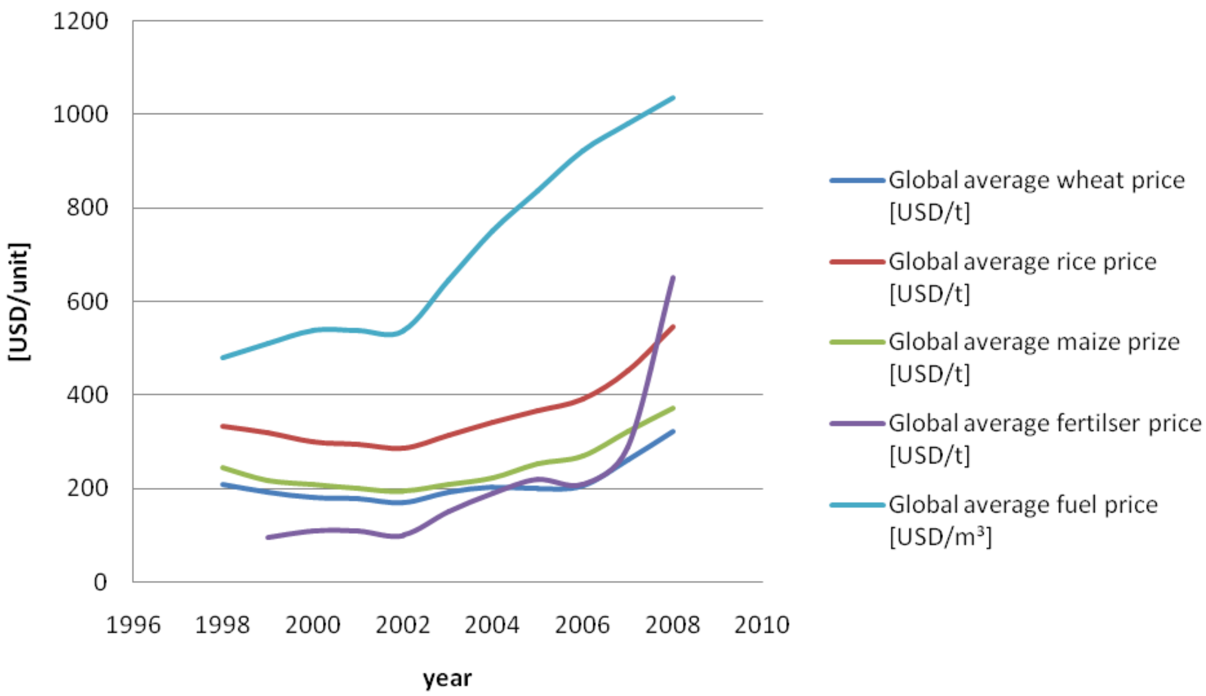

Figure 4: Global average prices of: wheat, rice, maize, fertilisers (aggregated values) and fuel in the period of 1998-2008 (based on: FAOSTAT, 2010, Yara, 2010 and World Bank, 2010, respectively).

[11] As additional drivers of rising food prices (cf. Figure 4) an increased demand and market value of grains being used for bio-fuel production and a weak US dollar are cited (Rosemarin et al., 2008, p. 14).

2.2.4 Alternative counter measures against soil depletion

As alternative to conventional agriculture, synthetic fertiliser application and linear nutrient flows, circular nutrient management approaches can be applied (cf. Box 1). Following this idea, the nutrients contained in human-, animal excreta and organic waste are utilised to sustain soil fertility, rather than the ones contained in synthetic fertilisers. Globally, farmers use approx. 160 million tons of synthetic fertilisers[12] each year, whereas in the same period 50 million tons of nutrients are discharged via conventional sanitation systems such as sewerage networks and pit latrines, thereby affecting surrounding environments and communities (Werner, 2004 cited in Rosemarin et al., 2008, p. 14). The Stockholm Environment Institute (SEI, 2005) for instance, calculated that Sub-Saharan Africa could be self sufficient regarding fertiliser application if circular nutrient management, as described above, would be implemented (cited in Rosemarin et al. 2008, p. 21).

According to Joensson (2001, p. 436), nitrogen, phosphorus and potassium, contained in urine and faeces can be recycled almost entirely to agriculture, "except for some nitrogen-losses in the form of ammonia" (also cf. Kirchmann and Pettersson, 1995). Additionally, the organic matter present in the faecal component improves "the humus content [...] of the soil [...] and thus the water holding capacity and prevents erosion" (Esrey et al., 2001 cited in Langergraber and Muellegger, 2004, p. 436). The nutrient content of excreta thereby varies according to specific diets, revealing high nutrient contents being excreted e.g. in China and South-Africa and comparably low values e.g. in Haiti and Uganda (cf. Figure 5). Values for industrial countries like Sweden can well be compared to the concentrations estimated for China (Joensson et al., 2004, p. 5).

Country		Nitrogen kg/cap, yr	Phosphorus kg/cap, yr	Potassium kg/cap, yr
China, total		4.0	0.6	1.8
	Urine	3.5	0.4	1.3
	Faeces	0.5	0.2	0.5
Haiti, total		2.1	0.3	1.2
	Urine	1.9	0.2	0.9
	Faeces	0.3	0.1	0.3
India, total		2.7	0.4	1.5
	Urine	2.3	0.3	1.1
	Faeces	0.3	0.1	0.4
South Africa, total		3.4	0.5	1.6
	Urine	3.0	0.3	1.2
	Faeces	0.4	0.2	0.4
Uganda, total		2.5	0.4	1.4
	Urine	2.2	0.3	1.0
	Faeces	0.3	0.1	0.4

Figure 5: Country specific nutrient concentration in excreta per person, per year (estimated values, Joensson et al., 2004, p. 6)

[12] Total weight of N, P_2O_5 and K_2O

Hence, it could be shown that undernourishment is influenced by sanitation in two ways: Firstly, sanitation-induced diarrhoea affects the nutrient uptake efficiency and increases the amount of undernourished people. Secondly, due to the common way of linear nutrient management, the nutrients present in human excreta are not utilised to mitigate soil depletion as significant factor of limited crop production.

2.3 Public health

The health status of a population is determined by the health risks it is exposed to. The term health risk is defined as “a factor that raises the probability of adverse health outcomes” (WHO, 2009, p. V). The manifestation of health risks can lead to disease, injury or death. For the purpose of operationalisation, international and disease/injury-related comparability the concept of Disability-Adjusted Life Years (DALYs)[13] has been developed by the WHO in the year 1990 and was refined in later publications regarding the Global Burden of Disease (WHO, 2010).

2.3.1 Ranking diseases

The latest publications on DALYs show that worldwide the main diseases or injuries affecting public health are lower respiratory infections, diarrhoeal diseases, unipolar depressive disorders and ischaemic heart diseases, contributing to 6.2%, 4.8%, 4.3% and 4.1%, respectively, to the global burden of disease[14] (WHO 2008, p. 44). In the African Region[15] HIV/AIDS displaces lower respiratory infections and diarrhoeal diseases from the first two ranks, the forth position is occupied by Malaria. The African Region’s contribution to the burden of disease is generally higher in comparison to the world list; revealing proportions of 12.4%, 11.2%, 8.6% and 8.2%, respectively[16] (cf. Table 1).

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[13] Expressed as Disability-Adjusted Life Years (DALYs) in order to measure the overall disease burden. The DALY is the result of the addition of „years of life lost“ due to premature death with „years lived with disability“. The DALY concept enables comparisons between diseases or countries (WHO, 2009, p. 5).

[14] Total global burden of disease: 1.5 billion DALYs (cf. WHO, 2008, p. 60).

[15] All African countries except: Morocco, Tunisia, Libya, Egypt, Sudan and Somalia (WHO, 2011).

[16] African Region’s total burden of disease: 0.4 billion DALYs (cf. WHO, 2008, p. 60).

Table 1: Leading causes of burden of disease in DALYs, in 2004 (adapted from WHO, 2008, pp. 44).

Rank	Disease or injury	DALYs (millions)	% of total DALYs	Disease or injury	DALYs (millions)	% of total DALYs
	World			***African Region***		
1	Lower respiratory infection	94.5	6.2	HIV/AIDS	46.7	12.4
2	Diarrhoeal diseases	72.8	4.8	Lower respiratory infection	42.2	11.2
3	Unipolar depressive disorders	65.5	4.3	Diarrhoeal diseases	32.2	8.6
4	Ischaemic heart disease	62.6	4.1	Malaria	30.9	8.2
5-10	*For a continuation cf. WHO, 2008, p. 44.*					

According to WHO (2008, p. 8) diseases and injuries can be classified into three groups. Group I: communicable, maternal, perinatal and nutritional conditions; group II: non-communicable diseases and group III: injuries. The above-mentioned selection (cf. Table 1) is confined to the first two groups. Lower respiratory infections, diarrhoeal diseases, HIV/AIDS and Malaria can be attributed to group I, unipolar depressive disorders and ischaemic heart diseases belong to group II. Injuries (group III) are not taken into account here.

2.3.2 Transmission pathways

Considering the transmission pathways underlying the diseases listed in group I[17], a diverse picture is created. For instance, lower respiratory infections are most commonly transmitted by already infected persons through droplet infection. HIV/AIDS is transmitted via interpersonal exchange of body fluids such as blood, ejaculate or vaginal secretion and Malaria via anopheles mosquitoes (Pschyrembel, 2010; Wörterbuch der Medizin, 1998). Diarrhoeal diseases are commonly transmitted by the ingestion of contaminated food or drinking water, person to person- or animal to human contact, as well as aerosol routes and are considered as “main disease burden associated with poor water, sanitation and hygiene”[18] (Prüss et al., 2002, cited in Hutton et al., 2007, p. 469).

Since being of special interest in this thesis the transmission pathways of diarrhoea, its complexity and closely related to this, the difficulty of erecting effective barriers[19] that prevent its spreading are illustrated in Figure 6. The left side of the illustration displays the pathogen sources; the right side shows their final destination. In between there are various stages and the transmission pathways do not necessarily proceed from the left to the right as

[17] The diseases or disorders listed in group II and III are neglected here.

[18] 88% of diarrhoea incidences can be attributed to unsafe water, inadequate sanitation or insufficient hygiene (Prüss-Üstün et al., 2008).

[19] Also cf. Esrey et al., 2001, p. 33; Black and Fawcett, 2008, pp.74-75.

can be seen for the example of “excreta – waterborne sewage – surface water – drinking water – humans”. Also changes of direction or leapfrogging can be perceived (“excreta – soil – hands – food/humans” or “excreta – flies – food – humans”) (cf. Figure 6).

If no counter-measures are initiated, diarrhoea can lead to dehydration and debilitation and might become life-threatening (Pschyrembel, 2010). Especially children are affected by repeated incidences of diarrhoea that lead to underweight or malnutrition and finally to death (cf. 2.2) (Prüss-Üstün et al., 2008, p. 7).

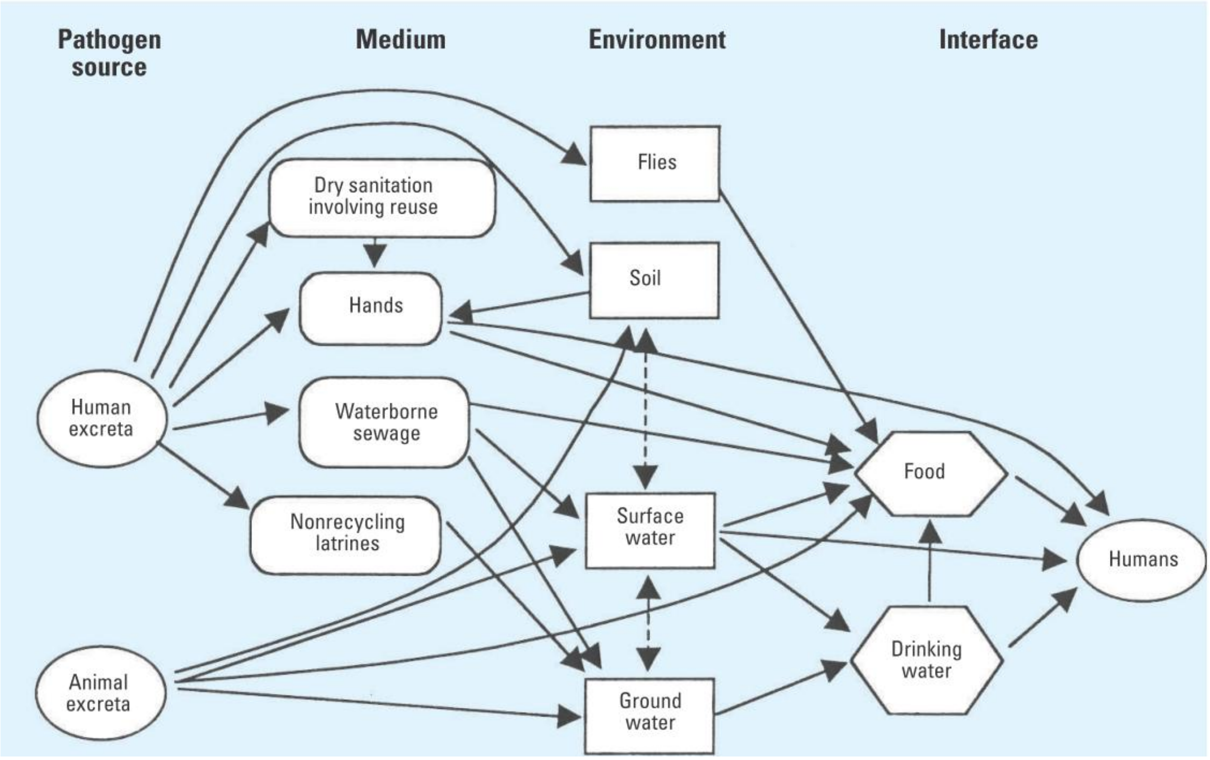

Figure 6: Transmission pathways of diarrhoeal diseases (Prüss et al., 2002, p. 538)

2.4 Sanitation – The status quo

As already mentioned in chapter 1, 2.6 billion people did not have access to improved sanitation facilities[20] in the year 2006. However, this number is not distributed homogeneously over the whole world. Close to every person in developed countries uses improved sanitation, but only about half of the people living in developing countries do so (WHO/UNICEF, 2010, p. 6). Figure 7 illustrates the proportion of improved sanitation used per country. The biggest proportions of people living without access to improved sanitation live in Sub-Saharan Africa and Southern Asia, and countries like Nepal, Papua-New Guinea and Bolivia, where less than 50% have access to improved sanitation facilities. The biggest countries of Southern-America and Russia itself range within the 76-90% class and China, Indonesia, Peru and Colombia can be attributed to the 50-75% class.

[20] Regarding the official classification cf. WHO/UNICEF (2010. p. 12). This chapter is confined to this classification. It does not take into account sustainable sanitation.

However, considering population numbers, it is quite apparent that the highest numbers of unserved people live in Southern Asia (1.07 billion), followed by Eastern Asia (0.62 billion) and Sub-Saharan Africa (0.57 billion people) (WHO/UNICEF, 2010, p. 6).

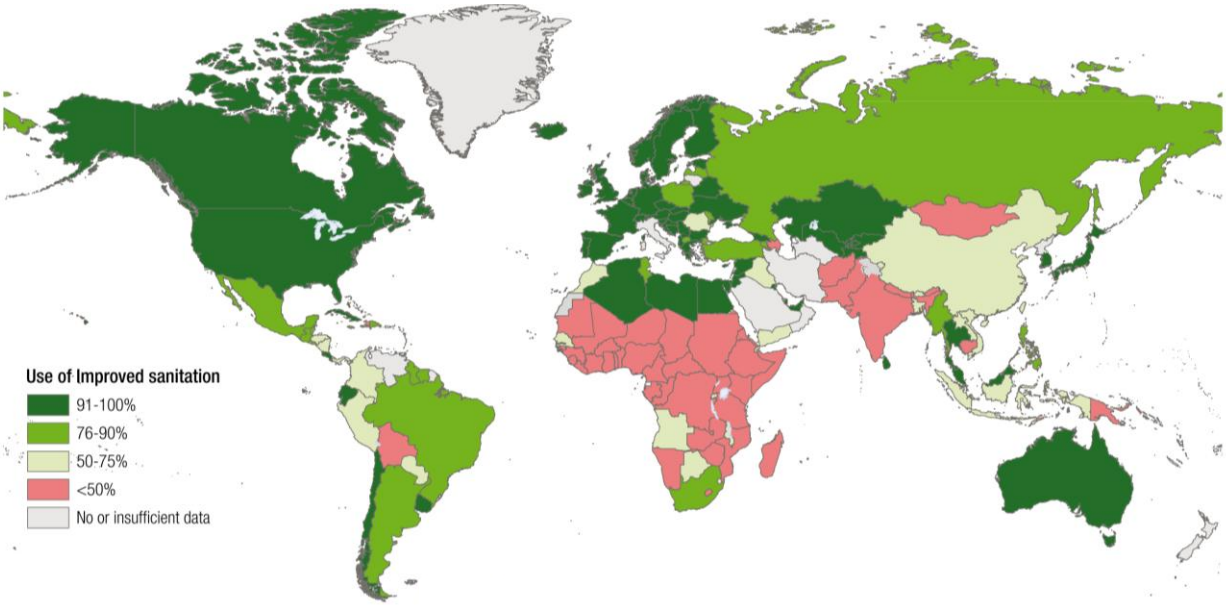

Figure 7: Worldwide use of improved sanitation facilities in 2008 (WHO/UNICEF, 2010, p. 6)

Unfortunately, considering future trends of sanitation coverage and keeping in mind MDG 7, target C: “Halve, by 2015, the proportion of the population without sustainable access to safe drinking water and basic sanitation” the world is only on track regarding the water component (WHO/UNICEF, 2010, p. 9). Due to population growth the number of unserved people will even increase. Projections show that in the year 2015 the number of people not having access to improved sanitation will add up to 2.7 billion (WHO/UNICEF, 2010, p. 8).

In order to display the quality of a sanitation system, various sources publish illustrations commonly known as *sanitation ladder*, whereby sanitation systems usually occupy rungs of a ladder according to their specific attributes (WHO/UNICEF, 2010, p. 12; Foster and Briceño-Garmendia, 2010, p. 325; Black and Fawcett, 2008, pp. 50). The higher the quality of such a sanitation system is, the bigger is the distance between the ground level and the specific rung. Figure 8 illustrates such a sanitation ladder based on the WHO/UNICEF (2010) classification used in chapter 1 with the additional dimensions costs and health benefits included. Furthermore it provides data about the proportions of different sanitation systems utilised in the Sub-Saharan context as gathered by WHO/UNICEF (2010) (cf. Figure 8 data in brackets).

Regarding costs and health benefits, the illustration shows open-defecation as free of charge, however no health benefits exist at the same time. The next rung imposes a higher price but also delivers more health benefits. This order can be continued until the highest rung is reached. However, the positive the message of this illustrations appears, the careful it has to be regarded: Despite moving up the ladder, three of four rungs still represent unimproved and inacceptable sanitation systems. Combined with the user data for Sub-Saharan Africa the illustration reveals that still 69% of the population are suffering from unimproved sanitation and its negative impacts on health and undernourishment.

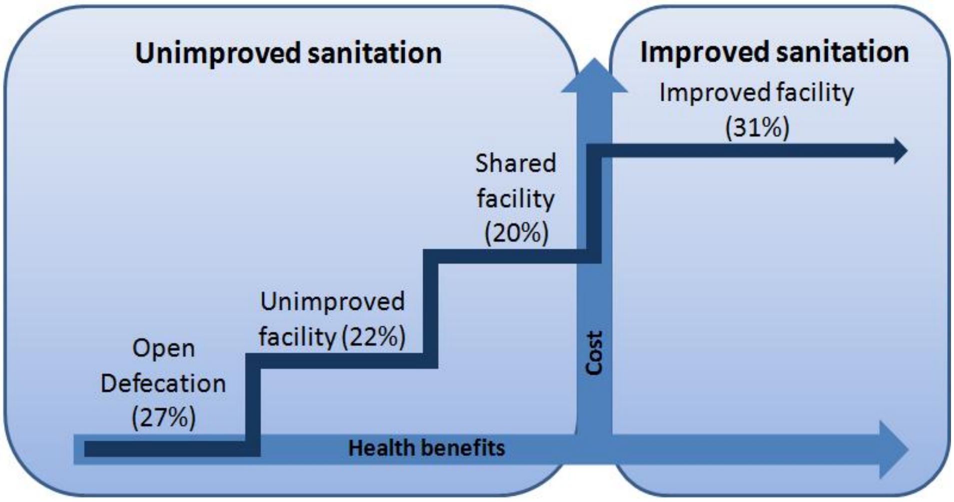

Figure 8: Conventional sanitation ladder – numbers in brackets represent the proportion of users in Sub-Saharan Africa (own contribution, based on Foster & Briceño-Garmendia, 2010, p. 325 and WHO/UNICEF 2010, p. 12)

3 Sustainable sanitation

The advantages of improved sanitation, (improving environmental quality, reducing societal and economic damages) have been briefly discussed in chapters 1 and 2.4. However, as already mentioned, there is an alternative approach, referred to as sustainable sanitation, which provides a whole series of additional benefits like reduced investment-, operation- and maintenance- (O&M) costs and the opportunity of fertiliser production (cf. chapter 2.2 and Box 1).

Chapter 3 will study this promising approach in depth. The first subchapter (3.1) will give an overview of sustainable sanitation, work out its differences to conventional sanitation, and give insights into the technology aspects of sustainable sanitation. Chapter 3.2 will then continue with the effects of sustainable sanitation, hence approaching the first research question: *What are the economic effects of sustainable sanitation?*

3.1 Sustainable sanitation – An overview

The JMP (WHO/UNICEF, 2010, p. 16) suggests classifying sanitation systems as illustrated in Figure 8. Unimproved sanitation consists of open defecation, unimproved facilities such as pit latrines without slab or platform, hanging latrines or bucket latrines and shared facilities. Improved facilities are considered to be flush/pour-flush toilets connected to either a piped sewer system, a septic tank or a pit, ventilated improved pit latrines (VIP), pit latrines with a proper slab and composting toilets (WHO/UNICEF, 2010, p. 12). However, this classification does not take into account whether a sanitation system can be considered as sustainable or not. According to the Sustainable Sanitation Alliance (SuSanA) the

> "main objective of a sanitation system [is] to protect and promote human health by providing a clean environment and breaking the cycle of diseases. In order to be sustainable a sanitation system has to be not only economically viable, socially acceptable, and technically and institutionally appropriate, it should also protect the environment and natural resources" (SuSanA, 2008, p. 1).

Other publications refer to sustainable sanitation as a "paradigm in sanitation, based on an ecosystem approach and the closure of material flow cycles. Human excreta and water from households are recognised as a resource (not a waste), which should be made available for reuse" (Langergraber and Muellegger, 2004, p. 435). The main characteristics of a sustainable sanitation system are (based on Rosemarin et al., 2008, p. 22):

- Minimised water and groundwater contamination leading to health benefits and improved environmental quality (cf. chapter 2.3)
- Nutrient recycling and preservation of soil fertility (cf. chapter 2.2)
- Water and resource saving (cf. chapter 2.2)
- More permanent installations than conventional improved sanitation facilities

- Lower cost option (depending on type of conventional improved sanitation facility) (cf. Rosemarin et al., 2008, p. 41)

Hence, when considering the above-mentioned classification of improved and unimproved sanitation through this lens, most of the systems do not qualify for being sustainable.
Open defecation, for instance, does not protect and promote human health. Regardless of the version, latrines rarely deliver the desired effects regarding environment and natural resources (partly, if proper emptying can be ensured[21] and nutrient reuse is included) and, do only in case of the improved versions contribute to human health improvement. The listed flush or pour flush systems do not meet any of the criteria of sustainable sanitation as they mix large amounts of clean water with small amounts of pathogen containing excreta, thereby not only diluting the nutrients present in excreta, but also creating large volumes of harmful wastewater, of which, considering global averages, only one out of ten litres is treated properly (Langergraber and Muellegger, 2004, p. 435; Werner et al., 2003, p. 24). In fact, the described practice leads to the invasion of faecal pathogens into aqueous environments, places where these substances do not belong to, leading to a degradation of human health as well as environmental quality. Additionally, the costs for construction, operation and maintenance of the necessary hardware are rejecting those systems from the list of sustainable sanitation systems (Langergraber and Muellegger, 2004).
Hence, solely, composting toilets comply with most of the requirements, only implying problems regarding the social acceptability in faecophobic[22] societies or negative effects due to misuse.

3.1.1 The aspect of source separation and technologies of sustainable sanitation

However, unlike it might be concluded from the section above, based on the JMP classification (WHO/UNICEF, 2010), sustainable sanitation systems are not limited to single technologies like composting toilets, they rather represent a variety of technologies capable of delivering the desired results (cf. remarks later in this chapter).
The first step in designing sustainable sanitation systems is to decide whether source separation of human excreta is applied or not. In this thesis as well as in other publications this practice is considered being a commonly applied strategy, optimising the process of

[21] Literature and personal experience showed that emptying is often done manually using buckets. The faecal matter is usually deposited into adjacent drains or the like (cf. WUP, 2003, p. 76; Still, 2002, p. 4; interview findings chapter 6.1.1.1)

[22] Societies can be classified as faecophilic and faecophobic. Countries like India, China and Asia in general, can be considered faecophilic as they look back to a long history of managing their excreta and reusing it as fertilisers. Other countries, like the ones of Europe are classified as faecophobic, as their inhabitants ceased performing this practice at the end of the nineteenth century, among others, caused by believing in the "miasma theory", a theory on the spreading of diseases due to volatile substances (cf. Bracken et al. 2006, p. 4).

treatment and potential reuse (Langergraber and Muellegger, 2004, p. 436). The reasons why source separation is considered a good practice are:

- The chemical properties in terms of nutrient value show that urine contributes a large majority to the total amount of nutrients present in human excreta (cf. Figure 5).
- The average volumes of urine (one to 1.5 litres) and faeces (0.14 litres) being excreted per person and day differ significantly from each other (Vinneras, 2002, p. 37 and 2009, respectively).
- Since urine and faeces show to have different levels of pathogens, there are different treatment requirements: The WHO (2006, p. XVI-XVII) for instance, recommends minimum one month of storage in closed containers for pure urine (that was not cross contaminated by excreta) and 0.5 to two years of storage and thereby dehydration of faeces. Additionally to storage there are other methods such as composting, incineration or chemical treatment (cf. Niwagaba, 2009).

Hence, urine and faeces have different fertilising values. Regarding their volume, different quantities have to be managed[23] and finally the duration and complexity of the treatment process is different.

Two common examples of source separating toilets can be seen in Figure 9. The two fractions of human excreta are immediately separated after leaving the body. The toilet room itself is usually raised accompanying a collection chamber for faeces underneath (cf. Figure 9, picture c)). Picture a) in Figure 9 shows a urine diversion dehydration squatting pan and picture b) a western style urine diversion dehydration seating toilet.

The use does not vary significantly from that of conventional toilets, only instead of flushing with water a mixture of sawdust, ash and soil is added into the faeces chamber to enhance the drying process and raise the pH level (Esrey et al. 1998, p. 11). Since the air pressure in the chamber is constantly lower than in the toilet room due to ventilation, no odours can be perceived.

After filling up one urine container, it is exchanged with another one and stored for at least one month according to WHO standards (WHO, 2006). The faeces chamber is either emptied[24] when full and the faeces are stored in a contained and sheltered area, or in case of a toilet with a two chamber layout, the empty chamber is used, while the full one is left for sanitisation, again according to WHO standards (WHO, 2006).

Apart from the urine diversion dehydration approach, there are also other technologies without dehydration of faeces and the application of composting instead, or toilets without separating pans or seats. The separation of liquids and solids in this type of toilet takes place

[23] E.g. different containers for collection, transport, treatment

[24] Ideally, a bucket, barrel or basket is used for the collection in the chamber, since it can be removed without directly touching the faeces.

in the chamber below and leads to a prolonged treatment period of urine since being cross-contaminated with faeces (Esrey et al. 1998, pp. 34-35 and 39-40).

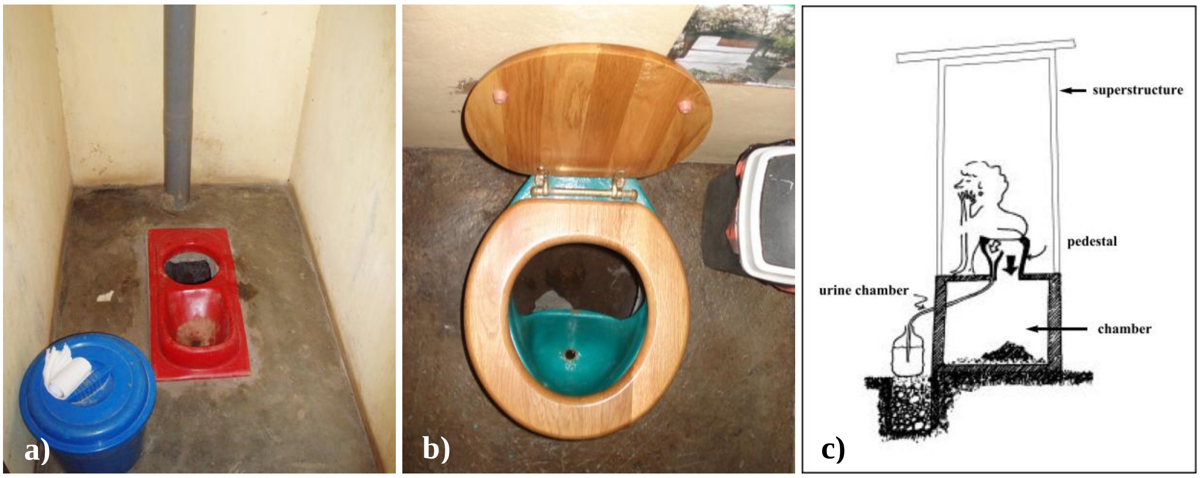

Figure 9: Source separating toilets. Picture a) shows a urine diverting dry squatting pan (Uganda), b) a western style urine diversion dehydration toilet (UDDT) (Mexico) and c) a sketch of a UDDT (own photographs and Esrey et al. 2001).

3.2 Effects of sustainable sanitation

A confined number of negative effects regarding deficient sanitation have been presented in the chapters 2.1, 2.2, 2.3 and 2.4 by discussing the problem of slum sanitation in the context of rapidly growing informal settlements, the situation of undernourishment or public health and their relationships to sanitation and the global status quo regarding sanitation itself. The present chapter will turn the tables and bring to light the positive effects of sustainable sanitation and create a comprehensive picture of the benefits that could be achieved by its implementation. Since being of special interest in this thesis, the economic dimension of the effects will be particularly focused and values will be expressed in monetary terms, where applicable and obtainable.

Before going into detail, there is one issue that has to be kept in mind: Measuring the effects of sanitation is a complex assignment. It is impossible to attribute e.g. mortality due to diarrhoeal diseases to sanitation alone. Rosemarin et al. (2008, p. 9) and Moe and Rheingans (2006, p. 47) for instance, describe sanitation, water and hygiene as issues, that are strongly interrelated and “irrevocably intertwined”, influencing each other in many different ways. Hence, isolating particular issues does not reveal reasonable results. As a solution to this problem aggregated risk factors[25] instead of single diseases have been compiled. All further considerations will be based on this type of aggregation.

Table 2 (p. 24) presents an overview of the positive effects of sustainable sanitation and their economic dimensions, if existing. There are various effect categories such as health, socio-economic, social, gender and political.

The first two categories can be attributed with an economic dimension. However due to a lack of data it was not possible to assign a monetary value to all of its effects. There are for instance health effects, probably being the most apparent manifestation of improvements in terms of access to sanitation. Their impact is expressed in terms of less morbidity and mortality and it is commonly measured in DALYs. However, due to a lack of data, it was not possible to include this item into the calculation.

The next effect category with an economic dimension involves socio-economic effects. Here, it was possible to clearly attribute a monetary value to most of the effects listed in Table 2. Based on various sources[26], examples for costs averted per person and year have been compiled. Those values were multiplied by the average number of diarrhoea cases per person and year[27]. Finally, based on the reduction impact of diarrhoeal diseases of 37.62% of one particular water supply and sanitation intervention[28] the averted costs were calculated (cf. Table 2 and Hutton et al., 2007, p. 483).

It is assumed that an average of 30% of people, being affected by diarrhoea visit a health facility whereof 8.2% are hospitalised and receive medical treatment (Hutton et al., 2007, pp. 485). According to Mulligan et al. (2005, pp. 27), the costs for a single visit of a health centre are 1.14 EUR. The costs for a 5 day stay in a hospital are 24.79 EUR. Added up and combined with the prevalence stated above, this yields to saved health care costs of 0.46 EUR per person and year.

Closely linked to this item are transport costs and expenditures for food and drinks. Regarding transport, it has been assumed that 50% of the people visiting a health centre use transport services, costing 0.4 EUR per return journey (Hutton et al., 2007, pp. 485 and Mulligan et al., 2005, pp. 27). Combined with the average number of trips, this adds up to 0.03 EUR. The cost for food and drinks are incorporated with 0.4 EUR per day (outpatient) and 8.04 EUR per 5 day stay in a hospital, amounting to 0.12 EUR per person and year.

The saved opportunity costs[29] are separated in two types. One type is limited to time savings due to less sickness. For adults, it was assumed that two days are lost per incidence. A value of time of 100% of the Gross National Income (GNI) per capita was used for valuation. Children under the age of five occupy five days of carer time from their parents per incidence. However, the value of time was calculated to be only 50% of the GNI per capita, since no full-time care is required. Considering the "future importance of proper schooling", children

[25] Examples for those risk factors are apart from unsafe water, sanitation and hygiene, tobacco use or unsafe sex (WHO, 2009, p. 10).

[26] Hutton, 2001; Hutton et al., 2007; Rosemarin et al. 2008

[27] In Africa 1.28 cases of diarrhoea per person/year are projected for the year 2015 (Hutton et al. 2007, p. 490).

[28] In Hutton et al. (2007) the impact of five water supply and sanitation interventions in terms of reduced cases of diarrhoea were modelled. For this calculation the intervention most similar to sustainable sanitation regarding costs and effectiveness (*universal basic access to water supply and sanitation*) was used.

[29] Regarding the opportunity costs of time, the value of one year was assumed to equal the Gross National Income per capita (GNI) for Africa, amounting to 565 EUR (UN DATA, 2011).

aged 5 to 15 years, contributed to 100% to the GNI per capita and it has been assumed that three days are lost per incidence (cf. Hutton et al., 2007, p. 486). As a result, 1.86 EUR are saved per person and year. The other type of opportunity costs is saved due to better access to water and sanitation facilities. For this, the number of hours saved per capita was combined with the GNI per capita (Hutton et al., 2007, p. 487). This resulted in a saving of 20.99 EUR per person and year.

The fertiliser value was calculated using the replacement cost approach[30] with fertiliser price information from Uganda. The average fertiliser expenditures per year could be reduced by 4.59 EUR by reusing the urine and faeces excreted from one adult. However, it should be kept in mind that not everyone is involved in agriculture and needs fertiliser. Yet, the example of Uganda shows that the majority of households are engaged in farming (approx. 79%) (UBOS, 2007b, p. 10). Due to a lack of data environmental quality was the only effect in this category that was not considered in terms of its economic dimension and thus not included in the calculation.

At this point, the categories social, gender and political will be considered. Even though they do not consist of effects that hold economic dimensions, the effects are interlinked in many other ways. There are, for instance the social effects privacy, dignity, safety, the gender effect and the political effect all concerning women and their link to sanitation. The following example will illustrate this:

People living in an environment which force them to rely on open defecation or insufficiently covered pit latrines, have no alternative than defecating openly. Men usually do that regardless of the time of the day. Women instead, often wait until nightfall in order to relieve themselves. Apart from posing health risks such as urinary tract infections, this also attracts criminals and increases the risk of being raped or assaulted (WaterAid, 2006, p. 101, UN, 2005, p. 25 and Amnesty International, 2010).

Another aspect regarding the gender issue is the burden of caring for the family. Apart from agriculture, cooking and bringing up children, women are also engaged with water, sanitation and hygiene activities occupying several hours per day (e.g. only collecting water consumes up to three hours/day) (Hutton et al., 2007, p. 488). The gender issue finds additional manifestation in political terms. Since, on the one hand, particularly relieving women with water, sanitation and hygiene interventions and on the other hand representing half of the population, considerable political power in terms of votes can be mobilised by targeted action (e.g. communal investments in sustainable sanitation facilities) (Rosemarin et al., 2008, p. 34). Another social effect, not related to gender issues, is perceived environmental quality.

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[30] The approach uses average fertiliser prices and multiplies them with the nutrient content of urine and faeces. Thereby, a value is attributed to urine and faeces that is lost due to uncontrolled dumping and would need to be replaced by synthetic fertiliser (cf. Drechsel et al., 2004). In this calculation, atmospherical losses of nitrogen were included with 50%.

Hutton (2001, p. 344), for instance mentions increased amenity value for recreational uses as positive effect due to improved aesthetics.

Even though Table 2 does not present a comprehensive list of averted costs the individual items can be added up to 28.06 EUR per person and year[31]. The aggregated averted costs can be either compared to the value of time, which equals approx. 16 days[42]. On the other side, they can be contrasted to the annual costs of providing *universal basic access to water supply and sanitation*, which amount to 6.42 EUR per person for the African Region and are thus considerably lower. Calculating the BCR based on these two values results in 4.37[32] – in other words, the return on investment of 1 EUR would be 4.37 EUR. Hence, apart from the benefit of the gained income, the BCR is likely to positively influence decisions to invest in sanitation infrastructure helping to promote its implementation from family- to international level.

For the purpose of comparison Hutton et al. (2007) is cited here, who modelled BCRs of conventional water supply and sanitation interventions in the African Region, such as *meeting the water supply MDG*, *meeting the water supply and sanitation MDG*, *universal basic access*, *universal basic access and disinfection at point of use* and *regulated piped water supply and sewer connection*. The calculated values ranged from 2.1 to 6.3 (cf. Hutton et al., 2007, p. 494). Hence, the BCR calculated for sustainable sanitation in Table 2 can be ranged well in this spectrum. However, recalculating the BCR including a more comprehensive data set would likely yield in results that rate sustainable sanitation superior in comparison to conventional solutions.

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[31] The total amount also considering not measureable- or not measured items, such as costs of premature death (included in the *health* category) or environmental quality is likely to be higher.

[32] Considering footnote[31], the BCR is also likely to be higher.

Table 2: Benefits and economic dimension of sustainable sanitation. Personal-level perspective (compiled from Hutton, 2001; Hutton et al., 2007; Rosemarin et al. 2008)

Effect category	Effect description	Economic dimension?	Examples of averted costs person/year in Africa in EUR	Comments	Source
Health	Less morbidity and mortality	Yes. However, not included due to lack of data.	-	Can for instance be measured in DALYs. Data was not available	Hutton et al. 2007, p. 484
Socio-economic	Saved health care costs	Yes	0.46	30% cases of diarrhoea would visit a health facility whereof 8.2% are hospitalised the average of 5 days.	cf. Hutton et al., 2007, p. 485; Mulligan et al., 2005
	Saved transport costs to health service	Yes	0.03	50% of people visiting a health facility use transport involving costs.	cf. Hutton et al., 2007, p. 485
	Saved expenditure for food/drinks	Yes	0.12	The cases that visit a health facility or are hospitalised have to pay for food and drinks.	cf. Hutton et al., 2007, p. 485
	Saved opportunity costs of time: Time gained due to less sickness (adults and school children), saved carer time (for children under 5 yrs.)	Yes	1.86	The GNI is taken as reference. Adults (15< yrs.) gain 2 days (100% GNI), school children (5-15 yrs.) gain 3 days (100% GNI), infants (5>) gain 5 days (50% GNI)	cf. Hutton et al., 2007, p. 486
	Saved opportunity costs of time due to improved access to facilities	Yes	20.99	4.24 day are saved due to better access (100% GNI)	cf. Hutton et al., 2007, p. 492
	Fertiliser value	Yes	4.59	Average value of nutrients excreted per person and year in Uganda with 50% atmospherical losses of nitrogen.	Joensson et al., 2004; Drechsel et al., 2004
	Improved environmental quality	Yes. However, not measured	-	Can for instance, be measured by applying the willingness to pay approach.	Hutton, 2001
Social	Increased privacy	Not measurable	-	-	Rosemarin et al., 2008, p. 34
	Increased dignity	Not measurable	-	-	Rosemarin et al., 2008, p. 34
	Improved safety	Not measurable	-	-	Rosemarin et al., 2008, p. 34
	Perceived environmental quality improved	Not measurable	-	-	Hutton, 2001, p. 344
Gender	Relief for women, as they are mostly engaged with water, sanitation and hygiene in a family and suffer under unimproved sanitation (e.g. large distance)	Not measurable	-	-	Rosemarin et al., 2008, p. 34
Political	Potential to raise votes (among others, from women, since they are often engaged with water sanitation and hygiene and represent half of the votes)	Not measurable	-	-	Rosemarin et al., 2008, p. 34
Total averted costs per person and year (not comprehensive)			**28.06**		
Total costs of providing *universal basic access to water supply and sanitation*			**6.42**		
BCR			**4.37**		

4 Design backgrounds – The Integrated Sustainable Waste Management concept

The Integrated Sustainable Waste Management (ISWM) concept represents an approach for (1) the assessment of existing waste management systems or (2) for the design of new systems and the selection of new technologies (Klundert and Anschütz, 2001, p. 17). Originally the ISWM concept had been developed for solid waste management in developing countries by WASTE[33] (Maessen et al., 2005, p. 3). However, it was adapted to sanitation in the beginning of the last decade. One of the basic messages of the concept is that "it is not money or equipment that provides solutions but rather changing social, institutional, legal or political conditions" (Klundert and Anschütz, 2001, p. 10).
The *ISWM* concept is based on four *principles* (Klundert and Anschütz, 2001, p. 11):

- *Equity*: Everyone, regardless of its socio-economic status, should have access to appropriate waste management and sanitation systems. This is not only motivated by moral obligation but can also be justified pragmatically by considering the negative effects of communicable diseases, insects, rats, polluted air and water moving from one part of the city to another. Polluted areas lead to poor living conditions and often affect a city's economy which in turn hampers its development.
- *Effectiveness*: All waste is safely removed and all recoverable materials – nutrients, in the case of sanitation – are recovered.
- *Efficiency*: The management of waste or excreta is done by maximising the benefits, minimising the costs and optimising the use of resources.
- *Sustainability*: The waste or excreta management system is feasible from a technical, environmental, social, economic, financial, institutional and political perspective always taking into account the respective local conditions.

According to the ISWM model (cf. Figure 10) waste and excreta management consists of three different dimensions (compiled based on Klundert and Anschütz (2001, pp. 13):

- There are the *stakeholders* that are involved in and at the same time affected by waste and excreta management. Examples for stakeholders in a sanitation system are users/participants, private sector responsible for service delivery, farmers as users of fertiliser, local authorities and donor agencies.
- The second dimension is *system elements* that can be considered as stages in the flow of the material of interest over the process time. Examples for those stages are

[33] WASTE is a Dutch organisation which advises in sustainable improvement of the urban environment. Its multi-disciplinary expertise lies on urban environment, solid waste management, urban planning, sanitation and environmental economy (WASTE, 2011).

generation, collection, transport, storage, agricultural (re)use, composting and urine disposal.

- The third dimension consists of aspects which help assessing existing- or planning new- systems. These *aspects* are:
    - *Technical*: concerning the practical implementability and maintenance of all above-mentioned elements, their design, practicability and effectiveness.
    - *Environmental*: focusing the effects of waste and excreta management on land, water and air; the need for conservation of non-renewable resources; pollution control and public health concerns.
    - *Financial and economic*: dealing with budgeting, cost accounting and efficiency within the system and in relation to the different levels of economy (local, regional, national and international); Specific issue are for instance privatisation, cost recovery and cost reduction; the impact of environmental services on economic activities; the commodities or fertiliser marketplace and how the system's infrastructure connect to it; macroeconomic dimensions or resource use and conservation (peak oil, phosphorous, potassium); and income generation.
    - *Socio-cultural*: including the cultural influences on waste- and excreta generation, handling and management; the relations between groups and communities and people of different age, sex, ethnicity.
    - *Institutional*: relating to the social and political structures which control and implement waste- and excreta management; organisational structures, procedures and methods; institutional capacities; and potential actors/stakeholders.
    - *Political/legal*: addressing the boundary conditions in which the waste and excreta management system exists, setting goals and priorities; determination of roles and jurisdiction; legal and regulatory framework; decision-making progress.

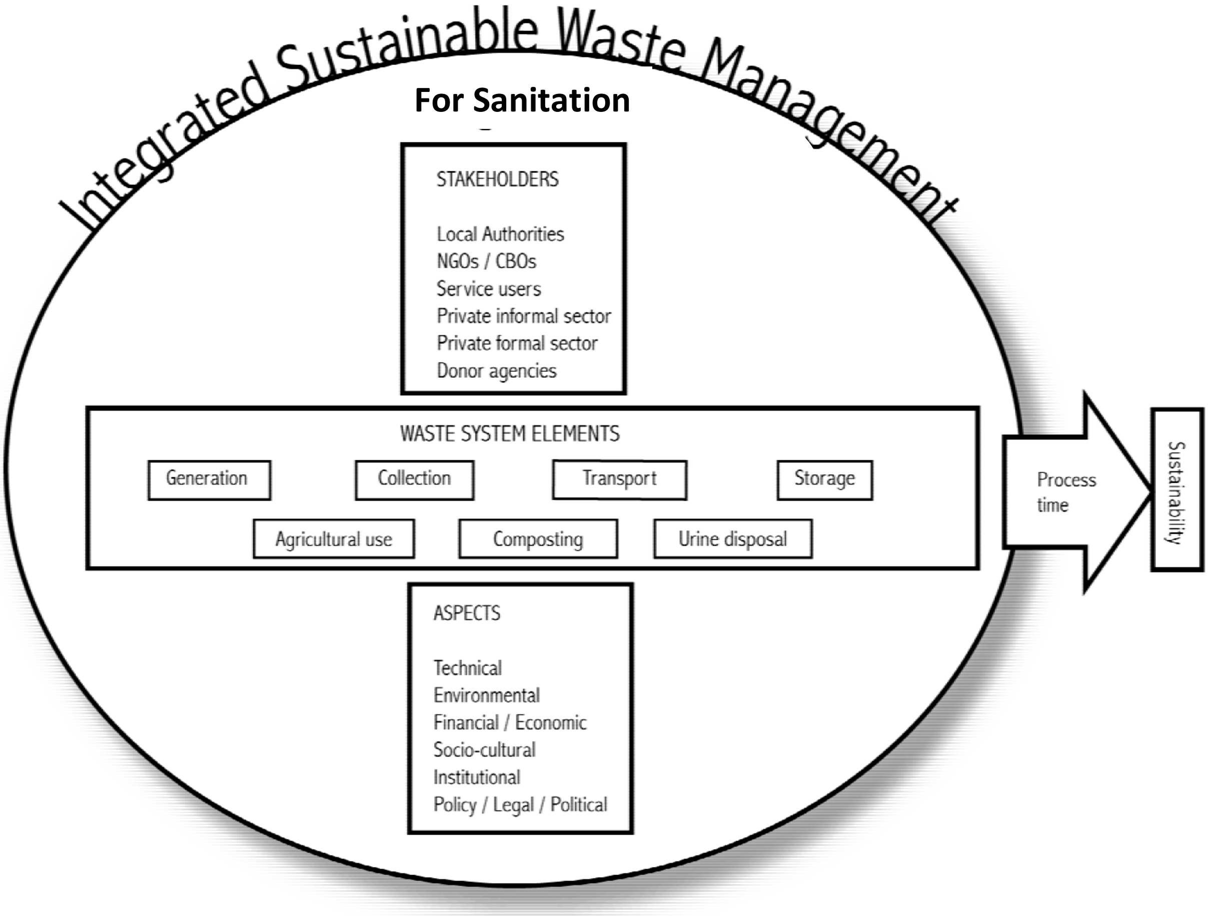

Figure 10: The ISWM model for sanitation (adapted from Slob, 2005, p. 25)

The system designed in chapter 6.2 is based on the ISWM concept and takes benefit of the practical experiences of the authors (cf. Klundert and Anschütz, 2001, p. 9). However, the approach is not fully emulated. Since applying qualitative research (focus group discussions and face-to-face interviews) the stakeholder analysis (Figure 10, first dimension) is not comprehensive on a city-wide scale. The waste system elements (Figure 10, second dimension) are mostly represented, whereas the aspects (Figure 10, third dimension) do not include institutional and political/legal issues. Still, the validity of the results is not diminished by those reductions, since the main objective was to test the technical and economic feasibility.

5 Methods

Generally, methods are used in research as “investigative techniques” to answer research questions (cf. Winchester, 2005, p. 4). Methods in human geography can roughly be divided in two factions – qualitative- and quantitative methods. Each method is used to “answer different research questions, employ different research methods, have different limitations, and ensure rigour differently” (Bradshaw and Stratford, 2005, p. 69). Winchester (2005, p. 10) even considers the two as generally being “in opposition or as conflicting methodologies”. He continues by citing Brannen (1992) stating that “qualitative approaches view the world through a wide lens and quantitative approaches through a narrow lens”, meaning that qualitative methods are more open, “soft and subjective”, whereas quantitative methods yield to “focused, objective and generalisable” outcomes (Winchester, 2005, p. 10; Reuber and Pfaffenbach, 2005, p. 107). This is supported by Bradshaw and Stratford (2005, p. 69) on the one hand considering qualitative methods as being utilised for eliciting how processes work in particular cases, what are the motivations underlying a specific type of behaviour, and what could be applied to trigger change? On the other hand, they characterise quantitative methods as being used for identifying “regularities, patterns, and distinguishing features of a population” or field of interest, however involving the risk of lacking explanatory power (Bradshaw and Stratford, 2005, p. 69).

Whilst the sample size is not meant to be representative in qualitative research and hence can be confined to a couple of informative interviews as long as plausibility can be assured, it is important to consider representativity in quantitative research which is designated for statistical analysis and transferability to larger scales (cf. Bradshaw and Stratford, 2005, p. 72). Despite this dichotomous setting, the two factions have often been combined in research, working hand in hand to increase the broad and at the same time in depth investigation of certain issues from different perspectives (cf. Winchester, 2005, p. 12).

Qualitative research in geography mainly investigates two fundamental questions. One is asking for social structures, the other for individual experiences and behaviour, whereas the latter are less likely to be determined by the “personal characteristics, but by the [individuals’] position in the social structure” (Winchester, 2005, p. 5). Qualitative research can be separated in three main types: oral (e.g. interviews), textual and observational (Winchester, 2005, p. 7). The oral type is considered to be the most popular and widely used method in human-geography. However, there are several subtypes within this class. The most individual and qualitative methods are (auto-) biography and oral history. Moving towards the quantitative end of the ‘qualitative-methodological spectrum’ un-, semi- and structured interviews and focus group discussions can be listed. The most ‘quantitative’ methods in this field of research are surveys and questionnaires (cf. Winchester, 2005, p. 7). The methods applied in this thesis belong to the oral type and can be placed in the middle of that spectrum: A mixture of semi-structured interviews and focus group discussions was conducted.

Flick, Kardoff and Steinke (2000, pp. 22) cited in Reuber and Pfaffenbach (2005, p. 118) listed 12 characteristics of qualitative research partly incorporating above-mentioned issues, partly introducing new findings, developing principles or best practices that were considered in the preparation and conduction of the interviews and focus group discussions for this thesis:

1. According to the issue it can be chosen from a variety of different methods. There is no standard method.
2. The choice of a method depends on the specific issue – not vice versa.
3. Data (e.g. interviews) are collected in the everyday life of the interviewees.
4. The interview statements should always be considered in the context of the interview- and living situation of the interviewee.
5. Different interviewees have different perspectives on the same issues. The goal should be gathering the diversity of these perspectives.
6. Both, experience and influence of the researcher on the issue itself and the interviewees should be included into the research process.
7. Instead of establishing causalities, the reconstruction of motives and contexts of meanings is used to clarify complex structures and connections.
8. Research questions, progress of research and process of interviewing should be open and modifiable.
9. As a first step, the focus of qualitative research is on identifying and understanding individuals, their perceptions, opinions and behaviours. In a second step those insights are compared and generalised.
10. The interviewee’s reality is a construction of the first order. The researcher’s scientific reality is a construction of the second order based on the first order.
11. Qualitative research can be considered a textual science. All data (apart from pictures and films) is transformed (transcribed) into texts.
12. Theory is not verified by empiricism. It is empiricism that leads to theories.

5.1 Research design

Before going into detail about the specific types of qualitative methods applied in this thesis in the chapters 5.2 and 5.3, the research design, including the sampling of interviewees is presented in this chapter. Research design is commonly defined as the flexible process of planning and conducting an empirical study (cf. Bradshaw and Stratford, 2005, p. 68; Lamnek, 2005, p. 719). In detail the process involves the formulation of the research questions, choice of method(s), place(s) and participant(s) (cf. Lamnek, 2005, p. 719).

The design of the empirical part of this thesis was based on the second research question: *How can a system for the removal of human excreta from slum areas look like according to the principles of sustainable sanitation?*

The stages for meeting this target consisted of a situation analysis and a stakeholder selection (cf. chapter 6.1 and 6.2.1, respectively), which were then complemented by two system designs with individual cost calculations (cf. chapter 6.2). The methods chosen for answering this question consisted of a mixture of semi-structured interviews and focus group discussions. The fieldwork was conducted from November 2009 to January 2010 in Kampala, Uganda.

In the first period of interviews, involving ten key informants or experts, the status quo regarding slum sanitation, agricultural situation and relevant stakeholders was investigated (cf. Figure 11 - *Expert Level*). The experts were identified in several conversations with Karsten Gjefle (SuSan Design[34]) and staff from Deutscher Entwicklungsdienst (DED) and Reform of the Urban Water and Sanitation Sector (RUWASS) in Kampala. In order to cover a broad range of different perspectives, a group of experts as diverse as possible was chosen. Based on the information gathered in the expert interviews and taking into account the ISWM concept (cf. chapter 4), a set of relevant participants of a logistics system had been identified and contacted (cf. Figure 11 - *Participant Level*). The sampling method underlying this process can be described as a mixture of two strategies. On the one hand, experts referred to certain *participant level* interviewees (snowball or chain sampling), on the other hand additional interviewees have been chosen according to their specific functions or characteristics (criterion sampling) (cf. Bradshaw and Stratford, 2005, p. 72; Reuber and Pfaffenbach, 2005, p. 151).

After establishing the contacts, the second period of data acquisition consisted of a mixture of 15 face to face interviews (private service providers and farmers) and 4 focus group discussions (residents). As Dunn (2005, p. 95) suggests, the interviews and focus group discussions were recorded and supplementary notes were made. While the interviews were usually conducted at the places of work of the various participants, the focus group discussions were held in local public meeting rooms or schools to maintain the typical milieu of the interviewees (cf. Reuber and Pfaffenbach, 2005, p. 132). During the focus group discussions there was usually at least one person fluent in English[35] that took over the role of the interpreter.

Additionally to those statements, relevant data about e.g. transport and infrastructure costs, fertiliser prices and incentives was gathered during the interviews and in field data collection. The focus group discussions with slum residents were conducted in the slum areas *Go Down-*

[34] NGO that is involved in delivering sustainable sanitation solutions to slum residents. The organisation is mainly active in Uganda and Kenya.

[35] Despite English being the first language in Uganda, many slum residents prefer using the languages of their origins in rural Uganda.

village in Namuwongo-Soweto, *Natete*, *Kasanvu* and *Mulago* (cf. Figure 12). The private service providers were interviewed in *Bugolobi*, *Industrial A* and *Civic Centre* (cf. Figure 12). The third group of interviews was conducted with farmers (small and medium scale) in agricultural areas surrounding Kampala (cf. Figure 12, p. 40) and farm managers (large scale) either in their office in Kampala, or on their farms outside of the city (cf. 6.1.2.1)

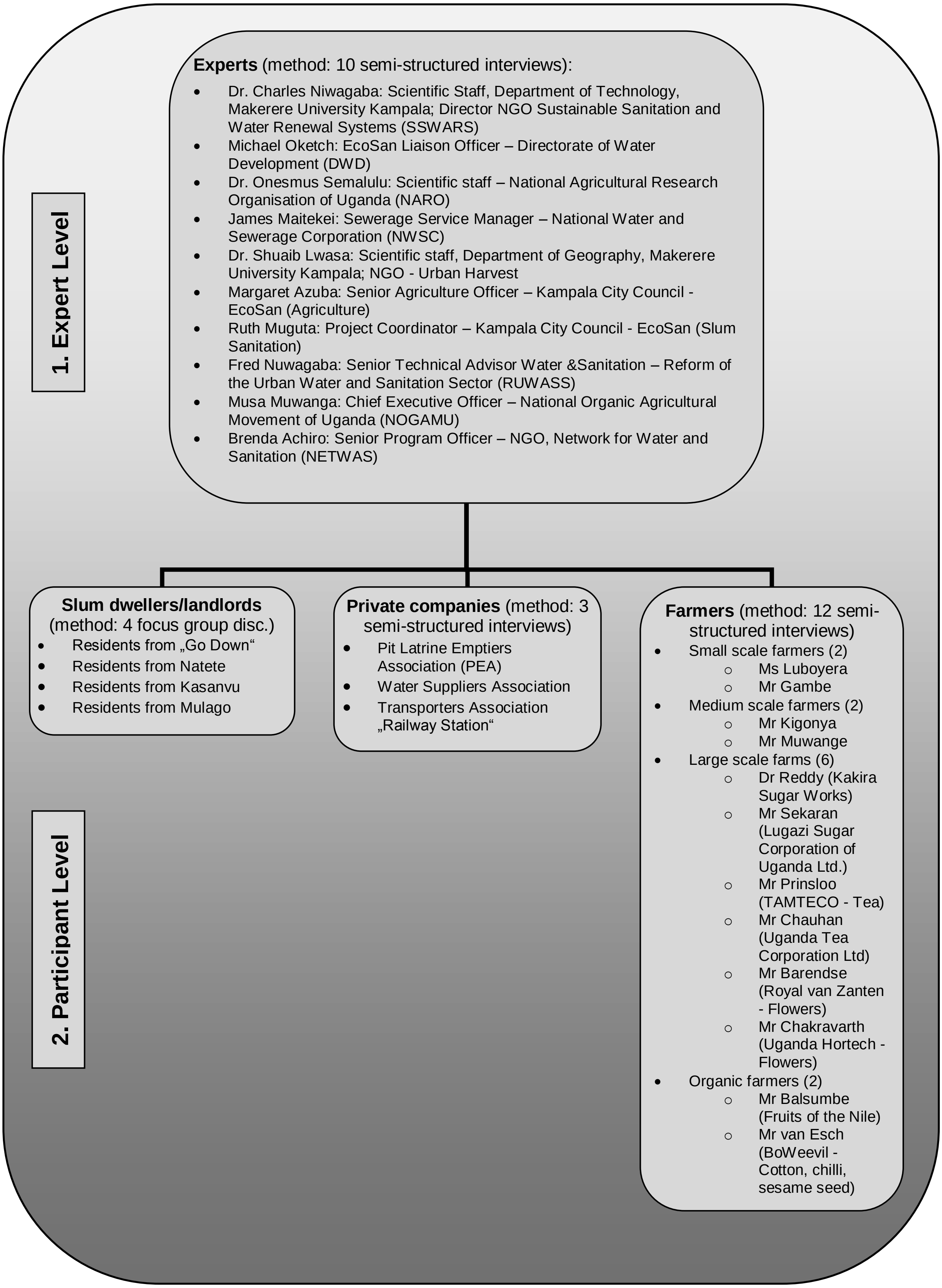

Figure 11: Stakeholders and the two level approach to the interviews (own contribution)

5.2 Semi-structured interviews

As mentioned above, the method of semi-structured interviews has been used for the expert and individual interviews. Unlike structured- or unstructured interviews, which are "question and informant focused", semi-structured interviews are "content focused" (Dunn, 2005, pp. 87). The interviews were conducted using guidelines that on the one hand helped to focus the issue and follow a certain structure, however on the other hand enabled the gathering of additional information and "allow[ed] the conversation to be as natural as possible" (Dunn, 2005, p 82). Considering the principle of processuality the guidelines were slightly modified over the course of interviews (cf. Reuber and Pfaffenbach, 2005, p. 137). Three different guidelines have been prepared according to each group of participants (experts, private service providers and farmers) (cf. chapter 9.2).

The guidelines for the expert interviews consisted of the categories:

- *Introduction*
- *Sanitation situation in Kampala*
- *Agricultural situation in and around Kampala*
- *Human excreta as fertiliser*
- *Useful contacts*
- *Closure*

The guidelines for the private service provider's interviews were structured as follows:

- *Introduction*
- *General information about the company and service*
- *Technical and financial information about the companies infrastructure*
- *Human excreta logistics*
- *Closure*

The farmer interviews were structured using the following categories:

- *Introduction*
- *Agricultural information*
- *Human excreta as fertiliser*
- *Closure*

The interviews started with a warm-up phase, where the persons present[36] were introduced to each other and the purpose of the interview was clarified. This was usually followed by some informal chatting e.g. about everyday life, culture or weather to create a relaxed atmosphere and increase the "success of the interview" (Gardner, Neville and Snell, 1983, cited in Dunn, 2005, p. 92). The formal part of the interview was initiated by asking to give an overview of

[36] The standard interview situation consisted of the interviewer (me) and the interviewee. However, in some interviews with representatives of large scale farms, the managers or directors were supported by their assistants.

the sanitation or agricultural situation or the situation regarding private service providers in the field of sanitation (depending on the type of interviewee). The question usually triggered an answer with a narrative character. The ongoing interview consisted of a mixture of “primary” and “secondary” questions (Dunn, 2005, p. 83). The primary questions served as opening questions for different topics such as “What can you tell me about the property situation in the slums?” or “How are sanitation facilities in the slums financed?” (experts); “What is the size of your farm?”, “What are you growing”, “What do you do with the crops you grow?” or “Would you be willing to use human excreta as fertiliser?” (Farmers); “What kind of business are you running”, “What can you tell me about your market environment” or “How is your technical infrastructure like?” (private service providers). Secondary questions were used to specify mentioned issues and redirect the interview according to the desired outcome. The interviews were closed by thanking the interviewee and asking for questions from his side (Dunn, 2005, p. 94). The average duration of the interviews belonging to the participant level was one hour. The expert interviews usually took 1.5 hours.

5.3 Focus group discussions

In general, focus group discussions are a method of discussing certain issues in small groups of preferably five to twelve people (cf. Cameron, 2005, p. 116; Lamnek, 2005, p. 435). The idea behind focus group discussions is to induce interaction between the group members rather than between the interviewee and the researcher. Hence, different perspectives are expressed informing both the researcher and other group members thereby not only generating data for research purposes, but also triggering a learning process within the group or even the creation of new knowledge (cf. Cameron, 2005, p. 119). The role of the researcher should thereby ideally be the one of the moderator, promoting interactions, encouraging reluctant members or curbing others and redirecting the situation when being off-track (cf. Cameron, 2005, p. 124). Furthermore, Cameron (cf. 2005, p. 117) characterises group discussions as dynamic and energetic processes that generate much more information than other research methods.

However, the application of focus group discussions is not confined to the above mentioned applications. Alternative use cases are combinations with questionnaires to test the findings in a bigger sample to enable generalisability, to develop targeted questions for a new survey or to refine or interpret survey findings (cf. Cameron, 2005, pp. 119).

In the present thesis, focus group discussions were conducted with residents and landlords from four slum areas in Kampala (cf. Figure 12). Comparable to the semi-structured interviews a guideline had been compiled. The objectives were to elicit information about the sanitation situation and the attitude towards sustainable sanitation solutions, including the reuse idea of human excreta. Apart from gathering direct information comparable to those derived from the semi-structured interviews, the objective was to induce dynamic discussions about the problems caused by bad sanitation, the importance of proper sanitation, the desired sanitation situation, the willingness to pay for proper sanitation and discussions about the

participation in a logistics system for human excreta potentially influencing different opinions of group members and creating new knowledge (cf. chapter 6.2.2).
Whereas Cameron (2005, p. 121) states that “it is best not to have people who are acquainted in the same group”, Reuber and Pfaffenbach (2005, pp. 146) consider the optimal group composition as natural, involving people that are somehow connected in their everyday life. Following the latter approach, the groups in this thesis consisted of seven to 13 slum residents, including different ages, sexes and tenants as well as landlords from the same neighbourhood. Since being of higher relevancy to women, their participation was generally superior to that of men (cf. chapter 3.2).
Similar to the semi-structured interviews (cf. preceding chapter), the procedure started with a warm-up phase, where the objective of the meeting was explained and the members introduced themselves. As a second step the residents were asked to describe their neighbourhoods, the environmental quality and the problems emerging from that. After little time the discussions usually revolved lively around the issues of sanitation and sanitation induced illnesses. By constantly moderating and redirecting the process of discussion, the issues mentioned above were covered. The meeting ended after completing the guidelines, concluding the results and re-discussing certain issues, that emerged in the meta-discussion. The duration of the focus group discussion ranged between 1.5 and two hours.

5.4 Analysis

The application of different methods also requires different types of analysis. This chapter is confined to the analysis of the qualitative data derived from the interviews and focus group discussions in order to generate the situation analysis, the stakeholder selection and the system designs (cf. chapter 6.1, 6.2.1 and 6.2.2.1/6.2.2.36.2, respectively). The analysis in terms of the cost calculations for the logistics system will be described in chapter 5.5.
All recordings from the semi-structured interviews and the focus group discussions have been transcribed. However, irrelevant information and empty or useless phrases were excluded and notes about situation, behaviours or mimic added. As Dunn (cf. 2005, p. 97) and Cameron (cf. 2005, p. 128) suggest, the transcripts were produced personally, short time after the interviews had taken place.
After this rather mechanical step, the interviews were coded. Coding is one form of content analysis that helps to reduce the amount of data from confusing extents to essential and processable quantities by labelling certain statements or sections of the transcript with codes, giving the opportunity to attribute these labelled fractions to certain topics according to the issue. Another purpose of coding is to organise the data and enable retrieval of certain information or statements hidden in the transcripts (cf. Cope, 2005, p. 225). This allows the researcher to e.g. combine and display information from different interviewees about the same issue or different information from a group of interviewees sharing similar characteristics.
As final and principal goal of coding, Cope (cf. 2005, pp. 225) lists analysis. However the analysis does not only take part after coding has finished, it is also the process of coding

itself, that is considered to be an "integral part of analysis" (Cope, 2005, p. 226). The other part of analysis is conducted afterwards, based on different codes that have been compiled[37]. After thorough and repeated reading of the transcripts of all interviews and focus group discussions, the code system as shown in Table 3 was developed. The main categories represent the three stakeholder groups and information regarding the system design. Additionally, the data required the introduction of a category about *general issues*. The interview sections were then attributed to certain codes from the developed system according to the information they contained. The whole process of analysis was conducted using MAXQDA[38]. Finally, the coded data served for compiling the situation analysis and facilitated the stakeholder selection and system design.

Table 3: Code System (exported from MAXQDA)

Code System

- *Sanitation Situation*
    - *General overview*
    - *Number of users*
    - *Property situation*
    - *Emptying practice*
    - *Problems related to sanitation*
    - *Ranking*
    - *Awareness*
    - *Adaptation*
    - *Responsibility for sanitation*
    - *Law enforcement*
    - *Financial issues*
    - *Sanitation options (in % per population)*
        - *Open defecation*
        - *Mobile/Household sanitation solutions*
        - *Landlord/shared units*
        - *Public units*
    - *Desired sanitation situation*
    - *Management*
    - *Issues regarding sustainable sanitation*
        - *Handling*
        - *Questions*
        - *Barriers/challenges against sustainable sanitation/products*
        - *Motivations for using sustainable sanitation or the products*
        - *Experiences/success from past sustainable sanitation projects*
    - *Incentives*
    - *Suggestions*
    - *WTP for proper sanitation*
- *Agricultural situation*
    - *General issues/farm perspective*
    - *Location*
    - *Crop*
    - *Scale*
    - *Market*
    - *Yield improvement*
        - *Type of fertiliser used*
        - *Quantity used*
        - *Price for conventional fertiliser*
        - *Market*
        - *Subsidy*
        - *Desired form of fertiliser*

[37] Later referred to as code system.

[38] MAXQDA is a software tool for qualitative data analysis.

Table 3: continued

-
  - *Organic*
  - *Effects of fertiliser*
  - *Reuse*
    - *General attitude towards sanitised human excreta as fertiliser*
    - *Barriers/challenges of reuse*
    - *Motivation to reuse*
    - *Infrastructure*
    - *Willing to reuse*
    - *WTP for the fertiliser*
    - *Consumer*
- *Suggestions*
- *Private service provider*
  - *Locations*
  - *Kind of business*
  - *Responsibility*
  - *Market environment*
  - *Barriers/challenges*
  - *Willingness to be involved in logistics of human excreta*
  - *Willingness to invest in infrastructure*
  - *Suggestions/Miscellaneous*
- *General issues*
- *System design*
  - *Collection*
  - *Transport*
  - *Storage*
  - *Target group*

5.5 Cost calculations

The cost calculations have been based on a variety of interview findings and field data collection. They were conducted by using Microsoft Excel and are presented in chapter 9.3. The worksheet can be roughly structured in three vertical and four horizontal compartments. The vertical compartments are *items*, *attributes* and *comments*. The horizontal compartments separate the calculation in *general assumptions*, *design*, *costs* and *overview/results*. The design compartment includes the dimensions, volumes and distances, whereas the costs compartment uses this information for multiplication with gathered financial information to generate the final costs. The fertiliser value was calculated in a separate worksheet using the replacement cost approach (cf. Drechsel, 2004).

A number of assumptions were utilised in the cost calculations[39]:

- Source separation by Urine Diversion Dehydration Toilet (UDDT) is the method applied
- The logistics system is going to be designed in an economically sustainable way
- The logistics of urine and faeces have to be performed by a private company
- The transport distance between producer and consumer has to be minimised in order to reduce CO_2 emissions
- The stakeholders involved are slum dwellers/landlords, private companies and farmers

[39] Detailed assumptions regarding the designed system can be found in chapter 9.3.

- The primary motivation of all stakeholders involved in the system is of economic nature (this assumption was formulated based on interview findings).
- Feasibility exists if the following components can be designed successfully/concluded positively: Technology/Design (Interviews/Model[40]) + Economics (Interviews/Model) + Acceptance (Interviews) = Feasibility

Besides the input data utilised in this thesis, all input variables can be modified and the model can be used for other scenarios.

[40] The information in brackets refers to the sources. In this case, e.g. both interviews and cost calculations from the model contribute to feasibility in terms of technology/design.

6 Case Study Kampala

In this chapter the general remarks of chapter 2, regarding slums, undernourishment, public health and their interrelationships to sanitation are considered. Combined with the idea of sustainable sanitation and motivated by its positive effects, a logistics system for human excreta delivering sustainable sanitation on a large scale is designed. Additionally to that the objective is to design the system as profitable as possible. Chapter 6.1 presents a situation analysis, whereas Chapter 6.2 proposes the above mentioned system.

6.1 Situation analysis

The situation analysis is based on the findings of the interviews and focus group discussions, complemented by information gathered from a literature review. The following analysis is divided into three parts, whereas the first is dealing with the sanitation situation, the second gives insights concerning agriculture and the third provides information about private service providers. The single thematic blocks themselves are introduced by giving a general overview of the situation followed by specific remarks establishing the connection to the proposed logistics and reuse of human excreta.

6.1.1 Sanitation situation in the slums of Kampala

After a general overview of the sanitation situation in slum areas of Kampala is given in the following subchapter, the second one will be dealing with sustainable sanitation in slums.

6.1.1.1 General overview

From 1.2 million inhabitants living in Kampala, 36% are dwelling in slum settlements (UNHABITAT, 2010). The slums are distributed throughout the urban- and peri-urban area (cf. Figure 12). The city population growth rate of the past five years is listed with 4.4%. 4.8% are projected for the upcoming five years, whereas the global average is 1.9% (UN, 2008).

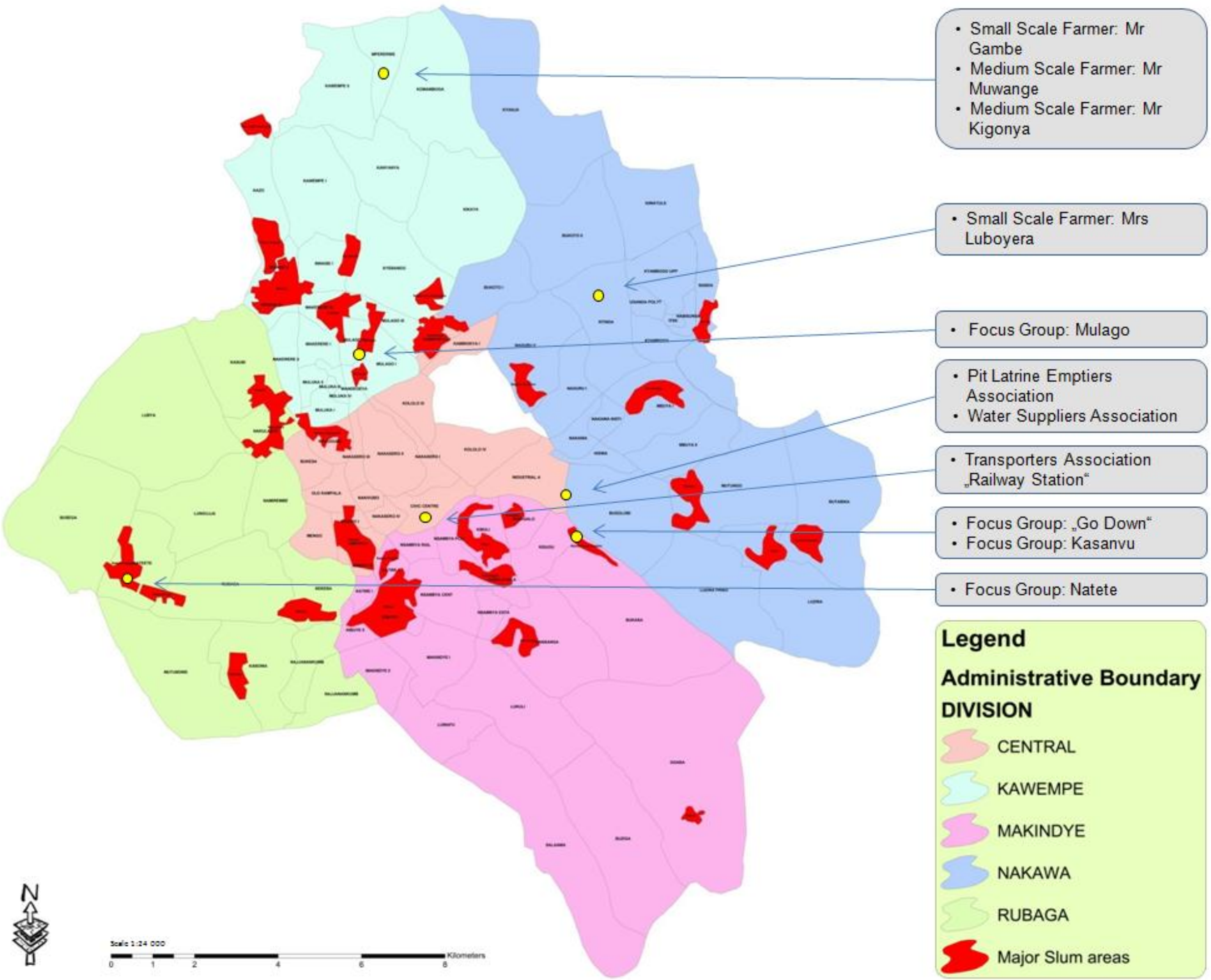

Figure 12: Kampala and the locations of interviews and focus group discussions (based on KCC GIS Unit Room B 109)

The sanitation situation in the slum areas of Kampala is precarious. The reasons for that are diverse: Many slums are located in drainage areas that are connected to Lake Victoria. Those areas are frequently inundated during tropical rainstorms. Another reason is the level of income of the residents and their inability or reluctance to pay for improved sanitation (either investing in proper facilities or arrange a proper emptying of existing facilities). Finally, sanitation is deficient because of a lack of planning and law enforcement from the local authorities. Where no centralised sewage network exists, it is the individual’s responsibility to implement a safe and suitable onsite sanitation facility. Kampala City Council’s (KCC) duty is to monitor this individual’s responsibility and to assure law enforcement.

The majority of residents of the informal settlements of Kampala are tenants (UBOS, 2007a, p.101). The accommodation provided by the landlords usually consists of several single room houses, shared by one family, roofed with iron sheets, having brick walls and earth as floor material (cf. UBOS, 2007a, p. 102). The houses themselves usually share a compound where a toilet facility and a washing area are provided by the landlord. The number of toilet users that has been reported ranged from 50 to 100 people per stance.

An estimated proportion of 60% of toilets in Kampala's slums are shared pit latrines that have been constructed above the ground due to the high groundwater table and in order to prevent flooding after heavy rainstorms. In higher elevated areas where a deeper groundwater table can be expected, conventional pit latrines without lining are dug into the ground and used instead. An estimated proportion of 30% of the people living in slums use public toilets that were e.g. funded by NGOs, official authorities like KCC or the Directorate of Water Development, Uganda (DWD) or indirectly by Official Development Assistance (ODA). There are quite a number of public toilets that are operated on a commercial basis where the users pay a fee of 0.04 EUR per visit. From this income the operator gets paid and expenses for water and cleaning material and the emptying costs are covered. Since the slum areas are places with high economic activity the public toilets are additionally frequented by informal traders from outside Kampala that visit the markets to follow their business activities during the day. The remaining 10% of slum dwellers, likely to be part of the poor fraction of the community, rely on 'alternative' means, meaning the use of polyethylene bags for defecation (referred to as 'flying toilets') or open defecation which considerably spoil the environment and contribute to various health problems such as cholera outbreaks, diarrhoea and different parasitic infections (cf. chapter 2.3).

But not only have these 'alternative' sanitation practices increased the risk of the outbreaks of diseases also the commonly applied emptying practices of the shared, landlord provided above ground pit latrines are contributing to the precarious situation: one popular way of dealing with the faecal sludge derived from the toilets is to empty them into the surrounding environment e.g. a drainage channel. This usually happens during the rainy season when a cork which is positioned close to the ground level of the pit is opened and the faecal sludge is released. Another popular option is to empty the pits manually with a bucket. In this case again the environment in the direct vicinity receives the faecal sludge. The basic version of the conventional underground pit is usually not emptied properly either, instead it is left for decomposition while a new pit has to be dug somewhere else on the compound. If enough money for a proper emptying can be allocated, KCC or the Private Emptiers Association (PEA[41]) get contracted and provide the emptying service with suction trucks. However, due to a scarcity of money and often unsuitable toilets without lined pits and bad road accessibility this option is chosen quite rarely. As opposed to this, public units get emptied by trucks which are financed by the income generated by the imposed user fees. If a 10 000 l truck provides the service, the costs for one emptying trip can easily add up to 64 EUR[42].

During the focus group discussions the residents of the slum areas were asked to rank basic needs such as shelter, food, sanitation, education and leisure regarding its importance. Sanitation was always allocated to the first rank and most participants showed a good

[41] Besides the emptying service of toilets and septic tanks, the PEA is also offering technical advice and guidance regarding onsite sanitation.

awareness regarding the connection between poor sanitation and bad health. However, at the same time a lack of alternatives on account of non-existing financial resources was expressed. The desired sanitation situation of the residents would ideally consist of household sanitation facilities. However, they were quite aware of the fact that this upgrade is not feasible in the nearer future. On the one hand there is the understanding that landlords cannot afford to construct toilets attached to or in every structure, on the other hand the residents do not see a proper way of financing this by themselves. The public units are generally associated with long queues and hence present a less attractive sanitation option compared to the shared landlord units.

In general, the focus group discussions revealed a picture of people willing to pay for improved sanitation. The amount varied from 0.04 to 0.07 EUR per adult and day. However, the interviewer’s impression was that most people only associated the question of the willingness to pay for sanitation with public units but neglected the fact that many of them already pay indirectly for sanitation with their rent, if facilities are provided by the landlord. Another interesting aspect that was revealed, dealt with children and sanitation. It was considered not to be feasible to provide money for children using public toilets. “Children can easily go four times a day to the toilet. And now imagine you have seven of them” (focus group discussion Kasanvu). The suggestion was to provide free entry for children at the public units in order to prevent them from defecating openly. In one interview the children were even blamed to be responsible for open defecation in general.

6.1.1.2 Sustainable sanitation

UDDTs, in Uganda more likely referred to as ‘ecosans’ are associated with an ambivalent history. While providing adequate sanitation options for rural communities with functioning pilot projects, the implementation, uptake and sustainability of UDDTs in urban areas cannot be considered as successful. During the expert interviews the general impression was created that UDDTs in urban areas have not yet succeeded and the majority of existing facilities are demonstration projects. Most people interviewed in the focus group discussions were not familiar with the idea of UDDTs and the reuse of human excreta as fertiliser. After being introduced into the idea of sustainable sanitation and especially UDDTs the discussions continued and revealed various issues whereof a selection is presented here.

The respondents generally mentioned the barrier of dealing with human excreta. In the Ugandan culture faeces are considered as a taboo. Not only was the handling of the material viewed with scepticism but also the distance from the user of the toilet to the faeces in the storage container below the UDDT was deemed to be too short. Additionally to these direct barriers people stated not to be willing to eat any kind of crop or fruit that has been fertilised with human urine or faeces and a big number of respondents mentioned the price for a

[42] The average daily income of a slum dweller was reported to be around 1.78 EUR.

UDDT[43] as too high. Since the willingness to invest in infrastructure such as sanitation is likely to be influenced by the planned time of residence at the very place and the fact that slums show a high rate of fluctuation, the willingness to allocate resources for that was considerably low. The small number of landlords sampled in the focus groups was initially hesitant against UDDTs, however after being presented the fact that no emptying costs occur or no need for constructing new toilets on a regular basis is going to arise, they became familiar with the idea and showed interest.

Another barrier mentioned by interviewees and experts was regarding the reuse of the sanitised products. The slum areas are densely populated areas where space is relatively scarce and agricultural activity is limited. Also in past projects the area of reuse had been identified as major bottleneck for a successful implementation of UDDTs in urban areas. Based on experiences from a former large scale ecological sanitation project in Kampala[44] the experts mentioned that a collection and distribution scheme to farmers outside of Kampala used to exist but has not been successful. As reason for that, high costs for transportation due to unsuitable means of transportation and a tiresome process of collection from the different units in the slums were blamed. The transport chain was kept up in the beginning of the project, but ceased to exist shortly after the end of external funding.

After these barriers had been identified in the interviews, possible motivations and ways to lower the barriers regarding sustainable sanitation were revealed and discussed. For the residents the major motivations would be a reduction of smells and flies and an improved hygienic situation in the toilets themselves. As mentioned above, the landlords would be motivated to switch to UDDTs instead of conventional pit latrines since the need of a regular construction of new units or the emptying costs could be eliminated. However, if these motivations would be sufficient to overcome the barriers against uptake and sustainable utilisation of UDDTs could not be clarified – due to strong cultural barriers, it has to be questioned.

The need for alternative and more powerful means to lower existing barriers, trigger behavioural change and assure autarchic sanitation solutions becomes obvious. In this thesis the utilisation of incentives as one instrument to achieve these objectives is investigated. The incentives do not necessarily have to be of monetary quality, also goods such as soap, condoms, fresh water or water purification tablets and vouchers (mobile phone airtime, mobile phones, medicine, solar lights, or sanitation hardware) could be considered as incentives in a slum context. The reactions of the interviewees regarding incentives were positive without exception, though monetary incentives were considered to be more accepted.

Finally, experts and residents mentioned that for a successful change to sustainable sanitation many efforts have to be put into sensitisation and awareness raising. Not only the residents,

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[43] Depending on the design the prices range from 89 EUR to 641 EUR per stance in Uganda.

also other stakeholders such as farmers and consumers should be involved in that process. These efforts are, combined with incentives, technically well designed and cheap toilets and a logistics system for human excreta likely to present an effective option for sustainable slum sanitation.

6.1.2 Agricultural situation in Uganda and around Kampala

A general overview about the agricultural situation in the first subchapter is followed by subchapters about fertiliser use in Uganda in general and the reuse of human excreta in agriculture in particular, giving basic information influencing the logistics system design.

6.1.2.1 General overview

In the early 20th century, Sir Winston Churchill named Uganda the “Pearl of Africa”. This quotation was motivated by Uganda’s rich flora and fauna influenced by its geographical position and the altitude, positively influencing the climate and a high soil fertility. Hundred years later, Uganda is still relying greatly on these resources and the role of agriculture is considered to be essential for the country. According to the latest National State of Environment Report for Uganda the agricultural production contributes to 21% to the GDP. The numbers declined from 47.7% in the late nineties to 41.6% in the early 2000s (NEMA, 2008, p. 29).

4.2 million from total 5.2 million households are engaged in agriculture in Uganda and 80.1% of agricultural households[45] are smaller than five ha (UBOS, 2007b, pp. 15). This leads to the conclusion that the agricultural situation can be considered as small scale or subsistence farming dominated. Of the remaining 19.9%, 95% of agricultural households operate 5 to 49.9 ha and only 5% of the remaining agricultural households operate more than 50 ha (UBOS, 2007b, pp. 15). The crops commonly grown in Uganda are corn (85.8%), beans (80.8%), cassava (74.3%), banana (73.1%), sweet potatoes (47.4%) and coffee (41.6%), based on the total number of agricultural households (UBOS, 2007b, pp. 46).

In the central region where Kampala is situated, slightly higher values for the medium and large scale farms occur, but still 75.7% of agricultural households are smaller than five ha. According to the experts interviewed, the major large scale agricultural activities around Kampala involve the cultivation of sugar cane, tea and flowers. However, the flower business

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[44] The Kampala City Council Ecological Sanitation Project (140 UDDTs; Project period: 2002 to 2007) (cf. Carlesen, Vad, Otoi, 2008).

[45] „An agricultural household or holding is an economic unit of agricultural production under single management comprising all land used wholly or partly for agricultural production purposes and all livestock kept, without regard to title, legal form or size” (UBOS, 2007b: p.10). Subsequently agricultural household and farm will be used synonymously.

Farms smaller than 0.4 ha were classified as small scale. Farms larger than 0.4 ha but smaller than five ha were classified as medium scale. Farms larger than five ha were classified as large scale.

cannot be considered large scale regarding the area cultivated but it can be by regarding fertiliser demand, turnover or net income.

The scales of the farms where the interviews for this thesis took place range from 0.4 ha (subsistence farming in the outskirts of Kampala) to 30 000 ha, (Kakira Sugar Works in Kakira including 20 000 ha outgrower's area). The interviewed small scale subsistence farmers are located in the outskirts of Kampala in the northern part of the town, cultivating an area with less than 0.4 ha (eight km distance to the city centre) (cf. Figure 12). The selection of crops grown was diverse and could well be compared with the national average. The medium scale farmers are also located in the northern periphery of Kampala (cf. Figure 12). One farmer was primarily cultivating bananas on four ha, the other was involved in zero grasing dairy farming and cultivated four ha bananas and 1.6 ha of elephant grass. The large scale farmers are located off the road going to Jinja and Iganga (sugar cane, tea and flower, all less than 90 km distance from Kampala). One interviewee's farming areas are situated in the area of Lira (350 – 400 km distance from Kampala) and Kibaale (300 km distance from Kampala).

According to the various scales of farms also different markets are addressed. Small scale farmers are usually producing for family consumption. If excess yields are harvested, the products are marketed locally. Medium scale farmers are producing for local - large scale farmers for local and national markets. Besides being consumed within Uganda, tea, coffee, flowers and a variety of organically produced commodities are also exported continentally and globally.

6.1.2.2 Fertiliser use

Small scale farmers in Uganda are not using fertilisers. Mainly two reasons are influencing this decision. In the first place the soil fertility is considered to be of medium to high productivity in the area north and north-west of Lake Victoria (Kamanyire, 2000, p. 10). Secondly the economic situation of the majority of small scale farmers does not allow expenses for fertiliser. However, alternatives for maintaining the soil fertility such as green manuring, application of cow dung or other manures that are available on farm are utilised. Since medium scale farmers are producing more income their willingness to pay for fertilisers is likely to be higher. The medium scale farmers interviewed, stated to buy small amounts of synthetic fertiliser but also to use similar alternative means which are applied by small scale farmers. The major consumers of synthetic fertilisers are large scale farmers. All interviewed farms are using a variety of fertilisers that are combined according to soil samples and plant needs. Some farmers were additionally involved in green manuring and mulching. Macro nutrients are most commonly given in the form of urea, diammonium phosphate, triple super phosphate, NPK 25 - 5 - 5 and muriate of potash. Additionally flower farms enrich their soils by using micro nutrients such as ferro-chelate, molybdenum or zinc sulphate. Furthermore there is another difference between flower farmers and other large scale farmers: the application of fertilisers in the greenhouses used for flower cultivation is done via the irrigation system.

In general the fertiliser market in Uganda is small, liberalised and not subsidised. The fertiliser use intensity compared to the world average for 2007 is 1 kg/ha to 177 kg/ha, respectively and can be even in the Sub Saharan African context where 9.6 kg/ha are used on average, considered as very low (World Resources Institute, 2010). The low level of fertiliser use can be explained by a variety of factors. Major factors that have already been mentioned above are high soil fertility and the economic situation of many farmers. Another factor that has been considered due to the repeated reference in the interviews is the fertiliser price. As Kelly et al. (1998, p. 2) discusses, the fertiliser prices for Sub Saharan Africa occupying a range from 189 to 397 EUR/t were significantly higher than those for e.g. Asia with a spectrum ranging from 55 to 164 EUR/t.

Various reasons for the high price level are given by Kelly & Crawford (2007, p. 12):

- Low volumes
- Long distances from the ports to the agricultural areas
- Lack of proper infrastructure such as roads or railways
- Inadequate and expensive financial services
- High risks of political uncertainty and corruption

Since there is no fertiliser production within Uganda, the fertilisers are imported from various locations around the world via Kenya. Major origins are Norway, United Kingdom, Pakistan, China, Israel, India and Holland. The two main companies that were mentioned during the interviews regarding import were Yara (Norway) and Balton (UK/Israel).

6.1.2.3 Reuse of human excreta

In the interviews most of the farmers were quite sceptical towards – and indicated not having been confronted with - ideas related to sustainable sanitation and the reuse of human excreta as alternative fertiliser. The main issues regarding reuse that have been pronounced by the various farmers are compiled below:

Small scale subsistence farmers (2 interviews):

The farmers were generally willing to use and buy human excreta, if the resources would be available and they would appreciate to produce excess that could be marketed in order to increase the farm income. However, no financial means for purchasing fertiliser or investing in infrastructure (tanks or vehicles) were available and one farmer indicated to have limited time for the collection, if it would have to be done by him. Another farmer considered the process of collection as tiresome.

The farmers indicated to have knowledge about the effects of urine: less about the fertilising value, but more about the fungicidal effect of urine (Banana Wilt Disease, or Panama

Disease)[46]. But they also fear that people (family members and/or consumers) might have a negative attitude against it and refuse consuming the products. They would rather prefer not to indicate that their products have been fertilised with human excreta.

Medium scale farmers (2 interviews):

Generally both were willing to use human excreta. One indicated to be willing to use it in a liquid form; the other would prefer a processed fertiliser. One farmer indicated some experience with the utilisation of urine and dried faeces from a UDDT. He even used to have one on farm. However, the toilet was abandoned because the people using it did not produce sufficient amounts to justify the effort. The pit latrine was used again instead. The same farmer runs two biogas reactors where he processes the cow dung from the shed. Both farmers indicated that they were not willing to care about the collection, they considered it as tiresome and expensive and they would appreciate a collection and distribution scheme, organised by a company.

The price for the alternative fertiliser would have to be competitive and the handling easy. Getting urine and faeces delivered and filled into a storage facility on farm followed by manual field application with jerrycans or buckets is considered to be feasible. However, both worried about the storage infrastructure, they finally agreed upon investing in a tank. The farmer producing biogas still would prefer to invest in such a reactor. Even if more financial resources are available than in case of the small scale farmers the allocation of money is still considered being problematic. In order to minimise the expenses for farming inputs, both farmers developed their own strategies of maintaining the soil quality. As mentioned above, a certain amount of synthetic fertiliser was used by one farmer (muriate of potash). Further practices consisted of applying cow dung, a mixture of chicken droppings and coffee husks and mulching. One farmer talked about dried faecal sludge from the treatment plant of Kampala being marketed unofficially as fertiliser. However, he was not interested in using this kind of fertiliser and considered it as too expensive[47] without knowing the price. The same farmer feared that the reuse of human excreta might seriously affect his sales. The other one reckoned it to be no problem.

Large scale farmers (8 interviews, incl. 2 organic farmers)

Repeatedly all of the large scale farmers indicated economic reasons as main levers influencing their business related decisions. Being pretty aware of the low value to weight ratio of human excreta[48] the farmers expressed doubts regarding an overall feasibility of the reuse in distant areas from the origin.

[46] Plant disease caused by Fusarium oxysporum. Affects the production of bananas.

[47] The price for 1 m³ is 3.56 EUR.

[48] If no atmospherical losses occur, average Ugandan urine contains 6.027 g N/l; faeces contain 0.822 g N/l (other nutrients are not mentioned here. Source: Jönnson, 2004). For comparison the N content of NPK 25-5-5 is 250 g/kg.

Four from eight interviewees considered sanitised human excreta as being absolutely inacceptable as fertiliser. One sugar cane farmer offered his fallow land for the controlled disposal of mixed human excreta, but did not show any willingness to pay for the urine and faeces. One organic producer stated that his outgrowers would adopt and pay for the separated and sanitised human excreta if it would be introduced correctly. The two flower farmers indicated a willingness to use and pay for urine if the effect of it is proven to be positive. The other four farmers would only accept a processed fertiliser where the human excreta is properly sanitised and transformed into a solid. As reason for that they mentioned not only cultural barriers the farm workers might have, but also handling on farm, application and transport. A dried fertiliser could be distributed via the same channels as synthetic fertiliser and would not necessarily have to be transported with expensive tank trucks. Furthermore one farmer mentioned the accessibility of the farms as essential to be considered, since many farms are located in remote areas.

In general the application of a liquid fertiliser was considered to be problematic. The farms are run in a labour intensive way meaning that a minimum of technology is used and human labour is employed instead. Hence, even synthetic fertilisers are applied manually. The low value to weight ratio of urine would require much larger volumes to be applied by the workers. Thus the costs for fertiliser application would increase enormously, being considered too high from the perspective of sugar cane and tea farmers. Yet, as already mentioned above, flower farms operate greenhouses that are fertilised via drip irrigation systems. Since no additional handling would be required, the application costs would not be increased by changing to urine fertilisation.

All farmers refused being involved in the collection, transport or processing of any kind of fertiliser. They did not want to be distracted from their own business and proposed a third party (private company) as ideal for that task. Most of the farmers expressed in an early stage of the interview that they would need a guaranteed quality and quantity in terms of nutrient values and delivery on schedule. One sugar cane farmer even suggested the application being part of the private company portfolio.

The majority of the large scale farmers were not willing to invest in new infrastructure, such as storage facilities or spreaders for liquid fertiliser. The tea farmers indicated that even if machinery would exist, they could not use it because of the nature of the terrain and the permanent and dense structure of the tea plantations. Contrarily the flower farmers could imagine integrating a urine storage tank into their fertigation[49] system. However, a prerequisite would be to eliminate any potential residues that could block the pipelines. The organic producer with a positive attitude towards the reuse of urine expressed a willingness to invest in a storage tank that can be shared by his various outgrowers concentrated in one location.

[49] Fertigation is the combination of fertilisation and irrigation.

The majority of farmers saw problems regarding the consumer attitude. The tea farmers described tea being a “hydroscopic plant that might easily adopt the smell or flavour of the urine and carry it into the cup” (interview Mr Chauhan, Uganda Tea Corporation Ltd.). One tea farmer, producing for Muslim countries expected zero tolerance for this kind of fertilisation practice from his customers. One of the organic farmers believed only a solid fertiliser would be acceptable while the other would agree with the use of urine. Also the sugar cane and flower farmers considered that people might not be offended by it. Since the flower farmers are producing non-edible crops and exporting to Europe and the industrialised World, they even considered the reuse of human excreta and thus the improvement of sanitation in slums as a good marketing tool helping to foster corporate social responsibility issues (CSR).

A general motivation to use human excreta would be improving the soil quality. The contribution to a potential improvement of the sanitation situation in Kampala’s slum areas was not considered to be a main motivation; however it was considered to be a good side effect. Another motivation would be of economic origin (e.g. when human excreta as fertiliser are less expensive or large increases in synthetic fertiliser prices occur).

One tea farmer brings up his worries about ground- or surface water contamination due to large volumes of urine or faeces needed to be applied to meet the nutrient demand of his plants. Since his workers are living in the vicinity of or on the farm and are totally dependent on the surface water and other natural water resources, he was worried about their health.

In general the level of acceptance of the farmers, workers and consumers was believed to be raised by sensitisation and awareness creation. The majority of farmers called for demonstration fields and test opportunities and considered this as best way to change attitudes. One organic farmer considered the project as extremely viable if the right financial inputs, support, knowledge transfer and proper management would be assured and if a solid fertiliser would be produced out of the human excreta. He indicated the existence of good communication channels and a well organised infrastructure including demonstration fields in his organisation (consisting of about 20.000 small scale farmers).

6.1.3 Private companies and other service providers related to sanitation

Finally, the following subchapter provides a general overview of the third group of stakeholders interviewed for this thesis: private service providers related to sanitation. The overview is complemented by a consideration of the logistics of human excreta from the perspective of the interviewees.

6.1.3.1 General overview

Sanitation related services in Uganda are provided by a variety of different stakeholders. The National Water and Sewerage Corporation (NWSC) is responsible for the centralised sewerage sanitation that covers 5% to 10% of Kampala’s population (cf. Carlesen, Vad, Otoi, 2008, p. 9 and Fichtner, 2010). The rest of Kampala’s population relies on different means of

decentralised onsite sanitation (cf. chapter 6.1.1.1). If resources allow expenses for toilets, they are constructed by the landlords or residents themselves; KCC is offering advice, subsidised emptying service (six, plus 13 recently purchased trucks) and is responsible for law enforcement. Advice and emptying is also provided by the PEA with 35 trucks. The PEA considers itself as having the biggest share in the market.
During the interviews a lack of presence of community health officers or “people from KCC” for advisory services was reported and the law enforcement is commented to be deficient.

6.1.3.2 Logistics of human excreta

Besides the interview with a PEA representative, two additional interviews have been conducted. One took place with staff from a Water Suppliers Association[50] (WSA) in order to sample all available options for the transport of liquids. In addition, in order to also sample the transport options for the solid fraction, interviews with truck owners and operators of the ‘Transporters Association Railway’[51] were carried out.
The person interviewed from the PEA would be willing to transport urine from UDDTs. However, it was found that the PEA trucks are contaminated and therefore not suited for the transportation of urine[52]. The interviewees from the WSA consider the business of urine transportation as impossible since the trucks would get contaminated and it would ruin their reputation. Since the faeces from UDDTs are ideally dry, transportation in suction trucks would not be possible. The interviewees from the ‘Transporters Association Railway’ indicated a willingness to transport faeces in closed boxes or other containers that can be sealed.
In general the interviewees indicated not being interested in household collection in slum areas. A need for collection points with good road accessibility was expressed. Except the WSA, the stakeholders interviewed, indicated to be very interested to open up new business opportunities. In all interviews offers regarding the transportation costs of the individual service providers have been surveyed in order to consider the potential of contracting them for the logistics system. However, preliminary calculations rated the costs as too high[53] as the owners or operators were probably including the profit margins commonly applied for individual trips. The interviewee from the PEA even recommended opening up a new separate business in order to maximise the efficiency and be able to offer a suited service.

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[50] A „Water Suppliers Association“ is a pool of private tank truck owners sharing official water pipes for filling up the trucks. The water is delivered to any destination for a fee. Within the city of Kampala there are three official water pipes for filling up tank trucks.

[51] This transporters association is a typical cluster of trucks with different capacities that can be rented out for any kind of transportation job. Those clusters can be found throughout the city.

[52] The storage time for sanitatisation of urine as recommended by WHO is at least one month. Cross-contamination with faeces requires a storage of 1.5 to two years (WHO, 2006, p. XVI-XVII)

[53] Prices varied according to the distance. The best price for e.g. a 10 000 l tank truck trip outside of Kampala to the nearest agricultural area (25 km) was 36 to 53 EUR. The price for a truck trip with 2 t capacity doing the same distance was 36 EUR.

6.2 Logistic system design - overview

In this chapter all gathered data regarding stakeholder selection and system design is analysed and summed up in order to design the logistics system. In a first step stakeholders were selected according to their interview statements (cf. chapter 6.2.1). In a second step two logistic systems will be presented. The first one will present a way to manage human urine (cf. chapter 6.2.2.1); the second one will deal with both constituents of human excreta (cf. chapter 6.2.2.3). After a detailed description, the economic feasibility will be tested (in chapters 6.2.2.2 & 6.2.2.4). Hence, chapter 6.2 will approach the second research question: *How can a system for the removal of human excreta from slum areas look like according to the principles of sustainable sanitation?*

6.2.1 Stakeholder selection

Recalling chapter 4, stakeholders are one of three dimensions of the ISWM model. Hence, this chapter compiles the interview results and reveals the stakeholder positions towards the proposed system. Furthermore, the reasons for their attitudes including the diversity of barriers and interests as well as a classification if a stakeholder can be looked upon as potential partner or not are presented. A partner was considered to be qualified if no barriers existed or the barriers where rated as negotiable. Table 4 presents and summarises the interview statements and illustrate the stakeholder selection in a comprehensible way.

As producers of human excreta both slum dwellers and landlords would be part of a logistics system for human excreta as well as the 'Transporters Association Railway' that would potentially join the venture as logistics provider for the faeces. On the part of urine, the interviews showed that none of the present companies would be suitable, since their trucks are either only designated for transporting drinking water (WSA) or contaminated by faecal sludge (PEA) (cf. chapter 6.1.3.2). Hence, as alternative, the establishment of a new company especially designed according to the needs of urine logistics would be best suited for service delivery. This was also expressed in one interview. However, on the part of the consumers the picture looks differently. Only flower growers, one organic farmer and the medium scale farmers would or could participate. The remaining stakeholders were excluded due to various reasons (cf. Table 4).

Table 4: Summary of stakeholder positions (stakeholder selection)

Stakeholder group	Stakeholder	Position (Comment)	Reason (Comment)	Partner (Yes/No; Type)
Residents				
	Residents	Willing to use UDDTs and improve sanitation (after sensitisation)	Awareness of the connection between bad sanitation and bad health situation	**Yes (Producer)**
		Not willing to carry the urine and faeces around (could be overcome by motivators/incentives)	Socio-cultural barriers	

Table 4: continued

Stakeholder group	Stakeholder	Position (Comment)	Reason (Comment)	Partner (Yes/No; Type)
		Willingness to pay for sanitation (0.04 – 0.07 EUR per adult and day)	Proper facilities are appreciated to some extent	
		Not willing to invest in solid, permanent sanitation facilities	High rate of fluctuation in the slums (tenancy)	
		Can be motivated by incentives	Money is scarce	
	Landlords	Willing to construct UDDTs (problem: money)	No need to keep on building new toilets or pay for emptying	**Yes (Producer)**
Logistic companies/ associations				
	PEA	Willing to be involved into the business of human excreta	Would not differ from their business as usual. But not possible due to cross contamination. (The price for the service delivery is high[53])	**No**
	WSA	Not willing to be involved into the business of human excreta logistics	Trucks are used for drinking water. (The price for the service delivery would also be high (similar to PEA))	**No**
	Transporters Association “Railway”	Willing to transport the dried faeces in closed boxes	Business oriented. (The price for the service delivery is high)	**Yes (Faeces logistics)**
	New logistics company that has to be established	This company does not exist yet. It is going to be developed according to the specific needs. Own trucks have to be purchased.		**Yes (Urine and faeces logistics)**
Farmers				
	Sugar cane growers	Not willing to use urine and/or faeces as fertiliser	Fear lack of quantity and quality. (Huge quantities needed: Up to 2 000 t/a of conv. fert. per farm) Application will be too labour intensive and thus expensive. All decisions are based on economic reasons	**No**
		No willingness/capacities for being involved into the process of collection	Want to focus on their own business	
		Mostly willing to pay (for a dried fertiliser)	Know about the value of nutrients.	
		No willingness to invest in infrastructure	Farm expenses have to be minimised. Why to change?	

Table 4: continued

Stakeholder group	Stakeholder	Position (Comment)	Reason (Comment)	Partner (Yes/No; Type)
		No motivation, only if synthetic. fert. prices increase dramatically or human excreta is much less expensive	All decisions are based on economic reasons	
	Tea growers	Not willing to use urine and/or faeces as fertiliser	Fear lack of quantity and quality. (Huge quantities needed: Up to 700 t/a of conv. fert. per farm). Tea might absorb the flavour (tea growers' fear). Application will be too labour intensive and thus expensive. All decisions are based on economic reasons	**No**
		No willingness and capacities for being involved into the process of collection	Want to focus on their own business	
		Mostly willing to pay (for a dried fertiliser)	Know about the value of nutrients	
		No willingness to invest in infrastructure	Farm expenses have to be minimised. Why to change?	
		No motivation, only if conv. fert. prices increase dramatically (problems with imports) or human excreta is much less expensive	All decisions are based on economic reasons	
	Flower growers	Willing to use liquid fertiliser (with exceptions)	Fertigation of flowers – no overhead costs to use liquid fertilisers. Fear lack of quantity and quality. (Large quantities needed: Up to 200 t/a of conv. fert. per farm)	**Yes (Consumer)**
		No willingness and capacities for being involved into the process of collection	Want to focus on their own business	
	Flower growers	Willingness to pay for urine	Know about the value of nutrients and appreciate having a liquid fertiliser	
		Willingness to invest in infrastructure (storage tank)	Only minor investments would have to be made	
		Motivated to use urine	Would appreciate the opportunity to help improving slum sanitation (CSR)	

Table 4: continued

Stakeholder group	Stakeholder	Position (Comment)	Reason (Comment)	Partner (Yes/No; Type)
	Organic producers	One willing and one not willing to use urine and faeces as fertiliser	One would appreciate if it is transformed One would only accept it after being transformed into a safe solid fertiliser	**Yes/No (Consumer)**
		No willingness and capacities for being involved into the process of collection	Want to focus on their own business	
		Willingness to pay for alternative fertiliser (rather dry than liquid)	Know about the value of nutrients and are always interested in organic alternatives	
		Would be willing to invest in infrastructure	If it is economically feasible, yes. However, all decisions are based on economic reasons	
		Would be motivated	Finding alternative fertilisers according to their certification standards[54]	
	Medium scale farmers	Would potentially be willing to use urine	The product has to be competitive and easy to handle	**Yes (Consumer)**
		No willingness and capacities for being involved into the process of collection	No spare time available. Some resources could be made available	
	Small scale subsistence farmers	Do not use fertiliser in general. Willingness to reuse urine and faeces as fertiliser, if resources would be available	No need (partly) and no resources (generally)	**No**
		No willingness and capacities to be involved into the process of collection	Neither spare time nor resources are available	
		Not willing and able to invest in storage and application infrastructure	No resources are available	
		Would be motivated to use human excreta	Would like to produce marketable excess, to increase income	

6.2.2 Logistics system design - implementation

In comparison to the amount of nutrients excreted in faeces, urine is more valuable. Hence, when thinking about the reuse as fertiliser in agriculture, urine is more attractive and faeces can be considered a by-product. However, not only considering the reuse aspect, but also the

[54] The Uganda Organic Standard does not allow fertilisation with human excreta (NOGAMU, 2006). However, when exporting the products the certification standard of the export market is relevant.

aspect of slum sanitation, it emerged during the preparation of the thesis that the faeces fraction of human excreta should not be neglected. Hence, two systems have been designed. System A (chapter 6.2.2.1) only dealing with urine and relying on the fact, that alternative means of faeces management will be developed. System B, (chapter 6.2.2.3) handles both fractions urine and faeces. After design and cost calculations have been conducted, it will be discussed which system is more suitable to deliver a sustainable sanitation service, both, in terms of profitability and impact on health and environment.
Furthermore, the system design is based on the finding that no company suitable to transport urine could be allocated. As a reaction to that, the logistics systems were designed from scratch involving a new company with own infrastructure. Even though, willingness to manage the solid fraction was expressed by the ‘Transporters Association Railway’, it was decided to include this component into the portfolio of the new company, thus being able to offer a cost efficient all-inclusive service.
The layout of the logistics systems is designed according to the principles, dimensions and aspects of the ISWM approach (cf. chapter 4). Each design chapter is followed by a chapter presenting the cost calculations (chapters 6.2.2.2 and 6.2.2.4).

6.2.2.1 Urine logistics system design

In system A (Figure 13, p. 58) solely the management of urine is considered. It can be roughly divided into three components: slum -, private company - and farmer level. The components can be seen as stages of the supply chain, or as *waste system elements* according to the ISWM-terminology (cf. Figure 10, p. 27)

Slum Level

It has been investigated in the focus group discussions, interviews and in field visits that different options have to be developed in order to achieve a maximum coverage of toilet facilities at slum level. Three different types have been classified:

- *Household units* are directly located in or attached to a housing structure. The toilets can be solid UDDTs, but can also consist of a combination of simple plastic urinals and PeePoo Bags[55] or a box toilet[56]. The residents were generally quite enthusiastic about the idea of having toilets in their houses, but since the majority only rent their places, it is not in their power to upgrade the houses. Additionally, due to a high rate of fluctuation investing in permanent facilities is unattractive.

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[55] The PeePoo Bag is a decomposable plastic bag used as single use toilet. It contains a certain amount of urea that helps to sanitise the content. After the time needed for sanitisation, the bag is decomposed and can be used as valuable fertiliser (http://www.peepoople.com/). The treatment method is the same as the one developed by the Swedish scientists[75].

[56] In this thesis the faeces containers are referred to as faeces-boxes. In order to present a complete household sanitation solution, the faeces-boxes can be designed and marketed with a urine diverting toilet seat that can be exchanged with the above-mentioned lid (For design and cost details cf. chapter 10.3).

- *Landlord units*: conventional UDDTs that are constructed by the landlords in the compounds.
- *Public units*: central UDDTs combined with collection tanks.

The urine from the various toilet facilities, listed above, is collected in jerrycans. The jerrycans are not only used for the collection but also for the transport. They are abundantly available in Uganda, either new or second hand (former frying oil jerrycans). Since the emptying of the individual toilets with a tank truck is not feasible, due to bad accessibility and high costs, the alternative is to allocate collection tanks throughout the slum area, where people deliver the jerrycans to (probably with simple auxiliaries like a handcart). They empty the jerrycans into the tanks and take them back for reuse. In this way the accessibility for a tank truck as well as the optimum location for the delivery in terms of minimised distance to the houses are taken into consideration. As already mentioned above, the collection tanks are combined with public units, further on referred to as collection points, that are located in areas, where high activity due to trade and commerce can be found. The collection points on the one hand improve the sanitation situation of adjacent areas. On the other hand they create income opportunities for the unit operators. Popular locations would for instance be markets.
The separation of human excreta and the delivery of the urine should be motivated by incentives[57] paid at the collection points. The most feasible solution seems to be attaching a value to each jerrycan that is delivered and a certain quality (e.g. pH value) is assured, to prevent dilution with water. With this incentive scheme private toilet owners as well as youth groups[58] or organised small collection enterprises can undertake the task of delivering and thus generate income. The more someone delivers, the more income can be generated.

Private Company Level

The collection points should be contracted by the logistics company and operated and maintained by one slum resident that is also in charge for handing out the incentives. In order to assure a sufficient storage time and to minimise the size of the collection points in the slums, a central storage site needs to be established. From the various collection points in the slum the urine is delivered with tank trucks to the storage site on a daily basis. Due to economies of scale, the biggest trucks available in Uganda having a capacity of 10 000 l were identified being the most viable option.
Since the period for sanitising urine through storage for agricultural reuse is recommended to be not less than one month, the storage site itself has to accommodate at least 30 storage tanks[59] (WHO, 2006, p. 70). One tank is filled up every day and after a period of one month the tank having been filled up first, is ready for distribution to the farmers.

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[57] Incentives are one way to trigger behavioural change (Mosler and Tobias, 2007).
[58] There are positive experiences reported from Nairobi, where youth groups operate public toilets and solid waste collection services (UNHABITAT, 2007a, p. 154).
[59] Crestanks is the local supplier. The maximum volume of a tank is 24 000 l.

Other reasons for the necessity of a storage site instead of the direct transport to farms are justified by the indication that farmers are not willing to be engaged in additional activities that keep them away from their major business. Also it could be maintained a constant quality and quantity in terms of nutrient levels and volumes. The quality control on the storage site can be assured with analyses, and if necessary, addition of synthetic fertilisers. Furthermore, since the farmers indicated to base their business related decisions on economic reasons, any expenses related to infrastructure have to be minimised in order to be able to market urine as competitive fertiliser. Since the proposed method of sanitising urine requires a large quantity of storage tanks, the sanitisation should be carried out at the storage site rather than on the farm thus minimising spatial extent and investments. Besides storage tanks, the site is also providing area for a small office.

Farmer Level

After sanitisation, the urine is distributed to the farmers again by using tank trucks. The farmers themselves have to invest in storage capacity. E.g. a large flower farm can have a nutrient demand of approx. 60 kg N/day that can be met by 19 998 litres of urine[60]; hence two tank trucks per day have to fill up the storage tank located on the farm. The urine can be used on the farm according to the specific needs.

There is a financial flow starting at the farmers paying the private logistics company and the collection point operators, finally arriving at the suppliers of the raw urine. In general the system was designed modularly. Depending on the fertiliser demand more tanks and trucks can be purchased and integrated into the system.

[60] Atmospherical losses of 50% provided. The data is based on samples from Uganda (cf. Joensson et al., 2004).

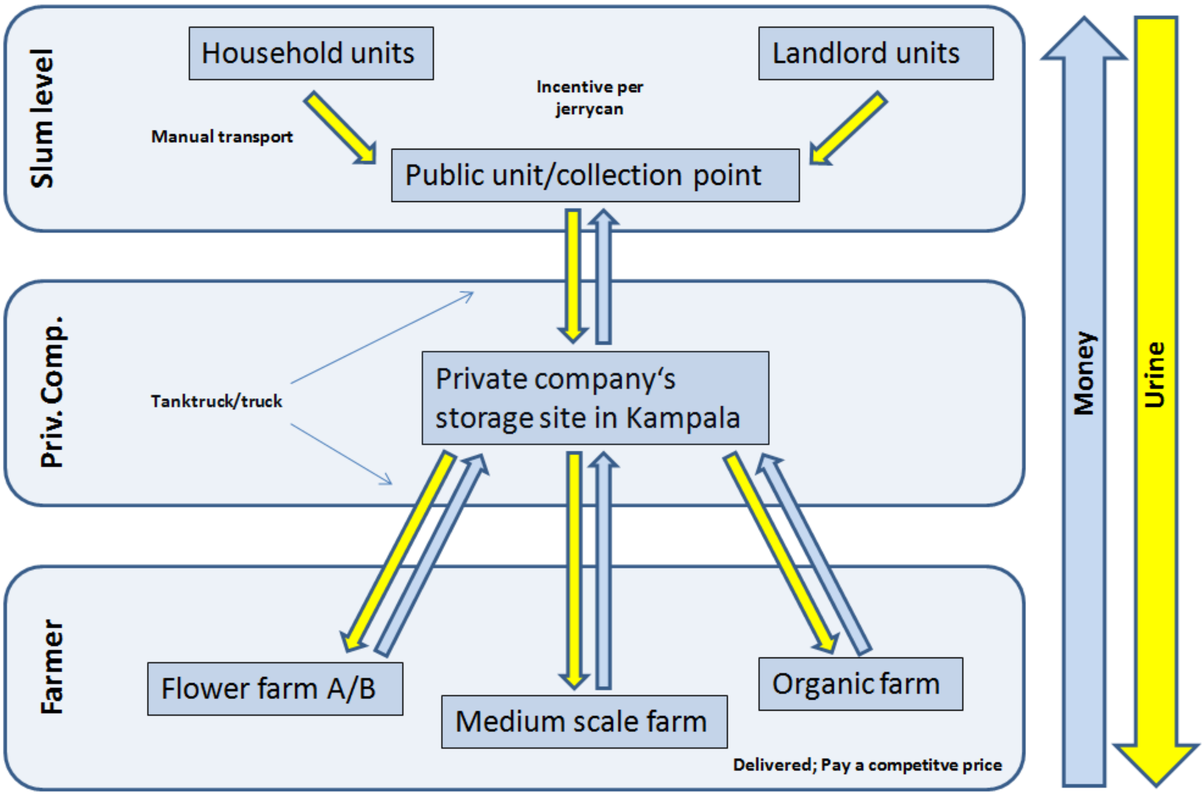

Figure 13: Logistics system for urine reuse - system A (own contribution)

6.2.2.2 Costs of the urine logistics

The costs of the logistics system have been calculated with the assistance of a Microsoft Excel based model (cf. chapter 9.3). The model was exclusively developed for this purpose. Various assumptions have been used in this model and different scenarios have been calculated in order to simulate different system sizes (cf. Table 5).

The income for system A is generated through the marketing of the sanitised, liquid fertiliser - human urine. A price for one litre of this fertiliser was calculated using the replacement cost approach (cf. Drechsel, 2004). In this context, the price adds up to 0.01 EUR per litre. The major input parameter in order to assess the scale of the system is the N demand of the farm. The location of the farm was set to be 50 km outside Kampala, which was considered to be the average distance from the city centre to the locations of large scale agricultural production outside the city. The distance of the slums to the storage site is estimated to be 10 km.

The scenarios are calculated with a five year lifetime and the system is working at full capacity in 10 000 l units[61]. A collection efficiency of 30%[62] is used for calculating the amount of people being affected by the system, considering that many people are absent during the day because of employments outside the area observed. The average volume of

[61] The capacities of the individual components are: collection point tanks (10 000 l), tank trucks (10 000 l) and storage tanks (24 000 l). Since a major share of the total costs is contributed by the transport costs and one truck has the capacity of 10 000 l this volume is used as reference value or unit for the workload.

[62] The collection efficiency of 30% is an assumption.

urine produced by one person in Uganda is estimated to be 1 litre per day[63]. The logistics company is operating 10 hours a day, 30 days per month and employs one operator per collection point. Each truck is operated by one driver and one tank/load boy and the number of employees at the storage site is subject to alterations. The labour requirement of the individual tasks has to be tested and cannot be estimated from this point. However, the influence of this item to the total costs can be considered as neglectable. The transport costs are largely influenced by the fuel prices. At the time of data collection (late 2009) the price for 1 litre of diesel fuel was 0.71 EUR. 0.04 EUR is included in the calculation as incentive for delivering one jerrycan to the collection point. For purposes of orientation, the price for the cheapest piece of soap available on the Ugandan market was 0.06 EUR[64] (Mukwano Industries, Ltd). Upfront investments for the proposed system that were incorporated in the calculation were:

- Collection point tanks
- Tank trucks
- Storage tanks
- Office building

The investments are financed with an interest rate of 6.6%[65]. The investment costs for toilet facilities have not been included in the calculations[66]. Regarding hidden costs e.g. through truck breakdowns or fuel price fluctuations, 5% based on the total costs were included in the calculation. The property costs have not been included as no satisfying offers could be obtained during the period of data collection. Since the system is providing sanitation services to slum areas, authorities might be willing to contribute land area for the storage site at attractive conditions or even free of charge. However, this will be subject to negotiations.

The scenarios *small scale I*[67], *small scale II*[68] and *large scale*[69] in Table 5 were calculated based on N demands of 1 200, 1 808 and 11 663 kg per month, respectively. According to those numbers the urine demand would sum up to 398 182, 599 927 and 3 869 995 l per month which would have to be supplied by 44 242, 66 659 and 429 999 people, respectively. A workload indicator has been calculated showing values of 0.664, 1 and 0.992 for the three

[63] Based on email communication with Björn Vinneras (2009).

[64] Data gathered late 2009.

[65] It was assumed that special conditions can be negotiated for this credit (e.g. donor financed soft credits). Commercial credit rates are higher.

[66] The toilet facilities have not been included in the calculations since they are considered to be personal contributions of the individual residents.

[67] *Small scale I*: The N demand is based on a flower farm where one interview took place. In this case, the demand is not sufficient to use the system to full capacity.

[68] *Small scale II*: Equal to *Small scale I*, but working to full capacity, because of a higher N demand.

[69] *Large scale*: The input parameter for this scenario was not the N demand of a fictive farm. Instead, the total number of people living in slum settlements in Kampala had been used.

scenarios, respectively. A range between 0 and 1 represents the difference between 'bad' and 'good' in terms of workload[70].

The incomes generated from the sales of urine as fertiliser yield to 4 267, 6 429 and 41 472 EUR and the costs add up to 5 353, 5 730 and 32 473 EUR per month, respectively. Hence the balance results are -1 086, 699 and 9 000 EUR, respectively. As reference values for further comparisons the monthly return on sales and the repayment period are utilised. For system A the monthly return on sales are 10.87% and 21.7% for the *small scale II* – and the *large scale* scenario[71]. The start-up investment for the *small scale* scenarios is 128 465 EUR and for the *large scale* scenario 732 775 EUR which leads to repayment period of 15.32 and 6.79 years for the *small scale II* and the *large scale* scenario, respectively. The results of this cost calculation show that the bigger the N demand of the consumers and hence the bigger the system is dimensioned, the higher is the return on sales and subsequently the shorter is the repayment period.

Table 5: Economic overview of the urine logistics (system A)

	Small scale I	**Small scale II**	**Large scale**
N demand [kg/month]	1 200	1 808	11 663
Urine equivalent [l/month]	398 182	599 927	3 869 995
# Of people producing it	44 242	66 659	429 999[72]
Workload indicator (Bad workload = 0; Good workload = 1)	0.664	1.000	0.992
Monthly income from urine fertiliser sales [EUR]	4 267	6 429	41 472
Monthly costs [EUR]	5 353	5 730	32 473
Monthly balance [EUR]	-1 086	699	9 000
Monthly return on sales [%]	**n/a**	**10.87**	**21.7**
Start-up investment [EUR]	128 465	128 465	732 775
Repayment period [yrs]	**n/a**	**15.32**	**6.79**

In order to show what components of system A are majorly contributing to its costs, the respective proportions are visualised in Figure 14. The *Urine varying transport costs* (38%, 35% and 40%)[73], the *Urine fix transport costs - monthly truck depreciation* (26%, 25% and 24%), the *Costs of incentives for the jerrycans per month* (14%, 20% and 22%) and the *Storage site salaries urine* (6%, 6% and 1%) are identified as major cost contributors of the

[70] The maximum capacity of a tank truck is considered to be the tipping point of the workload indicator. A rising volume to be transported is accompanied by an increase in the workload indicator. After being close to one, while accommodating the maximum capacity, the workload indicator drops back to a smaller value when the volume exceeds the capacity of the tank truck. This process continues with increasing volumes; however the margins between the two extremes decrease and approach stable values.

[71] Since the small scale I scenario yielded negative results in terms of the monthly balance, return on sales and repayment period could not be calculated and it was neglected in further considerations.

[72] More than 430 000 people live in informal settlements throughout Kampala (UNHABITAT, 2010b).

[73] The values in the brackets are related to *small scale I*, *small scale II* and *large scale*, respectively.

scenarios. The results of the comparison of the cost constituents create the impression that the increase of the components *Costs of incentives for the jerrycans per month* and *Urine varying transport costs* continue with a rising N demand. However, this assumption is misleading. All individual components approach stable proportions[74], as well are all affected by variations in the workloads of the systems. Lastly, the simulated steadiness supports pretty well the modularity of the logistics system.

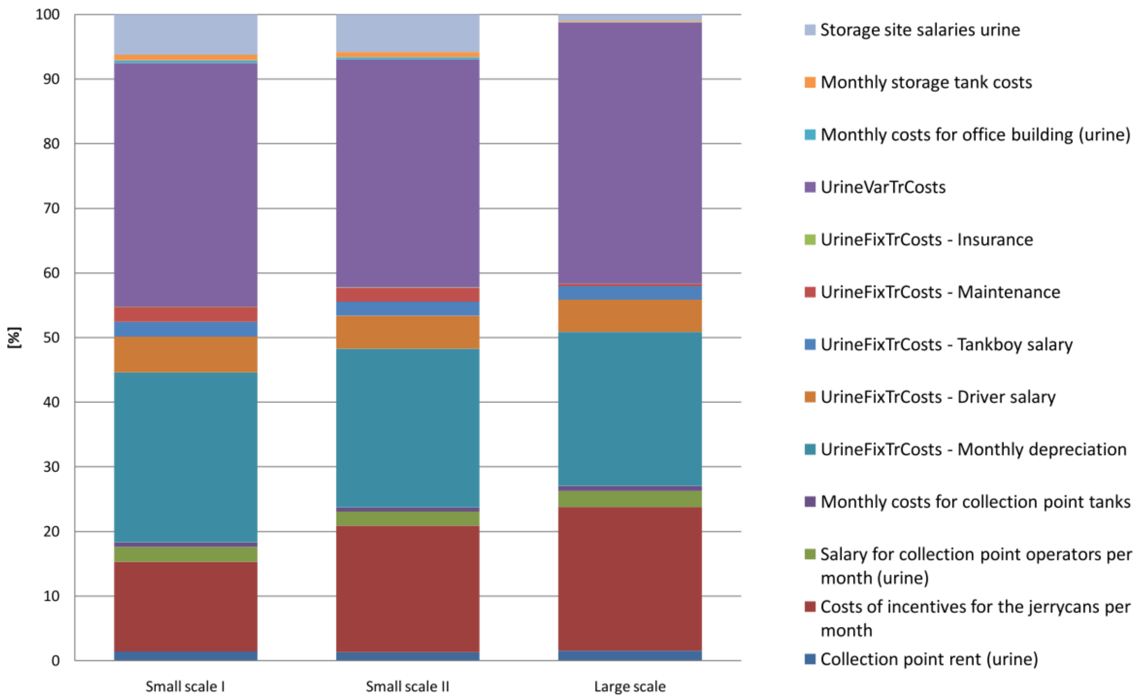

Figure 14: Cost constituent comparison of the urine logistic scenarios (own contribution)

6.2.2.3 Urine and faeces logistics system design

Since system A and B are alike regarding the urine logistics part, in this chapter additional components that have to be implemented to manage both kinds of separated human excreta are described. Figure 15 (p. 63) gives an overview of system B.

Slum Level

In the beginning of chapter 6.2.2.1 different toilet facilities have been presented. Those facilities are also the foundation of this system. Hence, the urine jerrycans will undergo the same process as described above. However, the faeces will be collected in containers that have to be designed with a proper lid and two handles, in order to allow an unoffending and easy transport, both having been indicated as crucial factors influencing the success of the logistics during the focus group discussions. The faeces containers also have to be stackable in order to reduce the area occupied for their storage. Furthermore, it could be considered to promote the containers as a starting point for low cost UDDTs on the household level (cf. chapter 6.2.2.1).

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[74] Except the storage site salaries, since they are not increasing with a rising volumes of urine.

Private Company Level

Since the faeces are possibly not dry and in an offending state when delivered to the collection points, the containers should be closed with a lid and not emptied until sanitisation is over. A pathogen free product can be produced after storage of six months to 2 years (WHO, 2006, p. XVI-XVII). This period can be reduced to one month with a urea treatment method developed by scientists of the Swedish University of Agricultural Sciences, Uppsala[75], which is also applied in this system. Hence for the delivery of a faeces container, one empty, clean container is handed out in exchange. Just as described in system A incentives in order to increase the collection efficiency, lower existing barriers and generate income are handed out for the delivery of a full faeces container[76]. The infrastructure on the ground in the slums is the same. Merely the area where the collection point is situated has to provide space for the storage of the full faeces-boxes that have been delivered and the clean and empty ones that are handed out in exchange. The faeces-boxes are also collected on a daily basis using a truck with 10 t capacity[77]. Besides the urine storage tanks, the storage site has to be dimensioned to accommodate an area for the storage of the faeces containers and a drying bed. After being delivered, workers add a certain amount of urea to the content of the faeces-boxes before they are closed again and stored away. After the period of one month, the sanitised faeces get emptied into the drying bed. After reducing the moisture level to a minimum, the organic fertiliser is filled into 50 kg bags, ready for sale as fertiliser. In contrast to the tank trucks for the urine, the faeces fertiliser bags do not require special means of transportation; hence pickup from the storage site by potential consumers such as horticulturists, gardeners and farmers from urban areas using bike, car or whatever means of transportation is viable. As a long term perspective the dried faeces fertiliser could also be marketed via the existing distribution channels of synthetic fertilisers, due to its solid characteristics being similar to those of synthetic fertiliser.

Alike system A, the extended version of system B can be considered as modular. Depending on the fertiliser demand, the infrastructure can be adjusted and implemented. The financial flow in system B stretches from the consumers that buy the dried faeces fertiliser bags at the storage site over the logistics company and the collection point operators to the suppliers of the raw human excreta.

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[75] 4 % of urea is added to the faeces. No mixing is required. The urea helps to destroy the pathogens in the faecal matter. Even though Nordin (2007, p. 36) indicates the addition of 2% urea assures sanitisation within 7 months, Gjefle (2010) based on values from Vinneras (2009) considers 4% to achieve sanitisation within 1 month.

[76] A full faeces-box is considered to have a weight of 20 kg (cf. chapter 9.3).

[77] Due to economies of scale this capacity is considered to be the most viable.

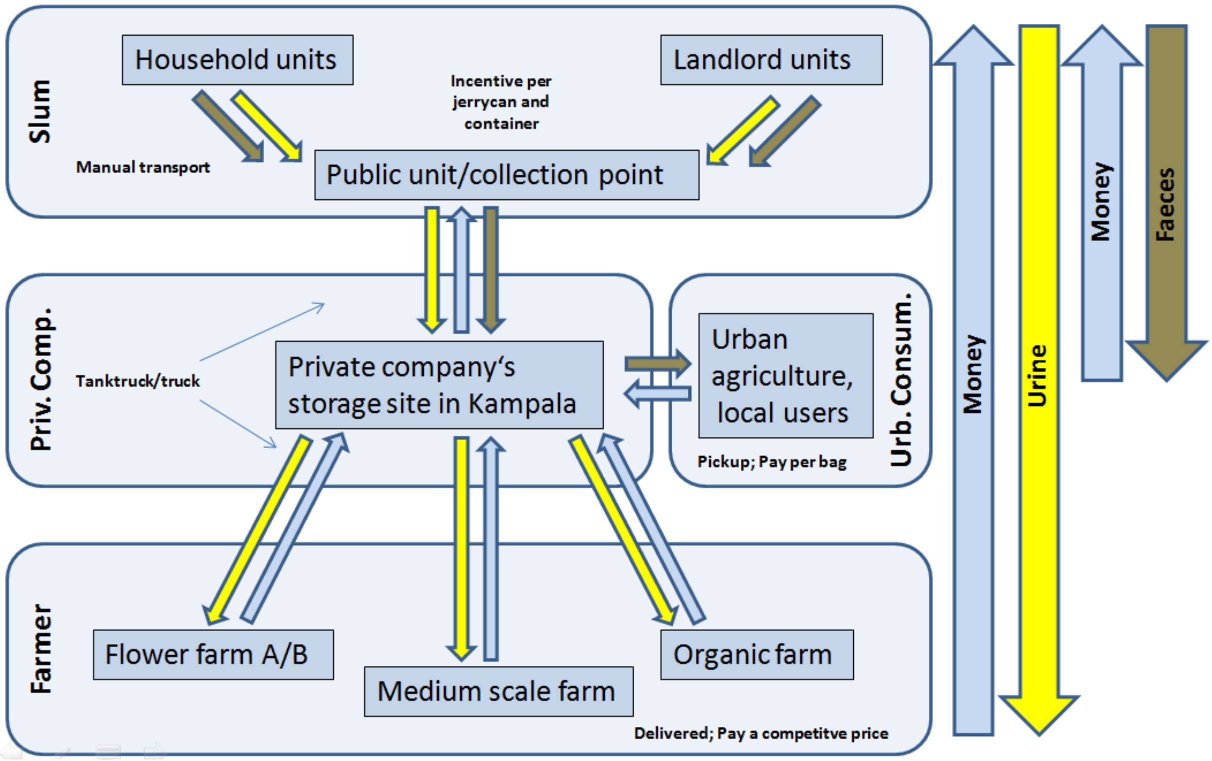

Figure 15: Logistics system for urine and faeces reuse - system B (own contribution)

6.2.2.4 Costs of the urine and faeces logistics

The costs of this extended logistics system have also been calculated with the assistance of the Microsoft Excel based model used in chapter 6.2.2.1 (for details regarding the model, cf. chapter 9.3). Various assumptions have been used and different scenarios have been calculated (cf. Table 6 and chapter 9.3).

The income for system B is generated through the sales of urine[78] and the dried faeces fertiliser bags. The bags have a weight of 50 kg and are sold for a price of 7.13 EUR[79] for collection.

Regarding the general framework, parameters such as project lifetime, working hours/days, labour requirement or delimitations (exclusion of toilet facilities or property issues), system A and B do not differ from each other. The scenarios from system B are also calculated based on monthly N demands. The number of people served is only affected by this parameter. The amount of faeces in turn is calculated based on the number of people living in the slum area. A collection efficiency of 50% is used. As average amount of faeces excreted by one person per day, 0.14 kg has been incorporated in the calculation (Vinneras, 2002, p. 37). In system B for both types of human excreta delivered to the collection point 0.04 EUR are paid as

[78] Values are the same as for system A.

[79] The value of the contained urea adds up to 4.29 EUR per bag. However, due to atmospherical losses the additional nitrogen content from adding urea is consumed again. The real nutrient level of dried, urea sanitised faeces has to be tested in further studies (cf. Appendix B). The margin between the urea value and the sales prices per bag covers the basic requirements for management and profit.

incentive for each container. Upfront investments that have to be financed in addition to the investments made for the urine system (system A) were:

- Faeces-boxes for exchange at the collection points
- Trucks
- Drying bed

The investments have been calculated with an interest rate of 6.6% and the investment costs for the toilet facilities have not been included in the calculations. The hidden cost's contribution to the total costs was in system B just as in system A included with 5%.
The scenarios in Table 6 were calculated based on the same N demands as used in Table 5 for system A. Hence the volume of urine and the number of people producing it are not changing. The amount of faeces generated by the individual numbers of people is 92 909, 139 983 and 902 999 kg/month for the scenarios *small scale I*, *small scale II* and *large scale*, respectively. The workload indicator for the urine share of the system remains the same as in Table 5. The workload indicator for the faeces share makes a difference, though. It rises from 0.310 for the *small scale I* scenario, over 0.467 up to 0.752 for the *small scale II* and *large scale* scenario. However, the mechanisms behind this monotonous increase are the same as in the urine system.
The income from selling the urine fertiliser is the same as in system A. The income from selling the dried faeces fertiliser bags is 2 860, 4 309 and 27 794 EUR, leading to 7 127, 10 738 and 69 267 EUR total income for the *small scale I*, - *small scale II* and - *large scale* scenario, respectively. The monthly costs of the same scenarios add up to 8 587, 10 076 and 56 917 EUR, resulting in a monthly balance of -1 460, 662 and 12 349 EUR. The *small scale I* scenario again had to be neglected due to a negative balance.
The monthly return on sales is hence calculated as being 6.16% for the *small scale II* and 17.83% for the *large scale* scenario. Compared to system A the return on sales is smaller (10.87% for the *small scale II* and 21.7% for the *large scale* scenario of system A).
Also the investments for system B show differences in relation to system A. Firstly, with 160 022, 163 376 and 843 427 EUR for the three scenarios, the values of system A are higher than for system B. This is influenced by additional investments for the infrastructure for faeces management. Secondly, unlike in system A, the values of the two *small scale* scenarios are different from each other. The trigger for that is located in the investments for the faeces-boxes that are handed out in exchange. The repayment periods are 20.58 and 5.69 years for the *small scale II* and the *large scale* scenario, respectively. The results of this cost calculation also show that the bigger the N demand of the consumers and hence the bigger the system is dimensioned, the higher is the return on sales and subsequently the shorter is the repayment period. Since resulting in a negative balance the return on sales and the repayment period for the *small scale I* scenario could not be calculated.

Table 6: Economic overview of the urine and faeces logistics (system B)

	Small scale I	Small scale II	Large scale
N demand [kg/month]	1 200	1 808	11 663
Urine equivalent [l/month]	398 182	599 927	3 869 995
# Of people producing it	44 242	66 659	429 999[72]
Amount of faeces [kg/month]	92 909	139 983	902 999
Workload indicator urine (Bad workload = 0; Good workload = 1)	0.664	1.000	0.992
Workload indicator faeces (Bad workload = 0; Good workload = 1)	0.310	0.467	0.752
Monthly income from urine fertiliser sales [EUR]	4 267	6 429	41 472
Monthly income from the "Faecifert" sales [EUR]	2 860	4 309	27 794
Total monthly income [EUR]	7 127	10 738	69 267
Monthly costs [EUR]	8 587	10 076	56 917
Monthly balance [EUR]	-1 460	662	12 349
Monthly return on sales [%]	**n/a**	**6.16**	**17.83**
Start-up investment [EUR]	160 022	163 376	843 427
Repayment period [yrs]	**n/a**	**20.58**	**5.69**

The proportions of the different components related to the total costs of system B are visualised in Figure 16. The major contributors to the costs of the respective scenarios are the *Monthly urea costs* (21%, 27% and 31%)[80], *Urine varying transport costs* (24%, 20% and 23%), the *Urine fix transport costs – monthly depreciation* (16%, 14% and 14%) and the *Costs of incentives for the jerrycans per month* (9%, 11% and 13%). Since not existing in system A, the effect of the urea costs for the sanitisation of the faeces becomes visible. Being the major proportion in this comparison the dependency of the system on synthetic fertiliser and their price variations has to be kept in mind. Similar to system A, the major cost contributors from system B are also approaching stable proportions which can be explained by the effects of economies of scale. The slight variations of all values involved are the consequence of changing workloads.

[80] The values in the brackets are related to *small scale I*, *small scale II* and *large scale*, respectively.

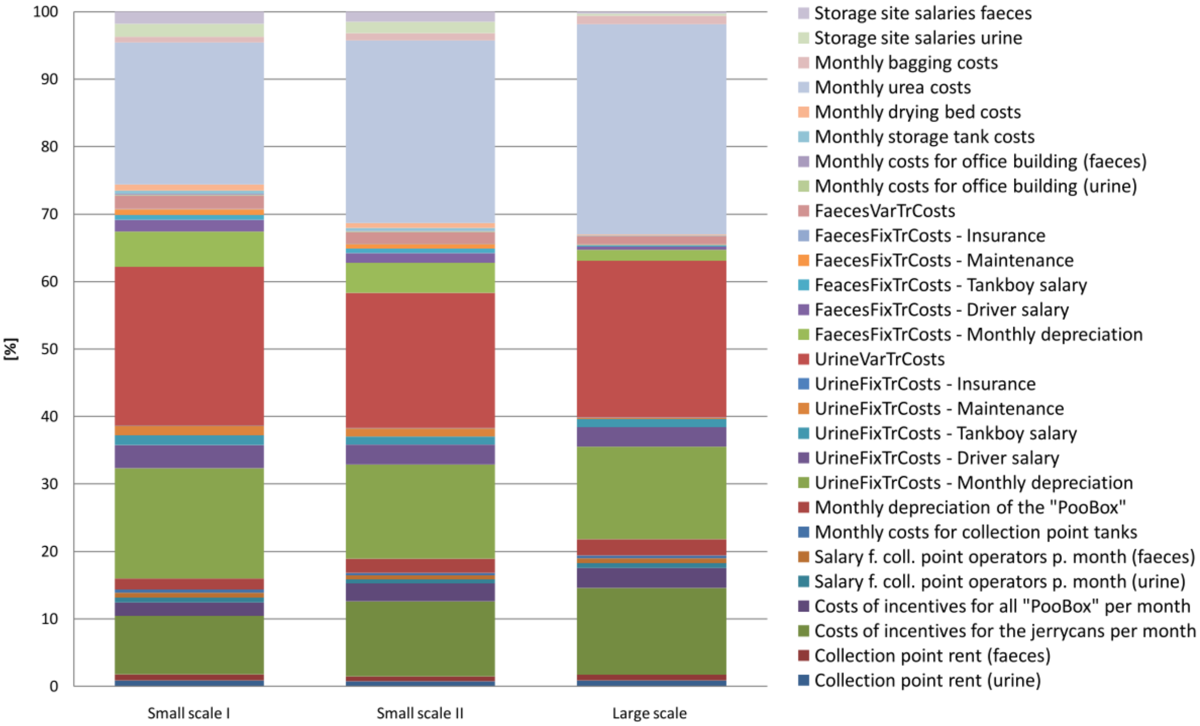

Figure 16: Cost constituent comparison of the urine and faeces logistic scenarios (own contribution)

6.2.2.5 Sensitivity analysis

Based on the different cost contributors identified in chapter 6.2.2.2 and 6.2.2.4, a sensitivity analysis has been carried out. In order to test the resilience of system A (Table 7) and system B (Table 8) against variations due to growing resource scarcity and variations in economy, the items fuel price and prices of tank trucks/trucks have been increased by 25%. Additionally, it has been calculated how the systems react if the incentives would be raised by 25% in order to increase the motivation to collect urine and faeces and attract more people. In order to show the effect of an increased project lifetime it was extended from 5 to 8 years. Furthermore, since representing logistics systems with high transport intensity, the effect of a supply chain failure due to truck break-downs or accidents has been included in the sensitivity analysis. For that, it was assumed that a private company would take over the transportation and charge 53 EUR per trip (cf. chapter 6.1.3.2). As failure frequency three days per month, with maximum three trips, was estimated to be reasonable. Another factor that is connected to the transport intensity is the transport distance. In this analysis the distance from the storage site to the agricultural area has been reduced by 50%[81]. Additionally to system A increasing nutrient prices were included in the calculations of system B, since the production of the dried faeces fertiliser bags involves the utilisation of urea. For the purpose of comparison the return on sales was utilised as indicator. In the following the effects of the modifications are shown.

[81] The distance of 50 km as used in the calculations of system A and B represents an average value that was set based on local experience. However, there are farms, which are located closer than that. If it would come to an implementation of the system, farms directly surrounding Kampala should be supplied preferably.

It has to be kept in mind that the effects cannot be compared to each other, since the input parameters of the modifications are different.

System A

The largest effect in the analysis for system A was caused by the reduction of the transport distance to 25 km. It resulted in an increase of the return on sales by 120.42% for the *small scale II* and 91.24% for *large scale* scenario. The values can be explained by several factors: Not only lower fuel consumption has to be mentioned, also less tanks trucks have to be purchased and fewer salaries have to be paid to the truck staff. The extension of the project lifetime resulted in an increase of 81.05% and 38.16% for the *small scale II* and the *large scale* scenario, respectively, reflecting the influence of the depreciation of the investments. The increase of the fuel price resulted in a reduction of the return on sales of 72.31% for the *small scale II*- and 36.45% for the *large scale* scenario, which again can be explained by the high proportion of transport costs in the balance of system A. Rising truck prices resulted in a reduction of the return on sales of 50.32% and 21.47% and the increase of incentives created a decreasing return on sales of 40.20% and 20.09% in the scenarios *small scale II* and *large scale*, respectively. The reduction triggered by the increased incentives illustrates the balancing act of finding the right level of incentives – the current level of incentives of 0.04 EUR was raised to still considerably low 0.05 EUR which already showed a significant decrease in the return on sales. The effect of a supply chain failure with 19.32% and 9.72% for the *small scale II* and *large scale* scenarios showed the smallest reduction in this calculation.

In general the *large scale* scenario is less affected by the modifications as the *small scale II* scenario. At the same time the return on sales for the *large scale* scenario is higher, which leads to the conclusion that a larger scale, yielding higher return on sales, thus delivering sustainable sanitation to more people positively influences the stability of the scenarios. Since yielding negative balances, the *small scale I* scenarios were neglected. Table 7 shows the effects of the modifications for system A.

Table 7: Sensitivity of system A to increasing fuel- and tank truck/truck prices, incentive costs, project lifetime, supply chain failure and transport distance reduction

	Small scale II		Large scale	
N demand [kg/month]	**1 808**	**1 808**	**11 663**	**11 663**
Scenario	**Current fuel price**	**Fuel price + 25%**	**Current fuel price**	**Fuel price + 25%**
Mon. return on sales [%]	10.87	3.01	21.7	13.79
Effect [%] (Fuel price incr.: 25%)[82]	-72.31		-36.45	
Scenario	**Current tank truck/truck price**	**Tank truck/truck price + 25%**	**Current tank truck/truck price**	**Tank truck/truck price + 25%**
Mon. return on sales [%]	10.87	5.40	21.7	17.04
Effect [%] (Truck price incr.: 25%)[83]	-50.32		-21.47	
Scenario	**Current incentive level**	**Incentive level + 25%**	**Current incentive level**	**Incentive level + 25%**
Mon. return on sales [%]	10.87	6.5	21.7	17.34
Effect [%] (incent. incr.: 25%)[84]	-40.20		-20.09	
Scenario	**5 years project lifetime**	**8 years project lifetime**	**5 years project lifetime**	**8 years project lifetime**
Mon. return on sales [%]	10.87	19.68	21.7	29.98
Effect [%] (incr. proj. lt.)	81.05		38.16	
Scenario	**No supply chain failure**	**Supply chain failure 3d/m**	**No supply chain failure**	**Supply chain failure 3d/m**
Mon. return on sales [%]	10.87	8.77	21.7	19.59
Effect [%] (sup. chain failure)	-19.32		-9.72	
Scenario	**50 km: storage site - farm**	**25 km: storage site - farm**	**50 km: storage site - farm**	**25 km: storage site - farm**
Mon. return on sales [%]	10.87	23.96	21.7	41.5
Effect [%] (dist. reduction)	120.42		91.24	

System B

Same as in system A the order of the items should not be mis- or over-interpreted, since the input parameters of the modifications are not comparable (cf. Table 8). The reduction of the distance *storage site to farm* by 50% led to the biggest effect. The return on sales rose by 127.27% in the *small scale II*- and 66.46% in the *large scale* scenario. The extension of the project lifetime caused the same effect in the *small scale II* scenario (127.27%) and the third largest in the *large scale* scenario (31.46%), illustrating the contribution of the depreciation or lifetime of the investments. Increasing nutrient prices, which are not applicable for system A, but have been included in this analysis, resulted in a reduction of the return on sales of 102.92% and 35.56% in the *small scale II*- and *large scale* scenario, respectively. Since urea is utilised in the sanitisation process of faeces, the price changes of synthetic fertiliser directly affect the profitability of the logistics system. Increasing fuel prices resulted in a reduction of

[82] At the time of data collection (late 2009) the price for 1 litre of diesel fuel was 0.71 EUR.
[83] Tank truck and truck prices are based upon interview information with logistic service providers.
[84] The incentive for the delivery of one container (jerrycan or faeces-box) is 0.04 EUR.

82.63% and 27.93%, the tank truck and truck price increases entail a reduction of 70.13% and 17.5%. The increased incentive costs contributed to a decrease of 52.27% and 18.06% and the effect of a supply chain failure to 20.29% and 6.5% of the return on sales for the *small scale II* and *large scale* scenario, respectively.

Alike as for system A the *large scale* scenarios were less affected by the modifications and since yielding negative balances, the *small scale I* scenarios were neglected.

Table 8 shows the results of the sensitivity analysis of system B.

Table 8: Sensitivity of system B to increasing fuel-, nutrient-, tank truck/truck prices, incentive costs, project lifetime, supply chain failure and transport distance reduction

	Small scale II		Large scale	
N demand [kg/month]	**1 808**	**1 808**	**11 663**	**11 663**
Scenario	**Current fuel price**	**Fuel price + 25%**	**Current fuel price**	**Fuel price + 25%**
Mon. return on sales [%]	6.16	1.07	17.83	12.85
Effect [%] (Fuel price incr.: 25%)[82]	-82.63		-27.93	
Scenario	**Current nutrient price**	**Nutrient price + 25%**	**Current nutrient price**	**Nutrient price + 25%**
Mon. return on sales [%]	6.16	-0.18	17.83	11.49
Effect [%] (Nut. price incr.: 25%)	*-102.92*		-35.56	
Scenario	**Current tank truck/truck price**	**Tank truck/truck price + 25%**	**Current tank truck/truck price**	**Tank truck/truck price + 25%**
Mon. return on sales [%]	6.16	1.84	17.83	14.71
Effect [%] (Truck price incr.: 25%)[83]	-70.13		-17.5	
Scenario	**Current incentive level**	**Incentive level + 25%**	**Current incentive level**	**Incentive level + 25%**
Mon. return on sales [%]	6.16	2.94	17.83	14.61
Effect [%] (incent. incr.: 25%)[84]	-52.27		-18.06	
Scenario	**5 years project lifetime**	**8 years project lifetime**	**5 years project lifetime**	**8 years project lifetime**
Mon. return on sales [%]	6.16	14	17.83	23.44
Effect [%] (incr. proj. lt.)	127.27		31.46	
Scenario	**No supply chain failure**	**Supply chain failure 3d/m**	**No supply chain failure**	**Supply chain failure 3d/m**
Mon. return on sales [%]	6.16	4.91	17.83	16.67
Effect [%] (sup. chain failure)	-20.29		-6.51	
Scenario	**50 km: storage site - farm**	**25 km: storage site - farm**	**50 km: storage site - farm**	**25 km: storage site - farm**
Mon. return on sales [%]	6.16	14	17.83	29.68
Effect [%] (dist. reduction)	127.27		66.46	

6.2.2.6 Conclusion case study

Firstly, designs and cost calculations revealed, that the logistics of human excreta financed by the marketing of the generated fertilisers and a collection system motivated by incentives are feasible. The number of people that are potentially served by the designed systems ranges from 66 659 to 429 999. However, there are also various restrictions that have to be considered.

The difference regarding the return on sales between system A and system B is significant. In system A the *small scale II* scenario yields 10.87%, whereas in system B 6.16% are achieved. In system A the *large scale* scenario shows a return on sales of 21.7% and in system B it amounts to 17.83%. Hence, in terms of profitability system A is superior. However, regarding the objective of sustainable sanitation not only to provide an “economically viable” solution, but also “protect and promote human health”, system B provides a more integrated solution. The overall situation in slums (diarrhoea) will only improve if faeces management becomes regulated (cf. chapters 3.1.1 and 6.2.2).

Secondly, it can be concluded that the logistics system for human excreta involves three stakeholder groups: On the side of the producers of human excreta, there are slum residents, receiving both, sustainable sanitation and income. The logistics would be covered by a newly established company that operates various tank trucks, trucks and a central storage site where sanitisation takes place. Being involved in the logistics of human excreta, the company generates profit. After safe fertilisers have been produced, the liquid urine fertiliser would be distributed to various farmers surrounding Kampala. The biggest share of the sanitised urine would be absorbed by flower farms. Additionally, one organic farmer and two medium scale farmers expressed willingness to use liquid urine fertiliser. The dried faeces fertiliser is bagged and sold from the storage site for urban consumption. The consumers would receive a safe and effective fertiliser whose price per fertilising value does not differ significantly from that of synthetic fertilisers.

Thirdly, apart from the above mentioned, the case study showed that the *small scale I* scenario had to be rejected due to the fact that it did not yield positive results in terms of the return on sales. As reason for that the dimension of the applied infrastructure (trucks and tanks) was identified. It proved to be oversized and did not work to full capacity based on the N demand of one medium scale flower farm. Increasing the N demand and thereby optimising the workload, for instance by supplying both, a medium and a small scale flower farm moves the system into the profit zone. However, designing the components according to the *small scale I* scenario’s N demand is not feasible either due to degraded economies of scale. Another aspect, showing the importance of economies of scale is the profitability of the *large scale* scenarios, which are in both systems presenting the highest results.

Finally, apart from the economies of scale, the sensitivity analysis shows the large effect on the profitability by reducing the transport distance. Hence, the importance of locating more farmers in the direct vicinity of Kampala has to be emphasised. Another aspect that was revealed in the sensitivity analysis is the dependency on and thus also the vulnerability towards changes of global nutrient prices.

6.3 Critical remarks on case study results

The case study contains two components that require critical assessment. The first component is of methodological nature. Since the fieldwork of this thesis took place during an internship with the Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ), I usually appeared as employee of that organisation during official meetings, interviews and focus group discussions. As a consequence, I often found myself in the role of a direct representative of that donor agency being confronted with several requests regarding not only sanitation, but also other issues such as health care, education and slum consolidation. Even though I always explained my role and status as student in detail, it cannot be excluded, that this situation might have influenced certain behaviour and statements in the interviews, especially during the ranking of the basic needs. However, due to the quantity of interviews, the diversity of interview partners and constant cross checks the information and data used in the cost calculations were not affected.

The second component that deserves critical consideration focuses on the system design and the cost calculations. All company assets[85] were depreciated over 5 years. This timeframe can be considered as short, contributing to high levels of investment costs. However, due to the risk of failure in the start-up period it was considered to be reasonable. This issue was discussed with several employees of DED, GTZ and SuSan Design.

[85] Excluding property.

7 Conclusion

It could be shown in this thesis that improving sanitation has various effects on the issues of slums, undernourishment and public health. Further on, the concept of sustainable sanitation was introduced and the effects of this sanitation practice, particularly economic effects were considered and their relevancy for sustainable development regarding the MDGs could be shown. Finally, all insights gained during the preparation of this thesis were combined and had been transformed into a real world example. The example showed that it is possible to combine convenient slum sanitation infrastructure with the idea of circular nutrient management in urban areas to design a large scale sustainable sanitation system.

Slums, home to about one billion people, are, apart from other structural, legal and organisational deficiencies, places which lack adequate access to water supply and sanitation. In various studies it could be proven that inadequate water supply and sanitation leads to high likelihoods of being affected by infectious diarrhoea (cf. chapter 2.3.2). As already stated, on a global scale, the burden of disease from infectious diarrhoea is ranked second. In the African Region infectious diarrhoea is ranked third. This in turn is considerably influenced by the number of people living in slums and suffering under inadequate sanitation.

But not only can the obvious example of poor slum sanitation be connected with a high rate of infectious diarrhoea. Also undernourishment and with it close to one billion people are considerably influenced. It could be shown that the causes of undernourishment can be roughly divided into two types. There is the macro-scale type, dealing with sufficient food supply in terms of its quality and quantity. This issue is among others influenced by degrading soils and linear nutrient management. Keeping in mind the information gathered about alternatives in this respect the circular nutrient management approach underlying sustainable sanitation takes effect. But not enough, also the second micro-scale type of undernourishment caused by different diseases hampering the nutrient uptake efficiency of human beings can be combated with the implementation and use of sustainable sanitation, due to the fact that infectious diarrhoea is one prominent representative of these diseases.

One objective of the thesis was to reveal the *economic effects of sustainable sanitation* in terms of costs that could be averted by implementing sustainable sanitation (cf. research question 1). Those costs included obvious items such as saved health care- or transport costs. But also unapparent costs like saved opportunity costs of time or saved fertiliser expenditures. Whilst the calculation in this study did not even include a comprehensive list of monetary values of all positive effects, the calculation of the BCR showed a positive result with a value of 4.37, promoting investments in sustainable sanitation infrastructure. However, even if the impact and profitability of investments in sustainable sanitation can be proven and have to be emphasised, the implementation of such investments is deficient. Singeling et al. (2009, p. 7) for instance constitute that public money alone in order to finance sanitation will not suffice. Alternative financing solutions, involving the private sector have to be developed and implemented.

Motivated by the above mentioned issues regarding slums, undernourishment, public health, the impact of economic effects and the fact that sustainable sanitation has rarely been applied successfully in slum settlements on a large scale involving the private sector, the second research question (*How can a system for the removal of human excreta from slum areas look like according to the principles of sustainable sanitation?)* was formulated and induced the practical part of this thesis: the design of a sustainable logistics system for human excreta and the calculation of its profitability.

The design was developed based on the ISWM approach which provided a useful framework. It was complemented by data gathered during qualitative social research in Kampala. The idea behind the design was to finance the logistics of sustainable sanitation by marketing human excreta as fertiliser to farmers outside the city. As a first and most important finding of this section it can be concluded that the design is feasible and the logistics of human excreta present a profitable and self-sufficient business for all stakeholders involved. Furthermore, it has to be emphasised, that system B, involving the integrated management of urine and faeces, is despite yielding lower profitability the solution to opt for according to the principles of sustainable sanitation, whose "main objective is protecting and promoting human health" (SuSanA, 2008, p. 1). The number of people that are potentially served varies according to the scale, but can be classed among 66 659 and 429 999. However, a number of prerequisites have to be met and various restrictions have to be considered. One important prerequisite that influenced the design was the assignment of the private sector for the proposed service delivery, making profitability a crucial criterion[86]. Another important restriction concerned the selection of farmers. Since more than 80% of Ugandan farmers can be accounted as small scale farmers that do neither have the financial resources for buying fertilisers nor do their soils need intensive fertilisation, the range is narrowed down significantly to medium and large scale farmers.

From a technological point of view the logistics of human excreta pose the problem of a considerably low fertilising value to weight ratio of the 'goods' to be transported. Due to this fact enormous volumes have to be transported on a daily basis in order to meet the farmer's demands. In connection with bad road conditions and a high rate of road accidents this potentially poses a risk for a successful project implementation and execution. Furthermore, due to the liquid nature of urine its transport can exclusively be carried out with tank trucks, which are more expensive than normal trucks. The tank trucks available in Uganda are either cesspool emptying trucks, which are contaminated with faecal sludge or freshwater trucks that are exclusively used for transporting drinking water. Hence, the establishment of a new company accompanied by investments in tank trucks that are specially designated for the transport of urine becomes inevitable. At the same time the proposed management of the

[86] Experience from the KCC/SIDA ecosan project showed, that external funding lead to a dependence and the system collapsed short after external funding.

dried faecal matter does not bring along these issues as normal trucks can be used and transportation only has to take place from the slum to the storage site. However, it might be most feasible to design the new company as full service provider offering an all-inclusive service, dealing with both urine and faeces, instead of out-sourcing the faeces fraction.

Apart from the aspect of transportation the design at slum level can be explained by the need of various toilet facility types, in order to achieve a maximum coverage with sanitation facilities. The design of the collection points and delivery scheme is motivated by the unfeasibility of emptying individual toilet facilities with tank trucks (due to bad accessibility and high costs). The storage site satisfies the need for processing the raw human excreta into a sanitised product. Most of the farmers interviewed expressed problems regarding the handling of liquid fertilisers due to a lack of appropriate infrastructure and only a selective minority consisting of two flower-, one (large scale) organic- and one medium scale farmer showed a willingness to utilise urine as fertiliser.

From an economic perspective urea costs (if applicable), transport costs and incentives cut deeply into the overall profitability of the proposed systems. Furthermore, the workload of the systems showed to have considerable effects on the profitability. However, it has to be mentioned that the systems do not only generate income in terms of incentives for the residents. They also provide jobs as collection unit operators (2-13 jobs) and private company employees (6-21 jobs) (*small scale I - large scale*, respectively) (cf. chapters 6.2.2.1, 6.2.2.3 and 9.3).

Beyond that, the investigations showed that the acceptance towards the handling of human excreta in general and the reuse in agriculture in particular proved to be restrictive. Therefore, the question on slum level is: are the proposed incentives sufficient to change the negative attitude and additionally provide a compensation or income for the efforts of the delivery? On the farmer level objections against the use of fertilising material that resembles urine or faeces has been expressed. On the one hand that might lead to farm workers rejecting the utilisation; on the other hand consumption of the agricultural products might diminish largely, showing a high need for sensitisation of all involved stakeholders.

Finally, a sensitivity analysis presented the effects of variations in fuel-, nutrient- and truck prices, raised incentives, increased project lifetime, supply chain vulnerability and transport distance reduction on the profitability of the logistics. In both systems the reduction of the transport distance from the storage site to the farmer showed to have the largest effect, followed by the extended project lifetime, the nutrient price increases for system B and the raised fuel price in system A. While the majority of modifications are based on external trends and factors such as changing fuel- or nutrient prices that cannot be altered, the transport distance and the project lifetime can be regarded as internal factors that can be influenced with the right management decisions. Fortunately, the sensitivity analysis showed the big potential the modifications of the internal factors can have on the profitability of the logistics systems. To be optimistic, it could even be argued that increasing the system’s profitability by minimising the transport distance and increasing the project lifetime, incentive levels could be raised and/or the threshold in terms of a farm's N demands could be lowered and/or the human excreta fertiliser price could be calculated more competitively, which in turn would increase the implementability.

Recalling the feasibility equation given in the list of assumptions in chapter 5.5, the theoretical feasibility in terms of technology (due to a feasible design), economics (due to positive profitability) and acceptance (due to participative planning of the systems), considering all requirements, restrictions and barriers amount to a positive result and could thus be proven. However, the practicability would have to be tested on the ground with the small selection of potential stakeholders that has been identified. This should also be considered for international transferability. Even though economic sustainability has been listed as prerequisite, kick-off funding covering part of the investment costs might be inevitable.

The findings of this thesis showed that further research is needed in different fields of interest: Since urine with its low fertilising value to weight ratio and its liquid state has been identified as crucial factor influencing the transport costs further research should be targeted towards nutrient recovery technologies such as struvite precipitation producing a concentrated, solid fertiliser (Udert and Wächter, 2010). Apart from that the faeces treatment technology depends on synthetically produced urea that on the one hand consumes fossil fuels and on the other is subject to global nutrient price variations. Hence, alternatives such as co-composting with organic waste could be considered in future research (Dalla Torre, 2010). Last but not least, the issue of resident motivations has to be investigated more in depth to obtain more information regarding the level of incentives and reveal possible alternatives such as prohibitions, sensitisation, argumentative persuasion and peer-pressure (Mosler and Tobias, 2007, p. 42).

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9 Appendix

9.1 Contact persons

Name	Contact	Comment
Brenda Achiro	+256 712216104	Senior Program Officer – NGO, Network for Water and Sanitation (NETWAS)
Dr. Charles Niwagaba	+256 772335477 cbniwagaba@yahoo.co.uk	Scientific Staff, Department of Technology, Makerere University Kampala; Director NGO Sustainable Sanitation and Water Renewal Systems (SSWARS)
Dr. Christoph Zipfel	christoph.zipfel@giz.de	PPP Promoter (DED)
Dr. Onesmus Semalulu	+256 772615009 o.semalulu@gmail.com	Scientific staff – National Agricultural Research Organisation of Uganda (NARO)
Dr. Reddy	+256 753770000	Agricultural Manager Kakira Sugar Works Ltd.
Dr. Shuaib Lwasa	+256 772461727 lwasa_s@arts.mak.ac.ug	Scientific staff, Department of Geography, Makerere University Kampala; NGO - Urban Harvest
Fred Nuwagaba	+256 772497458 nuwagaba@ruwas.co.ug	Senior Technical Advisor Water & Sanitation – Reform of the Urban Water and Sanitation Sector (RUWASS)
James Maitekei	+256 772486350 james.maiteki@nwsc.co.ug	Sewerage Service Manager – National Water and Sewerage Corporation (NWSC)
Jan-Michael Mock	jan-michael.mock@ded.de	Coordinator Water supply and Sanitation (DED)
Jeffer Matovu	+256 772665410	Director of the PEA
Karsten Gjefle	karsten@susan-design.org	Director of Sustainable Sanitation Design (SuSan Design)
Margaret Azuba	+256 772456140	Senior Agriculture Officer – Kampala City Council - EcoSan (Agriculture)
Michael Oketch	+256 782843648 oketch_michael@yahoo.com	EcoSan Liaison Officer – Directorate of Water Development (DWD)
Mr Balsumbe	+256 712467499 nakagorofd@yahoo.com fongrowers@yahoo.com	Agricultural Manager of Fruits of the Nile
Mr Barendse	+256 772785555 h.barendse@royalvanzanten.com	Production Manager of Royal van Zanten
Mr Chakravarth	+256 703666346 kchakravarthi@mehtagroup.com chakra2005rose@yahoo.com	Senior Farm Manager of Uganda Hortech Ltd.
Mr Chauhan	+256 752743232 gm@ugandateacl.com	General Manager of the Uganda Tea Corporation Ltd.
Mr Kigonya	+256 712724135	Medium scale farmer in Kampala, Kawempe Division
Mr Muwange	+256 792639684	Medium scale farmer in Kampala, Kawempe Division
Mr Prinsloo	+256 414259885	Technical Director of TAMTECO
Mr Sekaran	+256 41448279 or +256 31555500	Lugazi Sugar Corporation Ltd.
Mr van Esch	+256 712464110 +256 755464110 boweevil@xs4all	General Director of BoWeevil Organic Cotton
Ms Luboyera	+256 712383358	Small scale farmer in Kampala, Kawempe Division
Musa Muwanga	+256 772448948 mkmuwanga@nogamu.org.ug	Chief Executive Officer – National Organic Agricultural Movement of Uganda (NOGAMU)
Ruth Muguta	+256 77246606	Project Coordinator – Kampala City Council - EcoSan (Slum Sanitation)

9.2 Interview guidelines

Guideline experts

Introduction

What is your name and your profession and the field of work of your organisation or company?

Sanitation situation

Can you describe the current sanitation situation in the slum areas of Kampala? (type, owner, responsibility → percentage)

Can you identify them on a map?

Do you have statistics about the slums?

What are major problems caused by sanitation?

Are people aware of the connection of insufficient sanitation and environmental/health problems?

How are people dealing with it?

Are there financial flows in the current sanitation situation? If yes, please describe.

What do you think about a fee for using proper sanitation facilities? Would people pay that are recently paying anything?

What can you tell me about the success of ecosans in Kampala?

Why is it like this?

What do you think are motivations or barriers to use ecosan?

Can you think of motivations or barriers for landlords/operators to implement ecosan instead of pit latrines?

Agricultural situation

Can you describe the agricultural situation in Uganda? (Fertility, crops(needs), scale, market)

Can you identify agricultural areas in and around Kampala? (Fertility, crops(needs), scale, market)

What are major problems concerning agriculture in Uganda?

How are people dealing with it? (Strategies: fertilising vs. field shifting?)

What is the attitude towards fertiliser in Uganda in general?

Can you tell me what the most popular fertiliser in Uganda is?

Can you describe the fertiliser market in Uganda? (Subsidised? Who uses it? Imported or locally produced?)

Human excreta as fertiliser

Do you know anything about fertiliser value of urine or faeces – compared to urea, NPK or DAP?

Could you imagine that farmers use sanitised urine and faeces instead of conventional fertiliser? What would motivate them and what would be a barrier? (Price?)

Do you think they would pay? Do you think organic farmers would pay more?

Do you know anything about experiences in the reuse of urine or faeces?

Could you image that consumers buy products that have been fertilised with completely sanitised human excreta?

There are areas of origin of human excreta (the slums) and areas of reuse (the farmers)

> How do you think, those two areas could be connected?
>
> Where do you see the financial flows?
>
> Can you think of possible partners that might be interested in taking over that business? (liquid and solid transport and storage)

Maybe you already mentioned one, but what kind of option do you consider as possible?

> System with direct incentives for users (money or goods)
>
> System with indirect incentives for users (improved environmental and health situation)

Would you opt for household sanitation and/or public units?

What is your impression of transport costs and transport conditions in Uganda? What about salaries?

Closure

Would you like to add something that might help this study? Useful documents? Contacts?

Thank you for taking the time!

Guideline private companies

Introduction
What is your name and your profession and the field of work of your organisation or company?
What products and/or services do you deliver?
What is the location of your business?
Could you imagine that your company works in the logistics of human excreta? (give example...)
What do you think could be barriers for you, your employees or the infrastructure?
What is your infrastructure like? (trucks, storage capacity)
Would you be willing to invest in infrastructure?
What distance per day do your trucks travel on average?
How many hours do you/ your employees work per day?
How many days does your business work per week?
Monthly costs (ask for type of truck)

- Depreciation or life span?
- Salaries?
- Fuel?
- Maintenance?
- Insurance?
- Tax?
- Profit?
- Your prices? (distance and truck capacity)

Closure
Useful documents? Contacts?
Thank you for taking the time!

Guideline farmers

Introduction
What crops or cultures are you growing?
What is the size of your farm?
What is the distance from your farm to Kampala?
Are you producing for a market? If yes, what is the market you produce for?
Are you receiving any kind of subsidiy?
What can you tell me about your yields? Are you experiencing any change from the past to present?
If yes, why do you think so?
What are you doing against this?
Are you using fertiliser?
If yes, which type?
How much and in what frequency?
From where do you get your fertiliser?
How much do you pay?
Have you ever heard of human urine and faeces as fertiliser?

- What is your attitude towards that?
- Would you be willing to try this alternative fertiliser?
- Would you be willing to pay for human excreta as fertiliser? (If not, why not?)
- Do you think your infrastructure could handle sanitised human excreta? (tank? application?)
- What do you think your consumers would say?

Closure
Useful contacts?
Thank you for taking the time!

9.3 *Cost calculations*[87]

Nutrient value calculations

For calculating the value of urine the Replacement Cost Approach (RCA) was applied (cf. Drechsel. 2004).

Fertiliser prices and their nutrient contents - 50 kg bag				Prices: General Allied, Kampala (January 2010)	
Fert. Type	Amount (kg)	N in %	P in %	K in %	Price [UGX]
Urea	50,0000	46,0000	0,0000	0,0000	65000,0000
NPK 17 17 17	50,0000	17,0000	17,0000	17,0000	85000,0000
NPK 25 5 5	50,0000	25,0000	5,0000	5,0000	85000,0000
DAP	50,0000	20,0000	46,0000	0,0000	86000,0000
Average fertilizer price and nutrient content - 1 kg					
	Average price 1 kg	N content (kg)	P content ** (kg)	K content*** (kg)	1,0000
Urea	1300,0000	0,4600	0,0000	0,0000	0,4600
NPK 17 17 17	1700,0000	0,1700	0,0748	0,1411	0,3859
NPK 25 5 5	1700,0000	0,2500	0,0220	0,0415	0,3135
DAP	1720,0000	0,2000	0,2024	0,0000	0,4024
** P is in NPK fertilizer available as P2O5 which contains P to 44%				0,4400	
*** K is in NPK ferlilizer available as K2O which contains K to 83%				0,8300	
Average nutrient prices (derived as average values from conv. fertiliser)					
	Average	N	P	K	total
	price 1 kg	price prop.	price prop.	price prop.	sum
Urea	1300,0000	1300,0000	0,0000	0,0000	1300,0000
NPK 17 17 17	1700,0000	748,8987	329,5154	621,5859	1700,0000
NPK 25 5 5	1700,0000	1355,6619	119,2982	225,0399	1700,0000
DAP	1720,0000	854,8708	865,1292	0,0000	1720,0000
Average	**1605,0000**	**1064,8578**	**437,9810**	**282,2086**	**1785,0474**

[87] [87] The decimal places in the Appendix are separated by “,“, whereas thousands places are separated by “.“. UGX were converted to EUR in the report. 1 EUR = 2,807 UGX (10.04.2010)

Nutrient Content in excretions (Jönsen et al., 2004, for Uganda)			
Atmospherical losses [%]:		**50,0000**	(nitrogen loss 70% cf. Maurer, M. 2007)
		kg/a	kg/day or liter
Nitrogen	in urine	2,2000	0,0060
Nitrogen	in urine with atmospherical losses	**1,1000**	**0,0030**
"	in faeces	0,3000	0,0008
"	total	2,5000	0,0068
Phosphorous	in urine	0,3000	**0,0008**
"	in faeces	0,1000	0,0003
"	total	0,4000	0,0011
Potassium	in urine	1,0000	**0,0027**
"	in faeces	0,4000	0,0011
"	total	1,4000	0,0038

Weight of conv. fertiliser [kg] having the same fertilising value as in the urine produced by 1 pers./day (1 liter)						
	Nitrogen		Phosphorus		Potassium	
	kg	UGX	kg	UGX	kg	UGX
Urea	0,0066	8,5170	0,0000	0,0000	0,0000	0,0000
NPK 17 17 17	0,0177	13,2762	0,0110	3,6208	0,0194	12,0693
NPK 25 5 5	0,0121	16,3422	0,0374	4,4570	0,0660	14,8566
DAP	0,0151	12,8816	0,0041	3,5132	0,0000	0,0000
Average Value [UGX]		12,7543		3,8636		13,4629
SD		3,2206		1,9773		7,8557
Value per litre urine calculated following the replacement cost approach (Drechsel et al. 2004) [UGX] = **30,0808**						
Value of a jerrycan (20l) [UGX]= 601,6164						
Value of a tank truck (10000 l) [UGX]= 300808,1851						

Logistics systems cost calculations[88]

Overview		
	= Input variable regarding the quantity of the conv. fert. Demand of the farmer	
	= Variable. The variables can be found in the general assumptions section and additionally throughout the whole table. They all can be changed.	
	= Variable (Lever) has more effect than "variable". These levers can only be found in the general assumptions section.	
	= Investment (where 20% interests have already been included)	
	= Manual Excel (the round up is sometimes not giving the proper results… has to be checked manually)	
	= Urine totals	
	= Faeces totals	
Items	**Attributes**	**Comments**
General assumptions		
Perspective of the analysis	Private Company	
Type of human excreta	1,0	Urine = 1; Urine and feaces = 0,5.
Collection levels	Households, shared facilities, public facilites	
Type of system	Decentralised, incentive driven collection; Private logistic company; commercial farmers	

[88] Example of the model used for the calculations of the various scenarios. A copy can be obtained from the author.

Timeframe of the project [yrs]	5	Here it should be 5 yrs. And then property has to be excluded	
N demand by farm [kg/month]	1.808	System working to full capacity with a monthly demand of 1808 kg N.	
N demand by farm [kg/day]	60	30 days per month	
Corresponding urine volume per month [l]	599.927	Assumed an atmospherical loss of nitrogen of 50% (see table "fert_urine_price_equi")	
Corresponding urine volume per day [l]	19.998	Assumed an atmospherical loss of nitrogen of 50% (see table "fert_urine_price_equi")	
Workload indicator urine (system A)	1,000	Bad workload = 0; Good workload = 1	
Workload indicator urine and faeces (system B)	0,467	Bad workload = 0; Good workload = 1	
Percentage of urine collected [%]	30	Many people go to work during the day.	
Volume of urine produced per person and day [l/day]	1,0	Based on email communication with Björn Vinnerås	
# People producing it	66.659		
Faeces weight per pers/day [kg]	0,140	Jönsson et al., 2004	
Percentage of faeces collected [%]	50	From the same amount fo people living in the area	
Faeces volume per day [l]	4.666	Wet weight to volume ratio is 1:1	
Faeces volume per month [l]	139.983		
PooBox price [UGX]	60.000	Without a toilet seat but including a lid the price for a "PooBox" is 70000 UGX (Estimated based on the prices of CRESTANKS)	
Price of one bag of "feacifert" [UGX]	20.000	12.037,04	[UGX] nutrient value in one bag
Working days per month	30		

Working hours per day [h]	10	
Interest rate on investment (factor is used instead of %)	1,2	The interest rate on investment is 20%
Daily collection point operator salary [UGX]	5.000	Assumption
Daily worker salary [UGX]	5.000	Assumption
Daily site manager salary [UGX]	12.000	Assumption
Daily tank-boy/loading-boy salary [UGX]	5.000	Source: various interviews
Daily driver salary [UGX]	12.000	Source: various interviews
National Security Fund (factor is used instead of %)	1,1	10%, source: Fred Nuwagaba
Diesel price per liter [UGX]	2.000	
Incentives [UGX]	100	
Urea price per kg [UGX]	1.300	
Bagging costs for one bag [UGX]	500	Estimated by Fred Nuwagaba, GTZ Uganda
Nutrient price factor	1,00	(1,25 = 25% price increase)
Tank truck/truck price factor	1,00	(1,25 = 25% price increase)
Monthly income from urine fertiliser sales [UGX]	**18.046.303**	This value is calculated with the Replacement Cost Approach (RCA) cf. Drechsel, P; Giordano, M; Gyiele, L. 2004. Valuing nutrients in soil and water: Concepts and techniques with examples from IWMI studies in the developing world. Research Report 82. Colombo, Sri Lanka: International Water Management Institute.
Monthly income of "feacifert" bags sales [UGX]	**-**	
Total monthly costs [UGX]	**16.085.138**	
Total monthly balance [UGX]	**1.961.166**	
Monthly return on sales [%]	**10,87**	This value is taken from the end of the table. Only for the purpose of a better visualisation of the effects of changes of the input parameters.
Startup investment urine and faeces scenario [UGX]	**360.600.000**	
Repaid after [yrs]	**15,32**	

Design		
Collection		
Urine		
Urine volume per day [l]	19.998	
Volume collection tank [l]	10.000	Crestanks "CV-1000C" or "CV-1000C(SP)"
Space requirement of the tank [m²]	10	Crestanks "CV-1000C" or "CV-1000C(SP): 2,36 m to 2,82 m diameter
Calculated # collection points (10000 l tank volume)	2,0	
Real # of collection points	2	This one is used as input value for further calulcations
Volume jerrycan [l]	20	
# Jerrycans per month	29.996	
Faeces		
Faeces volume per day [l]	4.666	
Real # of collection points	2	
Faeces volume/mass per day per collection point [kg]	2.333	Wet weight to volume ratio is 1:1
Size of the "PooBox" [m³]	0,064	Cubical container with the dimensions of 0,4 m edge lengths with handles for carrying it.
Weight of the content of the "PooBox" [kg]	20	
# "PooBox" per collection point	117	
# "PooBox" in total per month	6.999	
# "PooBox" for exchange per collection point	233	The person delivering a full "PooBox" to the collection point gets a empty and clean one in exchange. This number is subject to testing
Space requirement for the PooBoxes at the collection point [m²]	9	If 4 boxes are stacked on top of each other. Additionally the same amount of space is required for the empty "PooBox" that are handed out in exchange

Collection point space requirements [m²]	29	10	m² of roofed "office" and working space
Transport			
Urine			
Urine volume per day [l]	19.998		
Volume tank truck [l]	10.000	Biggest volume available without using truck and trailer	
Calculated # of trips per day (volume)	2,0	When there are e.g. 1,5 trips per day the transportation of two loads every even day and one on the uneven days minimises transport costs.	
Real # of trips per day	2,0		
Distance slum - storage facility [km]	10,0		
Return distance slum to storage facility [km]	20,0		
Average speed on the collection trip [km/h]	10,0		
Driving time [h]	2,0		
Loading/offloading time [h]	1,0		
Duration for one trip [h]	3,0		
Duration of all collection trips [h]	6,0		
Daily collection distance [km]	40,0		
Calculation of truck # (slum - storage)	1,7	Only for calculation purposes	
Calculation of truck # (slum - storage)	1,0	Only for calculation purposes	
Real # of tanktrucks the company has to have (slum - storage)	1		
Distance storage facility - farmer [km]	50,0		
Return distance Kampala - farm [km]	100,0		
Average speed [km/h]	25,0		

Driving time [h]	4,0	
Loading/offloading time [h]	1,0	See above
Duration for one trip [h]	5,0	
Duration of all transport trips [h]	10,0	
Daily transport to farm distance [km]	200,0	
Calculation of truck # (storage - farmer)	1,0	Only for calculation purposes
Calculation of truck # (storage - farmer)	1,0	Only for calculation purposes
Real # of tanktrucks the company has to have (storage - farmer)	1	
Faeces		
Faeces volume per day [l]	4.666	
Capacity truck [kg]	10.000	If the capacity is increased, fixed and variable costs will also rise.
Calculated # of trips per day (volume)	0,47	When there are e.g. 1,5 trips per day the transportation of two loads every even day and one on the uneven days minimises transport costs.
Real # of trips per day (volume)	1	
Distance slum - storage facility [km]	10,00	
Return distance slum to storage facility [km]	20,00	
Average speed on the collection trip [km/h]	10,00	
Driving time [h]	2,00	
Loading/offloading time [h]	1,00	
Duration for one trip [h]	3,00	
Duration of all collection trips [h]	3,00	
Daily collection distance [km]	20,00	
Calculation of truck # (slum - storage facility)	3,3	Only for calculation purposes
Calculation of truck # (slum - storage facility)	1,0	Only for calculation purposes
Real # of tanktrucks the company has to have (storage - farmer)	1	
Storage		
Urine		
Urine volume per day [l]	19.998	

Volume storage tank [l]	24.000	Crestanks "CV-2400C"
Calculated # of storage tanks needed for that volume per day	0,8	
Real # of storage tanks needed for that volume per day	1	
Storage time [days]	30	
# Of tanks needed on the storage site [days or # tanks]	30	
Area occupied by one storage tank [m²]	20	Crestanks "CV-2400C": 3,65 m diameter
Minumum size of storage site [m²]	2.880	Including 2000 m² additional area (parking for trucks, office building). The plot in the industrial are in Bweyogerere has about 4000 m²
# Of site managers	1	
# Of workers		
Faeces		
Faeces volume per day [l]	4.666	
Faeces volume per month [l]	139.983	
Monthly number of "PooBox"	6.999	
Space requirement for storing the "PooBox" [m²]	280	4 "PooBox" are stacked on top of each other
Required size of storage bed (monthly volume) [m³]	140	
Size of the drying bed [m]	1*30*40	1200 m³ max. volume at the drying area.
Percentage of urea [%]	4	
Weight reduction during drying [%]	78	Jönsson et al., 2004
Sanitised and dried faeces weight to be bagged monthly [l]	30.236	78% reduction
# Of bags per month	605	
Weight of bag [kg]	50	
Weight of faeces for one bag before drying [kg]	231,48	
Urea weight per bag [kg]	9,26	
N content pr bag [kg]	4,26	
N content [%]	8,52	

Costs			
Collection			
Urine			
Collection point rent urine [UGX]	100.000	Since the space requirement for the urine tank is less than for the faeces the price is only half the price of the faeces collection	
Total collection point rent urine [UGX]	200.000		
Price for one tank [UGX]	2.300.000	Special GTZ price from CRESTANKS	
Price for all tanks [UGX]	4.600.000		
With interest [UGX]	5.520.000	20%	
Life time [yrs]	5	LAWA, 2005: Nr. 1.2.10.3. Dosier-Misch-Einrichtungen, Chemikalienbehälter. Tabelle 11, Durchschnittl. Nutzungsdauern wasserbaulicher Anlagen. In Leitlinien zur Durchführung dynamischer Kostenvergleichsrechnungen (KVR-Leitlinien), LAWA.	
Collection tank costs per year [UGX]	1.104.000		
Maintenance costs per year [UGX]	110.400	10	% of the price per year
Costs for collection point tanks per month [UGX]	101.200		
Factor: Urine, Faeces or both	1,0	0,5 = both; 1 = urine	
Salary for collection point operators per month [UGX]	330.000	One operator per collection point gets 5000 UGX per day	
# Jerrycans per month	29.996		
Incentive [UGX]	100		
Costs of incentives for all jerrycans per month [UGX]	2.999.636		
Monthly urine collection point and incentive costs [UGX]	**3.630.836**		

Collection point rent faeces [UGX]	100.000	This is double the price of the urine collection point rent
Total collection point rent faeces [UGX]	200.000	
"PooBox" price [UGX]	60.000	Without a toilet seat but including a lid the price for a "PooBox" is 70000 UGX (Estimated based on the prices of CRESTANKS)
"PooBox" total investment [UGX]	27.996.606	
With interest [UGX]	33.595.927	20%
Lifetime [yrs]	5	
Monthly depreciation of the "PooBox" [UGX]	559.932	
Factor: Urine, Faeces or both	1,0	0,5 = both; 1 = urine
Salary for collection point operators per month [UGX]	330.000	One operator per collection point gets 5000 UGX per day
# "PooBox" per month	6.999	
Incentive [UGX]	100	
Costs of incentives for the "PooBox" per month [UGX]	699.915	
Monthly faeces collection point costs [UGX]	**1.789.847**	
Transport		
Urine		
Price for one tank truck [UGX]	94.000.000	Price for a second hand tanktruck imported from Japan. Based on interview information.
Price for all tank trucks [UGX]	188.000.000	
With interest [UGX]	225.600.000	20%

Life time [yrs]	5	LAWA, 2005: 10 years recommended for Germany. Nr. 11.3.3 Spezialfahrzeuge. Tabelle 11, Durchschnittl. Nutzungsdauern wasserbaulicher Anlagen. In Leitlinien zur Durchführung dynamischer Kostenvergleichsrechnungen (KVR-Leitlinien), LAWA.
Monthly depreciation [UGX]	3.760.000	
Diesel price per liter [UGX]	2.000	
Fuel consumption per km[l]	0,375	Value obtained from interview. Used to calculate the fule consumption per km. The interviewpartner was Jeffer Matovu (director of the Pitlatrine Emptiers Association)
Monthly driver salaries [UGX]	792.000	Including 10% National Security Fund
Monthly tankboy salaries [UGX]	330.000	Including 10% National Security Fund
Maintenance [UGX]	330.000	Oil, Filters, Hydraulics
Insurance	6.000	
Fixed costs per month for all trucks[UGX]	5.218.000	
Varying costs per km (fuel) [UGX]	750	
Total daily distance [km]	240	
Total monthly distance [km]	7.200	
Varying costs "monthly distance" [UGX]	5.400.000	
Monthly urine transport costs [UGX]	**10.618.000**	
Faeces		
Price for one truck [UGX]	60.000.000	Price for a second hand tanktruck imported from Japan. Based on interview information.
Price for all trucks [UGX]	60.000.000	

With interest [UGX]	72.000.000	20%
life time [yrs]	5	LAWA, 2005: 10 years recommended for Germany. Nr. 11.3.3 Spezialfahrzeuge. Tabelle 11, Durchschnittl. Nutzungsdauern wasserbaulicher Anlagen. In Leitlinien zur Durchführung dynamischer Kostenvergleichsrechnungen (KVR-Leitlinien), LAWA.
Monthly depreciation [UGX]	1.200.000	
diesel price	2.000	
Fuel consumption per km[l]	0,38	
Monthly driver salaries [UGX]	396.000	Including 10% National Security Fund
Monthly loadingboy salaries [UGX]	165.000	Including 10% National Security Fund
Maintenance [UGX]	200.000	Oil, Filters, Hydraulics
Insurance	6.000	
Fixed costs per month for one truck [UGX]	1.967.000	
Real # of trucks	1	
Fixed costs per month for all trucks [UGX]	1.967.000	
Varying costs per km (fuel) [UGX]	750	
Total daily distance [km]	20	
Total monthly distance [km]	600	
Varying costs "monthly distance" [UGX]	450.000	
Monthly faeces transport costs [UGX]	**2.417.000**	
Storage		
Urine		
Factor: Urine, Faeces or both	1,0	0,5 = both; 1 = urine

Price storage site (4000 m²) [UGX]	300.000.000	This item should not be included in the calculation, since there might be the opportunity to get it in a special arrangement for a reduced price or provided by the city. This price be for 4000 m² industrial area in Bweyogerere, 30 m off Jinja road. Homes&Land - The Real Estate Professionals, Mugisha Arthur - Sales and Marketing Manager. The other option is to rent a plot of land but for that the prices are very high (15 USD per m²)!	
With interest [UGX]	360.000.000	20%	
Lifetime/timeframe of the project [yrs]	5		
Monthly storage site costs urine [UGX]	6.000.000	Should not be included in the calculation, since there might be the opportunity to get it in a special arrangement for a reduced price or provided by the city.	
Price for one storage tank [UGX]	5.500.000	Special GTZ price from CRESTANKS	
Price for all storage tanks [UGX]	165.000.000		
With interest [UGX]	198.000.000	20%	
Life time [yrs]	5	LAWA, 2005: Nr. 1.2.10.3. Dosier-Misch-Einrichtungen, Chemikalienbehälter. Tabelle 11, Durchschnittl. Nutzungsdauern wasserbaulicher Anlagen. In Leitlinien zur Durchführung dynamischer Kostenvergleichsrechnungen (KVR-Leitlinien), LAWA.	
Total storage tank costs per year [UGX]	39.600.000		
Tank maintenance costs per year [UGX]	3.960.000	10	% of the price per year
Factor: Urine, Faeces or both	1,0	0,5 = both; 1 = urine	

Storage site operators salaries [UGX]	891.000	1 site manager (10000 UGX) and 3 workers (5000 UGX)
Price per liter of storage per day [UGX]	0,20	
Price per liter of storage after storage time [UGX]	5,97	Supposd the tanks are always used at the maximum capacity of the system (20000 l) and storage time is 30 days.
Monthly storage tank costs [UGX]	119.342	
Factor: Urine, Faeces or both	1,0	0,5 = both; 1 = urine
Investment office Building [UGX]	3.000.000	Still waiting for the tender from AWE Engineering Bugolobi, Kampala, Uganda
With interest [UGX]	3.600.000	
Lifetime office building [yrs]	5	30 - 50 years recommended for Germany. Nr. 1.2.12 Betriebsgebäude. Tabelle 11, Durchschnittl. Nutzungsdauern wasserbaulicher Anlagen. In Leitlinien zur Durchführung dynamischer Kostenvergleichsrechnungen (KVR-Leitlinien), LAWA.
Monthly depreciation for office buidling [UGX]	60.000	
Monthly urine storage costs [UGX]	**1.070.342**	
Faeces		
Factor: Urine, Faeces or both	1,0	0,5 = both; 1 = urine
Price storage site (4000 m²) [UGX]	300.000.000	This item should not be included in the calculation, since there might be the opportunity to get it in a special arrangement for a reduced price or provided by the city. This price be for 4000 m² industrial area in Bweyogerere, 30 m off Jinja road. Homes&Land - The Real Estate Professionals, Mugisha Arthur - Sales and Marketing Manager. The other option is to rent a plot of land but for that the prices are very high (15 USD per m²)!
With interest [UGX]	360.000.000	20%

Lifetime [yrs]	5	
Monthly storage site costs faeces [UGX]	6.000.000	Should not be included in the calculation, since there might be the opportunity to get it in a special arrangement for a reduced price or provided by the city.
Factor: Urine, Faeces or both	1,0	0,5 = both; 1 = urine
Faeces volume per day [l]	4.666	
Faeces volume per month [l]	139.983	
Price of the drying bed [UGX]	10.000.000	
With interest [UGX]	12.000.000	20%
Lifetime	5	
Monthly drying bed costs [UGX]	200.000	
Factor: Urine, Faeces or both	1,0	0,5 = both; 1 = urine
Storage site operators salaries [UGX]	810.000	1 site manager (10000 UGX) and 3 workers (5000 UGX)
Percentage of urea [%]	4	
Urea consumption per month [kg]	5.599,32	
Urea price per kg [kg]	1.300	
Urea costs per month [UGX]	7.279.118	
# Of bags to be packed from the sanitised and dried faeces	605	
Urea price per bag [UGX]	12.037,04	
Bagging costs for one bag [UGX]	500	Estimated by Fred Nuwagaba, GTZ Uganda
Monthly bagging costs for all bags [UGX]	302.363	
Factor: Urine, Faeces or both	1,0	
Investment office Building [UGX]	3.000.000	Estimated (Still waiting for the tender from AWE Engineering Bugolobi, Kampala, Uganda...)
With interest [UGX]	3.600.000	20%
Lifetime [yrs]	5	
Monthly office building costs [UGX]	60.000	
Monthly faeces storage costs [UGX]	**8.651.481**	

Overview		
Costs		
Urine		
Collection point rent [UGX]	200.000	
Costs of incentives for all jerrycans per month [UGX]	2.999.636	
Monthly depreciation of the collection point tanks per month [UGX]	101.200	
Salary for collection point operators per month [UGX]	330.000	
Monthly urine collection point and incentive costs [UGX]	**3.630.836**	
Monthly depreciation [UGX]	*3.760.000*	
Monthly driver salaries [UGX]	*792.000*	
Monthly tankboy salaries [UGX]	*330.000*	
Maintenance [UGX]	*330.000*	
Insurance	*6.000*	
Fixed transport costs [UGX]	5.218.000	
Varying costs "monthly distance" [UGX]	5.400.000	
Monthly urine transport costs [UGX]	**10.618.000**	
Monthly depreciation for office buidling [UGX]	60.000	
Monthly storage tank costs [UGX]	119.342	
Storage site operators salaries [UGX]	891.000	
Monthly urine storage costs [UGX]	**1.070.342**	
Total monthly urine costs [UGX]	**15.319.179**	
Faeces		
Collection point rent faeces [UGX]	200.000	
Monthly depreciation of the "PooBox" [UGX]	559.932	
Costs of incentives for all "PooBox" per month [UGX]	699.915	
Salary for collection point operators per month [UGX]	330.000	
Monthly urine collection point and incentive costs [UGX]	**1.789.847**	
Monthly depreciation [UGX]	1.200.000	
Driver salaries [UGX]	396.000	
Loadingboy salaries [UGX]	165.000	

Maintenance [UGX]	200.000		
Insurance	6.000		
Fixed transport costs [UGX]	1.967.000		
Varying costs "monthly distance" [UGX]	450.000		
Monthly urine transport costs [UGX]	**2.417.000**		
Monthly costs for office buidling [UGX]	60.000		
Monthly drying bed costs [UGX]	200.000		
Storage site operators salaries [UGX]	810.000		
Urea costs per month [UGX]	7.279.118		
Monthly bagging costs for all bags [UGX]	302.363		
Monthly faeces storage costs [UGX]	**8.651.481**		
Factor calculation	0		
Total monthly faeces costs [UGX]	**-**		
Income			
Total monthly income from urine fertiliser sales [UGX]	**18.046.303**		
Monthly income of "feacifert" bags sales [UGX]	**-**		
Total monthly income [UGX]	**18.046.303**		
Costs			
Total monthly urine costs [UGX]	**15.319.179**		
Total monthly faeces costs [UGX]	**-**		
Hidden costs [UGX]	**765.959**	5	% of hidden costs per year
Total monthly costs [UGX]	**16.085.138**		
Balance			
Total monthly balance [UGX]	**1.961.166**	No taxes are subtracted here since the business is a non profit one and the benefits can directly be shared with the public	
Monthly return on sales [%]	**10,87**		

Investement		
Price for all collection tanks [UGX]	4.600.000	
"PooBox" total investment [UGX]	-	
Price for all tank trucks [UGX]	188.000.000	
Price for the faeces trucks [UGX]	-	
Price for all storage tanks [UGX]	165.000.000	
Investment office building urine proportion [UGX]	3.000.000	
Investment office building faeces proportion [UGX]	-	
Price of the drying bed [UGX]	-	
Startup investment urine and faeces scenario [UGX]	**360.600.000**	
Total annual profit of the urine and faeces scenario [UGX]	**23.533.988**	
Repaid after [yrs]	**15,32**	This is the time for repayment
Repaid after [yrs]	23.533.988	This is only for the purpose of illustration

Eidesstattliche Versicherung

Ich erkläre an Eides Statt, dass ich meine Diplomarbeit “Economic Effects of Sustainable Santiation – Logistics of Human Excreta in Uganda” selbstständig ohne fremde Hilfe angefertigt habe, und dass ich alle von anderen Autoren wörtlich übernommenen Stellen wie auch die sich an die Gedanken anderer Autoren eng anlehnenden Ausführungen meiner Arbeit besonders gekennzeichnet und die Quellen nach den mir angegebenen Richtlinien zitiert habe.

Kiel, den 21. April 2011

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Enno Schröder