MASTER THESIS

Submitted in partial fulfilment of the requirements for the degree

Master of Science in Environmental Engineering

Hamburg University of Technology

"Resource-Oriented Public Toilets in Developing Countries: Ideas, Design, Operation and Maintenance for Arba Minch, Ethiopia"

Aleksandra Drewko
Matriculation number: 33176

Supervised by:
Prof. Dr.-Ing. Ralf Otterpohl
Prof. Dr. oec. publ. Cornelius Herstatt

TUHH
Technische Universität Hamburg-Harburg

September 2007

"The conditions here are terrible. There is sewage everywhere. It pollutes our water. Most people use buckets and plastic bags for toilets. Our children suffer all the time from diarrhea and other diseases because it is so filthy."

Mary Akinyi, Kibera, Nairobi, Kenya

Declaration

I hereby declare that I am the sole author of this thesis entitled “Resource-Oriented Public Toilets in Developing Countries: Ideas, Design, Operation and Maintenance for Arba Minch, Ethiopia”. All literal content and quotations from other sources are clearly pointed out and no other sources other than those declared have been used.

Aleksandra Drewko

Hamburg, 19.09.2007

Acknowledgements

I gratefully acknowledge the financial support provided by the German Academic Exchange Service (DAAD) for my Master's Study Course in Germany.

I am deeply grateful to Prof. Dr.-Ing. Ralf Otterpohl, for his support in supervising this work, and Prof. Dr. oec. publ. Cornelius Herstatt, my second supervisor, thank you both for your support, assistance and help. I would also like to thank Dipl.-Ing. Franziska Meinzinger and Dipl.-Ing. oec. M. Sc. Dominic de Vries for their advice, valuable contributions, patience and kindness during the course of the work, thank you both.

With the kindness and contributions of the people who provided me with useful information at the time of working on this thesis, I would not have been able to obtain the data used in this work. Therefore, I would like to thank: Patrick Bracken, Paul Calvert, George Anna Clark, Linus Dagerskog, Madeleine Fogde, Mayling Simpson-Hebert, Richard Holden, Elisabeth von Muench, Michael Oketch Omwodo, Moyin, Almaz Terrefe, Mekonnen Tesfaye and other members of the EcoSanRes discussion forum.

I would also like to thank my family and friends who supported me all through the course of this work.

Abstract

The sanitation crisis in the developing world calls for action. Inadequate sanitation or lack of access to sanitation poses a great threat to human health, taking a heavy death toll especially on children, and degrades the environment. On the other hand, good sanitation saves lives and prevents degradation of the environment. In most of the developing countries, it is common practice for people to answer the call of nature in the open field or use so-called “flying toilets”, which results in a poor sanitary, health and environmental situation.

The conventional sanitation approach, such as “drop and store” (e.g. pit latrines) or “flush and discharge” systems, is not suitable for addressing the need for sanitary services in developing countries. First of all, they create environmental problems, such as groundwater pollution, pits are often not emptied and overflow, and sewage is not treated or only partially before being discharged into water bodies. They only contain human excreta, not allowing for reuse of nutrients. Moreover, they are not suitable for conditions found in developing countries (e.g. high congestion, high groundwater table, poor soil condition, lack of infrastructure, etc.). Last but not least, “flush and discharge” systems are expensive and most communities in developing countries cannot afford them. Ecological sanitation is a good alternative to the conventional approach. It is sustainable, inexpensive, offers a variety of technological options that can answer different local needs, prevents pollution through containment, sanitization of urine and feces and allows for reuse of nutrients.

The work discussed here involved drafting a concrete project for a resource-oriented public toilet in the city of Arba Minch, Ethiopia, which is located about 500 km south from the capital city, Addis Ababa. The city has a poorly established infrastructure, a growing population, and its sanitary situation, solid waste and wastewater management is rather poor. The majority of the town population use dry pit latrines and pit emptying is one of the problematic issues. Most houses use temporary toilets, as they call them due to their poor construction. Also, gorges and jungle sites are potential open defecation areas and solid waste disposal sites. Public toilets are a very important sanitation issue. There are only two public VIP toilets in the city and they are not even present in the vicinity of the markets or bus station. Inadequate access to clean water, poor environmental sanitation and malnutrition are the major factors contributing to problems of water-borne (diarrhea, gastritis) and water-washed (skin) diseases in the city. Thus, apart from other burning problems that the city is facing, the municipality needs help in designing an appropriate public toilet system.

The location for the public toilet to be built was chosen next to the bus station in kebele eleven, and there were two designs considered. Urine-diverting toilets were chosen instead of pour-flush toilets with anaerobic digestion. The reason for the choice was mainly the simplicity of building the units, and no need for effluent sludge management that would be required in case anaerobic digestion was employed. Based on estimations, it was decided that five toilet units would be built to serve 300 visitors daily. Harvested urine and feces would be sold to local farmers and users would pay 0.2 Birr for each visit. Investment costs would be covered by a loan provided by a local finance institution. Financial analysis of the project showed that the public toilet complex would make a profit, allowing for repayment of the loan within the first four years of operation. However, a very important issue shown by the sensitivity analysis of the project revealed that the public toilet complex must involve other means of generating income on top of providing toilets. The study showed that allowing for advertisements on the toilet cubicles, providing a showering facility or selling travel accessories should be practiced.

In conclusion, sanitation systems in developing countries cannot be resource intensive and unsustainable because they will not respond to the local problems, but on the contrary, create even more problems. Also, their impact on human and environmental health needs to be taken into account. Thus, locally suitable alternative sanitation options, which consider local conditions and needs of potential users, just like the urine-diverting toilets used for the public toilet project in Arba Minch, must become the focus, especially for developing countries.

Table of contents

Declaration…………………………………………………………………………… 1
Acknowledgments……………………………………………………………………... 2
Abstract………………………………………………………………………………... 3
Table of contents……………………………………………………………………… 4
List of acronyms……………………………………………………………………… 6
List of figures………………………………………………………………………….. 7
List of tables…………………………………………………………………………… 9

Chapter 1: Sanitation – definition, importance, problems, and different approaches 10
1.1. Definition of sanitation 10
1.2. Importance of sanitation 10
1.3. Water-borne diseases 13
1.4. The sanitation crisis 15
1.5. United Nations Millennium Development Goals and Sustainable Development 17
1.6. How people deal when nature calls in developing countries: examples of bad practice 19
1.7. Challenges to be tackled in the sanitation sector in developing countries 22
1.8. Different approaches to sanitation 26
1.8.1. The real costs of "flush and discharge" sanitation approach 27
1.8.2. Shortcomings of implementing the conventional sanitation approach in developing countries 28
1.9. Alternative approach to the conventional sanitation 29
1.9.1. Ecological sanitation 29
1.9.2. Importance of recycling of nutrients 32
1.9.3. Low-cost sanitation 34
Chapter 2: The need for public toilets in Africa 36
2.1. Africa- the scope of environmental and health problems 36
2.1.1. Water supply and sanitation coverage in Africa 37
2.1.2. Household sanitation in Ethiopia 39
2.2. Information on Arba Minch, Ethiopia 41
2.2.1. Location and topography 41
2.2.2. Climate 41
2.2.3. Geology, Geomorphology and Soil 42
2.2.4. Population and population growth 42
2.2.5. Socio-economic characteristics 43
2.2.6. Infrastructure 44
2.2.7. Water supply system 44
2.2.8. Sanitation 44
2.2.9. Solid waste management 47
2.2.10. Wastewater management 47
2.3. Peri-urban settlements 48
2.4. Importance of understanding culture for sanitation projects 49
2.5. Sanitation culture in Ethiopia 51
2.5.1. Ecosan and agriculture in Arba Minch 52
Chapter 3: Technology selection for the resource-oriented public toilet project in Arba Minch- comparison and evaluation 54
3.1. Dry toilet with urine diversion 54
3.1.1. General and technical considerations 54
3.1.2. Nutrients production, recycling and reuse 55
3.1.3. Applicability 58

3.1.4. Form and material selection 58
3.1.5. Advantages 60
3.1.6. Disadvantages 61
3.2. Pour-flush toilet 63
3.2.1. General and technical considerations 63
3.2.2. Advantages 65
3.2.3. Disadvantages 65
3.2.4. Biogas formation 66
3.2.5. Biogas generation and utilization 67
3.2.6. Sulabh experience 69
3.2.7. Bangladesh experience 70
3.2.8. Types of biogas digester plants 71
3.2.9. Digested slurry management 74
3.3. Greywater treatment 76
Chapter 4: Public toilets in developing countries- general considerations, financial and social aspects on the example of case studies 78
4.1. The need for public toilets 78
4.2. When and where public toilets should come in place 78
4.3. General considerations about public toilets from user's point of view 79
4.4. Willingness to pay for the use of public toilets 81
4.4.1. Price per toilet use 83
4.5. Potential problems and misuse of public toilets 85
4.6. Public toilet projects in Africa – success and failure stories 87
4.6.1. Case study: Public toilets in informal settlements in Nairobi, Kenya 87
4.6.2. Case study: Public toilets in Kano, Nigeria 91
4.6.3. Case study: Public private partnerships in Ghana 92
4.6.4. Case study: Small Scale Sanitation Providers of Sanitation Services in Kibera, Kenya 94
4.6.5. Case Study: Dignified Mobile Toilets System in Lagos, Nigeria 97
4.7. Sustainable public sanitation approach 99
4.7.1. Case Study: Sulabh International, community toilets in India 99
4.7.2. Case Study: Nakuru Central Business District 102
4.7.3. Case study: Community based sanitation program in Tangerang and Surabaya, Indonesia 102
4.8. Different operational concepts 103
Chapter 5: Proposed public toilet project for Arba Minch, Ethiopia 106
5.1. Location of the toilets 106
5.2. Stakeholders and considerations involved in the project 106
5.3. Population served 107
5.4. Detailed description of the toilet units and the operational concept 107
5.5. Cost analysis of the project 109
5.5.1. Investment calculation 109
5.5.2. Operation and maintenance costs and generated revenues 110
5.5.3. Financial statements of the company 113
5.5.4. Sensitivity analysis 119
5.6. Why not pour-flush with anaerobic digestion? 123
Chapter 6: Conclusions 126

Appendices........ 128
List of references........ 141

List of acronyms

AMU – Arba Minch University
ARB – Arba Minch Town Water Service
BEST – Bina Ekonomi Sosial Terpadu
BOD – biological oxygen demand
BORDA – Bremen Overseas Research and Development Agency
CBO – community based organization
CDRs – Committees for the Defense of the Revolution
COD – chemical oxygen demand
CSCs – Community Sanitation Centers
DMT – Dignified Mobile Toilets
EbIT – Earnings before Interest and Tax
EELPA – Ethiopian Electric Light and Power Authority
GTZ – German Agency for Technical Cooperation
ISAT – Information and Advisory Service on Appropriate Technology
KASEPPA – Kano State Environmental Planning and Protection Agency
KnSWB – Kano State Water Board
KUDB – Kano Urban Development Board
MDG – Millennium Development Goal
NCC - Nairobi City Council
NGO – non-governmental organization
NUPI – National Urban Planning Institute
OMFI – Omo Micro Finance Institution
P & L statement – profit and loss statement
PPP – purchasing power parity
ROSA – Resource-Oriented Sanitation concepts for peri-urban areas in Africa
SSPs – Small Scale Sanitation Providers
SUDEA – Society for Urban Development in East Africa
UN – United Nations
UNECD – United Nations Conference on Environment and Development
UNICEF – United Nations International Children's Emergency Fund
U.T.I. – urinary tract infection
VIP – ventilated improved pit
ZWMED – Water Mines and Energy Department

List of figures

Figure 1: Poor people account for most of the water and sanitation deficit 12
Figure 2: The F-diagram for transmission routes of pathogens from excreta 13
Figure 3: The global water and sanitation deficit 16
Figure 4: Coverage with improved drinking water sources in 2002 16
Figure 5: Improved sanitation coverage in 2002 17
Figure 6: Proportion of population using improved sanitation, 1990 and 2004 (%) 19
Figure 7: Kibera slum in Nairobi, Kenya (left), pit latrine in Kibera (right) 20
Figure 8: Dharavi slum in Mumbai, India 21
Figure 9: Annual growth of urban and slum populations, 1990-2001 (percentage) 24
Figure 10: Population of countries facing water stress or scarcity (billions) 25
Figure 11: "drop and store" (left) and "flush and discharge" (right) sanitation approach 27
Figure 12: Median percentage of wastewater treated by effective treatment plants 28
Figure 13: Shortcomings of the conventional wastewater systems (left) and advantages of ecological sanitation systems 30
Figure 14: Essential technological components used in ecosan 31
Figure 15: Characteristics of domestic wastewater flows with no dilution for urine and feces (wet weight) 33
Figure 16: Fossa-alterna soil-composting pit latrine 34
Figure 17: Double-vault urine-diverting dry ecosan toilet 34
Figure 18: Condominial and conventional sewerage 35
Figure 19: Africa's water supply coverage (left) and sanitation coverage (right) in 2000 37
Figure 20: Population without improved water (left) and sanitation (right) by region in 2002 in mln 38
Figure 21: Water supply coverage trends in Ethiopia 38
Figure 22: Sanitation coverage trends in Ethiopia 39
Figure 23: Toilet types used in residential areas in Arba Minch 45
Figure 24: Pit with squatting wood 46
Figure 25: Greywater disposal method in Arba Minch 47
Figure 26: Separation at source 54
Figure 27: Traditional toilet with urine diversion in China 54
Figure 28: Double-vault dehydration toilet with urine separation 59
Figure 29: Schematic representation of a urine-diverting toilet 59
Figure 30: Porcelain squatting pan with urine diversion used in China 60
Figure 31: Urine diversion seat pedestal: (a) fiberglass, (b) plastic, (c) mortar 60
Figure 32: Urine diversion toilet in Ethiopia (left) and in Burkina Faso (right) 62
Figure 33: Pour-flush latrine with the direct discharge (upper image), the offset pit (left) and offset double pit (right) 63
Figure 34: Pour-flush toilet with a septic tank and a soak away 64
Figure 35: Low-cost pour-flush slab in Bangladesh and schematic illustration of a U-trap 64
Figure 36: Toilet connection to a biogas digester 66
Figure 37: Three steps of biogas production 67
Figure 38: Schematic diagram of a gas burner (left) and a biogas lamp (right) 69
Figure 39: Excreta-based biogas and bio-fertilizer 70
Figure 40: Fixed-dome biogas plant 72
Figure 41: Water-jacket plant 73
Figure 42: Floating-drum plant scheme 73
Figure 43: Unsaturated flow (left) gives better filtration and oxygenation of the water than saturated flow (right) 76
Figure 44: Toilet charge versus PPP gross national income per capita of selected countries.. 84

Figure 45: Mobile squatting toilet (left), toilet with a separate urinal (right) 98
Figure 46: Two-pit pour-flush Sulabh toilet……………………………………………………100

List of tables

Table 1: Countries where coverage with improved sanitation was one third or less in 2002 .. 17
Table 2: Characteristic of flow streams.... 30
Table 3: Population with latrines, 2000 in percent.... 39
Table 4: Households by type of toilet facility 40
Table 5: Sanitation and public communal toilets in nine Ethiopian towns 40
Table 6: Population and annual population growth in Arba Minch 42
Table 7: Arba Minch Town Water Service water tariff 43
Table 8: Distribution of population by religion in Arba Minch 43
Table 9: Incidences of diarrhea 46
Table 10: Comparison of estimated excretion of nutrients per capita in selected countries.... 55
Table 11: Inactivation of microorganisms in urine, given as T_{90}-values (time for 90% reduction) in days 57
Table 12: Recommended Swedish guideline storage times for urine mixture based on estimated pathogen content and recommended crop for larger systems 57
Table 13: Consumption rates of different appliances for utilization of biogas 68
Table 14: Comparison of fixed-dome and floating-drum plant 73
Table 15: Processes occurring in treatment of wastewater 77
Table 16: Toilet charges in different countries 83
Table 17: Toilet charges and economic indicators of different countries 83
Table 18: Public toilet annual operation costs in USD 96
Table 19:General cost estimate for building of one urine-diverting toilet 109
Table 20: Operation and Maintenance cost calculation for five urine-diverting toilet units . 110
Table 21: Variables for operation and maintenance cost calculation.... 111
Table 22: Generated revenues from operation of the public toilet complex 112
Table 23: Variables for revenues calculation 112
Table 24: Financial statements for the first year of operation of the public toilet complex .. 115
Table 25: Financial statements for the second year of operation of the public toilet complex 116
Table 26: Financial statements for the third year of operation of the public toilet complex . 117
Table 27: Financial statements for the fourth year of operation of the public toilet complex 119
Table 28: Closing balance sheet for the fourth year of operation with the estimation of 150 visitors/day 120
Table 29: Closing balance sheet for the fourth year of operation with the estimation of 150 visitors/day in the first 3 months of operation.... 121
Table 30: Closing balance sheet for the fourth year of operation with the assumption of no sanitized excreta being sold.... 122
Table 31: Closing balance sheet for the fourth year of operation with the assumption of no advertisements being posted on the toilet cubicles 123
Table 32: Summary of local conditions in kebeles in Arba Minch, Ethiopia 128
Table 33: Summary of public toilet projects in different developing countries.... 134
Table 34: Detailed cost estimate of a urine diversion toilet unit.... 138

Chapter 1: Sanitation – definition, importance, problems, and different approaches

1.1. Definition of sanitation

The term *"sanitation"* has been given various definitions by different authors and has been used regularly in various aid programs. Yet what exactly is sanitation? The Oxford Advanced Learner's Dictionary defines sanitation as: "systems that protect people's health, especially those that dispose efficiently of human waste". Other dictionaries also mention prevention of transmission of diseases and insurance of public and private health. In the developing world, the term sanitation gained a meaning of excreta disposal facilities and for the purpose of this work, it will refer specifically to this denotation. Thus, sanitation refers to methods of hygiene that relate to safe collection, removal and disposal of human excreta and wastewater [46].

WHO and UNICEF (2000) stated that poor sanitation has serious consequences to health. It can be easily seen on the example of a simple illness like diarrhea that continues to be a major killer in the developing world due to the fact that a rather basic problem of how to deal with excreta still remains unresolved [46]. According to the WHO (2004), 1.8 million people die every year from diarrhoeal diseases (including cholera); of which 90% are children under five, mostly in developing countries [85]. The WHO also stated that an improved water supply reduces diarrhea morbidity by 6% to 25%, if severe outcomes are included, whereas improved sanitation reduces diarrhea morbidity by 32% [85].

1.2. Importance of sanitation

Sanitation as a method of containment and sanitization of human excreta is of utmost importance as it prevents spread of diseases and protects both human and environmental health. In other words, sanitation systems form a barrier against the spread of diseases caused by pathogens and other organisms present in human excreta. Therefore, sanitation and *human health* are closely linked together. This fact has been known already for decades. A provision of the infrastructure, basic services, sanitation systems, which meet user's requirements, and promotion of hygiene has proven to be one of the most effective ways of improving health and preventing diseases. Inadequate treatment or disposal of human excreta and other waste can lead to transmitting and spreading of diseases originating form excreta. Polluted water and inadequate sanitation cause 5.7% of all epidemics [29]. There are many examples in history that are good pieces of evidence for it, example of which can be the 19th century England, where cities were undergoing rapid industrialization and urbanization, and major cities such as Birmingham, London and Manchester became centers of infectious disease [82]. "Sewage overflowed and leaked from the limited number of cesspools into neighborhoods of the poor and ultimately into rivers like the Thames, the source of drinking water [82]". In the late 1980s in Great Britain, the infant mortality was 160 deaths for every 1,000 live births, which is roughly the same as in Angola today [45, 82]. Back then in Great Britain children died mainly of diarrhea and dysentery, for the very same reason children still die in many developing countries – sewage was not separated from drinking water [82]. Edwin Chadwick, an English social reformer, with his "Report on Sanitary Condition of the Laboring Population of Great Britain" provided an account of crisis, documenting in graphic detail the consequences of the water and sanitation problem [82]. "The annual loss of life from filth and bad ventilation is greater than the loss from death or wounds from any war in which the country has been engaged in modern times". His recommendations concluded a private tap and a latrine connected to a sewer for every household and municipal responsibility for providing clean water [82]. The story from 19^{th} century Great Britain has parallel to what is happening in the developing world nowadays, especially in relation to how water and sanitation constraints social progress.

Water is indispensable for all life, but at the same time it also represents a major threat to human health. The main reason for it is that everything in nature depends on water, which also attracts certain substances and bacteria that might be life-threatening [28]. People are extremely vulnerable to diseases that are transferred through water due to the fact that their life is dependent on water. Together with the increasing global population there is more waste than the natural processes could handle. The vicious circle starts with waste getting into water sources, which become contaminated by bacteria. Water in a natural environment with a balanced lifecycle undergoes self-purification processes. However, if the environment looses its balance, water becomes polluted. If it is used as drinking water (containing a number of harmful bacteria types), human health is put at a great risk. Diseases that spread through water are the world's number one cause of death [28]. The most important water-related diseases will be discussed in the next section.

Sanitation is also directly linked to *environmental health* due to the fact that lack of sanitation can lead to release of untreated excreta to the environment, which in turn leads to pollution and degradation of water and soil quality. When raw wastewater is discharged into the environment, water bodies become contaminated by organic pollutant overload, pathogens or pollutants originating from industry, e.g. heavy metals. Accumulation of pollutants in water bodies may cause potentially irreversible environmental problems, especially groundwater pollution. Pollution of rivers, lakes, oceans and groundwater with sewage damages aquatic biodiversity and as a result, only a few forms of life survive [46]. Local people might be dependent on some of the affected species for food and livelihoods [46]. Also, aesthetic qualities of water bodies may be damaged leading to lost revenues from tourism. One of the major problems is also related to nutrient loads. With large urban centers the massive load of pollutants dumped into surface waters as sewage, is too heavy for the natural environmental mechanisms to act upon and break it down [46]. As a result, there is an increase in algal growth, oxygen depletion and blocking out light penetration to lower levels, which in turn leads to death of many aquatic species. Nutrient overloading takes place in rivers, lakes and oceans. Environmental degradation as a result of lack of adequate sanitation is as important as threat to human health and should be also given the highest importance.

"*Gender* roles of men and women determine access and control over water supplies, sanitation and hygiene in most developing countries [46]." It is generally women who manage water resources of the family and also suffer the most when they are faced with lack of proper sanitation. Also, when there are no safe nearby water sources, they have to walk long way in order to fetch drinking water. Moreover, they are at greater risk of physical abuse when they need to go outside at night in order to relieve themselves outdoors, in case they do not have an access to a private toilet. Also, when children are infected, they are the ones who need to care for them and cannot work at that time. In many sanitation projects worldwide, women were the motivating force for the sanitation improvement. For young girls, the lack of basic water and sanitation is often equal to lost opportunities for education. The time burden for collecting and carrying water is normally borne by girls and women. One estimate suggests that about 40 billion hours every year are spent on collecting water in sub-Saharan Africa [82]. When the distance from home to safe water source is short, girls attend school more often than if the distance is long [82]. Attendance rates for boys are normally not sensitive to distance from home to water source [82]. Moreover, young girls after puberty are less likely to attend classes if the school does not have suitable hygienic facilities. Also privacy and security of separate toilets is much more important for girls than for boys. "On one estimate about half the girls in sub-Saharan Africa who drop out of primary school do so because of poor water and sanitation facilities [82]". Disparities in education based on water and sanitation have lifelong impacts transmitted across generations. The physiology of women makes it harder for them to bear when they need to relieve themselves in the open, and they need more privacy especially at the time of menstruation and postnatal discharges.

It is normally the poor that cannot afford sanitation systems. City centers, where wealthier people reside, pump the contaminated effluents as far from themselves as possible and, in many instances, they ultimately end up in the poor areas. The urban poor are forced to live in environmentally fragile areas. People in developing countries often live on less than one dollar per day and in case of sickness they do not have any financial reserves to pay for their medical treatment. In such a case, they are even pushed forward to poverty and debt, continuing the cycle of *poverty*. In most cases, poor people lack resources to get medical treatment and they do not have political voice to demand better sanitation services [46]. Poverty and economy are interconnected; only healthy people are strong and can work to earn their living as well as take care of their and their families needs. There is an overlap between poverty and lack of access to improved water and sanitation (see figure 1). "About a third of people without access to an improved water source live on less than one dollar a day [82]". Also in sanitation, there is a strong association between poverty and access and the poorest two-fifths of households account for more than half the global sanitation deficit [82]. Almost 1.4 billion people that do not have access to sanitation live on less than two dollars a day [82].

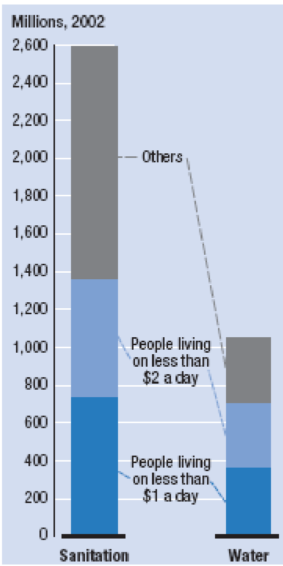


Figure 1: Poor people account for most of the water and sanitation deficit [82]

Human dignity is another important issue linked to access to safe water and sanitation. Access to safe, hygienic and private sanitation facilities is one of the strongest indicators of dignity [82]. Especially for women, lack of access to such facilities is a source of shame, physical discomfort and insecurity [82]. Women often wait till dusk in order not to be seen defecating in the open, but delaying bodily functions may lead to liver infections, not mentioning the physical discomfort they must endure. As already mentioned, women attach more importance to sanitary provision, because they feel the loss of dignity much stronger than men. People in general put a lot of importance to convenience, privacy and safety. Children, elderly and sick might find it difficult to go out at night in order to relieve themselves, so having an access to sanitation is also a matter of convenience.

On top of all the above-mentioned issues that are linked to water and sanitation, there is one more that needs to be recognized, namely the right of every human being to water and sanitation as a *basic human right*. In 2002, the United Nations Committee on Economic, Social and Cultural Rights approved a General Comment on "*the human right to water*… for personal and domestic uses" [82]. Right to water can be seen as a component of the right to life, health, housing, education, etc. Sanitation cannot be seen as a luxury but as a basic need and right of every human being and as such it is based on principles of equality, universality and freedom from discrimination [82].

1.3. Water-borne diseases

The main concerns about the safety of excreta are with feces due to the fact that urine contains few disease-producing organisms, whilst feces contain many [89]. The cause for pathogens contained in feces to spread can be mainly attributed to poor sanitation and hygiene. The routes, through which pathogens are spread, can be seen on the F-diagram presented in figure 2 below. The most important pathways for the transmission of diseases from feces are hands, flies, water, soil as well as food that have been contaminated by any of the first four factors [89]. Sanitation has an important task to fulfill, namely to break the pathway of infection by acting as a barrier against the spread of pathogens contained in excreta [89]. Thus, shortage or lack of safe drinking water and sanitation will lead to transmission of excreta related diseases.

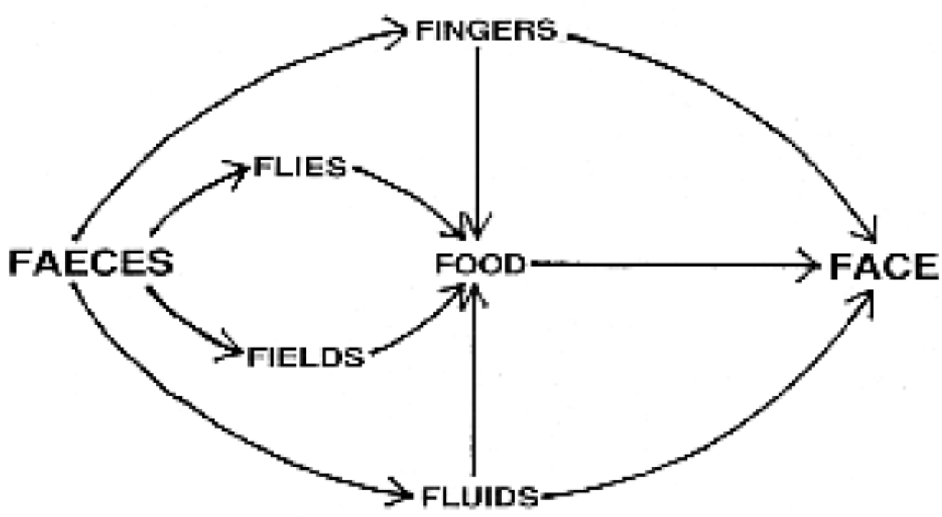


Figure 2: The F-diagram for transmission routes of pathogens from excreta [89]

There are many methods of classification of diseases that are spread by water, and the classification into four groups will be further discussed [28]:

- Diseases spread passively by water
- Diseases caused by water in the area
- Diseases caused by poor personal hygiene
- Diseases from water via a "host animal".

The passive diseases spread by water are transmitted by contaminated water. If wastewater is discharged without treatment into the environment or runs in open sewers through the cities, the drinking water resources will sooner or later become contaminated. In developing countries, especially poor people cannot afford safe drinking water. They sometimes draw the water from open sewers, even though it contains many bacteria. The most common diseases caused by these actions are *typhus, diarrhea, cholera and paratyphus* [28]. Diarrhea is one of the most important excreta-related diseases and it is caused by several bacteria and viruses [29]. According to the WHO (2004), 88% of diarrhoeal disease is attributed to unsafe water supply, inadequate sanitation and hygiene. Diarrhea is "… an acute malfunction of digestive system which causes watery excrement and continuous need for excretion. It creates rapid weakening of liquid and salt balance and the body starts to dehydrate [29]." Children are more vulnerable to diarrhea than adults. There are as much as 5 billion cases of diarrhea in children in developing countries each year [82]. Diarrhea is the second largest killer of children, with acute respiratory tract infection being the first. Diarrhea claims 1.8 million of lives of children under five each year (4,400 young lives every day) [82]. The transition from unimproved to improved water and sanitation source can reduce the probability of childhood death. Household data survey dealt with this assumption in 15 countries and the findings are striking. Both having piped water in the house lowers the incidence of diarrhea, e.g. by almost 70% in Ghana, 40% in Viet Nam and flush toilets reduce risk by more than 20% in Mali and Egypt [82].

One of the main *diseases that are caused by water in the area* is *malaria* [28]. The disease is caused by a microorganism carried by an Anopheles mosquito, which reproduces in standing sweet and brackish waters [29]. The organism gets to the blood via the sting of the female mosquito and multiplies in the liver. Then, the disease gets to the blood and fever follows [28]. According to the WHO (2004), 1.3 million people die of malaria each year, 90% of whom are children under five. There are 396 million episodes of malaria each year and most of the disease burden is in sub-Saharan Africa [85]. Also, *yellow fever* belongs to this group of diseases, however, it can be prevented with a vaccine [28].

Diseases caused by poor personal hygiene are mainly caused by lack of access to water, and as a result, people cannot keep themselves clean. *Trachoma* is one example of such a disease. The organism that causes trachoma is transmitted by hands and flies that land on feces and feed from seeping eyes [82]. Trachoma may lead to blindness and it is strongly related to lack of face washing due to absence of nearby safe water sources [85]. According to the WHO, improving access to safe water sources and better hygiene practices can reduce trachoma morbidity by 27%. Ethiopia is thought to have the largest number of blind people, with trachoma implicated in a third of cases [82].

Diseases from water via "host animal" include *bilharzia* and *schistosomiasis*. Bilharzia is caused by a host slug [28]. The larvae multiply via this slug and if people bathe in contaminated water, they may come into contact with the larvae, which will penetrate into the body through skin [28]. Most of the victims of this disease live in Africa. *Schistosomiasis* is another disease that causes tens of thousands of deaths every year, mainly in sub-Saharan Africa [85]. The disease is strongly related to unsanitary excreta disposal and absence of nearby safe water sources. Basic sanitation may reduce the occurrence of the disease by up to 77% [85]. The disease is caused by helminths. The larva of the flatworm swimming in the water pierces through skin and causes infection [29]. All untreated and natural sweet water in the infected areas should be considered as possible sources of infection [29]. Human and animal excreta spread the helminth to water bodies. Man-made reservoirs and poorly designed irrigation schemes are main drivers of schistosomiasis expansion and intensification.

Prevention methods for water-related diseases include: improvement and increase of access to safe water and sanitation services, using adequate toilet and paying attention to proper handling and disposal of excreta, promoting hygiene education, proper cooking of drinking water and food, keeping food and water clean, washing hands before getting in contact with food, general improvement of living conditions, encouraging breast-feeding instead of bottle-feeding, avoiding contact with contaminated water (swimming), using appropriate footwear and avoiding contact to ground contaminated with human excreta [29].

There are many more diseases that are related to water, but the point is not to discuss all of them in detail, but to make it understandable that none of these diseases gets a chance if good quality drinking water and adequate sanitation is at hand. If it is not the case, there is a high probability that contaminated water will be used for such purposes as drinking, food preparation, washing, swimming, etc. The result of which will be infection, sickness or even death. Provision of adequate sanitation and safe drinking water is of utmost importance with the purpose of assurance of public and environmental health.

1.4. The sanitation crisis

There have been many reports and studies published that deal with the issue of the sanitation crisis. The problem of access to safe drinking water and adequate sanitation has been addressed for the past two decades. As a result, millions of people gained access to safe water supply and adequate sanitation (see figure 3) [82]. However, as a consequence of the population growth and lack of sustainability in many of the conducted projects and investments, there is still a lot be done. How much remains to be done can be easily illustrated by the numbers provided by the WHO/UNICEF Joint Monitoring Program 2004, where they state that 1 out of 6 people worldwide, which can be translated to *1.1 billion* or 17% of the global population, remain without access to a safe water supply. Also, *2.6 billion* (2 out of 5 people), which represents 42% of the world's population, do not have an access to adequate sanitation [86]. These numbers are shocking and call for an immediate action. In sub-Saharan Africa, 42% of the population is still without improved water [85]. Even though global sanitation coverage rose from 49% in 1990 to 58% in 2002, the sanitation coverage in developing countries (49%) remains only half that of the developed world (98%) [86]. The biggest need for action is in developing countries as most of the people without access to improved sanitation reside in Asia and Africa. The term "improved sanitation" refers to connection to a public sewer, to a septic system, pour-flush latrine, simple pit latrine and ventilated improved pit (VIP). In sub-Saharan Africa a mere 36% of the population has an access to improved sanitation, with only 4% change between 1990-2002 [86]. Table 1 shows the list of countries where improved sanitation coverage in the year 2002 was a third or less, with Ethiopia being on top of the list.

What do these numbers actually mean? No access to improved sanitation may be translated to the fact that people are forced to defecate in ditches, plastic bags or on roadsides and are deprived of human dignity and privacy. Not having access to clean water means that people live more that one kilometer away from the nearest safe water source, so they are forced to collect water from drains, ditches or streams that might be infected with pathogens and bacteria or walk over long distances in order to fetch drinking water [82].

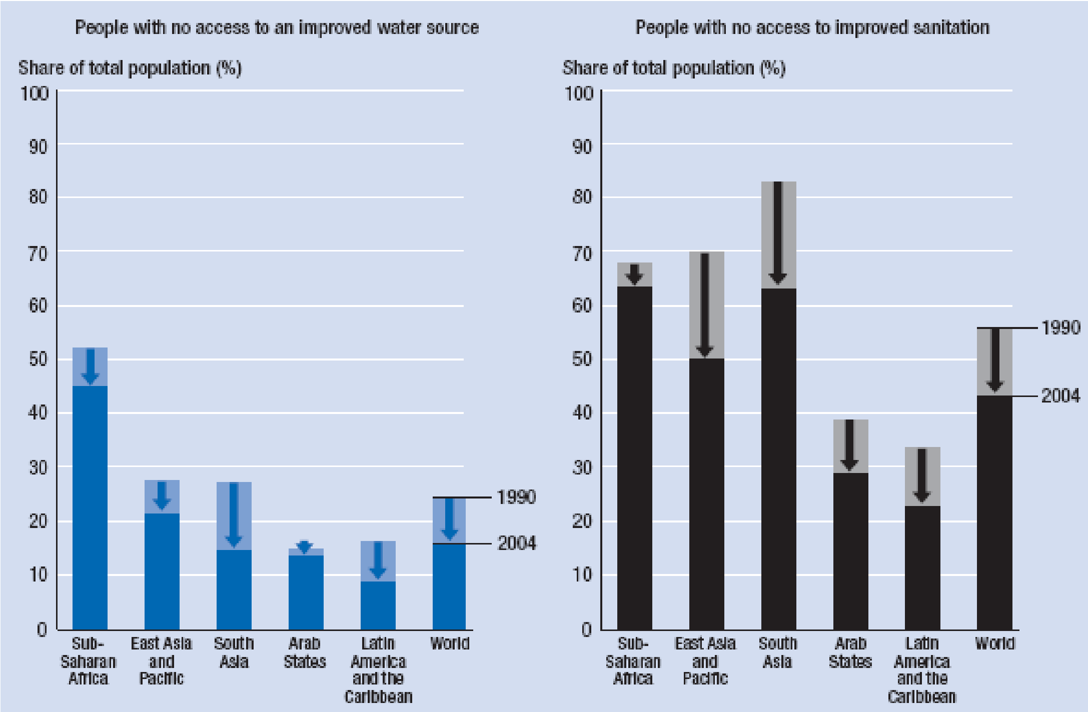


Figure 3: The global water and sanitation deficit [82]

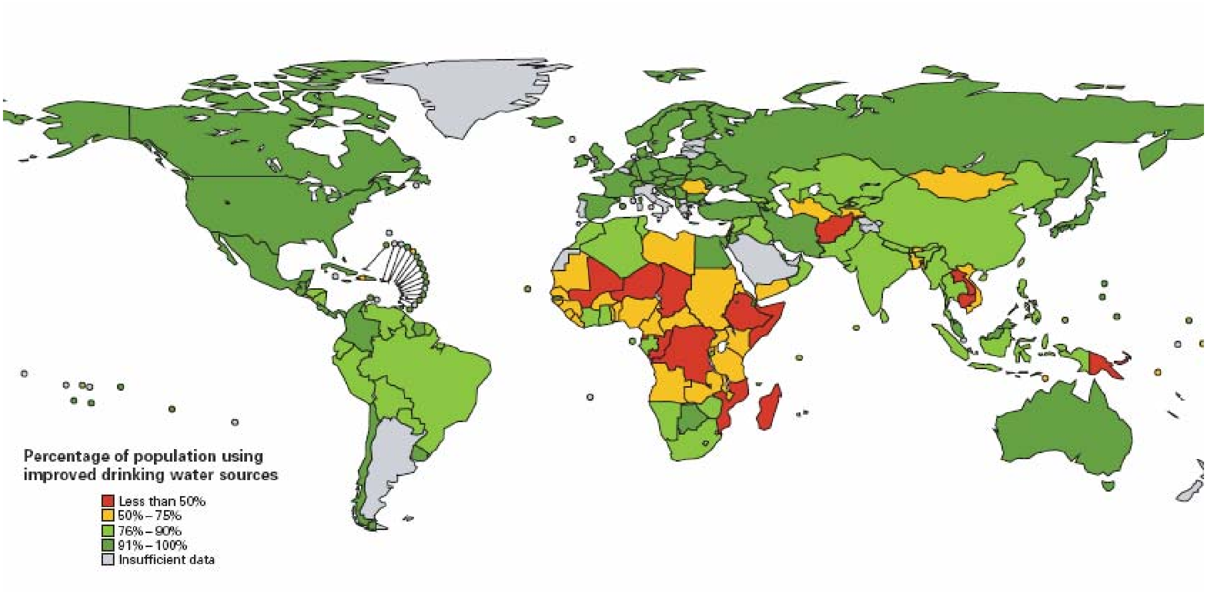


Figure 4: Coverage with improved drinking water sources in 2002 [86]

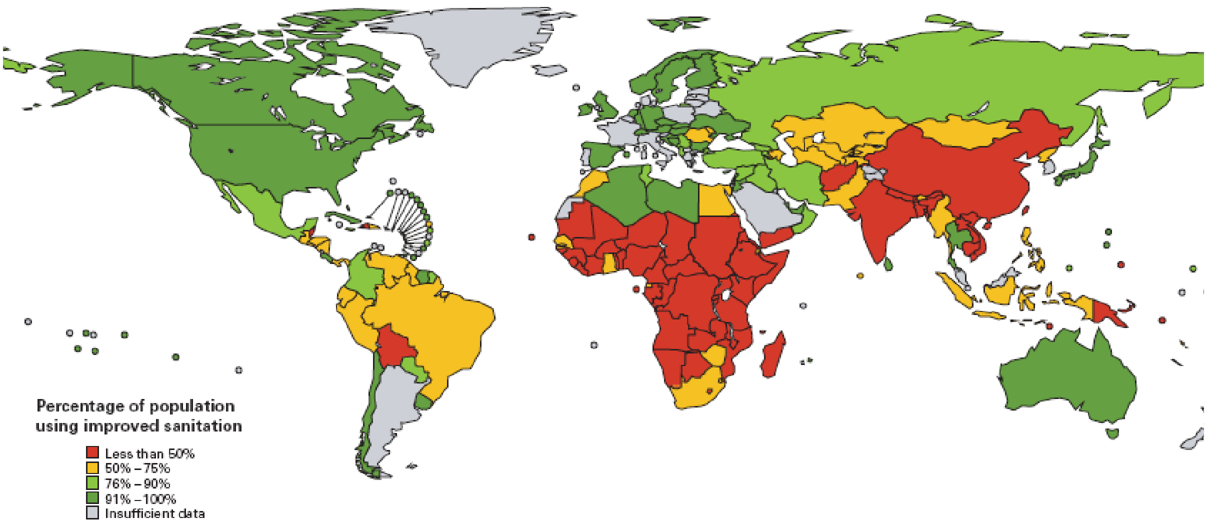


Figure 5: Improved sanitation coverage in 2002 [86]

Country	Sanitation coverage 2002 (%)	Country	Sanitation coverage 2002 (%)
Ethiopia	6	Central African Republic	27
Afghanistan	8	Mozambique	27
Chad	8	Nepal	27
Congo	9	Micronesia (Federated States of)	28
Eritrea	9	Congo, Democratic Republic of the	29
Burkina Faso	12	Angola	30
Niger	12	India	30
Guinea	13	Namibia	30
Cambodia	16	Yemen	30
Comoros	23	Solomon Islands	31
Lao People's Democratic Republic	24	Benin	32
Sao Tome and Principe	24	Madagascar	33
Somalia	25	Timor-Leste	33
Liberia	26		

Table 1: Countries where coverage with improved sanitation was one third or less in 2002 [86]

1.5. United Nations Millennium Development Goals and Sustainable Development

Following the report of The World Commission on Environment and Development in 1987, referred to as The Brundtland Report, and the United Nations Conference on Environment and Development (UNECD) held in Rio de Janeiro in 1992, *sustainable development* has been established as one of the major issues of our times. The Brundtland Report defines sustainable development as *"a development that fulfils the needs of the present generation, without compromising the ability of the future generations to fulfill their needs"* [92]. Sustainability means evaluating not only the consequences of choices for the present situation, but also taking into account the consequences for the future. Therefore, sustainable solutions must include components of achieving goals "now", whilst not neglecting the needs of "the future". Under the notion 'to sustain' one should understand *"to support", "to endure"* or *"to continue"*, which imply that sustainable practices must incorporate elements of making something last [11].

The notion of sustainable development is closely linked to the *United Nations Millennium Development Goals*. The United Nations Millennium Development Goals are eight goals that all 191 UN member states have agreed to try to achieve by the year 2015. The United Nations Millennium Declaration, signed in September 2000 commits the states "*to reduce by half the proportion of people without* <u>*sustainable*</u> *access to safe drinking water and sanitation by 2015*", which is formally referred to as goal 7, target 10 [74]. As of 2002, in order to meet the water supply MDG target, an additional 260,000 people per day up to 2015 should gain access to improved water sources, whilst to meet the sanitation MDG target, and additional 370,000 people per day up to 2015 should gain access to improved sanitation [85]. These numbers seem rather enormous and mean that huge amounts of investment are required, in case the conventional sanitation is considered. The reports on progress towards meeting the water supply and sanitation MDG target are not optimistic at all. In the latest report (2006), it was stated: "with half of developing country populations still lacking basic sanitation, the world is unlikely to reach its target" [71]. For details on progress towards reaching the 2015 MDG sanitation target, refer to figure 6 below.

Between 1990 and 2004, sanitation coverage in the developing world increased from 35 to 50% [71]. This meant that 1.2 billion people gained access to sanitation during this period. However, another 300 million people should have been served, in order to keep the world on track towards the 2015 target [71].

The problem with meeting the sanitation MDG goal seven is that access to improved sanitation does not always mean the same as sustainable access. For instance, pit latrines often fail to sanitize excreta and they contribute to groundwater pollution due to infiltration of liquids into soil and further seepage to groundwater reservoirs. Moreover, septic tanks and sewage treatment plants often discharge sewage into the environment with little or no sanitization as well as nutrient removal. Taking into account the above-mentioned circumstances, the number of people that need to get access to effective and sustainable sanitation might be much higher than 2.6 billion. Also, if investment on the conventional sanitation was made in developing countries, they would become indebted and, in most instances, it would prove not affordable for them. In other words, they would pay for systems that are most likely bound to fail either way and that would not be sustainable in the long run. Therefore, provision of sanitation in the developing world needs to be carefully chosen and implemented, taking into account the local conditions and preferences.

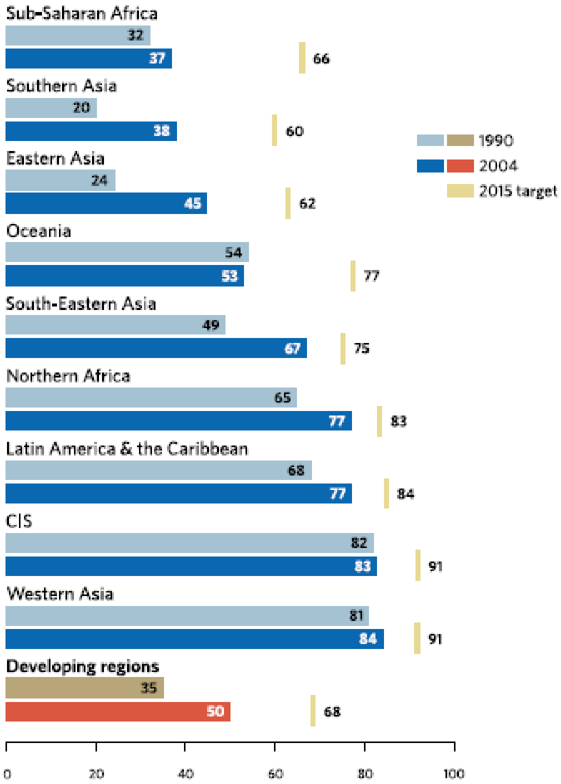


Figure 6: Proportion of population using improved sanitation, 1990 and 2004 (%), [71]

1.6. How people deal when nature calls in developing countries: examples of bad practice

The sanitation coverage values for Africa and other developing countries are low, but still people living there need to relieve the call of nature every day. When one does not have access to a toilet or does not have money to pay to visit one, the most common solution for them is a so-called “flying toilet”. It is nothing else but human feces wrapped into a plastic bag. People living in slums, like in the largest one in sub-Saharan Africa - Kibera, Kenya are quite disciplined and you may even not find them relieving themselves throughout the day. They tend to do it in between the houses when the sun goes down. They put their waste into a polyethylene bag and throw it as far away as possible, so it normally lands on someone else’s roof or a pathway. When the rain comes and washes the plastic bags out, there is a good chance that someone will see a bag and use it again, to carry firewood or maybe even food. This practice together with the massive congestion, lack of a sanitary infrastructure, inadequate housing, no latrines, no water supply, no waste collection, no repairs or maintenance and open sewers filled with raw sewage leads to very poor health and environmental conditions of these areas. Children are often found playing barefoot and when they step on human feces, pathogens are further transferred. Thus, it should be no surprise that sub-Saharan Africa is a region with the source of one half of the world's victims of mortality for children under five years old. Even if there are a few toilets around in the area, they are never enough to serve the number of people living there. Thus, for the majority the only way of answering nature’s call is a “flying toilet”. Where this solution is practiced, the excreta are not collected and their disposal is largely unregulated. Hence, it is a clear danger to human health. Not only “flying toilets”, but also open defecation and urinating are largely practiced. In a nutshell, people do what they need to and wherever they find a place for it without any regard for environmental health. However, people living in such surroundings are generally aware of the poor sanitary and health conditions they are faced with and they are willing to make things better. Many initiatives like the one in Kibera slum are good evidence for it.

In Kibera, the vast populous slum in Nairobi, Kenya, where the only accessible existing facilities can hardly serve half of the population, people practice the "flying toilet" way of dealing with lack of adequate sanitation services and they dump the plastic bags into ditches or onto the streets. "Two in three people in Kibera identify the flying toilet as the primary mode of excreta disposal available to them [82]". Kibera's inhabitants experience some of the worst deprivation in water and sanitation in the world. The slum settlement is among the most densely populated areas in sub-Saharan Africa (about 2,000-3,000 people per square hectare) [82]. In some areas of the settlement even 150 people share one toilet, which in many cases lacks privacy and security and is poorly maintained with broken walls and overflowing pits [82]. In one slum area- Laina Saba, there were 10 functioning pit latrines to serve 40,000 people at the end of the 1990s [82]. Sanitation coverage in Kibera is probably well below 20% [82]. A community-based organization (CBO) together with the African Medical Research Foundation (Amref) is campaigning to stop "flying toilets" in Kibera [61]. They select sites to build toilets and bathrooms and dig the pits, whereas Amref provides the materials [61]. Then, the community maintains the toilets and the users need to join their funds to pay for the toilet to be emptied [61]. The managers of the toilets earn the equivalent of 0.40 USD from every user [61]. However, this amount of money is still a lot to pay for the people living there, who do not generate any income, so they still relieve themselves elsewhere. So far, 62 toilets have been built there and 13 are under construction [61]. However, one may say it is just a drop in the ocean since there are about 4,000 toilets that are still needed [61].

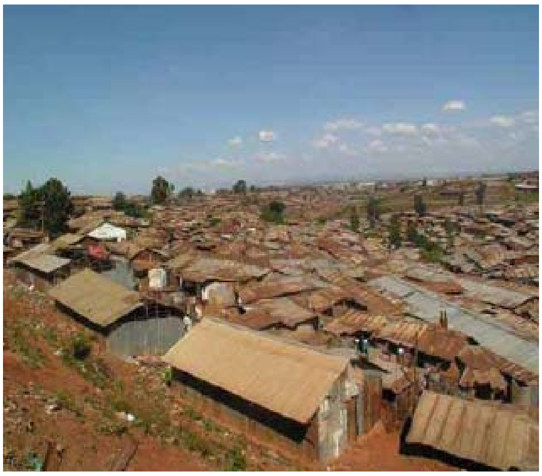



Figure 7: Kibera slum in Nairobi, Kenya (left), pit latrine in Kibera (right) [37]

In Dharavi, the Asia's largest slum in Mumbai, India, there is only one toilet per 1,440 people, and during the monsoon rains, flooded lanes run with human excrement [16]. "Across the countryside in Asia and Africa, people are forced to squat in streams, backyards and fields, befouling the water they drink, the places where their children play and the plots where their food grows" [16].

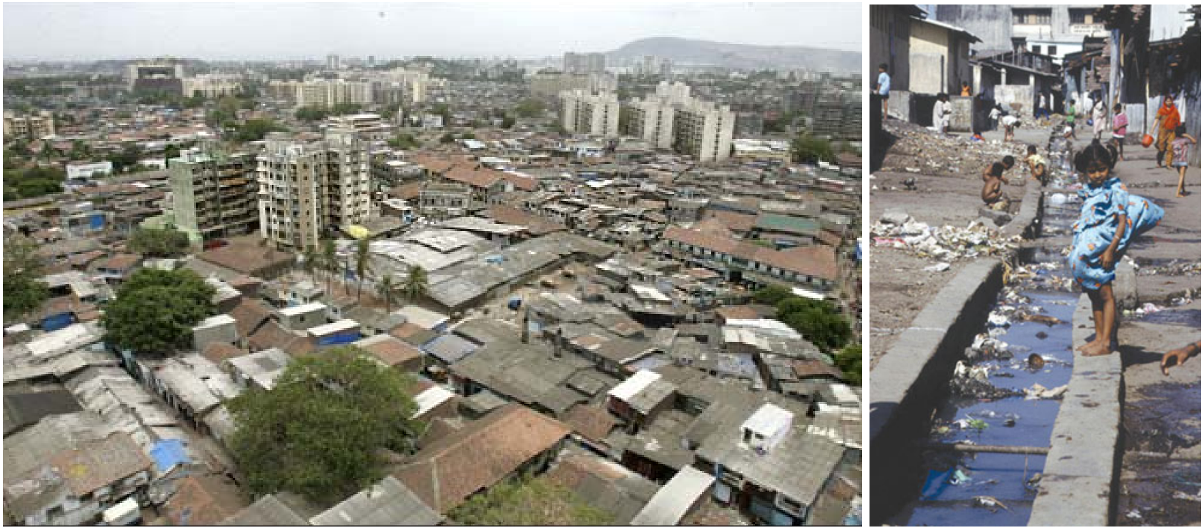


Figure 8: Dharavi slum in Mumbai, India[1]

When there are toilets available, they normally serve much more people than they were originally designed for. Thus, the condition of the toilets is rather poor with little maintenance being performed. Moreover, these toilets are normally pit latrines or their variants (e.g. a ventilated pit latrine), which require emptying, however, people using them either cannot afford to order a desludging truck or the lack of the infrastructure in these areas does not allow the truck to reach them. Thus, pits overflow quite often, especially during the rainy season and human excreta is flowing through the settlement, polluting drinking water resources. If there is manual emptying performed, it generally poses great health risks to the workers. They sometimes do not even wear protective clothes and are directly exposed to pathogens contained in human excreta. The majority of people also choose open defecation due to poor condition of available toilets. They pick a nearby bush or a roadside to do their business. In most of the developing countries such a behavior is not subject to fine because there is no regulation against it. Thus, people continue to behave in this manner and the problem does not vanish, but becomes of a larger magnitude with the ever-increasing population and no or little improvement of sanitary conditions. Pit latrines are already one step forward to the practice of open defecation or "flying toilets". However, they do not allow for reuse of nutrients contained in human waste. Also, their use is normally combined with nuisance of odor and pollution of water resources due to infiltration of solids into the ground. Moreover, pit's depth can be limited depending on soil conditions and water table. If local conditions allow only for shallow pits to be dug, they get full too fast and again the problem related to their emptying prevails. Also, there are instances of pits failure and collapsing due to poor soil structure. The above-mentioned practices can be grouped into two sanitation systems: so-called "do nothing" with open defecation and "flying toilets" and "drop and store" with pit latrines and their variants. Neither of these systems is able to provide adequate human and environmental health protection due to the fact that various vectors still have access to excrement, and fecal-related diseases still rife with millions of people dying of diarroheal diseases every year [86]. If there are water flush sanitation systems available, there is another problem to be tackled, namely the fact that treatment plants for the generated wastewater either do not exist or do not function properly. Thus, in most instances raw or

[1] http://news.bbc.co.uk/nol/shared/spl/hi/world/06/dharavi_slum/img/skyline_629_300.jpg

http://www.dfait-maeci.gc.ca/canada-magazine/issue30/site/images/current/main_littlegirl.jpg partially treated sewage is discharged into receiving water bodies. According to the World Resources Institute, as much as 95% of sewage in developing countries does not receive treatment and is discharged into receiving water bodies [93]. In Africa, virtually no wastewater receives treatment before it is discharged.

The above outline of available sanitation solutions in developing countries clearly shows that there is a need for action. There are many considerations that need to be taken into account such as the problem of illegal land occupation. Most residents in illegal settlements live in temporary mud houses on public land that has been illegally distributed or appropriated. It is an uncertain existence with regular disputes over plot ownership [61]. Given that the settlements are illegal, landlords are not obliged to provide any water or sanitation services, electricity, solid waste collection, the infrastructure and repairs or maintenance. Thus, provision of sanitation services is a multifold problem. Firstly, the municipality does not feel responsible for it due to the fact that the land occupation is defined as illegal. Secondly, landlords are also “illegal” in a sense and they are not obliged to provide sanitation services. Also, tenants do not feel a sense of ownership over their housing structures due to the risk of being removed from the land in case the municipality decides to get rid off illegal settlements. One thing still remains obvious; sanitation practices in developing countries need alternative approaches. They should respond to local demands and be appropriately simple, durable and inexpensive in order to provide for the basic human right and dignity and protect human and environmental health.

1.7. Challenges to be tackled in the sanitation sector in developing countries

One of main challenges to be addressed within the sanitation sector is the problem of *unsustainable projects* being implemented in developing countries or elsewhere. Such projects involve inappropriate designs, which neglect user’s requirements and preferences, as well as inadequate maintenance. Projects like these create a continuous drain on resources and a strong disincentive to the municipality and donors as far as further investment is concerned. Also, when users are disappointed by ill equipped sanitation systems they will revert back to unhygienic practices because they consider the promised improvements as unreliable. Sustainable projects need to rely on user’s involvement in planning, choice of service levels, scale of investments, charges and cost recovery structures [95]. One of the methods of addressing the sanitation problem in developing countries is the use of the conventional sewerage systems. As a result of this approach, overexploitation of natural resources has been taking place. Operation of the conventional sanitation systems is resource-intensive, thus they cannot be called sustainable. Improper operation as well as use and inadequate maintenance will lead to irreversible degradation of natural resources. Even though sanitation practices in developing countries still leave much to be desired, the conventional approach is not an appropriate solution to the sanitation needs in developing countries. How could they be if they use a great amount of valuable resources and generate more waste than the environment can assimilate. Furthermore, only dry conventional systems are affordable in most developing countries. As far as the conventional approach is concerned, there is not enough financial capability to construct, operate and maintain waterborne systems in areas where water is scarce and the infrastructure does not exist, is not properly used or not affordable for most of the possible users. Moreover, there are no technical capabilities available in these areas. Therefore, waterborne systems in developing countries are mainly limited to wealthy upper and middle class areas. What is more, treatment is not always guaranteed. It is becoming more and more common to think that developing countries should be given a different sanitation approach. The advantage of developing countries is that the infrastructure for the conventional approach is almost not in place and there is a large room for implementation of an alternative approach. Also, as far as developed countries are concerned, there needs to be a lot of rethinking done in the area of costs, resource availability as well as potential for environmental degradation. Developing countries need locally sound and sustainable sanitation approaches that are most appropriate to the purpose and local conditions of intended users [30]. The main decisive factors include: low costs, low maintenance requirements, local availability of installation, operation and maintenance materials, resource and skills, adequate institutional capabilities as well as social acceptance [30]. There is no doubt that sanitation services need to be provided in developing countries, but failure of unsustainable sanitation projects will deter people from being willing to implement and use them. Thus, the projects that will be implemented in developing countries need to be in line with local conditions and take into account not only technological, but also cultural aspects, and only then they will not be doomed to failure. The World Health Organization estimated that in the year 2002 at least 2.6 billion people in the world did not have access to improved sanitation (defined as a connection to a public sewer, a septic system, a pour-flush latrine, a pit latrine or a ventilated pit latrine). Conventional pit latrines usually fail to sanitize and add to groundwater pollution. Moreover, septic systems and sewage treatment plants often discharge no or only partially treated sewage into the environment and insufficient nutrient removal [17]. Thus, in reality more than 2.6 billion people worldwide need access to effective and sustainable sanitation. According to the EcoSanRes fact sheet on the sanitation crisis, pit latrines of various kinds serve about 2.8 billion people and often pose health and environmental hazards. Also, of the 1.1 billion people served by sewage systems, only 30% have advanced end-of-the-pipe treatment. "Sanitation can no longer be a linear process where excreta is hidden in deep pits or flushed untreated downstream to other communities and ecosystems. Sustainable and ecological sanitation calls for a holistic approach [17]." Therefore, the sustainable sanitation approach is the future of dealing with the sanitation crisis worldwide, also in Africa.

Global projections on the *population growth* suggest that the world population of over 6 billion in 2000 will increase 20% to over 7 billion by 2015, and to 7.8 billion by 2025, which equals to a 30% rise [94]. In 1950, 68% of the world's population was living in developing countries, with 8% in least developed countries [77]. By 2030, it is expected that 85% of the world's population will be in developing countries, with 15% in least developed countries [77]. On the other hand, the percentage of the world's population that lives in developed countries is declining, from 32% in 1950 to an expected 15% in 2030 [77]. The pace of *urbanization* poses a major challenge for the provision of the water and sanitation services that are so fundamental for health, dignity and economic well being of the urban population. Rapid urbanization growth in sub-Saharan Africa is mainly attributed to people migrating to cities in search for better livelihoods. According to the UN-Habitat, in 1800, only 2% of the world's population was urbanized, in 1950, 30% of the world's population and in 2000, 47% of the world's population was urban [77]. Estimates by the UN-Habitat (2003) show that ca. 70% of all urban citizens in sub-Saharan Africa live in slums. According to the United Nations Millennium Development Goals Report 2006, throughout most of the developing world the majority of people are already living in urban areas, which also means that the slums populations are becoming larger. As already mentioned before, sub-Saharan Africa is the world's most rapidly urbanizing region (refer to figure 9), and almost all of this growth has been taking place in slum areas, where overcrowding, inadequate housing and lack of water supply as well as sanitation services occur. For those involved in delivery of service in urban areas, the key challenge will be keeping up with the pace of rapid urbanization growth.

According to the World Health Organization, in order to meet the Millennium Development Goal of halving the unserved population by 2015, urban Africa will require an 80% increase in the numbers of people served [36]. This objective would require about 6,000 to 8,000 new connections every single day [36]. Looking at the worldwide statistics, one can see that most of the urban population growth is occurring in poor, unplanned and informal settlements. Given these circumstances, the task of reaching the unserved will become ever more difficult. In informal settlements such as slum areas, squatter or low-income settlements, water supply and sanitation provision are problematic due to the huge number of people living in these areas, inadequate housing, lack of a basic infrastructure and difficult geographical and environmental settings. On top of this, slum settlements are considered as illegal and as such they do not have legal recognition, thus there is no responsibility on the municipality side for provision of sanitation services. It is estimated that about 300 million Africans (half of the urban population in Africa) will be living in slums by 2020 [36]. This creates a new face of the sanitation crisis with significant proportion of the population living below the poverty line in overcrowded slums and sprawling peri-urban areas around major cities in developing countries. Lack of adequate services, including sanitation is one of the major problems that needs to be tackled in slum areas. Sanitation services need to be locally appropriate due to the high congestion, accessibility problems, lack of space and the infrastructure.

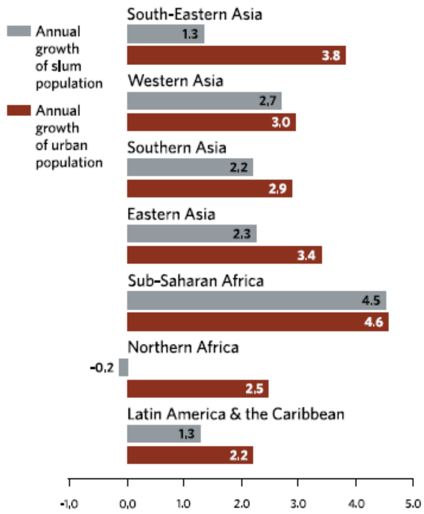


Figure 9: Annual growth of urban and slum populations, 1990-2001 (percentage) [76]

Hydrologists define *water scarcity* when less than 1,000 cubic meter of water is available per person and 500 cubic meters fall to the so-called "absolute scarcity" category [82]. The national threshold for meeting water requirements for agriculture, industry, energy and the environment is 1,700 cubic meters [82]. Nowadays, about 700 million people in 43 countries live below the water-stress threshold [82]. "Sub-Saharan Africa has the largest number of water-stressed countries of any region. Almost a quarter of Sub-Saharan Africa's population lives in a water-stressed country today - and that share is rising" [82]. Moreover, many of water-stressed countries experience population growth. Thus, water availability per capita is further shrinking. It is estimated that the water stress across Sub-Saharan Africa will intensify, with the share of the region's population in water-stressed countries rising from just above 30% to 85% by 2025 (refer to figure 10) [82]. What is more, the water use has been growing much faster than the population for at least a century—and that trend is continuing. Over the past hundred years the population quadrupled (from 1.6 billion in 1990 to 6 billion in 2000), while the water use grew by a factor of seven (water withdrawals have increased from ca. 500

km^3 in 1900 to ca. 3,830 km^3 in 2000) [82]. Moreover, climate change poses even more threat to the subcontinent, which with its large rural areas is highly dependent on agriculture. Sub-Saharan Africa has already quite variable and unpredictable climate and is highly vulnerable to droughts and floods. Along with the climate change, even more areas will become drier, increasing the number of people at risk of hunger and poverty. Climate-induced changes in crop yields will especially affect some of the poorest living in the subcontinent. With increasing water scarcity, sanitation systems implemented in sub-Saharan Africa should consider dry systems in order to avoid using the useful resource in order to flush human excreta when it could be used for crop production or elsewhere.

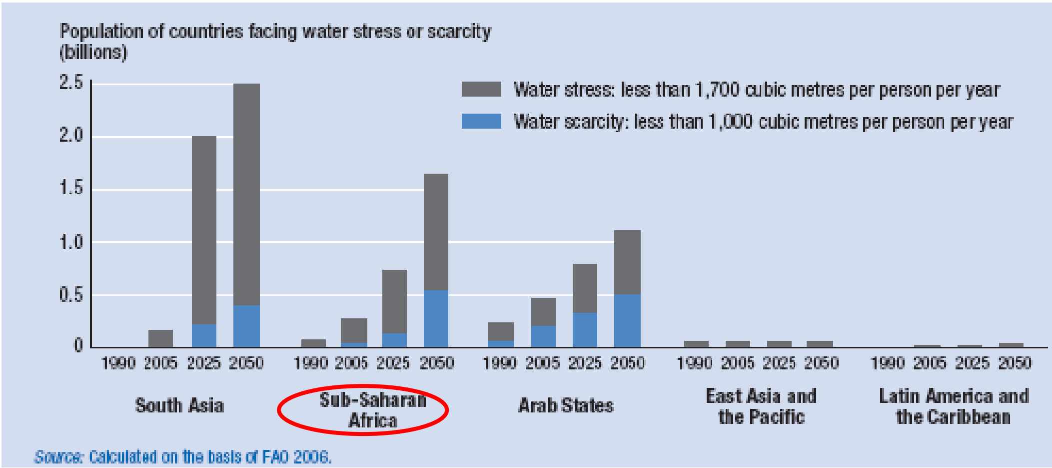


Figure 10: Population of countries facing water stress or scarcity (billions) [82]

Provision of sanitation in sub-Saharan Africa, like in a number of different regions worldwide, lags behind water supply and the lag in coverage equals 18% [82]. Access to clean water and adequate sanitation is one of the foundations for progress in human development. It is estimated that costs of water and sanitation deficit for Sub-Saharan Africa total 23.5 billion USD, or 5% of GDP - a figure that exceeds total flows of aid and debt relief in 2003 [82]. In other words, this is theoretically what the subcontinent might save if the entire population had access to basic, low-cost water and sanitation technology. As already discussed, unclean water and lack of sanitation is a threat to *human health*, already at birth. “Water and sanitation are directly implicated in a large share of deaths in children under five. The link: the 5 billion cases of diarrhea in children each year in developing countries [82].” Clean water and sanitation belong to the most preventative medicines for reducing child mortality [82]. Children suffering from water-related diseases carry the disadvantage to school. Moreover, the link from water insecurity to health and education stretches into adulthood [82]. Also, a country or region is not able to achieve significant growth and development if a considerable share of its workforce is suffering from disease. Some water-related diseases reach epidemic proportions in developing countries, an example of which is trachoma with Ethiopia being thought to have the largest number of blind people, with trachoma implicated in a third of cases [82]. Trachoma is strongly related to overcrowding and the absence of safe water for washing. An estimated 80% of transmission of schistosomiasis takes places in sub-Saharan Africa, causing thousands of deaths every year [82]. Schistosomiasis is strongly related to unsanitary excreta disposal and is transmitted through human contact with contaminated water [82]. Another disease linked to high population concentrations and poor sanitation is cholera. During the first half of 2006 there was one of the worst epidemics in sub-Saharan Africa, taking more than 400 lives per month in Angola [82]. On the basis of these few examples, it is evident that the health costs of water-related diseases in developing countries are rampant.

Moreover, lack of water supply and sanitation services disables girls from attending school, because they normally carry the burden of fetching water over long distances. Moreover, girls after puberty will deter from attending school if appropriate sanitation services are not present. "On one estimate about half the girls in Sub-Saharan Africa who drop out of primary school do so because of poor water and sanitation facilities [82]." Furthermore, lack of access to safe, hygienic and private sanitation facilities undermines human dignity. Especially for women it is creating a physical discomfort and shame. Thus, women attach more importance to provision of sanitation than men.

Sanitation services in Africa need a strategic and holistic approach, which takes into account local conditions, climate, user's preferences, adaptation to availability of materials, skills and workforce in all phases of the projects including planning, implementation, operation and maintenance. Only sustainable approaches that are locally sound will be able to overcome all the challenges including the ever increasing population, urbanization processes, water scarcity and impact of sanitation on health and well being of the residents.

1.8. Different approaches to sanitation

There are several approaches to sanitation that will be discussed in this section. They generally fall into three categories: conventional, ecological and low-cost sanitation.

The conventional approach to sanitation includes systems that collect and store human excreta, so-called "drop and store" systems (also known as pitsan), or collect and transport the excreta further from the households, so-called "flush and discharge" systems (also known as flushsan) [60]. *"Drop and store"* systems are normally simple, low-cost and require no infrastructure, but they also have many disadvantages [89]. In this type of systems excreta is collected in a chamber or pit, kept out of sight, and stored there. Pit latrine and its variations is a good example of this type of system. This method of sanitation is for sure a better option than open defecation, and it has already successfully prevented disease in some places, however, it does not allow for reuse of nutrients contained in human excreta. Also, it has some limitations such as it cannot be built on rocky ground, in crowded areas (due to lack of space and accessibility for emptying trucks), where the groundwater table is high or in areas that are periodically flooded [89]. They also require access to open ground and digging of new pits every few years [89]. "Drop and store" systems are often accompanied with odor due to the fact that urine and feces are mixed and the problem of fly and mosquito breeding is also an important nuisance. Pit latrines may pollute drinking water wells if they overflow or are inundated by seasonal flooding. The liquid part of excreta stored in a pit might find its way to groundwater and pollute it with pathogens and nutrients. Moreover, in most parts of the world, pit latrines are poorly maintained and continue to be a source of disease and pollution [60]. *"Flush and discharge"* systems are a well-established form of sanitation in developed countries. They require large amounts of water for flushing and large investments in pipe networks and sewage treatment plants. This system relies on using water to transport human excreta through underground sewers, ideally, to treatment plants, where wastewater undergoes a series of treatment combining of physical, biological and chemical processes before it is discharged to the environment. Flushsan systems mix feces, urine, flush water, toilet paper, greywater and stromwater with industrial effluents, usually overtaxing the capacity of treatment plants [60]. Over a year for each person some 400-500 liters of urine and 50 liters of feces are flushed away with 15,000 liters of pure water [89]. Water from bath, kitchen and laundry may add up to another 15,000-30,000 liters for each person [89]. The use of huge amounts of pure water for transportation of human excreta is one of the main disadvantages of this system, especially in the times of water scarcity in many regions in the world. Valuable drinking water is used as a carrier or, in other words, simply wasted. Flush and discharge systems have proven successful in combating the spread of disease and providing convenience of use, however, they have a number of disadvantages such as environmental degradation, heavy investment on sewerage, threat to public health if not properly managed, which will be further discussed in detail.

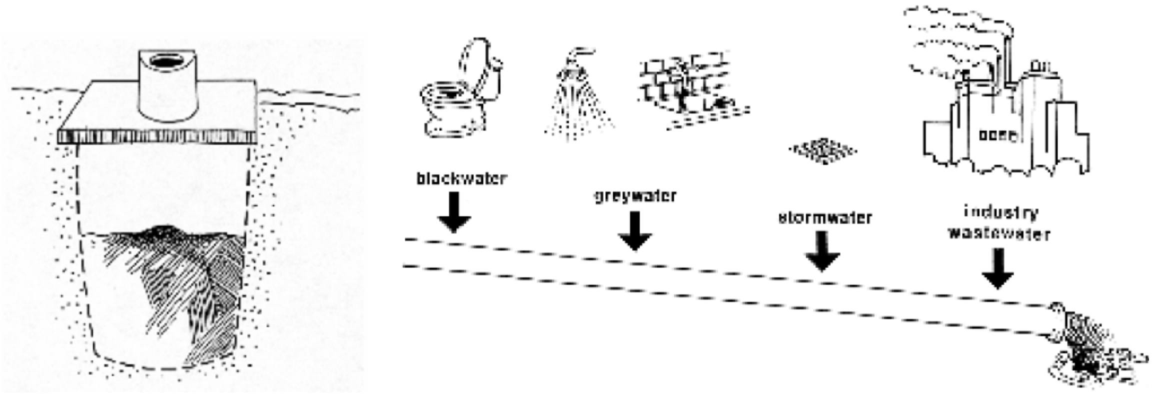


Figure 11: *"drop and store"* (left) and *"flush and discharge"* (right) sanitation approach [89]

1.8.1. The real costs of "flush and discharge" sanitation approach

This approach has high economic, environmental and public health costs. Sewer systems need heavy investment on constructing, maintaining of sewerage as well as sewage treatment plants [2]. Most developing countries, where such an infrastructure does not exist, cannot afford these costs. There are also a number of environmental costs of "flush and discharge" systems. Flush and discharge toilet is a big part of the model that is based on huge freshwater withdrawals, spending big sums of money for developing water resources, treating them to high standards, transporting into households and factories, then all the resulting wastewater is again collected, treated and dumped into surface waters [46]. In such a way the majority of urban water is thrown away after being used once, without nutrient reuse, without recycling, but spending huge amounts of money and great deal of energy for collection, transportation and treatment [46]. Looking at this description objectively raises many questions on the feasibility and sense of these actions. The process of treating water is energy dependent and it wastes a lot of energy, which is normally supplied from fossil fuels (a further problem in relation to the climate change) [46]. Environmental costs of flush and discharge systems involve heavy use of freshwater for urban areas, which leads to overexploitation of rivers [2]. Also, discharge of domestic sewage leads to heavy pollution of rivers and groundwater aquifers [2]. Figure 12 presents median percentage of wastewater treated by effective treatment plants in 2000. In Africa, virtually no wastewater receives treatment, but even in areas like North America or Europe not all wastewater is undergoing necessary treatment.

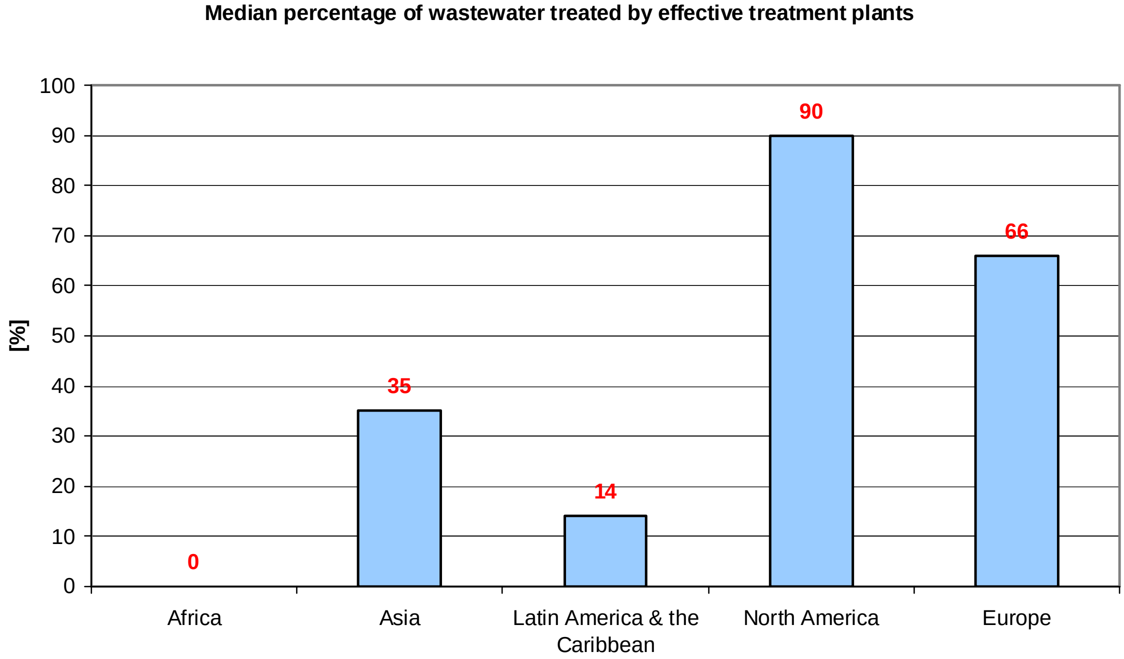


Figure 12: Median percentage of wastewater treated by effective treatment plants [84]

Moreover, by-products and waste products resulting from sewage treatment activities need to be disposed of in a safe way [46]. For instance, sludge resulting from biological treatment step contains pathogens, toxic organics and heavy metals and its disposal on landfills or reuse in agriculture is becoming more and more controversial [46]. Also, the nutrient cycle is disrupted due to the fact that sewer systems dump the nutrients contained in human waste into receiving water bodies [2]. This destroys them over time, leaves agricultural lands depleted of nutrients, and artificial fertilization follows [2]. If sewer systems are badly managed, they can become a serious threat to public health. There might be serious outbreaks of water-borne diseases resulting from river pollution, groundwater contamination, contamination of piped water supply systems (sewer leaks) as well as sewage backflows and sewer overflows. These problems are especially serious in areas prone to flooding. As a result of the above-mentioned economic, environmental and public health costs several political costs arise. There are growing tensions between urban and rural populations over increasingly scarce water resources [2]. Also, growing disparity between urban and rural populations in terms of waste disposal facilities has become an issue [2]. On top of this, there is also the already mentioned gender injustice as women suffer more than men in the absence of private sanitary facilities [2]. The points made in this section indicate that it is difficult to achieve sanitation with a general system of sewage treatment without introducing more complex and environmentally challenging effects [46]. In the light of the above-mentioned considerations there is a need for an alternative to the conventional sanitary approach that could solve the sanitary problems sustainably and more efficiently, which will be the topic of the next section.

1.8.2. Shortcomings of implementing the conventional sanitation approach in developing countries

Conventional sanitation systems are often used in developing countries. There is a perception that everything is better than so-called “do nothing” systems (open defecation), which are still often the case in many developing countries. As such "drop and store" systems can be viewed as a better approach than open defecation. However, due to the already mentioned disadvantages of these systems they do not provide adequate human and environmental health protection. When "flush and discharge" systems are implemented in developing countries, there is a high potential for them to fail due to the fact that investment costs are too high for the people to bear. Also, operation and maintenance costs of wastewater treatment plants are too high, so they either do not function well or do not even exist. As a consequence, raw sewage is discharged into rivers, lakes, etc. and pollutes them. None of the conventional sanitation systems is appropriate as a response to the sanitary needs faced in developing countries. "Drop and store" systems cannot be implemented in overcrowded areas and most of the sanitary needs emerge in such areas. "Flush and discharge" systems cannot be applied where people cannot afford the high investment costs on sewers and wastewater treatment plants and where water is too valuable due to water scarcity in many arid regions and cannot be wasted. In countries like Ethiopia, Mozambique, Ghana, Nigeria, Angola, Rwanda, Uganda, etc. where the average use of water per day in 1998-2002 was less than 50 liters, pure water cannot be used as a carrier for transportation of human excreta [82]. Developing countries often cannot provide continuous power needed to operate treatment plants or sewage pumping stations [46]. Over reliance on the conventional sewage systems can also be attributed to existing legal framework, which makes it easier to implement them [46]. Also, frequent subsidization of prosperous areas, and neglect of poorer settlements (particularly when water borne sewers are used) presents another problem. It is often the case in developing countries, where flush toilets can be found in rich settlements, whereas people living in slums are forced to defecate in the open. Despite the obvious shortcomings of the conventional sanitation approach, developing countries have a huge advantage, namely many regions have not been sewered yet. It can be translated to the fact that there is a potential for an alternative approach with efficient, feasible, and non-sewer systems to fulfill the sanitary needs.

1.9. Alternative approach to the conventional sanitation

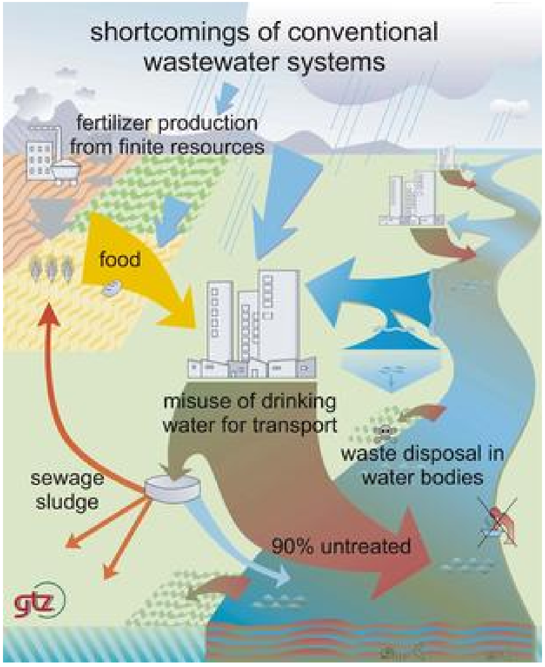
As already mentioned before, the conventional approach to sanitation is not the only existing one. This section will describe two alternative approaches; ecological and low-cost sanitation.

1.9.1. Ecological sanitation

Ecological sanitation (ecosan) is not a specific technology, but rather a holistic sanitary concept. It is based on three fundamental principles: preventing pollution rather than controlling it after the fact (the opposite of end-of-pipe systems), sanitizing of urine and feces and using resulting safe products for agricultural purposes [89]. Ideally, ecosan systems enable a complete recovery of nutrients in wastewater and their reuse in agriculture. This approach should be seen as a cycle, a closed-loop system that is *sustainable*. Ecosan treats human excreta as resources, which are stored, processed on site (further processed offsite if required) and the nutrients contained in excreta are recycled by using them in agriculture [89]. An essential part of ecosan is to contain and sanitize human excreta prior to their recovery and reuse. The basic differences between the traditional conventional sanitary approach and ecological sanitation may be seen on figure 13.

The principle of ecological sanitation is aiming at [55]:

- providing affordable, safe and appropriate sanitary systems,
- reducing the health risks related to sanitation, contaminated water and waste,
- improving the quality of surface and groundwater,
- improving soil fertility,
- and optimizing the management of nutrients and water resources



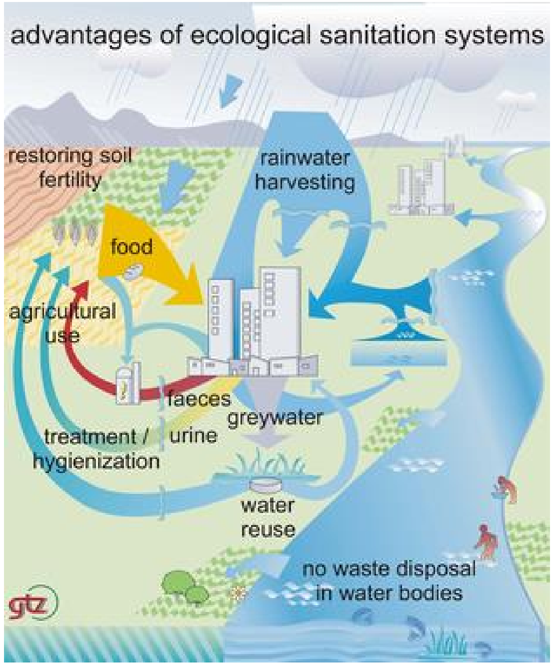


Figure 13: Shortcomings of the conventional wastewater systems (left) and advantages of ecological sanitation systems [GTZ, 2004]

Ecological sanitation approach is based on separate collection of separate flow streams. The characteristics of flow streams are presented in table 2:

Fraction	General characteristics
1. faeces	– hygienically critical, potentially containing a wide range of pathogens, leading to water-borne diseases (e.g. bacteria, viruses, protozoa, nematodes, worm-eggs) – consists of organics, nutrients and trace elements – improves soil quality and increase its water retention capacity – consists mainly of organic material, which can be submitted to decomposition processes, and a minor amount of nutrients – average production ca. 50 kg/cap/a
2. urine	– hygienically uncritical – contains the largest proportion of nutrients available to plants – may contain hormones or medical residues – consists mainly of nutrients available to plants and very little organic material, therefore no need for stabilisation – average production ca. 500 l/cap/a
3. grey water	– usually of no major hygienic concern – volumetrically the largest portion of wastewater – contains usually almost no nutrients (simplified treatment) – may contain a vast range of various substances – average production 25 – 100 m³/cap/a

Table 2: Characteristic of flow streams [55]

Ecosan systems bring back natural balance between the quantity of nutrients contained in excreta of one person in one year and that required to produce food. As such it will help to conserve limited resources, preserve soil fertility and safeguard long-term food security [55]. Recovering and reusing nitrogen, phosphorous, potassium, micronutrients and organics present in human excreta helps to minimize the energy and resource intensive production of mineral fertilizers and makes fertilization with recovered nutrients possible even to the poorest farmers residing in developing countries [55]. In the ecosan approach, flow streams with different characteristics; feces, urine, greywater are collected separately, as presented in figure 14. Thus, specific, cost-efficient treatment processes can be applied and optimized reuse follows. Also, unnecessary dilution of the flow streams is avoided, valuable drinking water is not wasted, and high concentrations of recyclables are produced [55]. Such concepts as rainwater harvesting and treatment of organic domestic and garden waster can also be integrated into ecosan projects [55]. What makes the ecosan approach even more valuable is the fact that it can also be implemented in centralized and combined flow systems. The ecosan approach by reducing water consumption and preventing contamination of water bodies allows for reduction of costs of water treatment and drinking water supply [55]. As a result of recovery and reuse of nutrients soil structure and fertility is improved, which in turn increases agricultural productivity [55]. The concept of energy recovery through anaerobic digestion of feces, organic waste and animal manure represents a significant step towards energy efficiency, providing biogas for cooking or lighting [55].

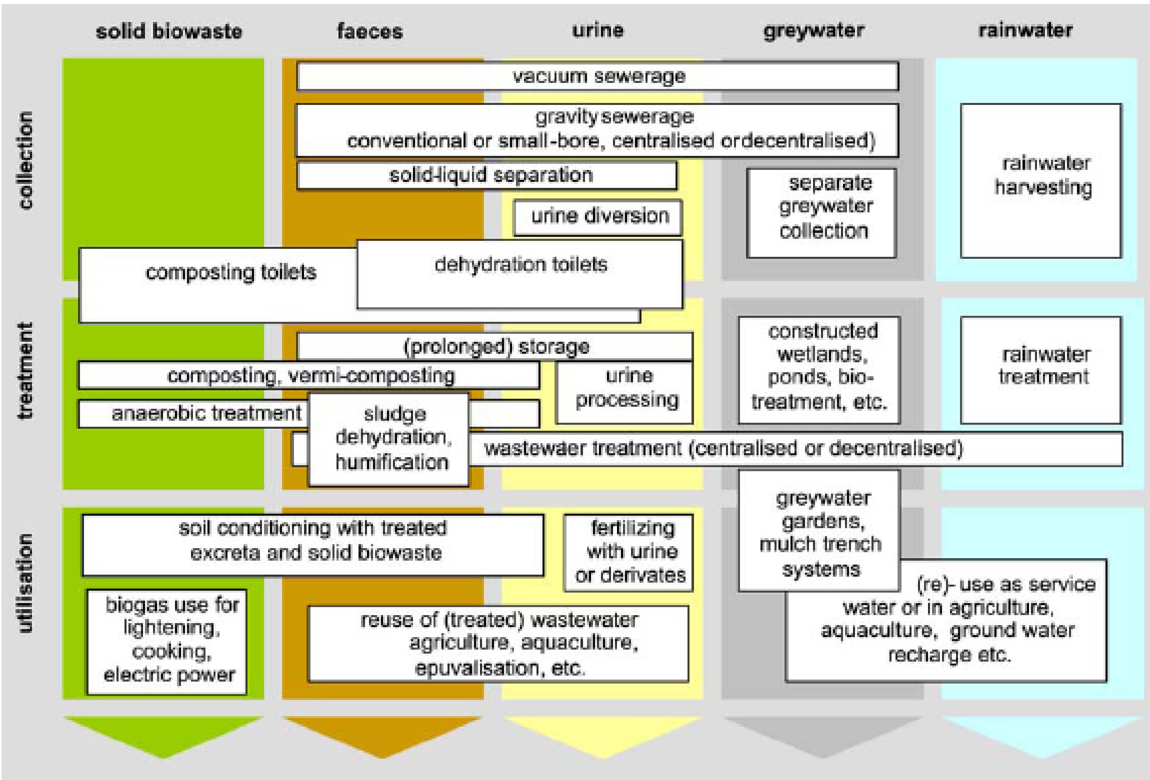


Figure 14: Essential technological components used in ecosan [55]

Ecological sanitation does not offer one technical solution, but recommends sanitary systems to fit the needs of social, economic and environmental sustainability in a given context [55]. Thus, a variety of technologies can be used under the common notion of ecological sanitation systems. They range from simple low-tech (e.g. urine diversion dehydration toilet, composting toilet) to sophisticated high-tech solutions (e.g. vacuum and membrane technology). Figure 14 presents the flexibility of choice of system technologies with wide range of technological components to collect, treat and use different flow streams, which makes ecosan suitable for all countries, no matter whether industrialized, developing or emerging.

To sum up, the advantages of ecological sanitation systems include [55]:

- improvement of health by minimizing the introduction of pathogens from human excrement into the water cycle,
- promotion of recycling by safe, hygienic recovery and use of nutrients, organics, trace elements, water and energy,
- conservation of resources, by lower water consumption, substitution of chemical fertilizers and minimization of water pollution,
- preference for modular, decentralized partial-flow systems for more appropriate cost-efficient solutions,
- possibility to integrate on-plot systems into houses, increasing user comfort, and security for women and girls,
- contribution to the preservation of soil fertility,
- improvement of agricultural productivity and hence contribution to food security,
- promotion of a holistic, interdisciplinary approach: hygiene, water supply and sanitation, resource conservation, environmental protection, urban planning, agriculture, irrigation, food security, small-business promotion.

The concept of ecological sanitation surely has many advantages. However, it also has some challenges due to the fact that it is a radically different approach from the conventional systems. As such it requires change in perception and behavior of users as well as local authorities. A shift away from the conventional pit latrine or flush toilet to ecosan is connected with change in behavior, which is what people generally find hard to undergo. There is also a perception that non-flush systems are of lower quality and convenience and people may find it hard to accept them. There also might be cultural constraints for reuse of sanitized excreta in agriculture. Also, current legislations are mainly focused on the conventional sanitary systems, which is another limitation to implement ecosan systems in many countries. Moreover, ecosan systems do not have much experience yet in implementation on a large scale, which could serve as a role model and be easily followed. Ecosan has all the characteristics to become a sustainable way of providing sanitation to all of these lacking access. The United Nations Millennium Development Goals urgently need an alternative approach to more and more criticized conventional systems in order to achieve the set sanitization target and ecosan has this potential. However, facing the above-mentioned challenges is crucial for the success of ecosan.

1.9.2. Importance of recycling of nutrients

As already mentioned, ecosan recognizes human excreta not as a waste, but as a resource that after being sanitized can be reused in agriculture. The conventional sanitation approach lacks nutrient recovery and the valuable organic material, nutrients together with trace elements flow linearly from agriculture, through humans to receiving water bodies. Even when sewage sludge is reused in agriculture only a very small fraction of nutrients contained in excreta is reintroduced into the soil [55]. Sanitation system should return nutrients into the soil. Failing to do so has caused an increasing demand for chemical fertilizers, for production of which large amounts of energy and mineral resources are used [55]. For instance, taking into account the current rate of exploitation of phosphorous reserves, in 60 to 130 years they will have become exhausted [55]. Figure 15 not only shows the huge amounts of wastewater produced per person per year and small urine and feces fraction in it, but also yearly loads of nutrients. Urine is a good resource for usage as a fertilizer, whereas feces with their humus-rich structure as a soil conditioner. Also, greywater can be treated for reuse in a more efficient way when it is not mixed with human excreta. When human excreta are mixed with large amounts of water (flush and greywater), they end up in a mixture that is potentially dangerous, difficult to treat and reuse of individual components is no longer efficient. More detailed information on reuse of urine and feces in agriculture will be given in the third chapter.

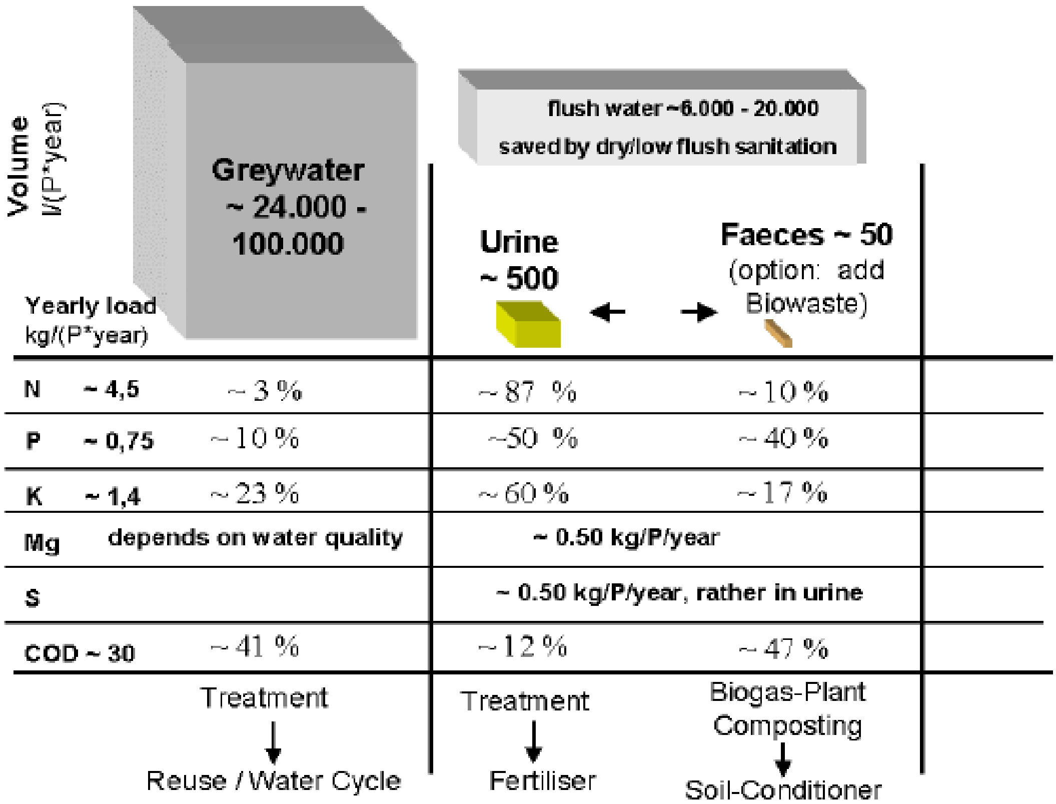


Figure 15: Characteristics of domestic wastewater flows with no dilution for urine and feces (wet weight) [53]

In a nutshell, ecosan promotes containment and sanitization of human excreta prior to their recovery and reuse. Human feces rather than urine are responsible for most diseases spread by human excreta [89]. Ecosan employs two methods of sanitizing feces: *dehydration* and *decomposition*. Dehydration is based on the principle of drying of feces, and is easier to achieve if urine is not mixed with feces. When feces decompose, harmful pathogens die and are further broken down. Both methods lead to destruction of viruses, bacteria and worm eggs. Only after being sanitized feces can be recycled. Urine, which is less harmful than fresh feces, can be used in agriculture after a short period of storage. On the contrary to the conventional sanitation approach, ecosan does not misplace the nutrients, but disposes of them and turns the cycle into a linear flow [89]. Figure 16 shows an example of a toilet based on sanitizing feces through decomposition, whereas figure 17- through dehydration. The Fossa alterna (figure 16) uses two alternating, shallow pits dug close to another. One is covered, whereas the other one is used for about a year [89]. Urine and feces are deposited into the pit and covered with soil after each deposit. After a second year when both pits are full, the first one is emptied (content is soil rich in nutrients and microorganisms) and used again [89]. In the urine-diverting toilet (figure 17), urine is never mixed with feces. If the first vault gets full, the second one is used. The contents of the first one are emptied, sanitized and further used as a soil conditioner, whereas separately collected urine as a fertilizer [89].

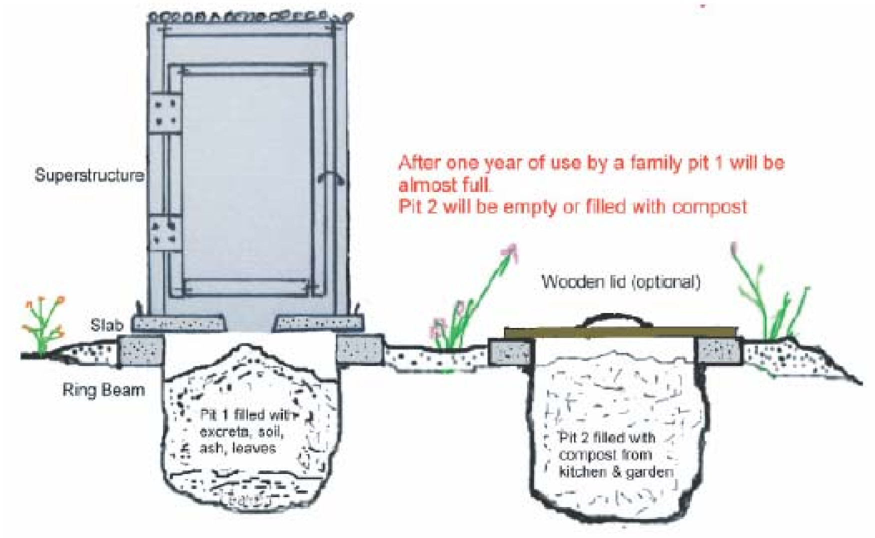


Figure 16: Fossa-alterna soil-composting pit latrine [60]

Figure 17: Double-vault urine-diverting dry ecosan toilet [60]

1.9.3. Low-cost sanitation

Low-cost sanitation approach is a cheap alternative to the conventional sanitation approach as it utilizes technologies that are similar to the conventional ones. However, low-cost sanitation is designed in such a way that it can be installed, operated and maintained at considerably lower costs than the conventional one. One example of low-cost sanitation is simplified or condominial sewerage, presented in figure 18. It employs pipes of small diameter laid at shallow depths to transport wastewater preferably by gravity offsite [54]. It is especially suitable in highly congested areas. Its lower costs are attained through reduced sewer length, pipes laid at shallow depths, and no need for deep and expensive manholes (junction or inspection boxes used instead). The success of this type of sewer systems is highly dependent on the community and it needs to be chosen upon the consultation with future users. Simplified sewerage can be seen as a conventional sewerage stripped down to its hydraulic basics.

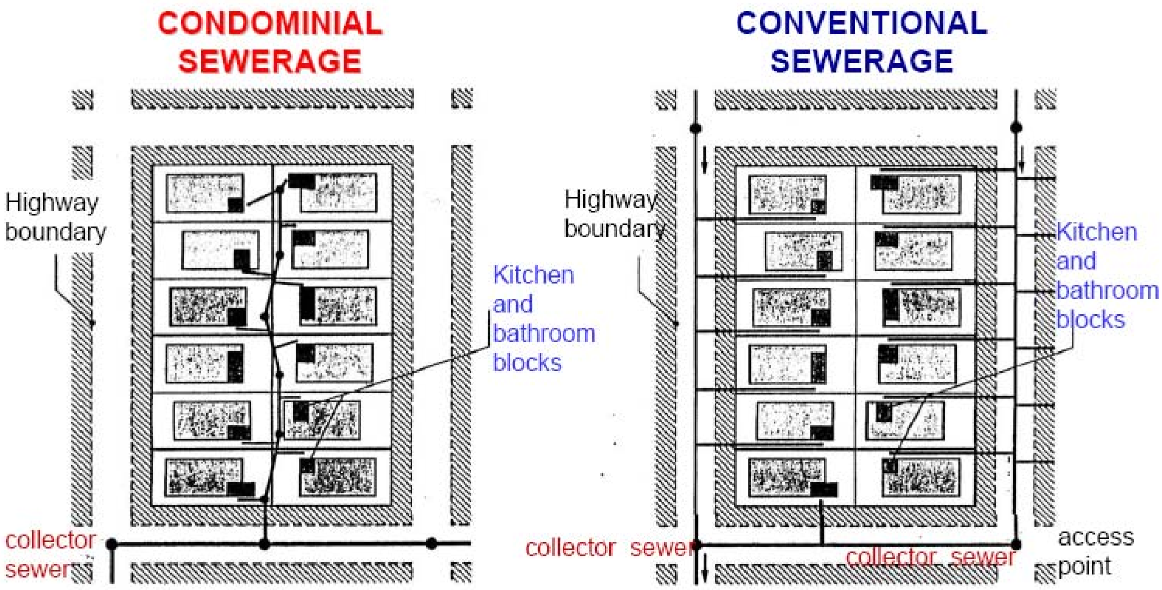


Figure 18: Condominial and conventional sewerage [54]

Low-cost sanitation technologies have many advantages, as they are quite similar to some of the conventional systems and their acceptance is normally not problematic at all. They utilize technologies that both users and authorities are familiar with and they have high potential acceptance. They can be built by using locally available materials, which saves costs and allows for community participation. If the systems are well designed, they are able to achieve all the objectives of a good sanitation system.

The described drawbacks of implementing the conventional sanitation systems in developing countries call for alternative approaches in the sanitation sector. Ecological sanitation and low-cost sanitation technologies offer a feasible and efficient option. Engineers worldwide should not limit themselves to over reliance on the conventional systems and try to answer local sanitary needs with alternative, sustainable and open-minded approaches in the light of meeting the Millennium Development Goals. Ecological sanitation together with low-cost sanitation approach offers a variety of solutions that could be adopted in both developed and developing countries.

The coming chapter will concentrate on the sanitary situation in Africa. It will present current condition, problems, challenges that have to be tackled and point out the need for public toilets in developing countries, with a main focus on Ethiopia.

Chapter 2: The need for public toilets in Africa

2.1. Africa- the scope of environmental and health problems

Not only is the African continent and its inhabitants daunted by civil wars and HIV/AIDS heavy death toll, but also its environmental and health problems are burning. Africa's residents are affected by a number of problems: strong poverty, civil wars, pollutants, diseases such as diarrhea, malaria combined with rapid population growth, poor education, lack of the infrastructure, lack of or inadequate sanitation and sewage treatment, poor environmental management, corrupt government policies, desertification, deforestation, overexploitation of resources and improper mining practices as well as overuse of pesticides and insecticides [11].

Sub-Saharan Africa with its 3% growth each year has the fastest growth rate of any region in the world [11]. Also, cities in Africa are growing tremendously fast because people come from rural areas to the cities in search for job opportunities and better life. The projection for the year 2010 envisages that 50% of the population will be living in urban and surrounding areas (as a comparison: in 1990 and 1991- 20%) [11]. Even though the fertility rates in Africa are so high, life expectancy in most African countries continues to stay lower than in most other regions in the world [11]. Also, infant and child mortality rates in many areas in sub-Saharan Africa are still among the highest in the world [11]. Top causes of death of children are mainly: respiratory infections, diarrheal diseases and malaria [82]. As already discussed in the first chapter, diarrheal diseases are most common where people live in crowded conditions, have poor food storage and sanitation and little potable water. According to the 1990 World Health Organization report, most of the estimated one to two million annual worldwide deaths from malaria occur in sub-Saharan Africa [11]. "Malaria thrives where stagnant pools of water provide breeding grounds for the Anopheles mosquito [11]." In order to combat the mosquitoes, DDT[2] or mosquito nets dipped in insecticides are still being used in many areas. What makes the environmental issues in Africa even more difficult to approach is lack of good data, especially solid baseline data [11].

As far as water supplies in sub-Saharan Africa are concerned, many of them are undrinkable and may be contaminated by a number of different pollutants: bacteria, sewage, heavy metals, silt from soil erosion, fertilizers, pesticides, mining tailings, industrial waste, etc [11]. Water and sewage treatment is rare in most African countries. As already mentioned in the first chapter, the WHO and UNICEF estimations in 2000 of the median percentage of wastewater treated by effective treatment plants stated 0% in Africa (refer to figure 8 in chapter 1). As far as solid waste collection is concerned, in many African countries waste is dumped in unauthorized dumping sites, including areas in the vicinity of waterways [11]. As a result, incidences of cholera, diarrhea, and dysentery are common [11].

High Africa's fertility rate requires higher agricultural production, which in turn results in excessive cultivation and grazing, which severely damages topsoil and leads to reduced agricultural productivity [11]. Moreover, when soil fertility drops, farmers start extensive use of fertilizers and pesticides, which in turn leads to contamination of local drinking water resources [11]. Air pollution is also prevalent since many households depend on coal and biomass fuels, e.g. wood, charcoal and crop residues, for cooking, heating and light [11].

[2] Dichloro-Diphenyl-Trichloroethane, pesticide

Resulting smoke contains particulates, carbon monoxide, nitrogen oxides, formaldehyde, benzene, and other simple and complex organic compounds [11]. Thus, children exposed to the smoke often develop acute respiratory infections [11].

2.1.1. Water supply and sanitation coverage in Africa

According to the Global Water Supply and Sanitation Assessment WHO/UNICEF 2000 Report [84], Africa has the lowest water supply coverage of any region in the world. The Report estimates that only 62%[3] of the population in Africa has access to improved water supply [84]. The situation is much worse in rural areas, where water supply coverage is only 47%, whereas in urban areas- 85% [84]. As far as sanitation coverage in Africa is concerned, the situation is also bad, and only Asia has lower coverage levels [84]. In the year 2000, only 60% of the total population in Africa had sanitation coverage, with coverage varying from 84% in urban areas to 45% in rural areas [84]. For graphical representation of water supply and sanitation coverage in Africa in the year 2000, refer to figure 19. As it can be derived from the figure, *Ethiopia* had the lowest water supply and together with Benin, Congo, Eritrea, Gabon and Niger the lowest sanitation coverage. According to estimations from 2002, the total population not served with improved water supply worldwide was equal to 1.1 billion, and the African continent was inhabited by 28% of the population not served [86]. It was estimated that 2.6 billion people worldwide live without access to improved sanitation and 437 million of them live in sub-Saharan Africa (refer to figure 20) [86].

An interregional analysis for Africa (2000) revealed that West Africa has a very bad sanitation coverage (48%), Central Africa has the worst (29%) while North Africa has the best (74%) followed by South Africa (63%) and East Africa (62%) [84]. It can be understood that more than one in three Africans lacks access to water and sanitation facilities [84].

According to the latest data from 2004, in sub-Saharan Africa only 42% of people in rural areas had access to clean water, and 63% of the entire population lacked access to basic sanitation facilities – down only from 68% in 1990 [76].

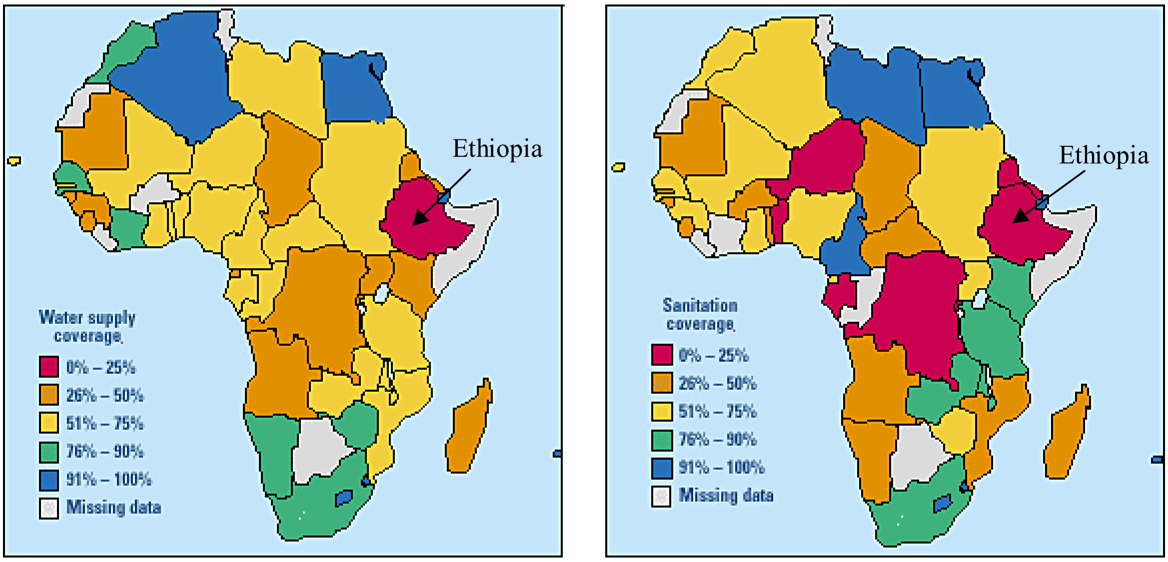


Figure 19: Africa's water supply coverage (left) and sanitation coverage (right) in 2000 [84]

[3] Based on estimates from countries that represent approximately 96% of Africa's total population

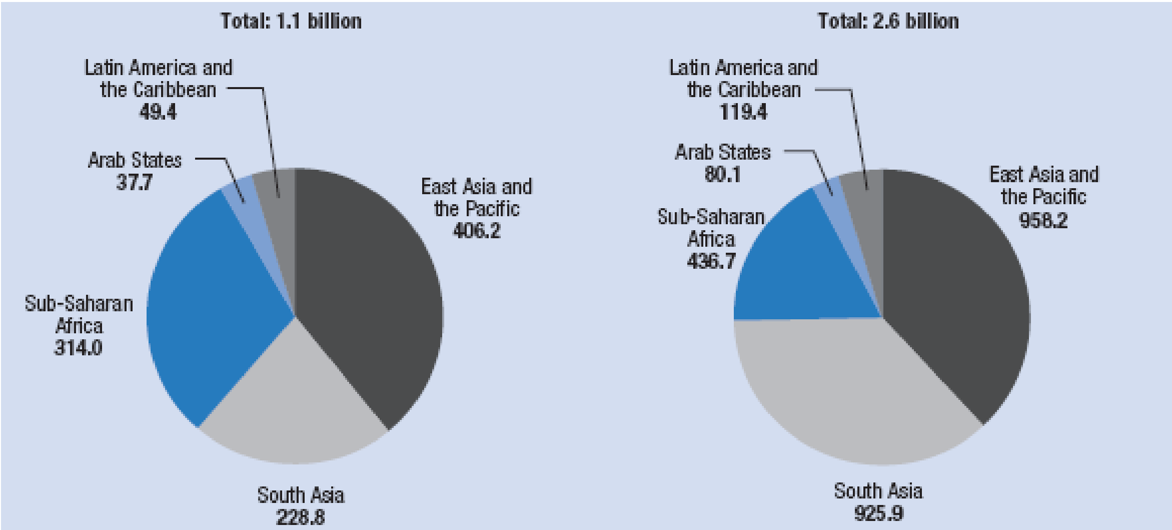


Figure 20: Population without improved water (left) and sanitation (right) by region in 2002 in mln [82]

Based on the UN Water Supply and Sanitation Sector Assessment 2000, the water supply and sanitation coverage trends for Ethiopia are summarized in figures 21 and 22 below [75]. Both urban and rural water supply coverage in 1990 and 2000 stayed the same and only total water supply coverage grew by 2 percent [75]. The same applies to the sanitation coverage considerations in Ethiopia. Thus, the problem of water supply and sanitation are one of the most important issues to be addressed there.

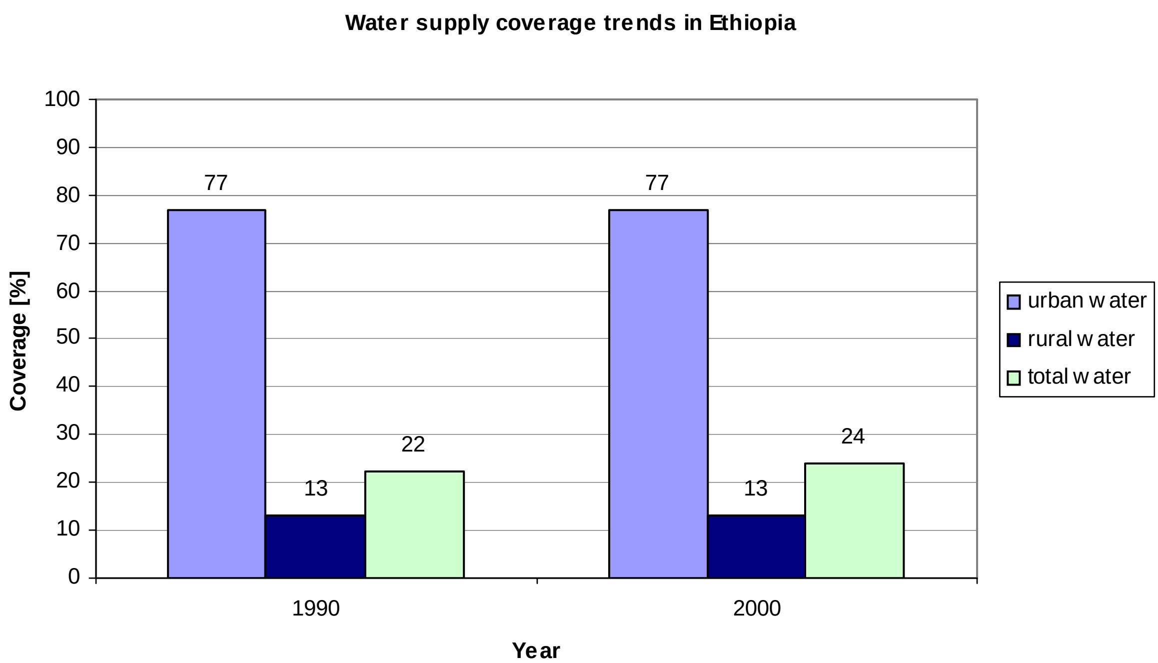


Figure 21: Water supply coverage trends in Ethiopia

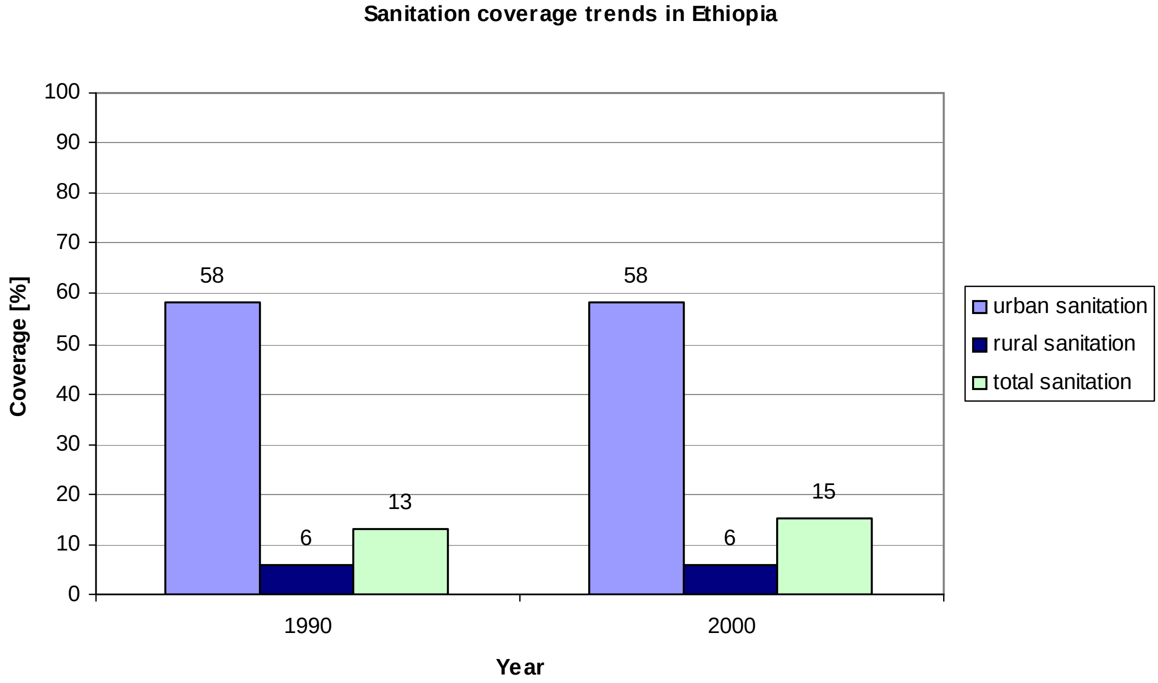


Figure 22: Sanitation coverage trends in Ethiopia

2.1.2. Household sanitation in Ethiopia

Census data on the prevalence of toilets in Ethiopia shows a very low percentage of households with their own or shared toilets [90]. The 1994 Census showed that only 6% of rural households had toilets [90]. Table 3 shows data from the Central Statistics Agency for the year 2000 for selected regions and the Ethiopian national data [90].

Selected Regions	Rural	Urban	Total
Gambella	24	56	31
Oromiya	10	73	18
SNNPRS	17	77	22
Tigray	3.4	59.3	40.4
Afar	1.4	40.4	10.8
Amhara	.6	53.9	7.1
National	8.9	71.6	18.1

Table 3: Population with latrines, 2000 in percent[4] [90]

The Central Statistics Agency in Ethiopia found a very low prevalence of toilets in the Welfare Monitoring Survey [90]. In the year 2000, 81.6% of rural households in Ethiopia had no sanitation facility in or near their homes [90]. As far as urban households were concerned, 27.6% of them had no sanitation facility (for details refer to table 4 below) [90].

[4] Based on Central Statistics Agency estimates for 2000. The data from Gambella, Oromiya and SNNPRS are taken from Kinde and Abebe, 2003; data from Tigray, Afar and Amhara are from Tekka and Mulugeta, 2003

Type	Rural			Urban			Total		
	1996	1998	2000	1996	1998	2000	1996	1998	2000
Flush toilet	0.6	1.4	1.7	2.4	4.4	7.0	0.9	4.4	7.0
Pit latrine	4.4	14.6	16.3	55.6	63.3	64.6	12.1	63.3	64.6
Container	0.1	0.3	0.1	0.2	0.9	0.7	0.1	0.9	0.7
Field/Forest	92.0	83.3	81.5	41.7	30.6	26.9	84.4	30.6	26.9
Other	2.9	0.4	0.5	0.2	0.8	0.8	2.5	0.8	0.8
Total	100.0	100.0	100.1	100.2	100.0	100.0	100.0	100.0	100.0

Table 4: Households by type of toilet facility [90]

The number of household toilets in the rural areas in Ethiopia is growing at a very slow pace. A rough estimate can be made of the time it would take, taking into account the present rate of expansion of coverage, until full coverage is obtained [90]. According to this estimate, it would take more than 100 years for all of the households in the rural communities of Ethiopia to have toilets (not taking into account the population growth) [90].

ULGA	% of population lacking pit latrines	No. of public latrines	No. of communal latrines
Awassa (SNNPRS)	30%	Included in number of communal latrines	6 (functioning and non-functioning)
Arba Minch (SNNPRS)	30%	None	none functional
Dilla (SNNPRS)	30%	None	none functional
Sodo (SNNPRS)	not known	none	none
Adama (ONRS)	26%	8	not known
Bishoftu (ONRS)	30%	5	6
Jimma (ONRS)	40%	2	not known
Shashemane (ONRS)	30%	7 incl. 3 for street children	not known
Harar (Harari PNRS)	overall 28% Jegol 43%	5	none identified

Table 5: Sanitation and public communal toilets in nine Ethiopian towns [1]

Table 5 above shows sanitary situation in nine selected Ethiopian towns [1]. It can be seen that the percentage of population without private toilets is between 26 and 43% and in most of the cases, public or communal toilets are present in a very small number or are not functional [1]. Thus, in places where provision of household toilets is not possible, more concern and effort should be put to construction of communal and public sanitation conveniences.

"Poverty remains one of the primary causes of most of sub-Saharan Africa's environmental health problems [11]". According to a 1994 report by the UNESCO Regional Office for Science and Technology in Africa, share of the world poor in Africa is 30% [11]. According to the United Nations, the proportion of people in sub-Saharan Africa living on one dollar a day or less is at 41.1% (down from 46.8% in 1990) [76]. In 2004, the number of extreme poor living in the sub-continent was equal to 298 million [76]. The high fertility rate in sub-Saharan Africa makes any progress one year an offset due to the increasing population in the following years. The United Nations proclaimed the 1980s the International Drinking Water Supply and Sanitation Decade [11]. At the end of the decade, the number served in many urban areas of developing countries had increased by as much as 80%. However, about 20 million more Africans were without safe drinking water and 30 million were without adequate sanitation at the end of the decade than at the beginning [11]. The reason for this is that population growth outpaced the improvements. The fastest growth rate in sub-Saharan Africa focuses attention and efforts of many organizations worldwide. There are many issues to be addressed and many improvements to be made. According to the latest UN Report from June 2007, despite the fact that there are already some "success stories", taking into account the current situation, none of the Millennium Development Goals will have been achieved in Sub-Saharan Africa by the year 2015 [76].

Previous considerations summarized needs, environmental and human health problems as well as many challenges, occurring globally, but with a main focus on sub-Saharan Africa. This work will concentrate on provision of resource-oriented sanitation service in the city of Arba Minch, Ethiopia. Thus, the next section will focus on providing information about the city, which was taken from the "Baseline study report of Arba Minch Town" drawn up as a part of the Resource-Oriented Sanitation Concepts for Peri-urban Areas in Africa (ROSA) Project.

2.2. Information on Arba Minch, Ethiopia

2.2.1. Location and topography [4]

Arba Minch in Amharic means "forty springs". The city is located in Gamo Gofa zone of the Southern Nations, Nationalities and Peoples Region, about 500 km south of Addis Ababa (the capital of the country) and 275 km south of Awassa (the capital of the region). Its geographic position is at 6°2'N 37°33'E.

The city of Arba Minch is divided into four sub-cities: Shecha, Nech Sar, Sikella and Abaya, which are further subdivided into sixteen kebeles (last administrative unit), named 1 to 16.

West and north of Arba Minch are steep and undulating chains of mountains and hills, which exposed the city to flooding and resulted in formation of several gullies and gorges within the town. In a nutshell, the topography of the town slopes in the direction north and northeast from Shecha and Nech Sar sub-cities, and gently dropping towards flat land in Sikela and Ababya sub-cities.

The territory of the town, which ranges between 1100 and 1350 m. a. s. l. in altitude, is classified as a lowland region.

2.2.2. Climate [4]

Arba Minch receives mean annual rainfall of 887.5 mm. It is characterized by bi-modal distribution, with two rainy and two drier seasons that occur intermittently. The highest total annual rainfall was recorded in 1997 (1253.9 mm) and followed by 2001 (1082.9 mm). The first rainy seasons occur mainly in April and May, and the second in October. The highest monthly total rainfall occurs in April and May while the lowest in December, January and February.

The mean minimum and mean maximum temperature amount to 17.37ºC±0.78ºC, and 30.30ºC±1.53ºC, respectively. The lowest possible mean minimum monthly temperature values were recorded in December (15.13ºC), while the highest (≥32ºC) mean maximum monthly temperatures are characteristic to the period covered three subsequent months i.e. December, January and February which are also the driest, the hottest days and the coldest nights months of the year. The annual average daily temperature is reported to be 20°C and the average relative humidity of the town is 53%.

2.2.3. Geology, Geomorphology and Soil [4]

Geo-morphologically, the city is located at the foot of the Ganta Mountain in the west and Lake Abaya and Lake Chamo in the east and south. The regional geological environment of the area is volcanics, composed of olivine basalt and tuffs, and undifferentiated quaternary deposits. The escarpment and plateau part of the Arba Minch area are made up of trap basalts, which form the highland areas west of Arba Minch, i.e. the Ganta Mountains. This unit is deeply weathered, fractured and faulted. This provides favorable conditions for the infiltration of water into the ground feeding the Arba Minch springs, as well as deeper percolation to the underlying aquifer systems within the alluvial deposits at lower elevations, between Lake Abaya in the east and Arba Minch town in the west. Alluvial deposits fill the rift valley floor near Lake Abaya and Lake Chamo at the eastern vicinities of the town. The sediments range from gravel to clay with varying proportions. Generally, the deposits are composed of gravel, sands, silts and clays. It is believed that the sediments are found in a loose way, i.e., not cemented, which helps to have good permeability and water holding capacity.

Commonly found soils include shallow sandy and rocky soils on slopes, deep sands on the valley bottom near the lakes, and thick clay soils in the valley below the “Bridge of God”, where the eroding sediments from the deep red soils on the cliff outcroppings are being deposited.

2.2.4. Population and population growth [4]

The population of Arba Minch is distributed in four major sub-cities and sixteen kebeles. According to survey data reported from the respective four major kebeles for the year 2006/2007, the total population of the town is estimated at 78,843. For the annual population growth and population of Arba Minch prepared by the Central Statistical Authority refer to table 6 below.

Year	1994	2000	2005	2010	2015	2020	2025
Annual growth	7.19%	4.94%	4.70%	4.46%	4.25%	4.02%	3.77%
Population	40,020	60,693	77,228	97,184	120,879	148,818	181,251

(Source: ESP- Component 3, 2002 and SNNPR Population and Statistics Office, 2004)

Table 6: Population and annual population growth in Arba Minch [4]

The National Urban Planning Institute (NUPI) estimated the population of the town to be 76,457 in 2005 and so the overall population density was estimated at 59 people/ha. The residential plot density was estimated to be 154 people/ha. Taking into account this number, an additional 681 ha of residential area would be needed to accommodate the projected year 2025 population (181,255). It is assumed that newly developed areas will have ever increasing population densities reaching an overall figure of 250 people/ha in 2025.

2.2.5. *Socio-economic characteristics [4]*

Water Mines and Energy Department (ZWMED) controls the water supply and sanitation services. However, the Regional Water Mines and Energy Bureau set the water tariff (for details of the water tariff refer to table 7). The water tariff depends on the rate of water consumption; the more water households use, the more they have to pay. Moreover, the regions have taken over the responsibility for implementing and managing water supply services. Nevertheless, the capacity to cope with increasing demands in terms of finance for investment, manpower, equipment, and spare parts is low at all levels. The regional government established local water service units as autonomous organization in selected urban areas. At present, the Arba Minch Town Water Service (ARB) is an autonomous governmental organization controlled by a board of management.

Consumption(m^3)	Birr/m^3
0-10	1.50
11-30	2.10
>30	2.70

(Source: ARB)

Table 7: Arba Minch Town Water Service water tariff [4]

The town is a mixture of various ethnic groups, but there is high tolerance among people to one another and respect to ethno-linguistically heterogeneous population of the town became the socio-cultural foundation of the society.

The overwhelming majority of the population is orthodox Christians while the next are the protestant followers. For further distribution of the population by religion refer to table 8 below.

S.No	Religion	% of population
1	Orthodox	75.53
2	Protestant	18.74
3	Muslim	3.86
4	Catholic	0.80
5	Traditional beliefs	0.17
6	Others	0.80
7	Not stated	0.11
8	Total percent	100.00
9	Total Number	40,020

(Source: CSA, 1994 Census)

Table 8: Distribution of population by religion in Arba Minch [4]

Generally, a typical household size of the town is 4.4 people and the total number of households is 12,835 (2006). Of the total 2,186 ha, 15 ha is the business center and 575 ha are built-up. The houses are mainly built of mud and about 57% of houses are owned (2002).

2.2.6. *Infrastructure [4]*

Arba Minch has a poorly established infrastructure. It has 15.5 km asphalted and 20.58 km gravel roads. The municipality reported that about 40% of the houses have electricity and 20% have a telephone. The town has two rather large open markets and some small petty trade markets.

About 48% of house units obtain water supply service from a neighbor as their main source and 17% use vendors.

2.2.7. *Water supply system [4]*

The water supply system of the town was extensively extended in 1987 and is based on 45 km of pipeline, a spring source, a 300m^3 and 500m^3 reservoir, four surface pumps and one stand-by generator. The distribution system covers all 16 kebeles. At the moment 5,332 households with a private tap and 34 public taps are connected to the distribution system. The Arba Minch Town Water Service (ARB) runs the water supply scheme. The present water supply coverage estimated by the ARB is 55% and is planned to be increased to 63.3% in the year 2006/2007.

The survey that was carried out indicated that out of 404 households only 3% have an in-house connection. Moreover, 57.9% of households have a yard connection, 22.3% use public water points and 20.8% buy water from vendors. The water demand for bathing and showering from a household connection is estimated at 20 l/c/d and for toilet 6 l/c/d.

The water supply system for Arba Minch town relies on abundant local springs from where water is pumped to two ground level storage reservoirs. Each reservoir serves two separate supply zones, which are further divided into two secondary zones by the use of pressure reducing valves.

The distribution system comprising 45 km of pipeline currently covers half of the town. It serves 34 public taps and almost 5,332 private connections. All connections and public taps are metered. The scheme is operated for 22 hours per day under normal conditions, producing the equivalent of about 30 liters of water per second.

Water quality analysis of the spring conducted in 2002 proved the water to be of excellent physical and chemical quality. Two hypochlorite preparation tanks were used at the spring site, however, they are no longer functional. Currently, a temporary chlorination is used at the 500m^3 reservoir site, but there are no facilities available for checking the chlorine residue levels.

2.2.8. *Sanitation [4]*

Ensuring appropriate sanitation for the entire town is the responsibility of the city municipality, however, it lacks the necessary infrastructure, manpower, financial resources and organizational setup for developing the sanitation system of the town. Crosscutting organizations such as the town health office do carry out some health, sanitation and hygiene promotion activities but their impact has been minimal. Arba Minch is facing serious sanitary-related problems due to the fact that a plan for implementation of management of solid and liquid waste is hardly in place.

The majority of the town population use dry pit latrines. According to the survey[5] on 1,100 houses the private toilet use was 53%, open field 12%, river 4%, and communal use was 31%. Another problem is related to pit emptying. The municipality does not own a vacuum truck. Thus, people normally depend on manual emptying carried out by people belonging to the Konso tribe. Nowadays, more and more often bigger institutions such as the Tourist Hotel and the Arba Minch University (AMU) are ordering vacuum trucks on a frequent basis, which come from different cities and their service is expensive. Bigger institutions might be able to afford their service, however, single households find it problematic, so they still depend on manual emptying. Also, sludge disposal is challenging and the municipality is now searching for a site that would be appropriate for it.

The baseline study results indicate that most households have squatting floors constructed of wood logs laid across the pits, with no or a temporary superstructure made of local material, a privacy cover of old clothes or pits without any privacy cover (refer to figure 23). People refer to these toilets as temporary structures, even though in some cases they have been in use for over 10 years. When the toilets are full, they are covered by soil and the depression is used for solid waste disposal. New toilets are also dug and two wood logs are placed for squatting. Gorges and jungle sites are potential open defecation areas and solid waste disposal sites.

Data from the transect walk survey revealed that 64% of the toilets surveyed were pits with squatting floor made of wood logs. Only 24% were made of pits with cement floor. About 10% of the households practiced open defecation (refer to figure 23).

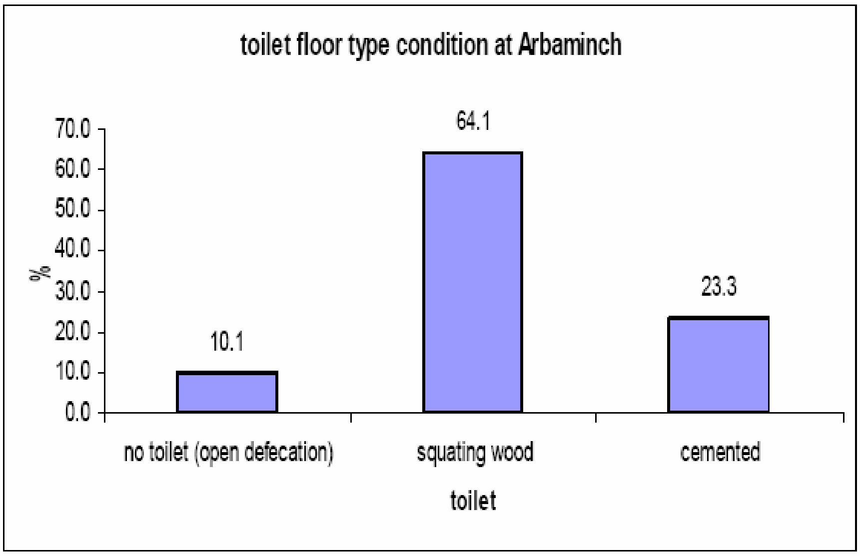


Figure 23: Toilet types used in residential areas in Arba Minch (transect walk survey results) [4]

[5] done by AMU students in 1996 on selected 7 kebeles

Figure 24: Pit with squatting wood [4]

The pits are normally rather shallow due to savings on excavation work and poor soil type. The contents of pits are normally soil, feces and urine so emptying with vacuum trucks is rather problematic. Thus, it is common practice to cover an old pit with soil and dig a new one. It is common to use papers ranging from hard to soft papers for anal cleansing. Practices of using water for ablution are also common, particularly among Muslim faithful and increasingly nowadays also among other non-Muslim residents.

Public toilets are another important sanitation issue to be considered. There are only two public VIP toilets constructed by the Red Cross in two parts of the Arba Minch town. Public toilets are not even present in the vicinity of markets or the bus station. Merchants and clients are using Kulfo riverside for defecation and urination. Passengers use nearby tearooms or hotels. Thus, the municipality needs help in designing appropriate public toilet system.

Inadequate access to clean water, poor environmental sanitation and malnutrition are the major factors contributing to problems of water-borne (diarrhea, gastritis) and water-washed (skin) diseases.

Age group	Cases	Bed Days	ORT	Other	Birr
Babies<3 months	2.00	20.00	0.00	1.00	245.00
Infants 3 to less than 12 months	1.50	11.00	2.50	10.50	19.5
Children 1 to less than 5 years	1.44	2.67	0.22	0.89	19.6
Children 5 to less than 15 years	1.13	3.88	0.38	1.00	47.1
Adult > 15 Years	1.40	5.30	0.30	1.80	29.4

(Source: ESP component-3, 2002)

Table 9: Incidences of diarrhea [4]

Table 9 shows that inhabitants of Arba Minch are vulnerable to water-borne diseases (diarrhea) due to the insufficient health infrastructure and poor sanitation facilities. Also, the trend of infection of the people diagnosed in 2001/2002 and 2005/2006 shows that there was much more cases of malaria, gastritis and urinary tract infections (U.T.I) in 2005/2006 than in 2001/2002.

2.2.9. *Solid waste management [4]*

Solid wastes in Arba Minch are poorly managed. Even though the municipality organizes the solid waste service, it covers only a minor part of the city (900 houses along main roads). Moreover, the location of disposing of the solid wastes is problematic. Currently, the solid wastes are disposed of in an open dump near Kulfo River in Sikela town and in gorge in the vicinity of town premises at Seicha. Solid waste is either dumped in gorges and open places, collected and left at household premises or burnt. The transect walk survey showed that ca. 60% of households taking part in the survey were throwing their solid wastes in their compound, 9% used the municipality collection service and the rest either burnt or threw their solid waste elsewhere, outside of the compound.

2.2.10. *Wastewater management [4]*

Arba Minch does not have facilities for wastewater collection and treatment. Most of households dispose greywater in their premises, whilst others outside of their premises (see figure 25). The latter want to avoid unpleasant conditions within their premises. Hotels, restaurants and other institutions produce large quantities of greywater. The practice of reuse of greywater is either limited or not present at all. Normally, a soak away pit is dug and greywater is collected there and when it gets full, it is manually emptied or channeled away through a hole dug sideways from the sidewalls.

The Arba Minch University, Arba Minch Teacher Training College, Arba Minch Hospital and Arba Minch Textile factory have their own wastewater collection and disposal facilities, but they sometimes do not operate well.

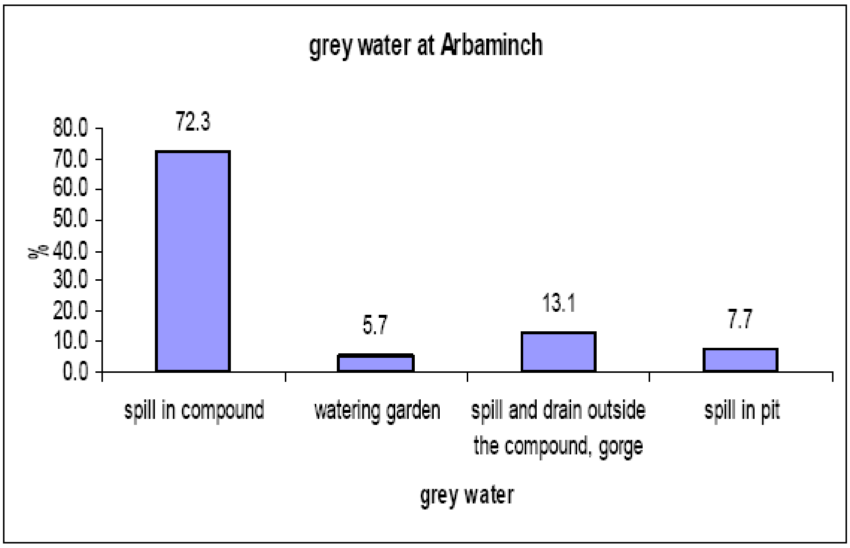


Figure 25: Greywater disposal method in Arba Minch [4]

Almost no public toilets facilities are available for inhabitants of Arba Minch, so some of them use hotel facilities for this purpose. Therefore, hotels have high wastewater production and blackwater together with greywater disposal is a major problem. Hotels and bars are using three ways of wastewater removal: manual emptying, vacuum truck or fill the old and dig new pits (for greywater disposal). When pits are full, a vacuum truck, which is ordered from other cities once in 4 years, empties them and the wastewater collected is disposed of in an open land far away from the city. Also, labor force might be used to empty pits. It works in a way that a new pit is dug next to the old pit. The old pit is emptied, its contents are transferred into the new pit and the first is left with the superstructure for further operation. The third way is to dig a new pit and leave the old one filled.

As discussed above, the Arba Minch town has a number of environmental problems that need to be tackled. As far as sanitation is concerned, there is a need for public toilets being built since the two existing ones are not enough. Public toilets are especially needed around the market places and at the bus station in kebele 11. A significant proportion of people living in Arba Minch practices open defecation, especially at the peripheries of the city where gorges are located. Also, open defecation is practiced along the Kulfo River and next to the market place, which poses serious health hazards to the population of Arba Minch. Looking at the summary of water, sanitation, housing etc. conditions in different kebeles (refer to appendix 1), it becomes obvious that water supply, wastewater treatment, safe disposal of solid waste, construction of toilets and their proper operation and maintenance are of utmost importance in Arba Minch. Resource-oriented sanitation projects are a good option for the city, especially due to the sustainability they bring along as well as reuse and recycling of urine and human excreta in the agriculture.

2.3. Peri-urban settlements

The word peri-urban may be used in quite a wide context. For the convenience of the reader the meaning it is and will be used in this work will be further explained. First of all, in many cities in the sub-Saharan African region the urbanization has spread into the countryside within the so-called peri-urban zones. What is more, rural and urban features tend to intersect within cities and beyond their limits. In this sense, peri-urban refers to the fringe of the city as well as to a context where both rural and urban features coexist in environmental, socio-economic and institutional terms [3]. In this context, peri-urban areas contain a mixture of population of poor households and producers. Environmental services together with natural resources are consumed in towns and cities. Peri-urban areas are characterized by presence of heterogeneous and rapidly changing socio-economic groups, whose livelihoods often draw on natural resource-based activities and urban opportunities [3]. Also, peri-urban areas have a mix of urban and rural land uses as well as economic activities. These areas are normally located outside of the core of formal water supply and sanitation network. Peri-urban settlements are also informal settlements commonly referred to as squatter settlements or urban slums and in this exact sense they will be understood in this work. The main characteristics of these settlements include: unplanned housing structures with houses mainly built using mud and corrugated iron sheets (inadequate housing), lack of or minimal access to the infrastructure and services such as solid waste collection, storm water drainage, street lighting, roads, footpaths, low water and sanitation coverage and low-income settlement [37]. They also tend to be ignored in municipal planning. The low coverage of water supply and sanitation services in peri-urban areas may be mainly attributed to institutional issues, namely cost recovery imperative leads to neglect of the urban poor [37]. What is more, these settlements are not formally recognized. Another issue is affordability of these services by low-income users, with the majority living on less than one dollar per day. Daily water consumption in peri-urban settlements is constrained (e.g. Addis Ababa 20 l/ capita, day) and the cost of water provided by water vendors is simply unaffordable (Addis Ababa- about 1 USD/m^3) [37]. Especially in these areas, sanitation problem should be addressed by provision of appropriate and sustainable sanitation options and future users should be involved in selection of options. One of main problems that needs to be addressed in these areas is lack of adequate policy to address peri-urban issues and lack of a clear regulatory framework. In these areas it is common that there is not enough space available for individual toilets to be built and used by single households. A good example of this is Addis Ababa, the capital of Ethiopia, with the estimated population of 2,640,000 in 2000 [36]. The majority of low-income households in the city live in houses owned by kebele, which is the smallest administrative unit of the city administration. Many houses are mud and wattle constructions. Sanitation in households is normally provided through pit latrines and septic tanks. The 1994 census stated that 75% of households in Addis Ababa had toilet facilities [36]. What is more, congested areas, where urban poor live, do not have enough space for individual toilets to be built. Therefore, residents of low-income areas use community toilets that are shared by five to ten families. Operation and maintenance in areas like these might become problematic due to the fact that housing is occupied by tenants. It discourages investment and household's sense of responsibility for maintenance of shared facilities becomes diluted [36]. However, the sanitation project[6] undertaken by an NGO managed to improve sanitation conditions in four kebeles. Their approach was based on building an enhanced sense of ownership and responsibility on users by delegating management of these facilities to them [36]. This brief example shows that challenge of providing and operating adequate sanitation services in low-income areas, which do not have legal recognition, may be addressed by the authorities as well as by the users themselves. The latter need to feel a sense of ownership over the sanitation structures, otherwise they will not be maintained and taken care of accordingly and will sooner or later fail.

In the city of Arba Minch in Ethiopia, peri-urban settlements are not a significant problem and only some slum settlements, which are located around the market area, can be found in kebele 12. There are some parts of the town where congested settlements with rented houses are to be found. Also, in several parts of the town, there is not enough available land or the soil structure is not appropriate for digging pits, so people either share a single toilet or practise open defecation. However, the large-scale low-income settlements alike the one in the outskirts of Nairobi, the capital of Kenya is not to be found in Arba Minch. Thus, the above considerations are of general interest and do not apply to the area of the city for this particular project of a resource-oriented public toilet.

2.4. Importance of understanding culture for sanitation projects

The impact of socio-cultural aspects on sanitation projects cannot be underestimated as it clearly plays an important role, especially in developing countries. There are numerous examples where lack of such knowledge resulted in people reverting to their old sanitation habits instead of using the constructed toilets. One example comes from India where toilets were placed in the northeast corner of the plot and the local Hindi belief practiced by the inhabitants let them think that this location was inauspicious and so they refused to use them [44]. Cultural beliefs differ in various parts of the world, thus it cannot be assumed that sanitation practices that worked in one place can be easily transferred elsewhere. Understanding local culture is crucial for the sanitation project to become successful. Sanitation arrangements vary in different places in the world and so sanitation culture is different worldwide. The perception of human excreta and the resulting arrangements for

[6] Integrated Holistic Approach Urban Development Programme

managing feces and urine depend on a number of factors; mainly culture, economy, urban/rural population pattern and gender [20]. In some cultures, toilets themselves can be viewed as dirty and evil places. Thus, it might be even considered more sanitary to defecate in the open, far away from the housing structures. Provision of sanitation services needs to be in line with local beliefs, preferences and cultural sensitivity; otherwise it will be doomed to failure.

Choices and behaviors towards sanitation are deeply rooted in a cultural understanding [78]. When planning an ecological sanitation system, three social aspects must be taken into account, namely psychological deterrents associated with handling of human excreta, gender issues, and last but not least, the influence of religion [78]. “When developing an alternative toilet system, formulating a psychological contract with the potential users is just as important as designing the system itself [78].”

Attitude towards excrements is rather universal, and generally people are repelled by excreta. This attitude is based on three components: perception, cognition and behavioral tendency [78]. Perception can be defined as the way we feel about something [78]. Logic and rational thought have nothing to do with perception [78]. The common perception of excreta in different cultures is rather negative. Cognition deals with our rational thoughts [78]. As far as cognition of excreta is concerned, similar to perception, universal notions about excreta are rather threatening and harmful. Behavioral tendency explains why some cultures are more disposed to handling excreta than others [78]. Behavioral tendencies towards excreta are instinctive; we trust our instincts and behave accordingly. Moreover, our attitude towards excreta is influenced by experience, thus it evolves and changes over time [78]. For adults, privacy becomes a primary concern, and public conveniences are seldom considered as convenient [78].

Gender plays a significant role in sanitation considerations due to the physical differences as well as privacy issues. Women tend to have greater tolerance for handling waste. Women urinate more often than men, especially when being pregnant [78]. They also need more time in the toilet, e.g. for undressing. When public conveniences are concerned, women use them for a number of other reasons such as breast-feeding or changing diapers and they use them more often than men since they are more often in public places for doing shopping, etc [78]. Yet, many studies worldwide have shown that there are fewer public toilet facilities for women and they tend to be inadequately designed [78]. Women also tend to manage toilets at home more often than men due to the fact that they spend more time at home and are responsible for taking care of the family. Attitudes towards urine are harder to find out, however, it appears that people have less negative disposition towards urine than feces [78]. Also, urine’s richness in nutrients is well known. Fresh feces are normally perceived negatively. However, dried feces’ soil-like appearance and the fact that it is odorless does not relate to its fresh form. Still, some cultures might be reluctant to its reuse as a soil conditioner [78].

Religion also has an influence on people’s attitude towards excreta, but it tends to influence the toilet behavior and wastewater treatment more in Eastern countries and developing countries than in Western industrialized countries [78]. Spiritual cleaning, i.e. ablution is one of the aspects that needs to be taken into account. Muslim doctrine prescribes strict procedures to limit contact with fecal matter and water is used for anal cleansing [78]. However, the hygiene behavior of Muslims differs due to the fact that Koranic edicts are interpreted differently among different movements. In Iran, for instance, use of excreta in agri- and aquaculture is not condoned [78]. In West Java, application of fresh feces for aquaculture is an ancient practice that has not changed much under Islamic rule [78]. Also, waterless toilet systems have been successfully implemented in water-based Hindu cultures [78]. The followers of Artha Veda, belonging to upper casts, should wash their feet before elimination and cleanse anal region afterwards [78]. Moreover, they should rinse their mouth eight times to complete the ritual [78]. On the other hand, those who carry the night soil belong to lower casts- untouchables and they do not have religious attitudes towards handling excreta [78]. “Nowhere do we find excrement included more in a social context than in Buddhist cultures [78]”. Buddhism preaches reincarnation and natural process of recycling human energy- birth, growth, decay, death and re-birth [78]. Thus, Buddhist cultures treat reuse of excreta very positively. Apart from the already mentioned religious beliefs there are others that may practice different approach towards excrements, e.g. some bury feces in order to ward off the evil forces, others may use urine for purification and healing purposes [78]. Therefore, care should be taken to get to know religious beliefs and understand what influence they might have on planned sanitation projects in the area of interest.

The attitude related to the tradition of using sanitation facilities might be hard to change or modify but the understanding of it is crucial for planning and implementation, especially of alternative sanitation options. Many cultures have constraints or negative attitudes towards reuse of excreta, however, they can be successfully overcome if the community is participating in the planning and decision-making processes and is thoroughly informed about the technology to be applied. The switch from the conventional to other sanitation approach may be influenced by such arguments as no smell, safety, security, comfort, privacy, convenience, minimum handling of excreta and the quality of structures [78]. The acceptance of alternative sanitation solutions is better when people understand their problems and are able to identify solutions themselves [78]. Working in cultural context where handling feces is considered problematic might become successful, if proper communication is valued. One can generally distinguish between *feacophilic* and *feacophobic* cultures. Typically, Asian cultures belong to the first group, as they do not have any taboos against handling or talking about human feces, whereas African countries belong to the latter group [78]. “If the necessary care is taken and cultural concerns and fears are considered, it is possible to implement loop-based ecological sanitation systems also in feacophobic societies. Once the benefits of sustainable solutions are understood by people and if there is a mutual confidence and security that the treated and recycled excreta are something useful and safe, barriers can sometimes be overcome [78].” Therefore, user’s acceptance and understanding of a sanitation approach chosen in a particular location needs to be aimed at and valued. It is possible to encourage people to use an alternative sanitation option when enough care is given to understand their attitude and beliefs. Therefore, the next section will focus on discussing the sanitation culture in Ethiopia and the potential for ecological sanitation to be implemented there.

2.5. Sanitation culture in Ethiopia

The majority of Ethiopians belongs to the squatting sanitation culture, so toilets should be fitted with squatting slabs and not with seated pedestals for the preferred convenience of their users. Generally, handling of human excreta is a cultural problem in Ethiopia. In Arba Minch, people from the Konso tribe perform manual emptying of pit latrines, which they normally do at night. They are also involved in pit digging for pit latrines.

According to the Society for Urban Development in East Africa (SUDEA), "culture should not be taken as a hindrance to promote re-cycling of human excreta as a fertilizer even though cultural sensitivity is important [69]". People working with implementation of ecosan in Ethiopia, found it hard to foresee Ethiopians' attitude towards resource-oriented sanitation [69]. The cultural aspects have been discussed already prior to implementation of the SUDEA project in Ethiopia [69]. The opinion of people's acceptance was rather mixed [69]. SUDEA was encouraged to start off with the project, even though some people believed that as far as acceptance for using of urine-diverting toilet might not be problematic, the acceptance of reuse of harvested urine and feces might take more time [69]. SUDEA's successful experience in Ethiopia shows that within the first five years of their project in Ethiopia, the most difficult to convince were the groups of autocrats and medical personnel [69]. Easier to convince were the groups of agronomists, who are used to using animal excreta as a fertilizer [69]. Also, the method of convincing that proved best was showing how cleanly sanitized feces and urine is applied. This proves that when people see how the system works in reality and that it does not involve any odors, they are able to accept it. Therefore, the most important issue as far as convincing to implement ecosan solutions is concerned, is good communication. Also, promoters need to have adequate knowledge about how the system works and be very convinced themselves. They need to answer any arising questions without hesitation. Also, tolerance and respect of the audience are the key issues of "convincing" [69]. SUDEA suggests that a well organized and studied introduction to the ecosan system as a whole might help [69].

2.5.1. Ecosan and agriculture in Arba Minch [4]

A study conducted in Addis Ababa showed that there are about 200 urine-diverting toilets already constructed. SUDEA started promotion of ecosan toilets in 1996 and educates communities in recycling household refuse, including human excreta. In Arba Minch, Ecological Sanitation Ethiopia (ESE) introduced the first ecosan toilet in 2006 in Seicha town, in condominium housing sites. The harvested urine is transported to Arba Minch University, where fertilization trials on maize, lettuce and tomato are performed. Also, ROSA constructed two urine-diverting toilets in Seicha and an individual in his household constructed the third one (construction costs amounted to 1500 Ethiopian Birr, which is equivalent to ca. 165 USD). As already mentioned, the soil in most parts of the town is rather unstable, so there is a high potential for introduction of ecosan technology.

In Ethiopia, the agricultural sector has been given attention at national level, however, no significant activities have been undertaken to promote urban agriculture in Arba Minch. Only some small-scale fruit and vegetable production are performed in the town. There are about 15 cooperatives involved in these activities and more than 10 ha, outside Kulfo River catchment and significant portion along the catchment, are provided for this purpose. Arba Minch State Farm located in Abaya kebele is a place where major urban agriculture activities take place. About 973 ha of land are occupied for this purpose, where 788 ha of land are cultivated. The land is irrigated by Kulfo River, bearing in mind that along one of the river sides people frequently practice open defecation and dispose of solid waste. The main crops grown in the farm include cotton (2600 kg/ha), maize (3000 kg/ha) and banana (7000 kg/ha). It is stated that the soil has a problem of nitrogen deficiency and this is compensated by application of chemical fertilizer (100 kg urea/ha). This problem could be solved by application of sanitized urine harvested from urine-diverting toilets, once implemented. Arba Minch University (AMU) farm is another site where urban agriculture is practiced. The main crops include: maize (60 ha), banana (4 ha), tomato, radish, lettuce, pepper, mango, avocado and cabbage. Also here the soil demands nitrogen fertilizer like in the case of the state farm. Another site for urban agriculture is located at the edges of Kulfo River course, where sugar cane, banana, mango, carrot, pepper, radish and cabbage can be found. Generally, use of organic solid waste is not a common practice in the town, but people sometimes use wastewater for irrigation unintentionally, e.g. overflows from waste stabilization pond of the Arba Minch University irrigate maize and banana farm located nearby. Also, large proportion of the farmlands along the edges of Kulfo River is irrigated by its water. The only kebele with significant farming is kebele fourteen, where 184 households lead their subsistence from the income generated from agriculture. In Arba Minch, urban agriculture should be promoted and there is potential for ecosan toilets and the harvested urine being reused as a nitrogen fertilizer instead of using the chemical one, especially in the state and AMU farm. The obstacle of people not being willing to reuse sanitized excreta might be overcome through well-prepared and performed awareness and informative campaigns. They could explain the idea of reusing nutrients and showing that sanitized urine and feces do not resemble fresh excreta, to which people have a negative attitude. There is a high potential for ecosan sanitation projects in Ethiopia, which has already been proven by the work of SUDEA in Addis Ababa. This potential should be used and in places where, for different reasons, there is no or little possibility for people to have private toilets or where public toilets are asked for, urine-diverting toilets should be constructed so that the harvested urine and dried feces could be reused in agriculture.

The current situation on the sub-Saharan continent, with main focus on Ethiopia and the city of Arba Minch calls for alternative sanitation solutions. As already discussed, in the city of Arba Minch there is a need for environmental and health problems to be tackled, with provision of sanitation being one of the most burning. As indicated, the town needs public toilet facilities as a way of answering the need of its inhabitants in places of public interest, i.e. a market place, bus station. Next chapter will discuss two different sanitation options that could be used for such a public toilet facility: a dry toilet with urine-diversion and pour-flush toilet with anaerobic digestion.

Chapter 3: Technology selection for the resource-oriented public toilet project in Arba Minch- comparison and evaluation

Two technologies for the public toilet project in Arba Minch will be further discussed: a dry toilet with urine diversion and a pour-flush toilet with anaerobic digestion.

3.1. Dry toilet with urine diversion

3.1.1. General and technical considerations

Urine-diverting toilets are based on the principle of separating urine and feces at source before they mix [22], a graphical representation of which can be seen on figure 26. Thus, the toilet is comprised of two compartments, keeping urine and feces separate. The tradition of separating urine and feces for further use in agriculture has already been present in some cultures, e.g. in China for centuries (see figure 27) [21]. It is important for urine to be diverted into the correct channel in order to prevent mixing of urine and feces [21]. This is also the prerequisite for using sanitized urine as a fertilizer (it cannot be contaminated with feces in order not to pose serious health hazards by transmission of infectious diseases). Thus, men should be seated while urinating or a separate waterless urinal should be provided in the toilet complex [14]. The toilet is built above the ground, so no digging activities for its construction are required. Urine leaves the toilet through a pipe or tube to a collection container, whereas feces are stored in a chamber directly beneath the toilet seat or squatting plate and left there to dry [25]. Urine is collected in ordinary jerry cans or larger tanks, depending on the amount of urine that is expected for collection [63]. In order to facilitate the drying process, high temperature in the feces chamber and sufficient ventilation may be provided [24]. The ventilation system may consist of a pipe that leads from the collection chamber to the outside and ends above the toilet roof [25]. However, in the collection and storage of urine system, ventilation should be avoided in order to prevent losses of nitrogen (present as ammonium, which is a plant-available nutrient) and to prevent odor problems [63].

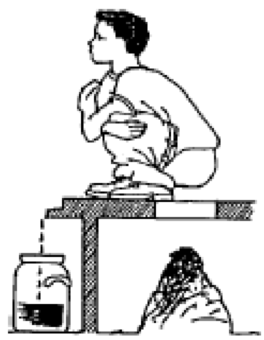


Figure 26: Separation at source [21]

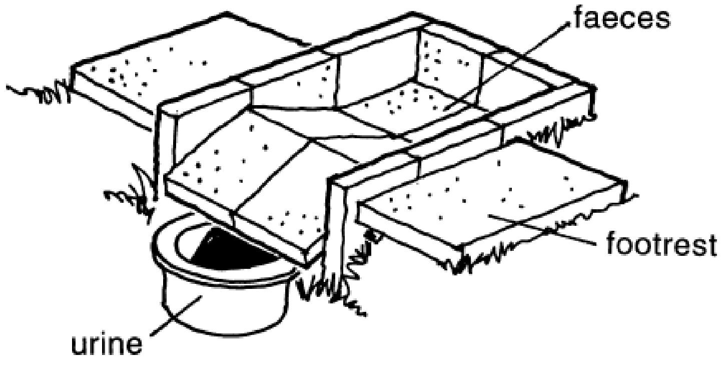


Figure 27: Traditional toilet with urine diversion in China [21]

After defecation, absorbents such as dry soil, ash or lime are spread over the feces, in order to absorb moisture, keep the alkalinity high, curtail odor and make usage of the toilet more convenient for the next user [24]. Thus, a bucket with these materials should be placed next to the toilet. In a dehydration system, moisture content lowered to 25% facilitates rapid pathogen destruction because it takes away the moisture that they need for survival [21]. Thus, this level of moisture should be aimed for. Low moisture content also helps to reduce smell and fly breeding.

A dry urine-diverting toilet does not require water for flushing, but very small amounts of water may be found useful for flushing of urine in some systems. However, urine should preferably not be diluted due to the fact that concentrated urine is harsher for microorganisms, increases the die-off of pathogens and prevents breeding of mosquitoes [64]. Therefore, the less water used for dilution of the urine, the better [64].

3.1.2. Nutrients production, recycling and reuse

Winblad et al (2004) claims that "on average each person produces about 5kg of elemental NPK in excreta per year, about 4kg in the urine and 1 kg in the feces" [89]. On average, 1-1.5 liter of urine can be collected per person a day, which contains enough nutrients to fertilize approximately 1m^2 of land [63]. It corresponds to a nitrogen application rate of ca. 40-120 kg/ha and most crops respond very well to application rates in this range [63]. "The urine from one person will thus be enough to fertilize 300-400 m^2 [18]". The concentration of nutrients in urine varies with the diet and therefore varies between countries and individuals [63]. A comparison of estimated excretion of nutrients per capita in different countries is presented in table 10 below.

Country		Nitrogen kg/cap, yr	Phosphorus kg/cap, yr
China	total	4.0	0.6
	urine	3.5	0.4
	faeces	0.5	0.2
Haiti	total	2.1	0.3
	urine	1.9	0.2
	faeces	0.3	0.1
India	total	2.7	0.4
	urine	2.3	0.3
	faeces	0.3	0.1
South Africa	total	3.4	0.5
	urine	3.0	0.3
	faeces	0.4	0.2
Uganda	total	2.5	0.4
	urine	2.2	0.3
	faeces	0.3	0.1

Table 10: Comparison of estimated excretion of nutrients per capita in selected countries [18]

Nutrients in urine are present in forms that are available for plants. Nitrogen is present as urea, which degrades to ammonium and nitrate, which are both plant available [63]. Phosphorous is mainly present as phosphate ions, potassium as potassium ions and sulfate as sulfate ions and these are all in forms that are readily taken up by plants [63]. The use of separately collected urine as a fertilizer after appropriate storage time is recommended, however, it might also be diverted into a soak-pit when locals do not approve of the usage of urine as a fertilizer [24].

Fresh feces contain pathogens. Thus, feces must always be treated before application onto field or in garden. The breakdown of organic material in dehydrated conditions is slow, so toilet paper and other cleansing material should be disposed of separately to a waste bin located next to a toilet and not into the chamber where feces are contained [24]. Then, it can be handled and composted separately. When the chamber gets almost full, its contents may need to be removed, further stored and then used as a soil conditioner, buried or composted [24]. The product that is left after feces dry has a form of a crumbly cake and is not a compost material but rather a carbon- and nutrient-rich mulch and fibrous material [24]. "The number of pathogens in fecal material during storage will be reduced with time due to natural die off, without further treatment [64]". Storage times will be dependent on the temperature, pH, moisture content, etc. At ambient temperature (2-20°C) recommended storage time is 1.5-2 years [89]. In warm climates (20-35°C) recommended storage time without treatment of the material is less than a year [89]. Storage time combined with alkaline treatment should be about 6-12 months if the pH value is kept above 9 due to the fact that high alkalinity inactivates microorganisms [89]. Storage time is required for the product to be free of most bacterial pathogens, reduce viruses, protozoa and parasites. Longer storage, sun drying, alkaline treatment (increasing the pH value to above 9) or high-temperature composting may be performed in order to decrease health risks linked to utilization of dehydrated feces [24]. Manual turning of the feces heap might be considered in order to facilitate the degradation rate. However, it will expose the person handling the material to unsanitized feces [64]. Moreover, desiccation is not a composting process and when moisture is added (e.g. when dried material is applied on moist soil) the organic compounds will facilitate bacterial growth [64].

Well-treated feces are normally safe to use and the resulting material can improve the soil structure, improve soil health and is a good fertilizer due to phosphorous, magnesium and potassium content [14]. Human excreta contain on average 0.5 kg N, 0.2 kg P and 0.17 K a year. This rather low nutrient content together with high humus concentration makes the use of sanitized feces best as a soil conditioner [14].

As far as storage time of urine is concerned, recommended storage time and temperature guidelines are based on the studies on pathogen inactivation in urine (see tables 11 and 12). The survival of various microorganisms in urine over time is affected by storage conditions. Elevated pH value of 9, which is caused by conversion of urea to ammonium, is beneficial for the inactivation of microorganisms present in urine [63]. "The pH of fresh urine is normally between 4.8 to 7.5 but after collection it is around 9.0 [63]". The change of pH is attributed to the fact that when urine is excreted, the major fraction of the nitrogen is present as urea and later within the collection and storage it is converted to ammonium.

	Gram-negative bacteria	Gram-positive bacteria	*C. parvum*	Rotavirus	*S. typhimurium* phage 28B
4°C	1	30	29	172[a]	1466[a]
20°C	1	5	5	35	71

[a] Survival experiments performed at 5°C.

Table 11: Inactivation of microorganisms in urine, given as T_{90}-values (time for 90 % reduction) in days [64]

Table 11 shows that gram-negative bacteria, which are responsible for gastrointestinal infections, were inactivated rapidly. Gram-positive bacteria had similar inactivation rates as Cryptosporidium parvum and had a slower die-off than gram-negative bacteria. However, gram-positive bacteria are considered to be less of a health concern in urine diverting systems. Viruses were the most persistent group of organisms. They were hardly inactivated at temperature of 5°C and at temperature of 20°C the T_{90}-values were of 35-71 days. Temperature seemed to affect all microorganisms that were tested and it is considered to be the most important parameter. [63]

Storage temperature	Storage time	Possible pathogens in the urine mixture after storage	Recommended crops
4°C	≥1 month	Viruses, protozoa	Food and fodder crops that are to be processed
4°C	≥6 months	Viruses	Food crops that are to be processed, fodder crops[d]
20°C	≥1 month	Viruses	Food crops that are to be processed, fodder crops[d]
20°C	≥6 months	Probably none	All crops[e]

[a] Urine or urine and water. When diluted it is assumed that the urine mixture has at least pH 8.8 and a nitrogen concentration of at least 1 g/l.
[b] Gram-positive bacteria and spore-forming bacteria are not included in the underlying risk assessments, but are not normally recognized for causing any of the infections of concern.
[c] A larger system in this case is a system where the urine mixture is used to fertilize crops that will be consumed by individuals other than members of the household from which the urine was collected.
[d] Not grasslands for production of fodder.
[e] For food crops that are consumed raw it is recommended that the urine be applied at least one month before harvesting and that it be incorporated into the ground if the edible parts grow above the soil surface.

Table 12: Recommended Swedish guideline storage times for urine mixture[a] based on estimated pathogen content[b] and recommended crop for larger systems[c] [64]

A shorter storage time at a lower temperature may involve higher risks for individuals handling urine and for those who will come into direct contact with the fertilized field or crop [63]. The general recommendations presented in table 12 above can also be adopted for larger systems in developing countries and regions. However, the withholding time of one month between fertilization and harvest should be adhered to [64]. Also, protection and awareness of risks, using suitable fertilizing techniques (applying urine to the ground, not creating aerosols) and working the urine into the soil will decrease the exposure of humans and animals to potential pathogens [63]. "Environmental factors will result in the inactivation of pathogens in the soil and on crops after application [64]". Thus, the risk of infection by ingestion of crop will be reduced during the time between fertilization and consumption [63]. To sum up, recommended storage time at temperatures of 4-20°C varies between one and six months depending on the type of crop to be fertilized. Crops that can be fertilized with urine should be the ones that normally are very limited by supply of nitrogen content, since urine has high concentrations of plant available nitrogen. Such crops include cereals (maize, rice, millet, sorghum, wheat) [63]. Also, vegetables such as chard, turnip, carrots and cale as well as fruit and bushes such as banana, paw-paw, oranges, tea and coffee should have a good response to fertilization with urine [63]. Care should always be given to apply the urine to the soil and not onto the plants [21].

There are either single-vault or double-vault toilets with urine diversion available for construction (see figure 28). Usage of a double-vault system prevents handling of fresh excreta as the vaults are used alternately [25]. When one vault gets almost full, the defecation hole is sealed and the toilet seat is transferred to the second vault [25]. In this way, one vault is in use and the other one is left for maturing [25]. When the second vault becomes nearly full, the first one needs to be emptied [25]. In case of a single-vault system the waste needs to be shifted to the rear by means of a hoe or rake and every 3 to 6 months the dry pile next to the rear is shoveled out of the chamber and further stored elsewhere before being used as a soil conditioner [26]. Feces that are removed from the vault in a form of sanitized powder or lumps can be either given secondary treatment (e.g. high temperature composting) or be dug into the ground or flowerbeds where the material comes in contact with the living soil [21]. Dehydrated feces should be applied, mixed in and covered by the soil before the cultivation starts [21]. It is mainly due to the fact that the high phosphorous content of the material is beneficial for root formation of young plants [18]. The average person produces about 50 liters of feces per year and this amount will fertilize 1.5-3.0 m^2 of crop if the application is made according to the organic content [18]. If it is based on phosphorous content, it will fertilize 200-300 m^2 [18].

3.1.3. Applicability

Urine-diverting toilets are applicable in "regions with high average temperatures, long dry and short rainy seasons or arid climatic conditions with high evaporation rates [24]". Their applicability is not suitable in very humid and cool climates due to the fact that feces will not undergo the drying process easily [25]. Dry toilets with urine diversion are suitable for both rural and densely populated urban areas [24]. Dehydration toilets do not use water so they are suitable for conditions and regions where water is scarce [24].

3.1.4. Form and material selection

Urine diversion toilets can be in a form of a pedestal seat, squatting plate or urine-diverting toilet insert [24]. The choice of the form is mainly based on cultural norms and preferences of users. For the representation of different seat pedestals with waterless urine diversion see figure 31. The toilet seat can be made of porcelain, concrete, fiber-reinforced materials or durable plastic and painted wood [18, 22]. It is important that the surface is smooth and hardened. Drainpipes and tubing are normally made of durable plastics such as polyethylene [22]. Storage containers may be made of plastic or concrete [22]. Metal components should be avoided due to the fact that urine may react and corrode them [22]. The chambers need to be easily accessible through hatches or doors [25]. In order to facilitate the drying effect the chamber lids might be painted black or made of metal [25].

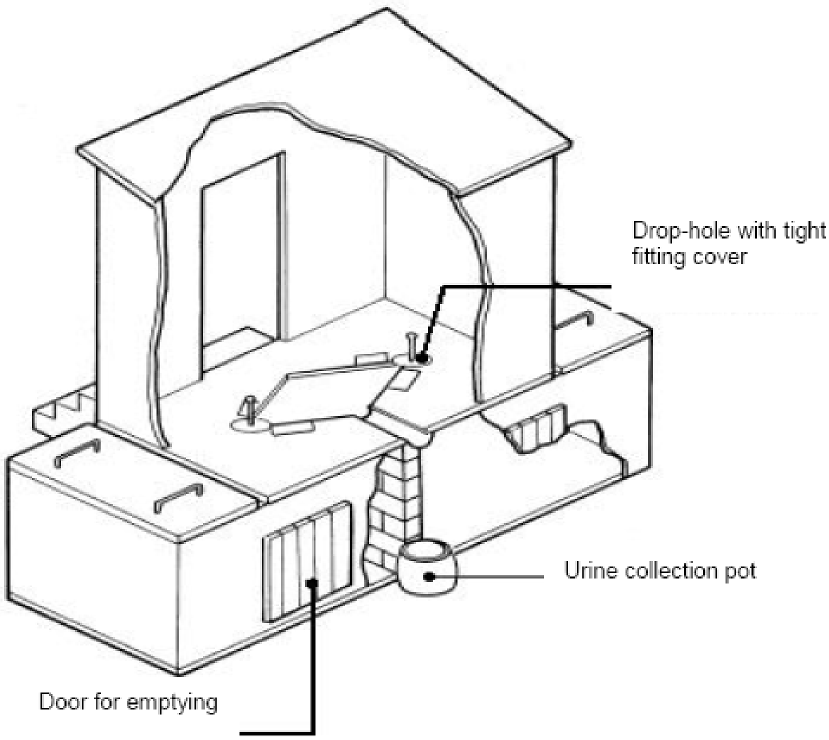


Figure 28: Double-vault dehydration toilet with urine separation[7]

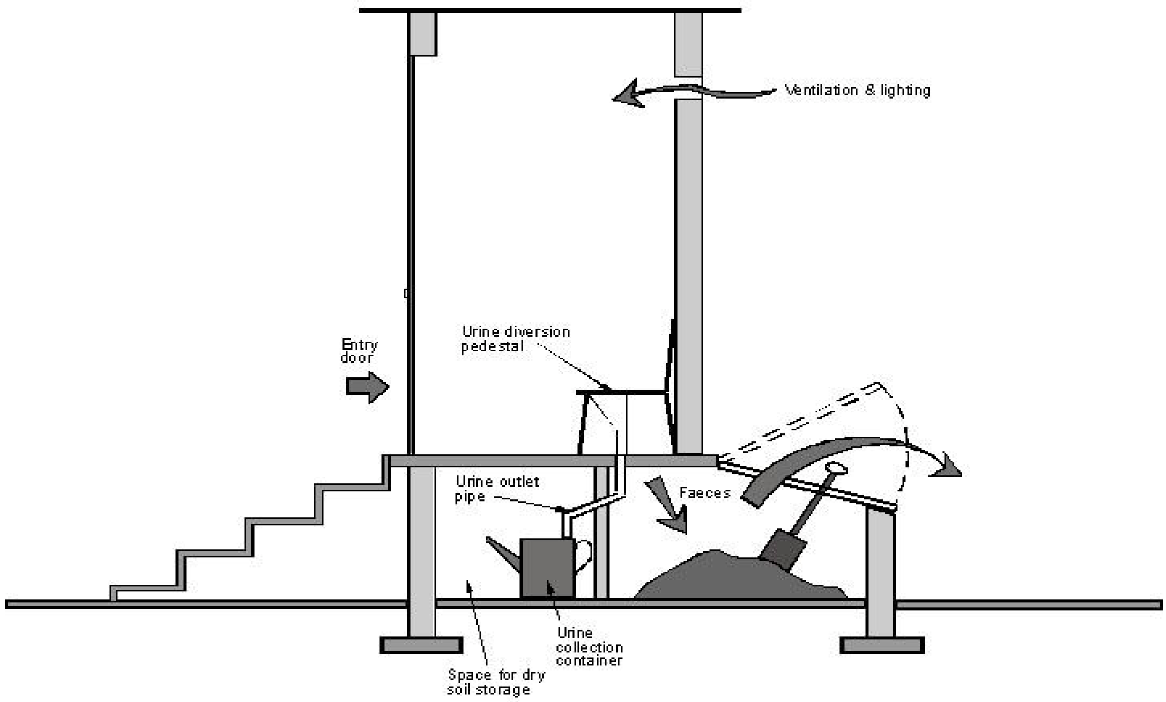


Figure 29: Schematic representation of a urine-diverting toilet[8]

[7] Reed B. and Shaw R, Using human waste, technical brief no. 63, WELL
[8] http://www.sustainablesettlement.co.za/howto/urinediv/images/fig1_big.jpg

3.1.5. Advantages

One of the advantages of urine diversion toilets is that they can be easily implemented as communal collection systems either with indoor or outdoor convenience. This type of toilet is suitable for different cultural settings and they can be designed to suit both sitting and squatting cultures as well as the ones that use water for wet-anal cleaning [24]. The latter can be diverted through a separate funnel [25] and can be then treated for instance in an evapotranspiration bed [8]. The components of urine-diverting seated pedestal toilets and squatting plates can be constructed with local resources or as pre-fabricated purchased from a manufacturer [22]. Dry systems are a suitable option in water scarce regions, as they do not require water for flushing. Also, they find applicability in flood prone regions with impermeable and high groundwater table as they are built above ground. With the usage of urine diverting system large-scale nutrient recovery is possible. When collected urine is not contaminated with feces and contains low levels of metals, it poses minimal hygienic risk [22]. Urine can be easily treated and hygenised in order to be applied as a fertilizer in agriculture [22]. Through collection of urine for reuse in agriculture, the burden of nutrient pollution of ground- and surface waters is reduced [22]. The cost of building a urine-diverting toilet may be kept low. For countries where squatting position is preferable, a squatting plate made of porcelain that costs 10 USD may be used (see figure 30) [21]. The 2004 price of a seat-riser plus a urinal in polished concrete in Mexico is the equivalent of 46 USD [89]. The price of seat-riser and urinal in fiberglass is 105 USD [89].

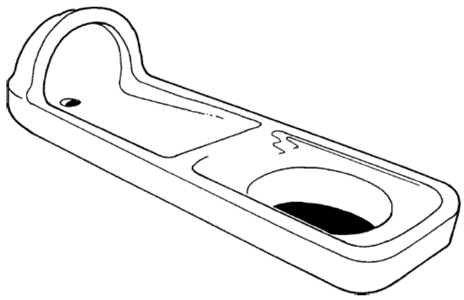


Figure 30: Porcelain squatting pan with urine diversion used in China [21]

(a) (b) (c)

Figure 31: Urine diversion seat pedestal: (a) *fiberglass* [21], (b) *plastic* [7], (c) *mortar* [6]

3.1.6. Disadvantages

The design of the toilet seat or squatting pan needs to be functionally reliable as well as socially acceptable for it to work properly as only uncontaminated urine can be used as a fertilizer. Also, the feces chamber needs to be kept dry, so no urine or water can enter it in order not to hinder the drying process, pathogen destruction and not to allow for fly-breeding and odor accumulation. The public health risks are mainly limited to proper handling of human excreta so there needs to be sufficient public awareness about the risks related to handling of urine and feces. Also, it is recommended that neither urine nor composted feces should be spread on the top of the soil, but should be applied under the topsoil.

In order to assure toilet's proper operation clear instructions of usage are essential and need to be provided to the users. Thus, general instructions of usage should be put on the wall for all the users of the toilet to get acquainted with them. Operation and maintenance plays an important role in the functioning of the system. When dry urine diversion toilets are constructed and operated as public toilets, the maintenance works need to be taken care of by a trained caretaker, who understands the functioning of the facility. Above all, regular removal of collected urine and feces needs to be performed. The commitment to the proper use of facilities and maintenance needs to be assured; otherwise the toilet will not serve its purpose for a long time [22]. Moreover, regular inspection of the toilet, pipe connections and storage tank are encouraged [23]. Prior to the implementation a strategy plan for urine treatment and its final utilization needs to be outlined [22]. Efficient and safe use of dry urine-diverting toilet involves education of the users and commitment in latrine waste handling and utilization of the composted material for a soil conditioner. Such considerations as additional child seats also need to be taken into account in order to keep their urine and feces separate.

Dry sanitation systems do not handle greywater. Thus, separate system for greywater treatment, in case of a showering facility also present, needs to be taken into account and will be discussed later in this chapter. While comparing single- and double-vault systems, the main concern is connected with handling of fresh feces [26]. Single-vault system poses more threat to human health than double-vault, as far as handling of feces is concerned [26]. The pile situated in the rear of the chamber might get contaminated with fresh feces and managing of such a pile may be problematic [26]. The understanding of the fact that these solids are only partially processed and require secondary processing in different location prior to usage as a soil conditioner needs to be assured [26]. However, if proper operation and maintenance can be guaranteed, single-vault systems have an advantage over the double-vault ones as far as costs and spatial requirements are concerned. In developing countries both types have found their application and the choice between the two depends on local conditions.

A urine-diverting toilet was developed by the Society for Urban Development in East Africa (SUDEA) in Ethiopia (see figure 32). In their design, urine is collected in one special container, whereas feces are collected in different container and mixed with ashes, soil, leaves, grass or sawdust. Collected urine and dried feces can be used as a fertilizer and soil conditioner. The toilet is constructed from locally available and appropriate materials. The total cost is about 100 USD per toilet. SUDEA stresses the importance of a holistic approach to a toilet installation and use, from the initial contact, construction and maintenance to the re-cycling process for urban or household agriculture [57].

Figure 32: Urine diversion toilet in Ethiopia (left)[9] and in Burkina Faso (right) [41]

[9] http://www.wsp.org/filez/pubs/af_ecosan_esa.pdf

3.2. Pour-flush toilet

3.2.1. General and technical considerations

Pour-flush toilets have water seals beneath a squatting plate or pedestal seat [35]. They may use a pit for excreta disposal. A special pan cast in the floor provides the water seal of 20-30 mm. A vent pipe can also be fitted to the pit [87]. There are many available designs of this type of toilet. One of them is with the direct discharge and another one with the offset pit or offset double pit (see figure 33).

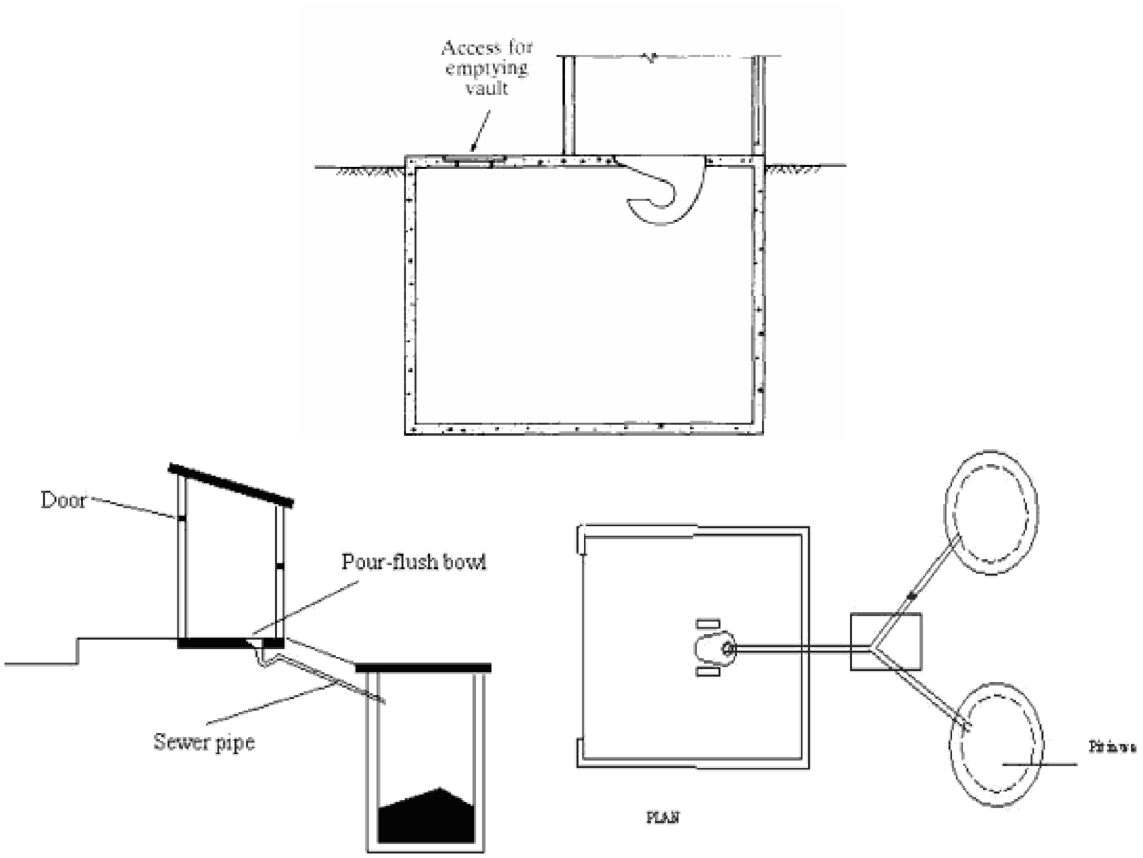


Figure 33: Pour-flush latrine with the direct discharge (upper image) [35], the offset pit (left) and offset double pit (right)[10]

As the name itself suggests, pour-flush toilets require little water for flushing. A toilet with the direct discharge requires about 1-2 liters of water for each flush. Water is poured by hand with a scoop. In the type with the offset pit, the pour-flush bowl is connected to a short length pipe that discharges into the adjacent pit. Here, also 1-2 liters of water are required for each flush [87]. However, the amount of water required for flushing is highly dependent on the actual design of the toilet and water seal. In the literature, normally 1 up to 4 liters for flushing of pour-flush toilets is given [79]. The design with two pits allows for alternate use of pits. The pour-flush toilet can also be connected to a septic tank and to a soak away or sewer (see figure 34). In case of a pour-flush toilet with an offset pit, water added for flushing and the liquid part of excreta need to infiltrate into the soil, so the soil permeability needs to be

[10] http://www.schoolsanitation.org/BasicPrinciples/WaterFlushToilets.html

taken into account while planning to build such a pour-flush toilet [87]. However, as far as resource-oriented sanitation is concerned, a toilet design with a pour-flush slab that allows for connection to a biogas digester is preferable. The slabs have a U-shaped facility partly filled with water under the slab (see figure 35). This so-called U-trap overcomes problems with flies, mosquitoes, and odor by serving as a water seal [79]. As far as material selection is concerned, toilets can be made of plastic, ceramic or galvanized sheet material [79]. Pour-flush toilet might also have an option of separating urine from feces by having a urine-diverting channel. However, this option might not be found useful for public toilets in developing countries due to its complexity.

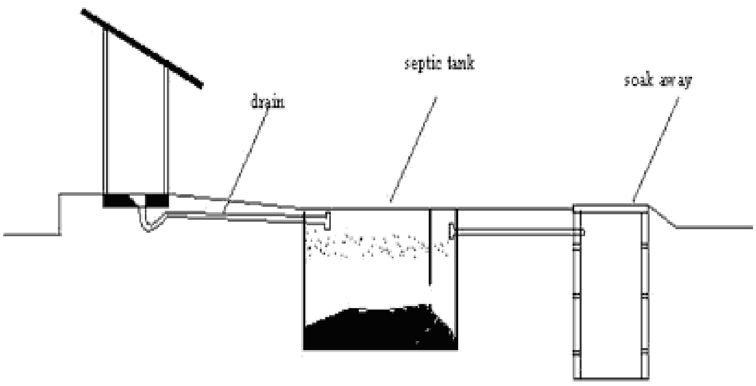


Figure 34: Pour-flush toilet with a septic tank and a soak away[11]

The costs of a ceramic pour-flush pan is about 4-8 USD (Tamil Nadu, India, 1999) and of easy-flush polypropylene pan 2 USD (Chennai, India) [79]. As far as material selection is concerned, the pan and water trap can be made of ceramic, PVC, ferro-cement or fiberglass. If a vent pipe is provided to allow gas to escape from the pit, it should be made of a 50mm PVC pipe, which should be covered with a fly screen [87].

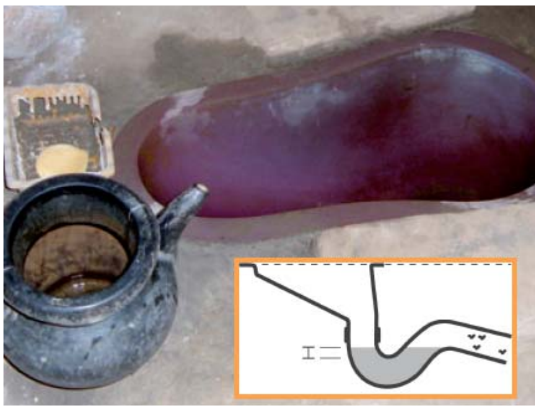


Figure 35: Low-cost pour-flush slab in Bangladesh and schematic illustration of a U-trap [79]

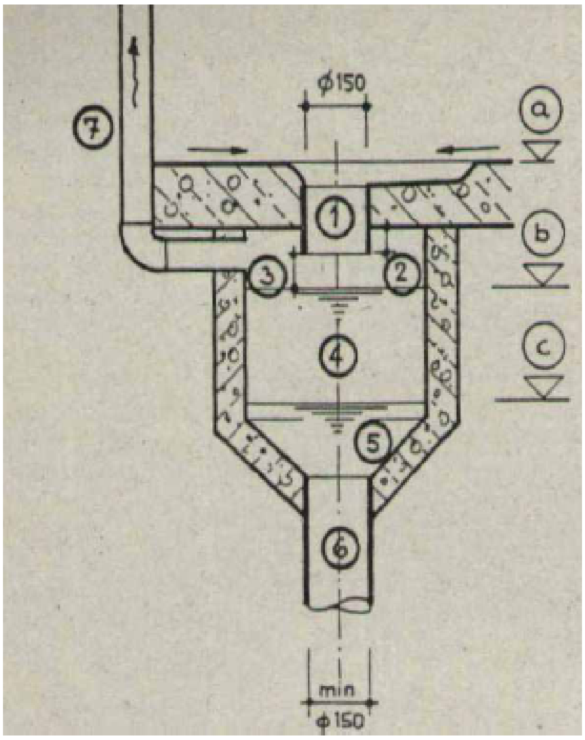
[11] http://www.schoolsanitation.org/BasicPrinciples/WaterFlushToilets.html

3.2.2. Advantages

If the pour-flush toilet is operated and managed properly, no odor or fly and mosquito breeding will take place. This type of toilet, especially with the two-pit option, allows minimal risks to health as the design reduces the need for handling fresh excreta. The annual costs of operating and maintaining this type of toilet are kept low. Normally, they only include the cost of water for flushing. The construction as well as maintenance of this type of toilet is rather easy. The toilet can be combined with a biogas digester so that biogas is generated from human excreta under anaerobic conditions and then used for cooking, lighting or electricity generation purposes (see section 3.2.5. "Biogas generation and utilization"). Then, only the remaining effluent sludge needs to be taken care of, no infiltration of liquids into the ground is necessary, and so groundwater resources will not get contaminated. The effluent after being treated might be used for washing of the floor of the toilet complex or for watering grass or flowers in the vicinity of the complex. The treated slurry might be used as a fertilizer. The information on management methods of effluent slurry will be discussed later on. Pour-flush toilets are an appropriate sanitary option in densely populated areas where biogas production is feasible and where handling of fresh excreta is not socially acceptable. Pour-flush toilets are appropriate in regions where people use water for anal cleaning. Pour-flush slabs are suitable where people squat to defecate. It should be instructed that bulky material used for anal wiping or cleaning cannot be thrown into the toilet as it may clog it due to the little amount of water used for flushing. Also, as far as maintenance is concerned, the toilet needs to be regularly checked for possible blockages. This type of toilet is relatively easy to construct and once constructed properly, it provides good health benefits. Also, the water seal provides an effective barrier against odors and insects and the excreta is kept invisible from the toilet users.

3.2.3. Disadvantages

Pour-flush toilet requires some, but still significant amounts of water for flushing so its use in water scarce regions where fetching water is problematic might be a bad option. However, if water is available for flushing, then the combination of pour-flush toilet with a biogas digester might be an economically feasible option if there is a large number of visitors of the toilet complex (see figure 36 for connection of the toilet to a biogas digester). If improper maintenance is provided, the toilet might get blocked easily (especially the U-trap) and then the threat of disease transmission is higher. Pour-flush toilets are not appropriate for very cold climates due to the risk of water seal getting frozen. One of the disadvantages of this type of toilet is mixing of pathogens present in human excreta with water, which increases the volume to be treated. However, if the system is linked to a biogas digester, then this consideration might be neglected. Also, the simplest form of a pour-flush toilet is linked to a pit, which involves soil absorption, so there is a danger of groundwater contamination. Therefore, an upgraded option with a biogas digester plant should be considered in order to prevent groundwater contamination as a result of liquids infiltration. Details about biogas formation, generation and utilization will be given further on in the next sections.



a-toilet floor,
b-highest slurry level,
c-lowest slurry level,
1-inlet pipe,
2-bottom rim of inlet pipe,
3-inlet piece always above slurry level,
4-feeding chamber,
5-slope,
6-down pipe,
7-vent pipe

Figure 36: Toilet connection to a biogas digester [4]

3.2.4. Biogas formation

Biogas is produced under anaerobic conditions in the presence of different bacteria, among which methane-producing bacteria are essential. Biogas production takes place in three main steps: hydrolysis, acidification and methane formation (see figure 37). In the hydrolytic step, the organic matter is broken down by extra cellular enzymes. Bacteria decompose carbohydrates, proteins and lipids into shorter parts (from macro- to monomolecules), e.g. polysaccharides are transformed into monosaccharides, proteins split into peptides and amino acids, etc. Then, in the acidification step acid-producing bacteria convert the intermediates of fermenting bacteria (sugars) into short-chain acids, mainly to acetic acid, hydrogen and carbon dioxide. These bacteria are facultatively anaerobic and are able to grow under anaerobic conditions. In the final step, methane-producing bacteria decompose compounds with a low molecular weight and so they utilize hydrogen, carbon dioxide and acetic acid to form methane. These bacteria are obligatory anaerobic and very sensitive to changes of the environment. [38]

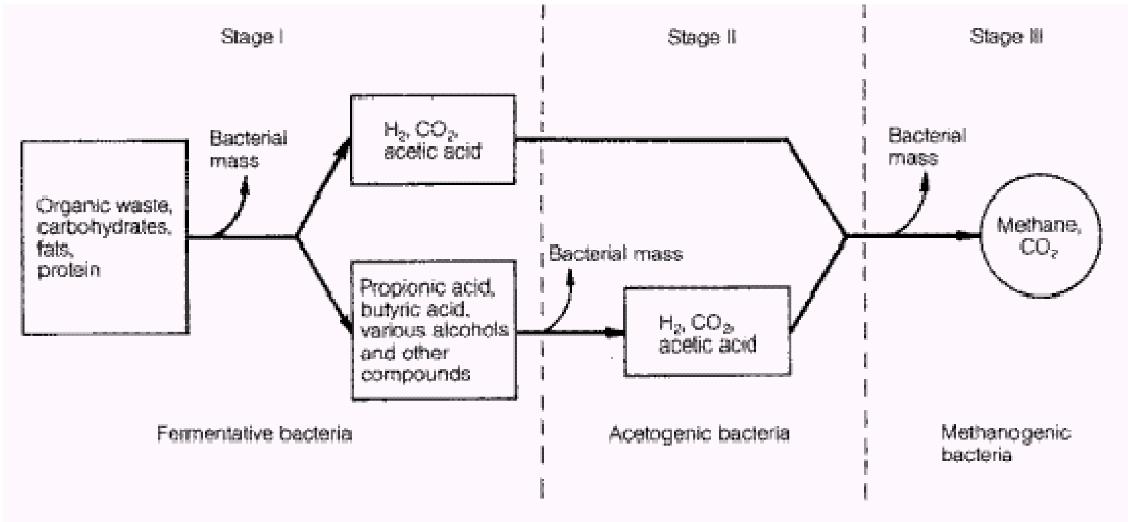


Figure 37: Three steps of biogas production [43]

The production of biogas is highly dependent on environmental factors. Bacteria involved in the process need special conditions for their activities and are influenced by nutrient content, pH level, C/N ratio, moisture content, agitation of the substrate, substrate temperature and presence of inhibitory factors, e.g. heavy metals. Numerous bodies of literature provide information on appropriate level of all the above-mentioned factors.

There are many different types of biogas plants available, among which the most popular are balloon plants, fixed-dome plants and floating drum plants. In a nutshell, only dry and pour-flush toilets are suitable for connection to biogas plants of less than $30m^3$ digester volume due to the danger of diluting the slurry and reducing the retention time [42].

3.2.5. Biogas generation and utilization

It is estimated that 1 kg of human excrement will produce minimum of 60 liters of biogas [42]. The produced biogas has a high-energy content and can be used directly for cooking, lighting, heating or cooling purposes.

1 m^3 of biogas is equivalent to [42]:
- Diesel, kerosene 0.5 kg
- Wood 1.3 kg
- Cow dung 1.2 kg
- Plant residues 1.3 kg
- Hard coal 0.7 kg
- City gas 1.1 m^3
- Propane 0.24 m^3

Sometimes the generated biogas must be treated or conditioned before its use. The most well known forms of treatment include reduction of the moisture content, hydrogen sulfide content or carbon dioxide content [39]. For details about conditioning of biogas one may refer to “Biogas Digest Volume II. Biogas - Application and Product Development Information and Advisory Service on Appropriate Technology”, a publication by ISAT and GTZ.

Prior to linking a biogas digester plant to a public toilet facility, it is advisory to check the availability of specially designed biogas burners or modified consumer appliances so that the generated biogas will find its utilization. One of the most popular ways of utilizing biogas is in biogas burners (see figure 38). Compared to other gases, biogas requires less air for combustion and about 5.7 liters of air are needed for complete combustion of one liter of biogas [39]. It is possible to modify or adapt commercial-type burners into biogas burners. The calorific efficiency of using biogas is 55% in stoves, 24% in engines and only 3% in lamps and the most efficient way of biogas utilization is in a heat-power combination, where efficiency reaches even 88% [39]. Table 13 presents consumption rates in liters per hour for the utilization of biogas:

Appliance	**[l/h]**
Household burners	200-450
Industrial burners	1000-3000
Refrigerator (100l) depending on the outside temperature	30-75
Gas lamp, equivalent to 60 W bulb	120-150
Biogas/diesel engine per bhp	420
Generation of 1 kWh of electricity with biogas/diesel mixture	700

Table 13: Consumption rates of different appliances for utilization of biogas [39]

Biogas appliances may include: gas cookers/stoves, biogas lamps, radiant heaters, incubators, refrigerators and engines. As far as cookers are concerned, two-flame burners find large applicability. It can be estimated that gas consumption per person and meal ranges between 150-300 liters of biogas [39]. "For one liter of water to be cooked 30-40 l biogas, for 1.2 kg rice 120-140 l and for ½ kg legumes 160-190 l are required [39]". As it was already mentioned before, biogas lamps are not very energy-efficient. They get very hot and should not be placed right below the roof in order not to pose fire hazard. The light output is measured in lumen (lm) and "at 400-500 lm the maximum light-flux values that can be achieved with biogas lamps are comparable to those of a normal 25-75 W light bulb [39]". One lamp consumes approximately 120-150 liter of biogas per day [39].

Refrigerator is another appliance where biogas found its utilization as an external source of heat. It is estimated that for 100 liters refrigeration volume, about 2000 liters of biogas per day must be assumed [39].

"If the output of a biogas system is to be used for fueling engines, the plant must produce at least 10 m^3 biogas per day [39]." There are different types of engines that are well suited for operating on biogas and these include four-stroke diesel engines, four-stroke spark-ignition engines, converting diesel engines and converting spark-ignition engines [39].

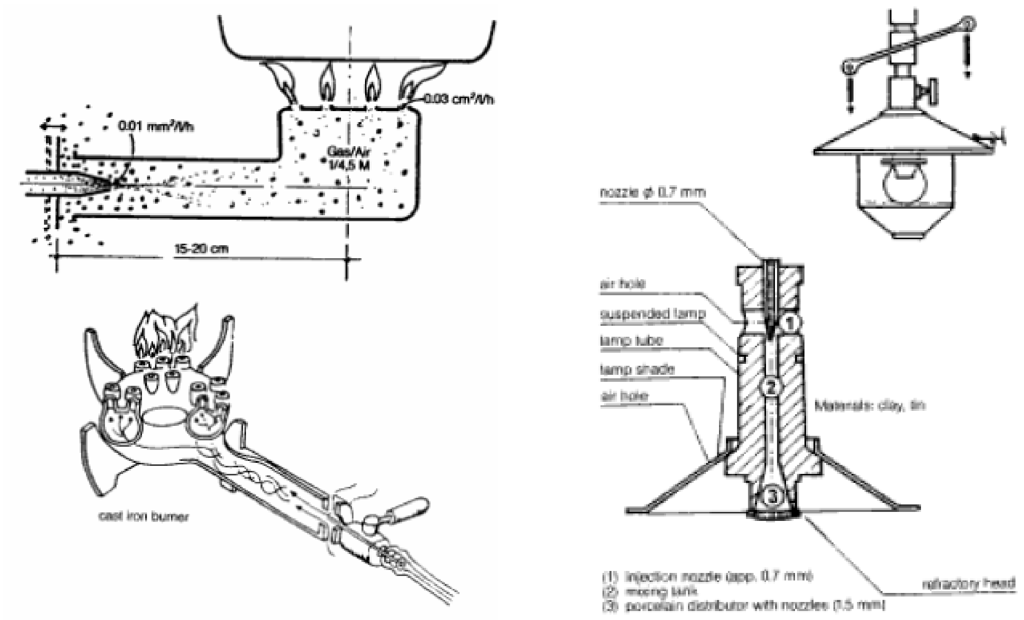


Figure 38: Schematic diagram of a gas burner (left) and a biogas lamp (right) [39]

As far as biogas utilization is concerned, there were instances of problems with social acceptance of biogas generated from human excreta. There might be people who will consider biogas as dirty and unhygienic since it is produced from human waste. Also, its utilization might be not accepted due to local religious beliefs. What is more, people may not understand the importance of health and sanitation as well as savings that they might achieve whilst using biogas technology. It is also critical that the whole local community accepts the use of biogas; otherwise single units will feel under pressure not to accept it.

3.2.6. Sulabh experience

For more detailed information about the Sulabh organization in India and its achievements in the sanitation sector refer to the case study in the next chapter in section 4.7.1.

Sulabh has constructed its first excreta-based biogas digester linked to a public toilet in Patna in 1982. The idea behind it was to obtain biogas from human excreta collected in large-sized public toilets used by 2,000-5,000 people per day. The Sulabh biogas plant consists of an inlet chamber, an anaerobic digester and an outlet chamber. A symbolic representation of it is illustrated in figure 40. “The digester is cylindrical with arched bottom and domed top and is installed underground. Excreta from the toilet seats flow under gravity through covered drains into the inlet chamber and then into the digester. The digester slurry comes out of the digester through the outlet pipe, reaches the outlet chamber and then flows out through covered drains into soakage pits [68].”

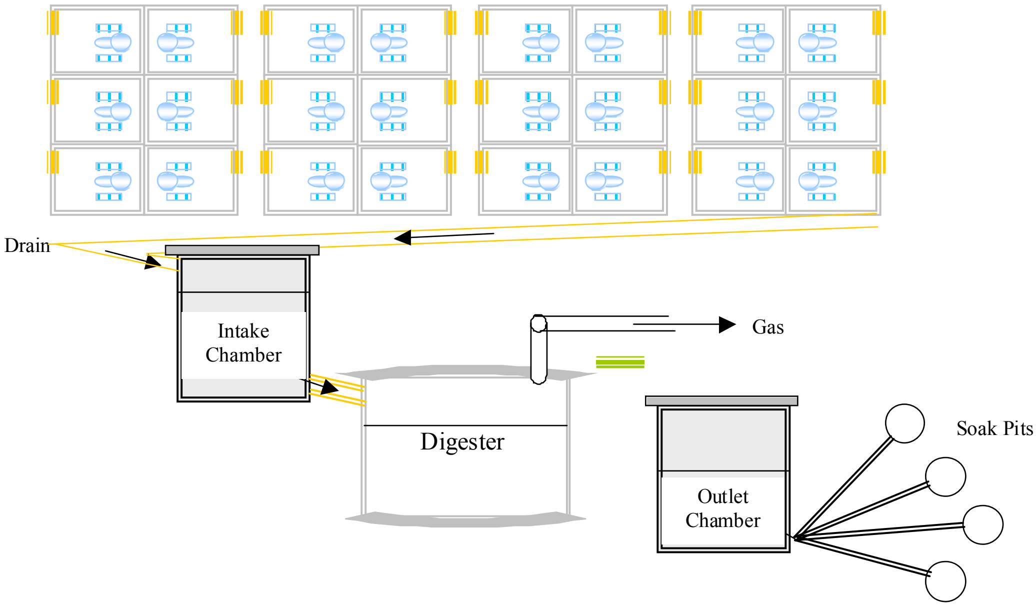


Figure 39: Excreta-based biogas and bio-fertilizer [68]

From Sulabh's experience, a public convenience visited by approximately 2,000 users per day would produce roughly 60 m^3 of biogas. As a rule of thumb, about 30 liters of biogas are produced from human excreta of one person per day. The existing toilet complexes linked to biogas digesters constructed by Sulabh often rely on electricity generated from biogas being supplied for lighting, like in the case of the one in Patna (Ghandi Maidan Park), at the bus stand Ranchi in Bihar state and in many others [67]. The organization also suggests using biogas for supply of warm water for bathing and for warming up the visitors of toilet complexes in the winter. The organization has constructed 160 biogas plants of 35 to 60 m^3 capacity across the country linked to its public toilet complexes [56].

The organization argues that biogas digester plants linked to public toilets may find application in community toilet complexes, high-rise buildings, hotels, housing colonies, etc. [67]

3.2.7. Bangladesh experience [66]

There were two community latrines constructed for nine neighboring poorest families in one of the villages in Bangladesh. Before the construction of the toilets, 31 members of these families practiced open defecation. A fixed-dome biogas plant with an underground cylindrical shaped biogas digester was constructed there. Human excreta are the only raw material used in this plant. The biogas produced from the plant is supplied to one house, where it is used for cooking of three meals per day for a five-member family on a two-burner stove. The total cost of the plant was 250 USD, but the family saves about 4.4 to 5.8 USD monthly due to biogas utilization. The family has no problem in using the biogas plant, however, when asked about their preferences they admitted that they would rather use an auto-firing oven. It was found out that the users were not given enough information about sanitation and hygiene issues related to the use of biogas plants. Thus, sludge is being disposed of in the open in a very unhygienic manner. Also, the community latrines are not clean. Sludge is used for improvement of soil on the land, however, no testing was carried out in order to determine the quality of the sludge.

Another biogas plant was constructed in a Muslim religious institution in one of the villages in Bangladesh. The institution homes about 200 children. Taking into account the amount of excreta generated in the community latrines at the orphanage, it was decided to build a fixed-dome digester plant in order to generate biogas that can be used for cooking purposes. The digester is connected to the two units of toilets including 6 urinals and 5 lavatories that are regularly used by about 200 people, mainly children. Here, also only human excreta are fed into the digester. The generated biogas is enough to cook for 20 to 25 people, which saves roughly 51 USD per month. In this particular case neither users nor cooks had any complaints about using human excreta as a source of energy for cooking. Also, they did not experience any operational difficulties and the plant area was very clean. The sludge disposal was done in a very hygienic way. It is collected from the plant and disposed of into a hole with other solid organic waste, e.g. leaves and kitchen waste. After 10 to 15 days the compost is used for cultivating vegetables.

The two examples from Bangladesh show that biogas plants may work well when linked to community toilets. However, the important issue of community training and explanation of sanitation and hygiene whilst handling effluent sludge and condition of the latrines should not be neglected. The users might have no problem with utilization of biogas, but they should be reminded that whilst handling effluent sludge, they need to use some precautions in order to do it a hygienic and safe manner.

3.2.8. Types of biogas digester plants

Fixed-dome plants consist of a digester with a non-movable gasholder and a displacement pit (see figure 40). The gas is stored in the upper part of the digester as long as the gas valve is closed. Biogas can only be produced under anaerobic conditions. That is why a gas-tight lid closes the gas plant. "The accumulating gas needs room and pushes part of the substrate into an expansion chamber, from where the slurry flows back into the digester as soon as gas is released. The volume of the expansion chamber is equal to the volume of gas storage. Gas pressure is created by the difference of slurry levels between the inside of the digester and the expansion chamber [62]". "When the expansion chamber is full, slurry overflows into the slurry drain for use as manure. When the main valve is opened, the gas escapes off the gas storage part until the slurry levels inside the digester and inside the expansion chamber balances [62]". Gas pressure increases with the volume of gas that is stored in the digester.

The costs of a fixed-dome plant are relatively low. This type of plant has no movable parts and no rusting steel parts [39]. Therefore, its life span is rather long. The underground construction saves space and protects from the influence of amplitudes in temperature. However, the construction of the plant has to be supervised by a biogas technician because it is not easy to build and it has to be assured that the plant is gas-tight. Above all, the top part of a fixed-dome plant must be gas-tight. Thus, the gas space must be painted with a gas-tight layer. The digesters of this type of plant are generally made of cement and ferro-cement [39]. "Fixed-dome plants must be covered with earth up to the top of the gas-filled space to counteract the internal pressure" [39]. The minimum size of this type of plant should be not less than 5 m^3 [39]. The main advantages of this type of biogas plant include low initial costs and long useful life span. Also, as already mentioned, it does not include any moving or rusting parts. The design saves space and is well insulated [39]. On the other hand, gas-tight construction requires technical supervision. Also, one of the main disadvantages is fluctuating gas pressure, which makes gas utilization rather complicated [39]. Moreover, the amount of gas produced is not immediately visible [39]. The plant needs to be built underground, so in areas where excavation is problematic this type of plant cannot be constructed [39].

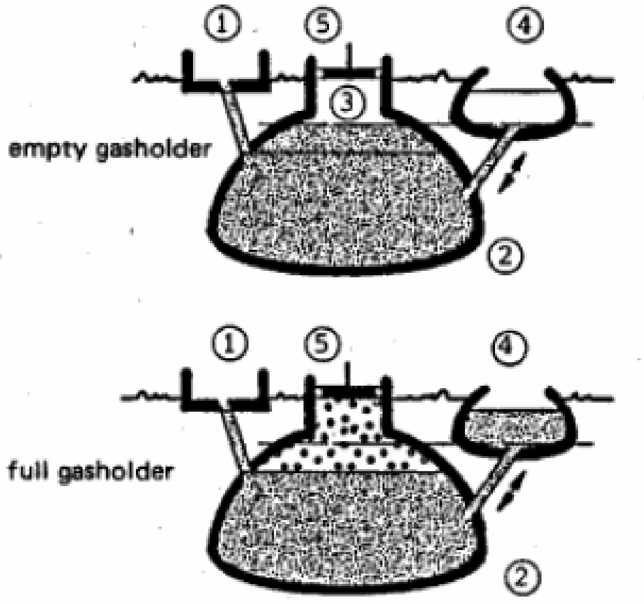


Figure 40: Fixed-dome biogas plant; 1-mixing pit, 2-digester, 3-gasholder, 4-displacement pit, 5-gas pipe [39]

Floating-drum plants consist of a cylindrical or dome-shaped digester with a moving, floating gasholder or drum. It can float either directly in the fermenting slurry or in a separate water-jacket (see figure 41). When biogas is produced, the drum moves up and when gas is consumed, the gasholder sinks back [39]. Thus, the stored gas volume is easily recognizable by the position of the drum. This type of plant is normally used on a continuous feed mode of operation [39]. Thus, it can be considered for the purpose of linking it with a public toilet. This type of plant is easy to understand and operate. The gas is provided at a constant pressure, which makes its utilization easier than in the case of fixed-dome plants. Also, the construction of a floating-drum type of plant is relatively easy. The gas-tightness is also not a problem as long as the gasholder is maintained properly. However, the steel drum is relatively expensive and requires regular maintenance work; removing of rust and regular painting has to be carried out [39]. Thus, running costs of this type of plant are rather high. Also, the useful life span of the drum is rather short, while compared to the fixed-dome type [39]. As far as construction material is concerned, the digester is normally made of brick, concrete or quarry-stone masonry with plaster [39]. The drum needs protection against corrosion. Materials that can be used for this purpose include: oil paints, synthetic paints and bitumen paints [39]. Coating needs to be applied carefully, with two preliminary coats and a topcoat. Floating drums can be made of steel, wire-mesh-reinforced concrete, glass-fiber reinforced plastic or high-density polyethylene [39]. Floating drums always require a guide that keeps the drum upright and provides stability [39].

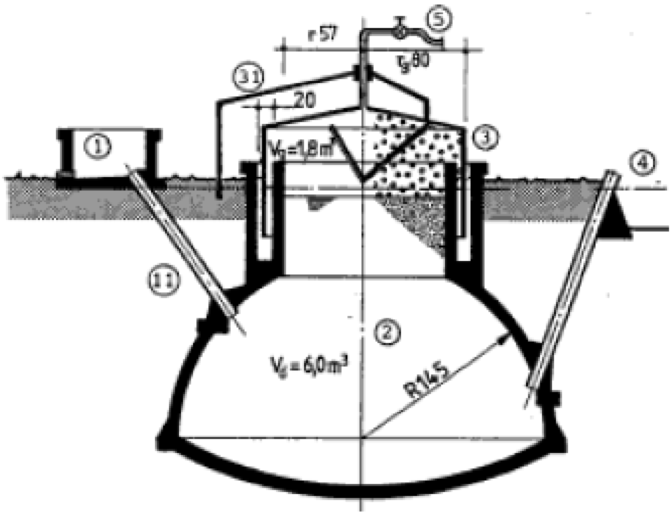


Figure 41: Water-jacket plant, 1-mixing pit, 11-fill pipe, 2-digester, 3-gasholder, 31-guide frame, 4-slurry store, 5-gas pipe [39]

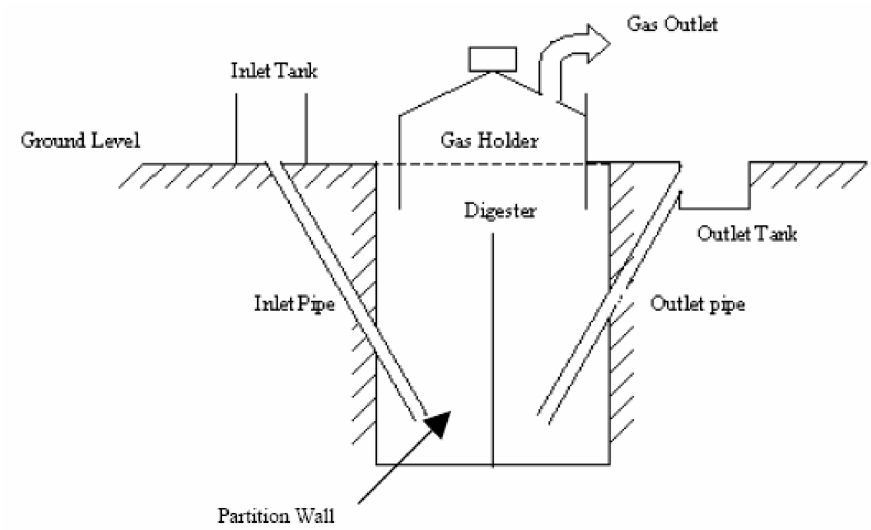


Figure 42: Floating-drum plant scheme [10]

A short comparison of the two types of biogas plants is provided in table 14 below:

Fixed-dome plant	Floating-drum plant
Requires high masonry skills and close technical supervision	Does not require high masonry skills
Low reliability due to high construction failure (gas-tightness)	High reliability, gas-tightness not a problem
Variable gas pressure	Constant gas pressure
Low cost	Steel drum-expensive, high running costs
No rusting steel parts	Steel parts need to be protected against corrosion
Longer life span (20-50 years)	Shorter life span (up to 15 years)

Table 14: Comparison of fixed-dome and floating-drum plant

Balloon biogas plants consist of a heat-sealed plastic or rubber bag, which combines a digester and gasholder [39]. “The inlet and outlet are attached directly to the plastic skin of the balloon. The gas pressure is achieved through the elasticity of the balloon and by added weights placed on the balloon [38]". The maintenance of this type of system is rather uncomplicated. Also, the cost of construction is rather low and the construction is easy. The skin of the balloon might get damaged if the gas pressure exceeds a limit that the balloon can withstand [39]. Thus, safety valves need to be applied [39]. As far as material selection is concerned, stabilized materials such as reinforced plastic or synthetic caoutchouc work best due to their UV- and weather-resistance [39]. Also, red mud plastic, Trevira and butyl can be used [39]. This type of biogas plant is applicable in regions with high groundwater table due to its shallow installation [39]. However, balloon plants tend to have a shorter life span (2-5 years) [39]. They are also easily susceptible to mechanical damage, so they should be installed if local repair is possible. This type of biogas plant can be recommended in areas with high temperatures.

All the three above-mentioned types of biogas digester plants have a number of various options among their main design types. These different designs belonging to one of the three main biogas digester types have some technical alterations, however, the main idea and their functioning remains the same. For more information about different designs and available options of biogas digester plants one should refer to the publication of the German Agency for Technical Cooperation (GTZ) and Information and Advisory Service on Appropriate Technology (ISAT): "Biogas Digest Volume II, Biogas - Application and Product Development Information and Advisory Service on Appropriate Technology".

3.2.9. Digested slurry management

Slurry or effluent slurry is the name given to the by-product of the anaerobic digestion system. "Anaerobic digestion draws carbon, hydrogen and oxygen from the substrate. The essential plant nutrients (N,P,K) remain largely in the slurry [39]". Digested slurry has fertilizing properties, which are dependent on its content of mineral substances and trace elements. "All plant nutrients such as nitrogen, phosphorous, potassium and magnesium, as well as the trace elements essential to plant growth, are preserved in the substrate [39]." The digested sludge has a lower C/N ratio, which improves the fertilizing effect due to the fact that a lower C/N ratio has a favorable phytophysiological effect [39]. Phosphate and potassium content, which is available to plants, is not affected by fermentation [39]. However, some nitrogen compounds undergo modification in the process of anaerobic digestion [39]. The effluent sludge contains about 50% of organic nitrogen and 50% of mineral nitrogen, which can be directly assimilated by plants [39]. Organic nitrogen needs to be first mineralized by microorganisms in the soil and then can be taken up by plants [39]. When applying digested sludge as a fertilizer, proper amounts should be calculated in order not to lead to over-fertilization of ground and surface water, which can be caused by excessive amounts of nitrogen being washed out [39].

When applying slurry onto the soil, it is assumed that it should receive enough nutrients that were extracted at harvesting time. For instance, it might be estimated that each hectare requires about 33 kg N, 11 kg P_2O_5 and 48 kg K_2O to compensate for an annual yield of 1-1.2 tons of peanuts [39]. "Depending on the nutritive content of the digested slurry, 3-6 t of solid substance per hectare will be required to cover the deficit [39]", which corresponds to the annual capacity of a 6-8 m^3 biogas plant [39].

In order to retain the maximum fertilizing quality of the slurry, it should be stored only shortly in a liquid form and then applied onto the fields [39]. There are mainly three techniques for slurry management. First one is called *liquid storage* and when this technique is chosen, the effluent outlet leads directly to the collecting tank [39]. When the sludge is needed for application, the content of the tank is agitated and filled into a liquid spreader or spread by other means, e.g. irrigation sprinklers. Liquid storage facilitates preservation of nitrogen, however, requires a waterproof storage facility of quite significant size. The second technique involves *drying* of digested sludge so that reduction of volume and weight is obtained and manual spreading is made much easier. Drying can be performed in shallow earthen drying basins, construction cost of which is rather low. However, the drying process affects the nitrogen content of the sludge [39]. It results in “ (…) a near-total loss of inorganic nitrogen (up to 90%) and heavy losses of the total nitrogen content (approx. 50%) [39].” The third option is *composting* of the digested sludge. This process effectively destroys pathogens and parasites that might have survived the anaerobic digestion process in the biogas digester [39]. The compost is moist, compact and can be spread out on the fields by using simple tools. Also, its transportation prior to being applied as a fertilized is much easier than in the case of the liquid slurry.

The choice of a biogas digester plant connected to a pour-flush public toilet facility needs to be based on inspecting local conditions of soil type and permeability, groundwater level, proximity to water supply, easiness of soil excavation, availability of skilled labor, possibility of experienced technical supervision, availability of construction materials, weather conditions and local culture. There is no general rule for application of particular biogas digester type, but its choice needs to be tailored to the local needs and available resources. Thus, a careful study of local conditions needs to be performed prior to the decision of constructing a particular plant. The same applies to the choice of slurry management due to the necessity of its acceptance by the communities.

3.3. Greywater treatment

As already discussed before, if a shower facility is to be provided in the public toilet complex and washing of clothes is practiced, greywater treatment needs to be incorporated into the overall system. Greywater is relatively harmless both from environmental and hygienic point of view. However, it contains some levels of organic pollutants, heavy metals, pathogens and other microorganisms [59]. Pathogens will be normally present if greywater will get contaminated with feces [59]. Greywater contains very low levels of nutrients. Tensides and other residues from soap, shampoos and detergents will be present as well [59]. The greywater environment is favorable for bacterial growth and thus it needs to be treated before reuse (e.g. for irrigation of green space in the vicinity of the complex) [19]. Also, untreated greywater easily turns anaerobic and so might become a source of odor [19].

Planted vertical soil filters are normally an appropriate option for greywater treatment. Horizontal filters also exist and, as the name suggests, horizontal flow through the soil filter is taking place. If vertical soil filters are used, greywater is normally applied to the filter from the top, where it pours down through the media vertically by gravity [59]. In order for the treatment to work, water should percolate through the soil in an *unsaturated flow* because the filtering capacity and the aeration to bacteria is much better than in soil with saturated condition (see figure 43) [59].

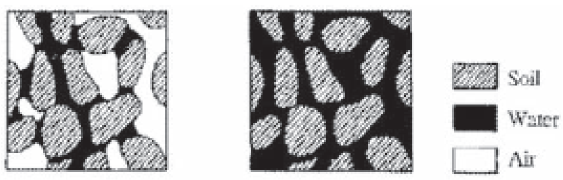


Figure 43: Unsaturated flow (left) gives better filtration and oxygenation of the water than saturated flow (right) [59]

In an unsaturated flow "water pours hygroscopically within the finest pores while the bigger pores are left open and aerated [59]", which is essential for the treatment capacity. If the vertical soil filter is operated and maintained properly, it has high removal efficiency for suspended solids and organic compounds, which may reach 90-99% [59]. Also, bacteria and virus removal is high and 95-99% removal can be expected for most pathogens [59]. Phosphorous and heavy metal removal is also significant [19]. Phosphorous removal efficiency can be between 30-95% and it mainly depends on soil properties, depth of the unsaturated zone and wastewater load [19]. Nitrogen is reduced by nitrification and denitrification processes, usually in the range of 30% [59, 19]. Dimensioning of the filter is based on the hydraulic load and the BOD load [59]. Typical loads for soil infiltration filters are 40-80 l/m^2/day or 6-8 g BOD m^2/day [59]. Soil used for the filtering purpose should not be too coarse or too fine. Generally, the fraction of fine sand should not exceed 10% [59]. When working with soil filter systems, even spreading of wastewater should be assured, otherwise clogging might occur.

Treatment of wastewater in planted vertical flow soil filters is achieved through a number of mechanical (soil surface acting as a filter), physical (adsorption on substrate particles), chemical (precipitation in the soil) and biological processes (microorganisms settled in the pore system of the substrate) [70]. Table 15 below illustrates the main processes affecting carbon, nitrogen and phosphorous. Plants play a minor role in the treatment process. They provide their root system for the transfer of oxygen, help decompose organic matter and help to prevent the filter medium from clogging and function as a temporary storage of nutrients [70]. The most common species of plants used in the planted filter soil systems are the cattails, bulrushes, sedges and reeds [32].

Contaminant	Site	Process
BOD_5	Stems and Leaves Roots Bed media (gravel/sand) Bed media (gravel/sand)	Microbial respiration Microbial respiration Microbial respiration Settling
Nitrogen	Leaves Algae in water column Roots Soil Bed media (gravel/sand)	Volatilization (as N_2 and N_2O) NO_3 and NH_4^+ -> Soluble Organic Nitrogen Ammonium -> Nitrate Nitrate -> N_2, N_20, or NH_4^+ Settling
Phosphorus	Stems and Leaves Roots Roots Bed media (gravel/sand) Bed media (gravel/sand)	Microbial respiration Microbial respiration Uptake Sedimentation/Burial Adsorption

Table 15: Processes occurring in treatment of wastewater[12]

Pre-treatment is needed prior to the planted soil filter; otherwise fats and other biodegradable organic products might clog the filter. Generally, pre-treatment serves to remove mechanically suspended solids. Available methods of pre-treatment include screens, filters and a septic tank system [59]. "A septic tank is constructed for gravimetric separation of particles from the water. Floating particles are collected as a scum in the top of the tank and sinking particles are collected as sludge at the bottom [59]."

After treatment, greywater might be discharged to surface water, percolated to groundwater or used for irrigation [89]. In the case of a public toilet complex, the treated greywater can be used for irrigation of the green space and flowerbeds in the vicinity of the complex or for washing of the toilet.

[12] http://www.fujitaresearch.com/reports/wetlands.html

Chapter 4: Public toilets in developing countries- general considerations, financial and social aspects on the example of case studies

This chapter will focus on explaining the need for public toilets, showing the importance of adoption of a proper operation and maintenance concept and presenting various case studies from Africa, India and Indonesia dealing with implementation of public toilets. Presentation of various projects will serve as a means of showing different operational concepts that might be adopted as well as demonstrate how a public toilet facility should be operated and maintained in order to become successful.

4.1. The need for public toilets

A public toilet is a toilet that is accessible to general public. For the convenience of the reader, it will be distinguished between two types of public toilets. The first type is named a *community toilet* or *shared toilet*. These toilets come in place in overcrowded settlements, where residents do not own a private sanitation facility. In such a case, community toilets serve a role of facilities shared among residents of a local area. The number of users might vary depending on the settlement. Sometimes, commuters and other floating population will use these toilets as well. The second type of public toilets is a typical *public sanitation facility placed in areas accessed by many people*, especially at railway stations, bus stops, market places, shopping areas, parking lots, entertainment events, etc. These toilets are normally used by a larger number of visitors, not necessarily living in the vicinity of the toilets, but rather people who are passing by. Both types of toilets are needed in two different surroundings due to the fact that if they are not provided, people will be forced to relieve themselves outdoors or use so-called "flying toilets". Thus, provision of public toilets is needed due to protection of human and environmental health.

The World Health Organization (WHO) in the fact sheet on "Sanitation in public places" clearly states that toilets should be provided on bus and railway stations [88]. These places are visited by continually changing groups of people. People, who have traveled over long distances or are just about to do so, will need to use toilet facilities and have access to water. The WHO also suggests that there should be a member of staff present in order to clean the toilets and ensure the presence of toilet paper, soap and clean water. His presence also reduces the chances of vandalism and prevents the toilet facilities from becoming fouled and a health hazard [88]. The WHO continues its guidelines about provision of toilet at markets, where food is handled and eaten by a large number of people. Sanitation needs to be properly planned at markets; otherwise they can become the centre for spread of infectious diarrhoeal diseases. Also, the toilet facilities in markets should be placed away from food storage or display areas. Hand washing basins with soap and water have to be provided. Also, sanitation in schools needs to be sufficient for the number of students and staff members, normally one toilet cubicle is sufficient for 25 users [88].

4.2. When and where public toilets should come in place

As already mentioned above, there are two types of public toilets, namely community toilets and public toilets located in places visited by many people. There is a common need for provision of public toilets in places where a large number of people might be present, especially in places of common use. A public toilet facility might be offered in places where there are restaurants, cafeterias and business districts with office buildings, which do not offer enough toilet facilities themselves. A public toilet complex sometimes includes other facilities such as a dressing room, clothes washing, showers, ablution blocks, breast-feeding station, nappy changing station, water vending, etc. People who are not in the vicinity of their homes for a longer time will be, sooner or later, willing to use a public toilet. Residents regard it as a responsibility of the authorities to provide them with public toilets in such places as bus terminals, airports, railway stations, market places, etc. This rule applies in both developed and developing countries, even though in the latter ones it is not always the case. Generally, the rule “privacy first” applies, which means that if a person does not have to use a public or community restroom, they will choose to use a private one. However, if there is no other choice but to use the public facility because one is far away from home or does not own a private toilet, they will use the public one.

There is a good example of low-cost housing technology project performed by the German Agency for Technical Cooperation (GTZ) in Ethiopia [27]. The program allowed for construction of living space by means of simple technology with prefabricated components. People who wish to move into the apartment buildings become owners and have to pay about 30% of the construction costs. The rest is financed through building loans. The residents take responsibility for maintaining their facilities. Seven model settlements with a total of 800 housing units have been built in different regions in the capital of Ethiopia. As a result, housing has for the first time become affordable for lower income groups. In the areas where these housing units have been built there is no urgent need for public toilets as people were finally able to afford the apartments, which have sanitation facilities integrated into their design. However, if the system is water-based it is often the case that there might be a problem with water supply and the toilets will block. Therefore, also in places where there are private toilets in housing units, public toilets are sometimes asked for. They are especially wanted in the case when the system is not working or for maids to use public toilets instead of the ones at home. Therefore, the location of public toilets needs to be carefully chosen. Some people will deter from using public toilets because they value the privacy the most and so they will try to have their own toilet at home. However, in some cases it is not possible due to lack of space in densely populated settlements or in places where there is no possibility for truck to empty the pits. Like in the case of a settlement in the vicinity of Jakarta, where migrant workers find shelter in rented housing units[13]. The landlords erected housing units and due to lack of space decided to provide for community toilets in order not to incorporate private toilets into each housing unit so that they have more space for rooms for rental, which means more profit for them. In this case, the migrant workers needed to accept this form of sanitation provision, otherwise they would be left without any. The considerations about where and when public toilets should come in place deals with the following aspects: presence of demand for public toilets, acceptance of this form of sanitation provision, danger of community health risk and environmental damage and last but not least, financial feasibility of the project.

4.3. General considerations about public toilets from user’s point of view

Pay-and-use public toilets are becoming a more and more popular option for sanitation provision in the developing world. This is especially the case in highly congested areas, where there is not enough place for private toilets and in places of general public attendance, such as

[13] private communication with Stephan Reuter from BORDA

markets, bus stations, etc. However, the opinion of the users and their attitude towards this form of sanitation plays an important role in them being willing to use it. It is rather obvious that people living on less than a dollar per day are more willing to spend money on food or clothing rather than on paying to answer the call of nature. However, a vast majority of them is concerned about the sanitary situation that they are faced with, and they generally recognize problems it causes.

The Sulabh organization in India studied behavior and attitude of people who did not use available public toilets in towns and cities and it was discovered that people would use such toilets if facilities for bathing and washing clothes were provided and if the toilets were kept clean all the 24 hours of the day [68]. Thus, one of the main reasons that people can refuse to use public toilets is not the fact that they are charged a fee for it, but the condition of the toilet itself. Experience from developing countries shows that people are willing to pay for the use of a public toilet if the facility is clean and appealing. If it is not the case, they will choose to use any nearby roadside or gorge. Security and privacy is another concern, especially for women. They want to use a toilet facility when they are sure it is safe to do so. It should be assured that there are no gaping holes in the walls or broken door and locks that would make the use of toilet dangerous for women. There were instances of women being robbed while using a toilet, not mentioning the danger of being sexually abused. People sometimes choose to urinate and defecate outdoors because they are afraid of being trapped in a dark toilet and having human excrement smeared over one's clothes by local youngsters, especially at night. Therefore, the conditions in the facility are of utmost importance to the users and they will determine the fact whether they will choose to use it or not.

From user's point of view, the toilet should be clean, should have water available and such basic accessories as toilet paper and soap should be in place. Maintenance is therefore one of the main concerns. Another issue is people being aware of the drawbacks of urinating and defecating outdoors. For some, this practice is so common that they do not even think about the effect it might have on human health and the environment. On the other hand, if they were educated and visualized the routes by which pathogens can make their way into drinking water, etc. they would think twice before relieving themselves outdoors or into streams and rivers.

As already discussed, there are two main types of public toilets. Community toilets are normally built in densely populated settlements such as slums. They are built in places where people do not have a household toilet due to a lack of space for it or money to build it, etc. In such a case, community toilets play a role of a household toilet, however, designated for more than one household. The other type of public toilets is the one placed in public places, such as bus stops, railway stations, parking places, public events, etc. The attitudes of users of these two types of toilets are different. As far as community toilets are concerned, people are more "bonded" to the facility and they tend to keep it clean since it is a direct substitute for a household toilet. When it comes to public toilets, their users do not feel a sense of ownership over them, so their condition and maintenance is relatively more problematic. Operation and maintenance mode of a toilet complex mainly depends on the community, management, ownership, location and culture. Also, since users name a bad condition of a toilet as the main factor rendering them from using a toilet, it should be realized that this plays the most important role. Also, the fee needs to be affordable to the users. Especially for the ones who have to use the facility a few times per day. Like in the case of Sulabh public toilet complexes, users find it affordable when they use the facility once per day [12]. Whenever users visit the facility more often and make use of not only the toilet, but also showers and lockers they already find the accumulation of fees not quite affordable, so they would request reduced rates for multiple usage [12].

The majority of people living in densely populated settlements recognize the inconvenience of lack of sanitation facilities. The ones who are more concerned are normally women, due to the shame and danger of urinating and defecating outdoors. They are faced with dehumanizing living conditions, which deprive them of their human dignity. If residents are not provided with sanitation facilities, they have no other option but to ease themselves in public or use the so-called “flying toilets”. Following this practice, plastic bags filled with human waste are thrown as far as possible from “the owner”. However, they do not vanish, but are simply placed elsewhere in the settlement. One can imagine the smell of urine and feces, children playing barefoot, people using the same water where others defecate and bathe for washing and cooking. When one is confronted with such a sight, it seems obvious that hygiene is rather made obsolete in these settlements. If public toilets exist, they need to be shared by many people. If there is no caretaker and the toilets are not kept clean, people will not use them but defecate in the open, where they do not have to be confronted with bad smell of other users’ excrements.

4.4. Willingness to pay for the use of public toilets

The idea of collecting a fee for the use of public toilet is not new at all. “The earliest pay toilets were erected in Ancient Rome in 74 AD during the rule of Vespasian, after a civil war in Rome affected greatly the Roman finance. His initiative was derided by his adversaries, his son Titus even criticised him, to which Vespasian replied by holding up a coin from the first collection to his son's nose and asking him whether its smell offended him. Titus responded negatively, to which Vespasian replied “e lotio est” (“And yet it comes from urine”)”. [51]

One of the most important considerations whilst planning construction, operation and maintenance of public toilets in developing countries is to estimate the willingness of potential users to pay for the usage of the facility. The model of operation and maintenance of public toilets in developed countries is much different from the one applied in developing ones. One of the main differences is that users in developed countries, in most of the cases, are not obliged, but rather encouraged, to leave a tip to a caretaker present on site or leave some change on a small plate next to an exit of a toilet. There is normally no one keeping track on an actual amount of money being paid. Also, users are normally allowed to use a facility even if they do not leave any change behind. Users, however, in most of instances leave some change, especially when they find a toilet facility clean and appealing. Only in the case of a freestanding coin-operated public toilet a user must pay a toilet charge in order to enter a stall. In developing countries, users would decide not to leave money if there was no one on site to collect it from them. First of all, another visitor could take the money that was left unattended. Moreover, people living in developing countries are faced with poverty and hunger so if a caretaker did not collect a fee, they would choose not to pay for usage and spend the money on food or clothing. Therefore, pay-and-use public toilets in developing countries should have a caretaker, who is always present on site in order to collect a toilet charge, keep a facility clean and maintain it on a daily basis.

Another important consideration deals with an issue of what amount of money one should charge for a toilet use in developing countries. According to the director of BORDA[14]: "the price for using a toilet and a shower should be the equivalent of the price of one cigarette in a particular country". However, there are countries or regions where smoking is generally not a common practice, and then this rule seems to be difficult to apply. The table 16 below presents some examples of toilet charges collected in developing countries. There is normally an opinion among public toilet users that toilet charges are too high. Especially when users are confronted with a filthy and poorly maintained facility, they are not willing to pay for the use of such a toilet. Many of regular public toilet users do not own a private toilet at home. This might be due to poor sanitation condition in their region, limited space in densely populated areas or lack of financial resources. However, they feel that being able to relieve their nature in privacy has to do with basic human rights and dignity. Thus, due to the fact that they cannot have a private toilet, they feel that they should not be charged for the use of a public convenience. Some do not make use of public toilets for this reason and, instead, they use toilets of the nearest household or urinate and defecate in public. Thus, while drafting a plan of a public toilet project, one should keep in mind that estimating the willingness of potential users to pay for the toilet use is crucial. There are some public toilets already being operated in the capital city of Ethiopia- Addis Ababa. In the case of Addis Ababa there is a different fee being charged for defecating (0.028 USD) and for urinating (0.017 USD). In Ethiopia a packet of twenty cigarettes costs about 6 birr, which means that one cigarette costs about 0.033 USD. The fee for the use of a public toilet is less than a price of one cigarette, however, people in the area find it too expensive. It is estimated that about 30% of households in the city lack private sanitation facility and the minimum wage for daily laborers is estimated at 8 birr, which is an equivalent of 0.0627 USD[15].

[14] private communication with Stephan Reuter from BORDA

[15] Addis Ababa, private e-mail correspondence

4.4.1. Price per toilet use

Country	Toilet charge [USD]
Addis Ababa, Ethiopia	0.017-0.028
India[16]	0.02
Nairobi, Kenya[17]	0.02
Nairobi, Kenya[18]	0.025-0.064
Uganda[19]	0.03
Mali[20]	0.04
Kampala, Uganda[21]	0.05-0.1
Nakuru, Kenya	0.07
Nairobi, Kenya[22]	0.08
Nigeria[23]	0.15
Francistown, Botswana[24]	up to 0.16
Kano, Nigeria[25]	ca. 0.3-0.5
Botswana[26]	ca. 0.9

Table 16: Toilet charges in different countries

Country	Toilet charge, [USD]	Gross national income per capita, [USD], 2004	Gross domestic product per capita % growth 2003-4	PPP gross national income per capita, [USD], 2004
Ethiopia	0.017-0.028	110	10.9	750
India	0.02	620	5.4	3,120
Kenya	0.02-0.08	480	2.0	1,130
Uganda	0.03-0.1	250	2.1	1,450
Mali	0.04	330	-0.8	950
Nigeria	0.15-0.5	430	3.7	970
Botswana	0.9	4,360	5.0	9,580
Germany	ca. 0.67	30,690	1.6	28,170

Table 17: Toilet charges and economic indicators of different countries [91]

16 "Pay-and-use toilets in India", V. Chary, A. Narender, K. Rao, Waterlines Vol. 21 No. 3, January 2003
17 http://www.planetark.org/dailynewsstory.cfm/newsid/17632/newsDate/06-Sep-2002/story.htm
18 http://www.wsp.org/filez/pubs/3282007101231_afUnderstandingSmallScaleProvidersKibera.pdf
19 http://news.bbc.co.uk/2/hi/africa/4383812.stm
20 http://web.mit.edu/urbanupgrading/waterandsanitation/resources/examples-pdf/PublicToiletManagersMali.pdf
21 http://www.wupafrica.org/toolkit/resources/caseExamples/narrative-form.html
22 "Tenancy and sanitation provision in informal settlements in Nairobi: revisiting the public latrine option", Madeleen Wegelin-Schuringa and Teresia Kodo, Environment and Urbanization 1997; 9; 181.
23 http://news.bbc.co.uk/2/hi/africa/6133556.stm
24 http://allafrica.com/stories/200705150584.html
25 http://web.mit.edu/urbanupgrading/waterandsanitation/resources/caseExamples/narrative-form.html#Anchor-Private-47857
26 Acceptable price for public toilet use, Source: GTZ

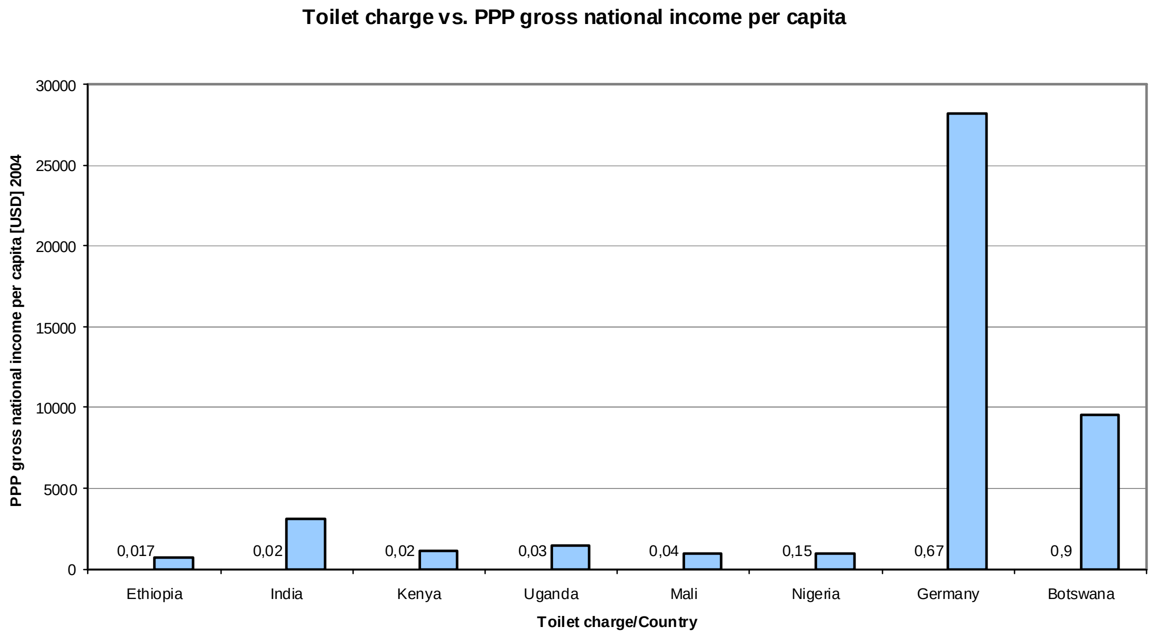


Figure 44: Toilet charge versus PPP gross national income per capita of selected countries

The above table 17 shows a compilation of toilet charges from different countries in Africa, India and as a comparison also from Germany in Europe. Table 17 also presents three economic indicators: gross national income per capita, gross domestic product per capita and PPP (purchasing power parity) gross national income per capita.

Gross domestic product is "the monetary value of all the finished goods and services produced within a country's borders in a specific time period, though GDP is usually calculated on an annual basis. It includes all of private and public consumption, government outlays, investments and exports less imports that occur within a defined territory [31]". This indicator measures the size of the country's economy. It differs from *gross national income* in a way that it includes all final goods and services produced by resources owned by that nation's residents, whether located in the nation or elsewhere. *Purchasing power parity* is a theory stating that exchange rates between currencies are in equilibrium when their purchasing power is the same in each of the two countries "This means that the exchange rate between two countries should equal the ratio of the two countries' price level of a fixed basket of goods and services [72]." "These special exchange rates are often used to compare the standards of living of two or more countries. The adjustments are meant to give a better picture than comparing gross domestic products (GDP) using market exchange rates." [52] Among all three above-mentioned indicators, PPP seems to be the best one in the case of less-developed countries since it compensates for the weakness of local currencies in the world markets. However, one should bear in mind that this indicator is still imperfect because it is assumed that the real value placed on goods is the same in different countries. In reality, it might be that in one culture something is considered a luxury, whilst in another it might be considered a necessity. When one compares the PPP values of different countries in Africa, it is quite clear that Nigeria, Mali and Ethiopia are the worst-off among the listed countries. In these three countries PPP in the year 2004 was less that 1,000 USD, which is twenty-eight times less than the one of Germany. Then come Kenya, Uganda and India, which had PPP above 1,000 USD (India even above 3,000 USD). The best off among the listed country is Botswana, where PPP was ca. 9,500 USD. When one takes the PPP values into account and compares the toilet fees charged in the listed countries, it is noticeable that users in Botswana are charged the highest fee (even more than the users in Germany), whereas in Ethiopia the lowest one. In India, Uganda, Mali, Kenya and Nigeria the toilet fee might be even less than 0.05 USD and it goes well with the PPP values of these countries. The table serves only as a general comparison between the above-mentioned countries so that it might be roughly estimated which value of the toilet charge will be affordable for an average user and whether it goes in line with the country's economic indicators. However, local conditions always need to be taken into account so while estimating an affordable toilet charge, it needs to be checked, e.g. what percentage of private sanitation facilities is in the region and how much an average capita earns per day. It might be also useful to find an object, which is mostly purchased and used or consumed in a particular country (not depending on the status of the user), and estimate the toilet charge based on comparison to the price of this particular object. In some countries it might be useful to use the price of one cigarette as already mentioned above. However, in regions were smoking is not generally practiced one needs to come up with a comparison of a price of another object, e.g. a cup of coffee. For example, in Addis Ababa the cost of one cup of coffee is 1.5 birr, which is equal to 0.17 USD and the toilet charge is between 0.017-0.028 USD so about ten times less than the price of coffee. As already mentioned above, one cigarette in Ethiopia costs about 0.033 USD so a bit less than the toilet charge.

4.5. Potential problems and misuse of public toilets

The caretaker's presence is crucial not only due to maintenance, but also because of one more reason; they need to make sure that toilet complexes are not misused. A student's study on public toilet complexes in Durban, South Africa depicted some of possible problems and misuse that might occur [49]. Public toilets placed in places with fluctuating number of users, especially where travelers arrive and start off their journey, may be confronted with large number of users willing to use the facility at the same time. Thus, urinals should be provided in order to reduce the time needed for users to stand in line and avoid congestion. On busiest days, if not enough toilets are provided, people will defecate and urinate outside toilets. In such places as bus stops and railways stations, people are also willing to use a toilet as a dressing room. In such a case when there is no separate entrance for men and women, the latter may be intimidated by the view of naked men. Therefore, for the convenience of both, separate entrance should always be provided. The toilet blocks investigated in Durban were supposed to be made available to users between 7 a.m. and 6 p.m. However, most of the blocks did not have locks or they were broken so the students observed misuse of the toilet complexes especially before their opening hours, where no maintenance staff was present on site yet. Main activities taking place before opening hours involved: stealing of water in bulks (according to the estimation- about 1,500-2,000 l of water were stolen between 4 and 6 a.m. in one of the toilet blocks), washing baby nappies, using of the toilet as a private bedroom and street children sleeping in the toilet blocks. The toilets had many malfunctions; some of them did not have light, which made it possible for men and women to have a shower in the same place. Also, absence of toilet paper was quite common, so visitors chose to use newspapers or hard paper instead of the toilet tissue, which lead to toilet blockages. It appeared that the toilet attendants were trading toilet paper for fruit or other food with informal traders present in the area. The 24-hour (illegal) operation of the toilet, due to broken locks and gates, made it impossible for the toilet attendants to clean the toilet before the scheduled opening hour. Therefore, cleaning and using of toilets overlapped, which made it inconvenient for the toilet attendants to do their job. Also, one of the toilet blocks did not have signs to differentiate the male and female toilets, making it inconvenient for the users. The fact that toilet blocks remained open unattended for the night made its use dangerous for their visitors. Also, some of the toilet blocks did not have proper ventilation and were dark inside. Moreover, some of the toilet blocks did not have roofing, so when it rained, they were rather dysfunctional. In the toilet blocks visited by students some of the urinary basins were defect and steel toilets seats were rusted and should be replaced with ceramic or concrete seats. Female toilets in one of the blocks lacked a hand basin for washing hands. In another block, washing basin did not work in a male toilet. The above description of the state of the public toilets observed by the students together with their defects serves as an example of what might happen if a public facility is not operated and maintained properly. In the case of public toilets in Durban, it made it unappealing for the visitors and the user's improper behavior and usage of the facilities was a result of it. It has to be borne in mind that a toilet facility needs to be in line with users' expectations as only then they will be willing to use it properly and to pay for its use.

Another important issue is related to instructions of a toilet's use. In the case of urine-diverting toilet or pour-flush toilet with anaerobic digestion, proper use of a toilet is crucial for its successful operation. When these toilets are operated in households, it is relatively easy to educate people (in this case- toilet owners) how to use, operate and maintain them. Such users also have interest in proper operation of a toilet since they make use of biogas that is generated or urine as a fertilizer and dry excreta as a soil conditioner. It is all taking place in "their backyard", so they have an incentive to operate and maintain the toilet properly, and still there were some cases where it all failed. Therefore, in the case of public toilets care needs to be given to instruct their users. It case of urine-diverting toilets, it needs to be made clear that urine cannot be mixed with feces, so smaller seats for children need to be installed and available for users. Also, a separate container needs to be placed next to a toilet for anal wiping material and female hygienic material, so that it does not enter a chamber where excreta is stored for drying. Otherwise it would hinder organic decomposition processes taking place in a collection chamber. In the case of pour-flush toilets, it is important to familiarize users with the necessity of small amounts of water that should be used for flushing in order not to dilute slurry in a biogas digester. These are just a few examples of what users should know. The best way of acknowledging them with all necessary information is to put instructions visible to all users inside of toilet cubicles. The instructions need to be clear, legible, easy to understand and follow for a layperson, who might be not familiar with the underlying technology.

To sum up, while planning a construction of a public toilet facility, the above-mentioned considerations need to be accounted for. Service providers need to make sure that a facility is maintained and kept clean on a daily basis. Moreover, a toilet fee needs to be set in a way that it is affordable for users. Otherwise they will continue to relieve themselves outdoors. A fee needs to be collected and a caretaker needs to be present on site to provide for cleanliness of the facility. One also needs to make sure that toilet complexes will not be misused. Proper operation of a facility is the only means for its success. Thus, all necessary equipment should be in place and a facility should remain locked when it is after its opening hours. Such issues as safety of users, convenience, privacy, cleanliness, accessories being in place and a responsible caretaker will definitely support proper use and operation of a public toilet complex.

Next section will present different case studies related to implementation of various public toilet projects in Africa, India and Indonesia. They will deal with both types: community and regular public toilets and describe obstacles that needed to be overcome for the projects to become successful. Also, some projects that failed will be presented and the reasons for their failure will be discussed.

4.6. Public toilet projects in Africa – success and failure stories

4.6.1. Case study: Public toilets in informal settlements in Nairobi, Kenya

This case study is based on the article by Madeleen Wegelin-Schuringa and Teresia Kodo: "Tenancy and sanitation provision in informal settlements in Nairobi: revisiting the public latrine option".

Situation in the informal settlements in Nairobi

In Nairobi, the capital of Kenya, informal settlements house over half of the city's population. The settlements have their own socio-economic, political and ethnic characteristics. Even though they are very densely populated, the city authorities do not regard provision of basic services as their responsibility in these areas since these settlements are considered as illegal. Therefore, water supply and sanitation services are insufficient and waste disposal simply does not exist. Because all informal areas are illegal, it is prohibited to build anything other than temporary structures. This usually means mud-and-wattle houses with galvanized iron roofing. The most common form of tenancy is illegal room rental from (illegal) landlords.

Settlements compounds consist of barrack-like structures with small rooms of ten square meters each under a common roof. The distance between one row and the next within a compound may be as little as one meter. A single room is generally resided by one household, consisting on an average of five people. Because the compounds are used to their capacity there is usually hardly any space for toilets and often there is only one toilet available for all residents living in the compound (25 to 200 people). Toilets are considered as a responsibility of the landlord who normally does not live in the settlement and is not interested in improving the sanitary situation in the area. Taking into account these circumstances, the only applicable solution to this problem is provision of some sort of public toilets. In this case public toilets could have a form of either community toilets or public pay-and-use toilets. Experience with the operation and management of public toilets in India (refer to the case study in the section 4.7.1.) demonstrates that pay-and-use toilets can work well for toilets in public places. The experience from other countries has proven that community toilets can work well if the user group is defined and involved in planning as well as management of the facility and employs a caretaker and cleaner. The most important prerequisite for the community to use public toilets in either of these forms is their condition. In other words, they have to be kept clean in order to be used by the residents. The following case study involves three slum locations in Nairobi, Kenya.

The Kitui-Pumwani community covers a small area in the southeast of Nairobi. In 1996, the total number of households was estimated at about 1,600. Undugu Society, a local NGO, has provided help for the community. Five blocks of toilets were built in 1990-1991 with the funds provided by the UNICEF. At the time, each family contributed the equivalent of about USD 1.65 to pay for the unskilled labor hired within the community. There are no water taps in the toilet facilities, but water is available for sale by jerry can in a number of water kiosks.

One of the five toilet blocks has a connection to a main sewer running through the area. This block is fitted with 20 cubicles. The toilet system comprises of an open trench at the back of each cubicle being automatically flushed every 10 minutes. Water supply is attained free of charge from the Nairobi City Council (NCC) water supply via a piped connection. This system requires a lot of water so it being provided free of charge is a prerequisite for it to work; otherwise people would not be able to pay for it. As far as maintenance is concerned, each cubicle is in possession of 20 households. Each of these has a key to the facility and is responsible for cleaning it in turns. The block has a committee that inspects the toilets every week. Within five years after its construction the block has never been blocked. The four remaining blocks are not connected to the sewer. Each block consists of a large pit, over which 12 cubicles have been constructed. Each block also has a committee inspecting the toilets on a weekly basis. It is a dry pit latrine system and when the pit is full, the committee arranges for the city council desludging truck to empty it. All the households contribute to the cost of desludging (ca. 33 USD per load- about 5,000 liters). Most committees consist of older women who take pride in keeping the toilet block under their care clean and well organized. Initially, all households were owners, which resulted in a sense of ownership over the toilets, and their cleanliness was never an issue. With an increase in tenancy, this is becoming more of a problem. Not only has the number of users doubled, but also the tenants do not feel the same kind of responsibility towards keeping the toilets clean. They feel that they are paying rent and, therefore, are excused from the responsibility of maintenance.

Mukuru Kayabaa settlement with a population of 30,000 is located in the industrial area of Nairobi. The land, which is owned by the government, is illegally occupied. The owners of the structures occupy about 60 per cent of the houses, and the rest of the rooms are rented out. Usually, there is one household per room with an average of five people per household. A survey carried out in 1994 demonstrated that one of the highest priorities for improvement was the provision of sanitation services. At that time there were only 30 toilets available for the whole population. In 1996, the community with the help of a local NGO and a community development office constructed two public toilet blocks. There were two clusters decided upon, one consisting of 506 households and the other one of 466, where sanitation problem was burning. Toilet committees were chosen there and they were held responsible for finding space for toilet blocks and selecting an appropriate type of toilet to be built. Landlords, tenants, men and women were members of these committees. Engineers from the city council provided them with advice. As sewers were present in the vicinity, a sewered connection seemed to be an appropriate choice and so the site location was based on the proximity to the sewers. However, in one of the clusters this involved demolition of a number of houses. All the costs involved with the demolition and what came with it were raised by community contributions. Both blocks have eight doors and a trench system that is flushed manually from a central point. There are two 200-liter overhead tanks directly connected to the municipal water system. In addition, there is a 400-liter overhead tank as a reserve supply. Both toilets have an outside tap, from which water is sold and, in both cases, the connection to the existing sewer is less than two meters long. A donor covered the material costs of about 7,000 USD for the toilets, whereas the community contributions covered the cost of labor, demolition of the rooms and construction of new ones (ca. 600 USD). It was also decided that landlords had to contribute at a rate of ca. 3 USD per room, which was paid by the tenant and then deducted from their rent. The end effect was such that the landlords paid for the toilets. Two women from each area, who were elected by the community and trained by the Department of Public Health, carry out operation and maintenance activities. Households pay a fee of 0.82 USD per month for use of the toilet. They normally pay 0.02 USD per 20-liter jerry can of water. The attendants keep the facilities clean and do the manual flushing in case it is necessary. The money collected each day is handed over to the toilet committee. Toilets are also used for bathing, which results in water draining from under the doors due to the fact that the floor of the cubicles does not drain sufficiently. Thus, there are instances of standing water in front of the toilet. The improvement of this flaw would involve construction of a small drain in front of the doors and connecting it to the sewer or cementing the floors in such a way that they would drain towards the trench at the back. More than a month after the construction of the toilets household membership was rather low. What is more, some landlords also constructed individual toilets along the river, in order not to be obliged to pay for the new toilets. These toilets are directly connected to the river, thus pollute it even more. Despite the low membership, toilets are operating at a profit, which can be mainly attributed to frequent use by non-members and to the sale of water.

Mathare Valley is a settlement with a total population of ca. 300,000 located in the southeast of Nairobi. Mathare 4B with its 30,000 residents is one of the poorest sections of the settlement. Houses are at best made of mud-and-wattle but many are made of wood and corrugated iron. None of the houses is fitted with a toilet. This area is not covered by any city council services. Normally, residents stay in a room for a short time and when they are not able to pay the rent they move to another part of the settlement. Water can be bought from private kiosk owners at a rate of 0.04 USD per 20-liter jerry can. The Wapenda Afya Bidi Group together with a local NGO managed to convince the city council to take over the management over the existing public toilet, which was not being used due to its poor condition. The toilet is comprised of a building divided into two gender sections of 12 open cubicles. The toilet system has a trench at the back, which is connected to the sewage system. The sewer was too small and the connection to the pipe was not properly designed, thus it got blocked on a regular basis. The group managed to keep the toilet in operation by scooping out the trenches with buckets and throwing the contents to the nearby river. After the local NGO ceased to function, the group gained support from WaterAid, a British NGO. They funded the reconstruction of the blocked sewer and provided a water connection and a water tank from which water could be sold. Two group members are in charge of the toilet each day and have to keep the facility clean. In return they earn 0.82 USD per person. At the time the group started operating the facility, they assumed that all households in Mathare 4B would become members and pay 0.41 USD per household per month. Non-members could make use of the toilet by paying 0.08 USD per usage. However, due to fairly low membership, total collection amounts to about 41 USD per month. It is estimated that about 600 people use the facility daily. It appeared that the few households who have paid for the membership are sharing their membership card with other households. It is impossible for the toilet attendants to keep track on the users since the population is so dense. On top of this, the level of knowledge and concern for the health effects of random defecation is rather low. This is also apparent when one observes the state of the facility. Even though it is cleaned on a daily basis, the state of it is not appealing. The group planned an installation of a water meter and vending of water for 0.03 USD per 20-liter jerry can, which would generate a profit to cover maintenance costs of the toilet. Also, two cubicles on each side will be converted into bathrooms, for which a usage fee will be 0.04 USD and water will have to be bought separately.

Conclusions

The case studies indicate an issue of selection of maintenance and operation management approach as a determinant for the sustainability of the public toilets. Water vending in the facility encourages hygienic behavior by users. A dry-toilet system seems to be more appropriate to water supply conditions in most of the informal settlements. The location of these toilets does not depend on their proximity to the sewer and as such has a wider applicability. On the other hand, this type of system needs regular emptying activities to be performed and its effectiveness depends on a reliable desludging service. Also, the accessibility of the toilet for the desludging truck needs to be assured. The users have to pay for the emptying of the toilets, which makes it not attractive to them and creates further problems if the organization of contributions is not managed properly. There are mainly two types of management methods of public toilets. The first method involves division of the public toilet cubicles among the residents. Then, each of them is in a possession of a key and needs to provide for cleanliness in turns. This type of management system will work with a clearly defined user group and constant, reliable supervision. It might easily break down when people stop feeling responsible for the facility. It could be seen on the example of Kitui village, where due to the increasing tenancy the maintenance of the toilets worsened. The other type of system can be described as a public pay-and-use system for residential use. In this type of system users have access to all cubicles and do not bear any responsibility apart from regular payment.

Where toilets are the result of a community effort, both in planning and implementation, the facility operators are likely to be residents from the area. The huge advantage of it is that they know the users, know who has paid the fee and know who has to pay per use. Also, due to the fact that the community hires them there is a level of control on the hygienic maintenance of the toilets. To ensure that the operators keep the facility clean and the user group is well defined and known, a minimum level of social control and pressure is essential. The experience in Mathare 4B demonstrates what happens when this social control is missing. In such a case, where poverty prevents people from paying per use, it may be better to consider raising the price of water to cover the operation and maintenance costs of the toilet instead of user fees.

The experience shows that the construction costs of public toilets for residential use need to be provided from government subsidies or donors (if they do not operate on a public-private ownership basis). Obviously, community contributions are necessary to generate a sense of ownership and could cover the labor costs and other unexpected costs. The extent to which owners and tenants contribute will always depend on the local situation. Based on the experience from Nairobi it seems that household user fees will never cover more than the cost of operation and maintenance. How these fees are collected (per use, on a monthly basis or through water fees) and whether a subsidy is possible for the poorest households needs to be determined by the resident users who, in most cases, will be tenants. The question of tenant willingness to contribute on a membership basis will depend on the nature of tenancy. For instance, temporary tenants such as those in Mathare 4B are unlikely to commit themselves to anything whereas long-term resident tenants are known to participate in community committees, as in Mukuru Village, and are very likely to be willing to support a service which responds to a felt need.

The next case studies will serve as examples of success and failure of public private partnerships for provision of public toilets. Case studies are taken from two African countries, Nigeria and Ghana.

4.6.2. *Case study: Public toilets in Kano, Nigeria*

Kano is the third largest city in Nigeria, and like most large cities in developing countries its sanitation conditions are rather poor. This is mainly due to the lack of sanitation facilities, especially in congested urban areas where there is not enough space for having household toilets and in public service areas such as markets, bus stations and car parks. The example of private public partnerships for provision of public toilets in Kano is quite successful. There are two types of privately run toilets in Kano. The first one is the one that is built and operated by individuals or organizations, whilst the second one is built by the government and rented to interested individuals [80]. The sanitation situation of public toilets prior to introduction of a public private partnership in Kano was not satisfactory. Kano needed improved sanitation due to many factors. Firstly, environmental health of the community was at stake and so it needed improvement. Moreover, Kano's community is mostly Muslim and so there was a need for ablutions before prayers and religious demand for privacy while relieving oneself [36, 80].

History of shift from public to private

In the 1950s some public toilets were built and maintained by the municipality [36]. They were built near the market in Kano, however, their number was not sufficient and their level of cleanliness was rather poor. Thus, some market traders got the permission to build and run the facilities on a commercial basis. By 1981, the Kano Urban Development Board (KUDB) started to encourage this practice [80]. In an instance when it was considered essential to build the facilities but there was a lack of financial resources, the KUDB itself would take over the installation and provide it to the interested individuals on a credit or lease basis [36]. In the case of private funding the owner is obliged to pay an annual fee of 8 USD to the government, whereas in the case when the government constructs a facility there is an allocation fee of 250 USD and an annual rent of 10 USD [36].

The operational concept [80]

Individual operators are wholly responsible for the management of the public toilet units. Some of them are managed by employed managers, whilst the others by the owners themselves. Generally, there is one staff responsible for collection of user fees, which are equivalent of 0.3-0.5 USD. Another staff is responsible for cleaning and inspection of the facility after its use. Also, Kano State Environmental Planning and Protection Agency (KASEPPA) inspects the facilities once in a while in order to check for cleanliness. Normally there is also an office at the entrance of the premises, which serves as a cash and supervisor's office.

Location, design and operation of the toilets [80]

Most of the facilities are located in public places, but there are also a few placed in congested residential areas. There are two standard designs issued by KASEPPA. One type of units comprises of 16 compartments with five toilets and three bathrooms for men and seven toilets and one bathroom for women. The other type consists of ten compartments with four toilets and two bathrooms for men and three toilets and one bathroom for women. Bathrooms are fitted with a shower and toilets with a squat flush facility and a water tap. The first type of toilet costs about 12,000 USD to build, whereas the second type – 8,000 USD. KASEPPA also has very specific site selection guidelines to avoid any nuisance or health hazard in the surrounding area, which must be met in order for an approval letter to be issued. Kano State Water Board (KnSWB) supplies water for operation of the conveniences. In the sites where there is no water supplied by KnSWB, boreholes are dug by the operators, which sometimes provide water for sale to the public as well. There are also strict conditions for operation of the conveniences. They must have a water connection and they must be kept clean. In general, privately financed toilets are built on a private land. In order to construct or operate such a facility, one needs to fill in an application to KASEPPA and an agreement for letting of land for use as a public convenience is signed between the agency and the tenant.

Conclusions

This case study is an example of a success story. This success can be attributed to the fact that communities have accepted the running model of a public private partnership in provision for public toilets. The operating units are very popular and people feel comforted that they do not have to relieve themselves outdoors whilst shopping on the markets or in-between traveling. Also, other states such as Kaduna, Plateau, Katsina and Sokoto replicated the Kano experience [36]. As a result of the program, many places were transformed from being filthy and unappealing to neat and safe. Moreover, the state of health of the communities was put first and the sanitary environment of the town has improved to a large extent. There are 145 such toilets currently in place [36]. As a result of allowing arrangements with private operators, the authorities managed to ring changes and improve the sanitation and hygiene service. They managed to set up public facilities, which would have not been installed or managed otherwise. This case study is an interesting example of how public private partnership program worked well in practice and managed to be extended to other states. Many cities in developing countries have already applied delegation of management of public toilets to a private sector and even included the construction of facilities in the process. In a sense, the municipality recognized the demand but due to lack of own resources, called for a private investment. This idea seems smart and easy to be carried out. However, next case study, which also deals with public private partnership in sanitation services, will show that it may also run wrong.

4.6.3. Case study: Public private partnerships in Ghana

The initiatives of contracting out the management of public toilets to private business and community-based organizations in the cities of Accra and Kumasi in Ghana have failed. The reason for this is mainly due to the fact that politicians captured the franchises, and the management as well as control over public toilets became an important source of revenue and patronage. Moreover, the state did not have the capacity to regulate and manage the private public partnerships. [8]

How it all started

Accra and Kumasi have suffered from a huge public health problem. As in many other cities in developing countries, urban infrastructure did not manage to keep up with a rapidly growing population. It is estimated that 38% of population in Kumasi and 25% in Accra rely on public pit toilets [8]. Thus, provision of public toilets was an important issue since they are one of the most important facilities for people living in poor, densely populated areas, where no or a few private toilets are in place. Failure of provision of public toilets would leave people without any other choice but to defecate and urinate in public or rely on using other's private toilets. Thus, public toilets serve the interest of public health. However, provision of urban sanitation is rather problematic. On one hand, failure of provision will result in public health hazards. On the other hand, it is fairly costly whilst the users' willingness to pay is rather low. By 1982, the use of public toilets was free of charge and the facilities were managed by City Councils and cleaned by paid sanitation workers [8]. However, the workers were not motivated and the toilets were not maintained properly. Then, the Committees for the Defense of the Revolution (CDRs) were involved in the management of public toilets and it brought some improvements. Also, minimal fees were charged to finance the maintenance of conveniences. However, CDRs started to misuse the fees, which led to poor maintenance, and again failure in provision of toilet facilities of good quality. Thus, the management of public toilets reverted to the municipal governments, which got the name of Metropolitan Assemblies. In 1989, as a result of decentralization program, the management was contracted out to local businesses and community participation was encouraged in the provision of cleaning and maintenance [8].

Problems and failure

Even though toilet management contracts were supposed to go to registered local companies with proven capacity, most of them were in hands of Assembly Members, mainly in Kumasi. "They were using them to supplement their allowances and sustain their ability to provide patronage to their constituents. At the same time the toilets had become crucial revenue earners for the Sub-Metropolitan Districts, yet remained poorly maintained. [8]" Control of toilets allowed Assembly Members to reward supporters with jobs and other benefits. The government elected in 2000 tried to introduce more transparent and competitive tendering agreements to tackle the problem of patronage politics. However, it only created conflicts with Assembly Members and Sub-Metropolitan District Councils. It was expected that community participation would result in improved service delivery, but it appeared that the most active groups were actually dependent on politicians. In other words, they relied on relationship with Assembly Members as far as jobs and other benefits were concerned. There were attempts aiming at challenging the authority of the Assembly Members, but they were always held back. The poor areas of Kumasi and Accra did not have well-established groups and adequate resources that would enable the community groups to operate independently. The main problem in Accra and Kumasi was that decisions about the allocation of publicly funded business opportunities became politicized [8]. Community groups were not able to operate with certain autonomy and the state did not have capacity and incentives to manage and regulate new arrangements [8]. "Sanitation is primarily a public health issue " [8], but in Accra and Kumasi the failed experiments with various forms of public toilet management (ranging from political groups- CDRs, through franchising to community business, to direct management by Metropolitan Assemblies) led to generation of public health crisis [8].

Conclusions

This case study depicts how political interference might lead to failure of adequate provision of sanitation services. Community involvement or even ownership could be an alternative to what was chosen in Accra and Kumasi. However, communities should be provided with resources and be well organized in order to have the ability to operate independently. The main prerequisite for the alternative approach to work is independence of community groups and their ability to challenge local politicians. Unlike in the case of Ghana, they should not be given political funds in order not to make themselves dependent on local political groups.

Otherwise, the provision of good quality service will no longer be of utmost importance, and political games will take over the situation. Moreover, contracts for delivery of public services need to be based on fully transparent and performance-based tendering procedures [8].

Next case study will deal with solving the sanitary situation in one of the largest informal settlements in developing countries- Kibera in Kenya.

4.6.4. Case study: Small Scale Sanitation Providers of Sanitation Services in Kibera, Kenya

Situation in the settlement

Kibera is the largest informal settlement in southwest Nairobi (Kenya), which is composed of nine villages. They all have different sizes and population. Kibera's total population is estimated at 2.3 million. It is the most densely populated area in sub-Saharan Africa with 2,000-3,000 inhabitants per square hectare [82]. Like in other informal settlements people live in single-room structures made of mud, timber and corrugated iron sheets. It is estimated that on average 3.4 people live in one room, which occupies 10 m^2 on average [81]. The single room serves as a kitchen, living room and bedroom with some people sleeping on the dirty floor. It is also not a big surprise that the informal character of the settlement makes it problematic for provision of sanitation services, mainly due to unplanned housing, high congestion and a lack of real infrastructure. The pit latrines overflow regularly, especially in the rainy season, garbage collection is not performed, channels on the roadsides are blocked and the existing roads are not made accessible for emptying vehicles [81].

Land ownership and sanitary situation

The land in Kibera belongs to the government, however, a large part of it has been informally allocated to so-called structure owners who let the temporary shelters to laborers seeking employment in Nairobi. The City Council is constantly threatening that they will demolish the temporary structures in Kibera. Thus, both structure owners and residents are not willing to risk. Also, entrepreneurs appear reluctant to invest in local infrastructure since it might be demolished at any time. Also, 90 percent of inhabitants are tenants and owners living outside of the settlement, which makes it discouraging for them to improve living conditions in the settlement.

The City Council does not provide sanitation services in the settlement. There are two sewer lines passing the settlement but most people use on-site sanitation, which means toilets being used by several households. Some people who live in the Kibera slum share an overflowing hole-in-the-ground toilet with about 90 people [48]. The condition of the existing toilets is poor with many malfunctions and a lack of security. The existing facilities cannot serve the whole population leaving many with no option but to use the “flying toilets”, so human excrement can be found anywhere in the settlement. Children living in the slum are more likely to die of water-borne diseases and malnutrition. Diarrhea, skin diseases, typhoid, tuberculosis and malaria are among the ten most widespread diseases in Kibera [81].

Sanitation provision

Small Scale Sanitation Providers (SSPs) of Sanitation Services play a crucial role in Kibera's settlement. Their service includes management of public toilets, their construction and removal of sludge. Independent SSPs are resident in the settlement and this is the reason why they are able to deliver what public services are unable to do. They understand the situation of the population served and their preferences.

What is characteristic about the public toilet blocks in Kibera is that they are neither owned nor managed by municipal authorities. Only one of the 20 toilet blocks has been constructed due to a donor/NGO funding. Management of the toilets is performed by CBOs (community-based organizations) on either commercial or volunteer basis. Users are charged a toilet fee, which covers operation and maintenance costs. The existing private public toilet was financed by a micro-credit loan for 35 percent of the total investment. The toilet block consists of 6 toilets and has a sewer connection. The user's fee is 0.038 USD and services and maintenance quality is perceived as good. In comparison to CBO-operated blocks the number of toilets is 105 and 24 for volunteer and employee-managed blocks respectively. They charge 0.025 to 0.064 USD per use. Services and maintenance quality is perceived as poor in the case of volunteer management and good in the case of employee management. Table 18 illustrates the financial viability of different toilet blocks.

Analysis of the three models of public toilets illustrates that voluntary maintenance does not result in effective and efficient service, whilst "commercial management leads to a quality service and well-maintained facilities [81]." Moreover, customers make use of accessories provided in the blocks as well as such a service as lending of sandals in the ablution block. Management by private owner is definitely financially viable, mainly due to much lower investment costs than in the case of donor-funded blocks. This is achieved by using cheap materials and a sewer connection, which is cheaper than pit emptying and even so they are able to provide facilities with similar convenience and hygiene to the expensive donor-funded blocks. Moreover, CBO-managed blocks are not financially viable after including depreciation in the annual running costs.

Model		1	2	3
Owner of facility		CBO	CBO	Private
Management mode		Volunteer	Employee	Employee
Investment funding sources		Subsidies	Subsidies	Private sector
Excreta disposal method		Pit	Pit	Sewer connection
Characteristics		8 latrines,4 showers	4 latrines, 2 ablution block	6 latrines, 1 ablution blocks
		Water connection with tank	Water connection with tank	Water kiosk with tank
Technology		Pour flush	Pit latrines	Pour flush
Village		Kianda	Soweto	Laini Saba
Investments (US$)				
Sanitation block construction		10,390	15,974	519
Sewer connection		0	0	32
Land purchase		Community contribution	Community contribution	130
Bribes		0	0	97
Total investments (US$)		**10,390**	**15,974**	**778**
Annual running costs (US$)				
Staff income				
Employees/volunteers		234	564	623
Functioning				
Water		779	31	312
Electricity		No electricity connection	47	47
Miscellaneous (toilet paper, soap, cleaning products, stationery)		450	468	545
Emptying		2,026	405	Sewage fee included in water tariff
Capital allowance/provision for depreciation (5 years)				
Sanitation block construction		2,078 (10,390 in total)	3,195 (15,974 in total)	104 (519 in total)
Total annual running costs (US$)		**5,567**	**4,710**	**1,631**
Number of users per day	Visitors	219	489	200
	Subscribers[1]	242	0	0
Average cost per user		0.033	0.026	0.022
Annual revenues (from user charges) (US$)		4,548	4,636	2,844
Annual margin (including depreciation)		-1018	-74	1,109
Annual margin (without depreciation)		1,059	3,121	1,213

Table 18: Public toilet annual operation costs in USD [81]

Conclusions

Different development organizations (CBOs, NGOs and UN agencies) have already finances toilets in Kibera's settlements, with the external funding fluctuating between 75-100 percent. However, these toilets were mainly constructed in areas of better accessibility but where needs were less urgent. The government still do not recognize the importance of SSPs in the sector of sanitation provision and normally consider them as manpower for construction of the toilets. Yet small-scale providers supply essential services. They should start being recognized as a resource and not as a problem. They do not even have a formal stake in the sanitation sector and so cannot influence sector decisions. Small-scale providers who reside in serviced areas have the potential of improving sanitation services, especially at comparatively low investment costs. They are familiar with the situation in the settlements since they reside in these areas. However, if they are to play a significant role in the sanitation sector they need to improve their organization and contact to other stakeholders (public authorities, utilities, development organizations). Having a formal service association they could increase their bargaining power and get proper recognition for the input they have in the sanitation sector. In settlements like Kibera standardization of construction could work well for establishment of training courses for toilet masons and the quality of construction would not vary as much as it does currently. Municipal authorities should promote and encourage investment of private sector in building of public toilet blocks. It is quite obvious that the authorities recognize the scope of problem as far as sanitation provision in Kibera is concerned. Moreover, they have a good example of financial viability of this type of partnership from the already existing toilet block so they should support private investment in this sector. However, regulation of commercial management over public toilets needs to be assured and agreements need to be transparent so that it does not end up like in the case of Accra and Kumasi in Ghana.

4.6.5. Case Study: Dignified Mobile Toilets System in Lagos, Nigeria

In Nigeria, like in other countries in Africa, many public places do not provide for public toilet facilities. Thus, people use open spaces when they need to relieve themselves. Then, people pass human excreta waste into streams, rivers and the Atlantic Ocean. People might use the same polluted water for drinking and washing purposes. In markets where food is sold, traders sometimes use the open sewage gutters right in front of their food stalls to dispose of their human waste. This manner of disposing of human waste is unhygienic and poses a great threat to human health. People in Nigeria are dependent on water resources from unfiltered water and they use it for their drinking, cooking and washing purposes. Thus, diarrhea and cholera are rather common and widespread in Nigeria. The government has tried to address the problem by building toilets in strategic sites in the cities, however, many of them did not have running water and were rather poorly managed and maintained. Like in other developing countries, the migration to cities in Nigeria is increasing. Thus, urban waste management and disease control are becoming more and more important.

Isaac Durojaiye started in 1992 the first mobile toilet initiative in Nigeria in order to provide decent toilet facilities in strategic locations across the country [9]. Nigeria is the most populous country in Africa with a population of more than 135 million[27]. At the time Mr. Durojaiye started his business, there were about 500 well-functioning public toilets in Nigeria. In the interview with BBC in November 2006 he stated: “Years back those who evacuated human waste in Nigeria were ashamed to do the job - they covered their faces so nobody could recognize them. But all that is changing now [9],” said Isaac Durojaiye “I named it dignified to show the world that there is dignity in the business,” he added. “There is nothing to be ashamed about human waste, it is a reality - we all have to answer the call of nature [9].”

The absence of toilets forces many people to defecate and urinate in open spaces. Thus, the provision of adequate sanitary facilities is one of main concerns in order to improve the hygienic condition of the cities. This was recognized by Mr. Durojaiye who embarked on the first mobile toilet initiative in the country. Mr. Durojaiye’s company supplies the physical units as well as handles the twice-weekly emptying. According to the general manager of the DMT[28]: “DMT handles the evacuation of waste and we dislodge at a government-approved location. For now nothing is being done to the waste but our next project is turning the waste into biogas and a fertilizer. We have trucks that do the evacuation.”

The plastic mobile toilets have been manufactured locally since 2002 and once built they are placed in different locations, e.g. markets, parks, street corners and other strategic locations. The toilets are made of liner low-density polyethylene. The company offers different types of toilets, among them: executive mobile toilets with re-circulating flushing, plastic squatting toilets and conventional w/c toilets. Also mobile bathrooms are offered for lease. The toilets meet the needs of different users. The squatting toilets are used in market places, parks and

[27] CIA Fact sheet
[28] Moyin, private e-mail correspondence

streets, whereas executive toilets are used at seminars, construction sites and parties [5]. The toilet cubicle has the following dimensions: breadth – 1080 mm, width – 550 mm and depth – 510 mm. The waste tank may have a capacity of 225 to 500 liters. The toilet cubicle may have all or some of the following features: re-circulating flushing system, wash-hand basin with urinal for men, solar powered light, soap holder, toilet roll holder, waste basket, air ventilation, cloth hanger and a dressing mirror. [15]

Figure 45: Mobile squatting toilet (left), toilet with a separate urinal (right) [15]

The toilets are leased to unemployed youth (so-called area boys) who make fixed returns at the end of the day and stay with whatever they make on top of the fixed amount. The young person from the area, who charges a fee for the use of the toilet, pays back a percentage to Isaac and stays with the rest as their income. It is estimated that each unit serves a hundred people a day paying equivalent of about 0.15 USD for the use of the toilet. In this way, the system is able to provide a lot of jobs and assures cleanliness and functioning of the toilet as it ensures a sense of ownership over the toilets and motivates them to keep the toilets clean and functional in order to continue making a profit. The toilets can be also rented and sold to churches, construction and other companies who are able to pay a premium price for them. With these funds, Mr. Durojaiye is able to build and place more basic toilets in heavily used public spaces. Also, businesses can advertise their products on the toilet doors after paying a monthly fee. The business generates 25% of its revenue from this advertising. [9]

1,500 toilets have been constructed since 2003, and 120 of them are situated in public places. Isaac has also been awarded 2,000 free toilets as a donation by the state government in Lagos [5]. They will be managed and cleaned in the exactly same manner like the others. He also started spreading the movable toilet model from Lagos to other parts of Nigeria. In addition, the company plans to implement a program of recycling the waste collected to generate biogas, electricity and fertilizer for farmers.

4.7. Sustainable public sanitation approach

Many examples of different public toilet projects have already been discussed. However, the given examples did not deal with resource-oriented sanitation. Next case studies will present the sustainable approach to public sanitation in India, Africa, and Indonesia.

4.7.1. Case Study: Sulabh International, community toilets in India

One of the burning problems in India is a lack of sanitation facilities. In the country with a population of almost 1,130 million[29], about 700 million people do not have access to toilets of any type and so they defecate in open spaces or to buckets. Sulabh International, an NGO founded in 1970 by Dr Bindeshwar Pathak, is addressing the sanitary problem in India. Both the World Bank and UN agencies are recommending the "Sulabh model" to be implemented in other developing countries.

The scope of Sulabh activities can be summarized by a provision of the three following sanitation facilities: 1) the construction of two-pit pour-flush toilets for individual households, 2) the construction and maintenance of community toilets on a pay-and-use basis and 3) the construction and maintenance of community toilets in slums and squatter settlements [12]. In the past three decades they have built and managed around 1.2 million toilets in private houses and 7,500 pay-and-use community toilet complexes catering to the poor and low-income sections[30]. These complexes are normally located at public places like bus stands, hospitals, markets and slum settlements. Thus, the target communities are the urban poor living in slums and squatter settlements living in the city and the low-income floating population in the served areas. The community toilets managed by Sulabh are normally located in low-income settlements, serving the residents where individual toilets are not available [12]. One example of a public toilet facility built by Sulabh is at the Old Delhi Railway Station in the heart of India's capital. Here, tens of thousands of people arrive everyday from all over the country. One of the first things they are looking for is a toilet. Before it had actually been provided for the public, people used to defecate and urinate on the train tracks or on the roads. The two-storey structure holds a total of 15 shower stalls and 36 squat toilets, for men and women [47].

For the construction, operation and maintenance of these complexes Sulabh plays a role of a catalyst and a partner between the official agencies and the users of the toilet complexes [12]. The municipal corporations are the key public partners. They enter into a lease agreement with Sulabh for the construction and maintenance of community toilets. In the pay-and-use approach, the corporations provide for land, utilities and construction costs as well as service charge, which is 20% of the project cost paid to Sulabh to meet its overhead, monitoring and supervision costs [12]. As far as community toilets are concerned, the corporations also have to provide a so-called block grant to the private operator in the view of maintenance costs, and so the toilets are provided free of charge to the users [12]. In the pay-and-use approach, Sulabh charges an equivalent of 0.02 USD per use of a toilet or bath and the use of urinals is free of charge [12]. Thus, Sulabh covers all its operational costs from user's fees and does not

[29] CIA fact sheet
[30] Sulabh website, http://www.sulabhinternational.org/

depend on foreign donors [12]. Poor, physically handicapped, aged people and street children are allowed to use the facility for free [12]. Sulabh is responsible for maintenance of the complexes, including materials needed for repairs, general upkeep, lighting, soap, staff salaries, etc [12]. Moreover, Sulabh is taking maintenance guarantee of the toilet complexes for not less than 30 years [34].

Sulabh's key success factor is round-the-clock management and monitoring system [12]. Normally, caretakers are appointed by Sulabh to maintain the facility round-the-clock. Lighting is provided during the night and 24-hour water supply is maintained. The employed person has a room within the premises of the pay-and-use toilet complex and is in charge of the overall management of operations that include: collecting of user's fees, operating of water pumps, maintaining the buildings, procuring chemicals and equipment and providing for the cleanliness. The toilets are are constructed by Sulabh and are easy to maintain. It is important from the viewpoint that everything including the design, materials used, ventilation and adequate space has to meet Sulabh's own standards [12]. Even if they take over a toilet facility, it is ensured that it is then tailored to the particular criteria before it is put in operation. The internal monitoring system comprises of social workers from the office that visit the pay-and-use complexes on a regular basis in order to ensure cleanliness and the collection of user's charges [12].

The largest community toilet complex is located at Shirdi and it consists of 148 toilets and 108 bathrooms with space for dressing, babysitting, breast-feeding, 5000 lockers and the electricity is made available for lighting of the complex through biogas generation from human excreta [68]. The complex is visited by up to 50000 visitors every day [68].

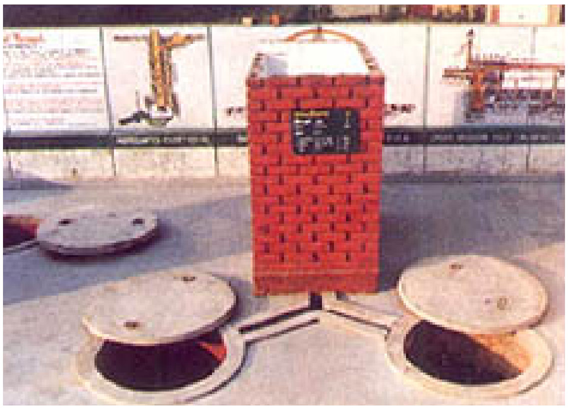


Figure 46: Two-pit pour-flush Sulabh toilet [www.sulabhinternational.org]

The Sulabh twin-pit toilets use 1.5-2.0 liters of water per flush as opposed to the 10-14 liters required by a conventional toilet [68]. Waste is deposited into two pits, which size and capacity may vary according to the number of users to be served. Normally, the capacity is kept for 3 years, but it can be extended to as long as 20 years. When the first pit gets filled up, the second pit is being used. Over the time of a so-called rest period (when the first pit is not being used), the waste in the first pit will undergo natural conversion into a rich, pathogen-free material that can be used as a soil conditioner. The system can be already built for as little as 10 USD, which makes it affordable for poor regions in India. In urban areas, the Sulabh system has been adopted as community toilets often with a modification of having a biogas plant. Along with community toilets, if facilities for bathing and washing clothes are provided and they are kept clean, people use them without hesitation to pay for use [34].

The cost of a Sulabh pour-flush toilet differs and depends on materials used for construction and so makes the toilet affordable for everyone. The materials used for pit may be bricks, stones, wood logs, burnt clay rings or even used coal tar drums. For superstructure such a variety of materials as gunny bag sheet, thatch, brick for walls and tiles, Reinforcement Concrete Cement for a roof and door may be used [34].

Human excreta contain a large number of pathogens, which are responsible for over 50 infections when transmitted. Anaerobic conditions in the bio-digester eliminate most of the pathogens from the digested effluent, which makes it suitable to be used as manure. The biogas technology from human waste has a number of benefits: sanitation, bio-energy generation that can be used for cooking, lighting through mantle lamps, electricity generation, etc. and manure production. Sulabh developed an efficient design of a biogas plant linked to public toilets under a project founded by the Ministry of Non-Conventional Energy Sources, the Government of India that approved the design for implementation under its Central Financial Scheme [56]. The system allows only human excreta with flush water to flow into biogas digester for anaerobic digestion. Bathing and washing water is collected separately and is reused after sand filtration or discharged into a drain. A biogas digester is built underground and excreta from public toilets flow there under gravity. Hydraulic Retention Time for feed material is 30 days. No manual handling of excreta is involved in the process. The biogas is collected over water in a separate gasholder or inside the digester itself, the method depends on the design of the digester. Biogas generated from human excreta has the following composition: 65-66% of methane, 32-34% of carbon dioxide and ca. 1% of hydrogen sulfide as well as traces of ammonia and nitrogen. Biogas is stored inside of the plant through a liquid displacement chamber. A biogas plant is made of Reinforcement Concrete Cement. Methane being the only combustible product of the anaerobic digestion is utilized in different forms of energy. The most common application is for cooking with a biogas burner. Electricity generation is accomplished through a dual fuel engine that runs on a mixture of biogas and diesel. The electricity might be useful for use in toilet complexes for operation of a water pump and lighting purpose inside the complex or adjoining areas. The expected average production of biogas per user per day is about 30 liters (equivalent of 1 cft[31]) [33, 34]. For a detailed description of possibilities of biogas utilization refer to the third chapter in the section 3.2.5.

During biogas generation there is up to 85% reduction of BOD of effluent of biogas plant compared to the affluent value. However, the BOD content (around 125 mg/l) is still too high for the effluent to be discharged into a water body or used for agriculture [33]. Also, the pathogen count is still higher than the permissible limit of discharge to any water body. The effluent contains nitrogen, potash, phosphate and other micronutrients, however its bad odor, yellowish color, pathogen and still elevated BOD content hinders its reuse in agri- and horticulture [33]. The Sulabh Effluent Treatment technology deals with the effluent through sedimentation, filtration of effluent on sand and activated charcoal and followed by ultraviolet rays [33]. The treated effluent is colorless, odorless, pathogen free and has a BOD content of less than 10 mg/l that enables its use in aqua-, horti- and agriculture or discharge into a water body [33]. The effluent may be also used for floor cleaning in public toilets complexes [33, 34]. A toilet complex of 13 WCs at Mahavir Enclave in New Delhi is under operation and is used by 600 people per day. Biogas generated from the complex is used for cooking, lighting mantle lamps inside the toilet complex and electricity generation and the treated effluent is used for irrigating the lawn and horticulture [34].

Conclusions

Sulabh activities in India show that public toilet complexes may be successful as long as their maintenance is performed on a round a clock basis. It was observed that an unsanitary and poorly maintained state of public toilets discourages people from using such complexes. It

[31] cft stands for a cubic foot, which equals to 28.3168466 liters

was also recognized that along with public toilets, bathing and clothes washing facilities should be provided and if kept clean, people would not deter from using them and would be willing to pay for their use. The operation model of the complexes shows the importance of financial viability of the projects. The cost of construction is borne by the local body and the maintenance of toilet complexes and day-to-day expenses are covered by the user's toilet charges. In this way, Sulabh remains independent from external agencies for finances and meets all the financial obligations through internal resources [33, 34]. Not only is the financial, operation and maintenance model worth looking closer at, but also the design of the toilet itself. It made handling of fresh human excreta obsolete and also due to the financial viability more and more people with higher social status are becoming engaged in the construction and maintenance of toilets. The successful activities of Sulabh enable them to work on R&D in the field of recycling and reuse of human excreta from public toilets and so they came up with the model of a biogas plant and effluent treatment that is already being used in some of their complexes. Not only is Sulabh involved in liberation of scavengers (people who were employed to empty the toilet buckets filled with human excreta), but also in improving conditions of sanitation, human health and the environment. That is why, the Sulabh model is being recommended for application in other developing countries.

4.7.2. Case Study: Nakuru Central Business District [65]

A public toilet located in the recreational park in Nakuru Central Business District in Kenya involves urine harvesting from a dry urine-diverting toilet. The harvested urine is sold to a fertilizer manufacturing company. Instead of water that could be used for flushing, a chemical called "blue seal" is used for clearing the smell. About 100 ml of the non-reactive chemical is used for 10,000 visitors. The toilet is managed by the Nakuru Environmental Consortium and its construction costs of around 30,000 USD were covered by Waste Advisers Netherlands. The sanitary facility has toilet cubicles that are also accessible for disabled visitors. The average number of customers per day is 200 and the toilet charge is equivalent to 0.075 USD. Also, visitors may have a shower, for which they are charged 0.3 USD and they are provided with a towel, soap and slippers in return. Two cleaners are appointed, one working in the male and the other one in the female wing.

4.7.3. Case study: Community based sanitation program in Tangerang and Surabaya, Indonesia [58]

Another example of the sustainable approach towards sanitation services is the Community Sanitation Centers (CSCs) located in the satellite city of Tangerang in the vicinity of Jakarta. The project started in 1999 as a cooperation between Bremen Overseas Research and Development Association (BORDA) and a local Indonesian NGO "Bina Ekonomi Sosial Terpadu" (BEST). So far, 35 Community Sanitation Centers consisting of a toilet, bathroom and washing facilities together with a community "water point" for drinking water supply have been built. Their beneficiaries include inhabitants of densely populated low-income workers' settlements located in urban areas of industrial concentration in the vicinity of conurbations of the cities Jakarta and Surabaya in Indonesia. Prior to the implementation of CSCs, the sanitation infrastructure consisted of open rainwater drains and empty lots that were used both for defecation and disposal of waste. Also, most of the inhabitant relied on fetching water over longer distances or buying it from vendors. Each CSC unit has about 1,000 visitors daily and it has an integrated wastewater treatment with part-stream treatment of black and greywater. The sanitation centers are linked to biogas digesters, thus there is no need for an external energy input. Moreover, generated biogas is used for cooking in the neighboring households (80 households use it for an annual fee of 2 USD). Operation and maintenance are provided by the NGO and maintenance costs are low since no high-tech equipment parts are required. Users are charged a fee between 0.05 and 0.1 USD, which covers the operation and maintenance costs. Full-time staff present on site provides operation and service. Wastewater pollution is reduced by up to 90% (BOD/COD) and treated wastewater can be discharged to the environment and is partly reused for gardening and fishponds. Furthermore, collected sludge is treated by the municipality and reused for soil improvement. Investment costs for one CSC unit including land and construction amount to 12,000-15,000 USD. Total annual operation costs amount to 1,500 USD, whereas the annual turnover from user's fees equals 2,000-2,500 USD. Thus, once investment is provided, no further financing is required. Moreover, increasing the number of units will bring the costs down. In case when CSCs were implemented on more profitable locations such as market places, railways stations or main roads, the pay back periods could be as little as 10 years. The positive impact of CSCs on the community should not be undervalued. It motivates the neighborhood to improve their living environment on their own. The participation of beneficiaries in planning and implementation was one of the most important prerequisites for the project to become successful. CSCs have proven a well-accepted form of sanitation provision in low-income urban settlements where bathroom, toilet, washing and drinking water facilities are not available in households. The project takes account of the resource-oriented sanitation approach with reuse of treated wastewater and sludge for gardening, fishponds and farming. Moreover, toilets linked to biogas plants do not need external electricity source and provide energy for cooking in the neighboring households.

The three cases studies should serve as good examples of implementation of sustainable sanitation facilities in developing countries. It is often the case that in places where no sanitation services are provided any projects will be accepted since anything is considered better than no sanitation provision at all. However, if one decides to ring some changes in the sanitation sector, it should be taken into account that sustainable sanitation projects will have a longer lifetime, function more efficiently and are able to reflect preferences of communities and stakeholders better. Nowadays, much effort is being put in order to meet the promise of the Millennium Development Goals, however, the implementers should not only be concerned about reaching the number of toilets, but put the appropriateness and sustainability promised by the MDGs first.

4.8. Different operational concepts

Appendix 2 presents a summary and comparison of most case studies presented in this chapter. It serves as an overview for comparison of different operational concepts.

In the case of *community toilets*, groups of households or landlords may pool their resources together to build blocks of toilets shared by the residents in the defined area [36]. They might get some external funding from the municipality or donors (e.g. NGOs). The case of slum settlements in Nairobi in Kenya is a good example of this type of community organization (see appendix 2). As in the case of Makuru village, where a donor covered the material costs and the community together with landlords covered labor costs. Households gain membership through payment of a membership fee, which allows the family members to use the complex. Also, non-members are allowed to use the complexes upon payment of a toilet charge. The operation and maintenance of this type of toilets is different from a typical public toilet facility. Normally, residents need to take over the responsibility for management and maintenance of the facility. Community also needs to collect joint funds for emptying of pits and rehabilitation of complexes if necessary. The exact conditions of management and maintenance might differ from one settlement to another depending on the agreements about cost sharing, financing support, ownership type, etc. Generally, public or other means of financing is becoming more and more available for communal conveniences, however, a lack of clear ownership remains one of the key issues that must still be addressed. The example of communal toilets operating for five to ten families is Addis Ababa shows that operation and maintenance is often difficult, mainly due to the fact that housing is occupied by tenants, which "discourages investment and dilutes the household's sense of responsibility for maintenance of the facilities [36]". Sometimes "kebeles" (the smallest administrative units of the city administration in Ethiopia) assist users to service the toilets and collect contributions. Normally, users make an effort to organize cleaning of complexes themselves and pay for emptying of latrines. Sometimes families have a key to a toilet room assigned to their household (like in the case of Kitui village in Nairobi) and they share it with a few other households. Then, they have to agree among themselves and clean the toilet in turns. Also, community might select a representative who deals with the general management of a toilet. He will then coordinate the cleaning roster and money collection for emptying of latrine pits. Sulabh community toilets in slum areas are delivered to users free of charge, whereas their pay-and-use community toilets require users to pay for the use of a toilet. In both cases municipality finances the construction of the complexes and Sulabh takes over maintenance, which is financed through charged toilet fees from pay-and-use toilets. As far as community toilets are concerned, corporations provide a block grant to the private operator for coverage of maintenance costs. Therefore, the Sulabh community toilets in slum areas can be delivered free of charge to their users.

Growing populations make the installation of toilets more and more difficult, also for private investors. The management of *public toilets* might be improved through delegating it to private operators. Municipal authorities might lack financial resources either for construction or operation and maintenance of public toilet facilities. Thus, they might call for private investment for provision of public toilets. There is a mixed experience with this type of provision, depending on local politics and ability of the authorities to control the agreements (refer to the case study from Accra and Kumasi in Ghana). There are also different methods available for charging toilet users and these include: a cost recovery rate, a token amount or no user charge [36]. A cost recovery rate allows for funding of new toilets. An annual rent is charged per unit, and users are charged a commercial rate [36]. A token amount means that users are charged a small user's fee, which encourages private participation and allows access to low-income residential areas such as slum settlements [36]. In some developing countries, NGOs or other donors funded construction of public toilets and there is no fee charged to users, but at the same time there is no policy to promote public sanitation facilities [36]. When authorities decide to apply a public private partnership for provision of public facilities it might function in two ways. One method is that municipality funds the construction of facilities and delegates the management and maintenance to a private sector through lease or rent agreements. The other method already delegates the construction of facilities to the private sector. In Kano, Nigeria both ways were practiced. In case of private funding, the owner had to pay an annual fee to the government. In case when the government funded the construction of the facility, the allottee had to pay an allocation fee and an annual rent. If authorities decide to allow a private investment on a lease basis, it is generally assumed that location of toilet complexes plays a key role. It is estimated that facilities located in markets, transport terminals and public event areas are more profitable than the ones situated in low-income residential areas. If local authorities are interested in encouraging investment in the latter areas, they need to offer incentives, e.g. by offering lower rents in this type of areas or allowing for the development of small business centers alongside public toilets. Such business centers might include a telephone box, fax services, water vending, article selling, etc. Also, it needs to be assured that the contract duration will encourage managers to maintain facilities. In a nutshell, there is a choice that authorities have, either construct and operate public toilets or delegate one or both to the private sector. As far as pay-and-use public toilets are concerned, a caretaker is appointed to be on site in order to collect a toilet charge as well as assure for cleanliness and maintenance of a facility. In case of movable toilets leased to individuals in Nigeria, the private company constructs movable public toilets and bathing units, provides them to the individuals, charges a lease fee, whilst operators (individuals) charge a toilet fee and maintain a facility.

There are certain ways in which public toilets can be operated and managed. The considerations need to include which service is provided in facilities (toilets, showers, water vending etc.), who takes over the construction of a complex, operation and maintenance activities, desludging (if a pit latrine is chosen), repairs, inspection and fee collection (both in case of a household membership fee or visitor fee per use). The above-mentioned operational concepts summarize methods that have been chosen in many developing countries. The actual operational concept always needs to be adjusted to local conditions. In some cases there might be an option of delegating management of a complex to a local NGO. However, the actual operation mode should be always in line with local aspects. Above all, in case of pay-and-use public toilets in developing countries there needs to be a caretaker present on site that will be responsible for fee collection and will assure for cleanliness of a complex as well as prevent vandalism and misuse.

Chapter 5: Proposed public toilet project for Arba Minch, Ethiopia

5.1. Location of the toilets

The baseline study for the city of Arba Minch mentioned the need of building public toilets in the city. As already discussed, there are only two VIP public toilets constructed by the Red Cross (located in kebele two and twelve), but they are simply not enough. The most problematic zones, where public toilets should be located, include the market places in kebele four, ten and twelve as well as the bus station in kebele eleven. Kebele eleven is the one where boutiques and stationary shops are located and income is mostly generated through making business. In this kebele, there are also no public toilets and the vicinity of the bus stop is actually the only place where open defecation and urination is practiced. The bus stop has been chosen as the first location for the public toilet complex. Also, the market places, especially the main market in kebele twelve should be provided with public toilets due to health hazards related to open defecation being practiced and the slum settlements located around the market area. However, the bus stop has been chosen as the first location. Normally passengers practice open urination next to the bus stop or use nearby tearooms or hotels. Provision of public toilet at the bus stop will surely allow for comfort and protect the health of passengers leaving and arriving Arba Minch as well as of the environment.

5.2. Stakeholders and considerations involved in the project

The project will involve a micro enterprise that will be given a loan in order to built five urine-diverting toilet units at the bus station in kebele eleven. The loan will be given by the Omo Micro Finance Institution (OMFI), which provides micro businesses, agricultural, small investment and working capital loans to its diverse clients. The OMFI charges a 10% interest rate on all term loans and a 1% service charge on all its loans[32].

The toilet units will be built one next to another and will employ two caretakers that will be working in two shifts. The daily wage for each of them is 13.5 Birr[33] and they will be responsible for all five toilet units[34]. Based on the bus timetable, it was estimated that the toilet complex should stay open between 5 a.m. and 9 p.m. every day of the month. It was assumed that the municipality would allow for the micro enterprise to built and operate the toilet complex for its own profit, without the obligation to purchase the land. In case land had to be purchased, the price would have to be added to the initial investment costs.

Arba Minch Town Water Service (ARB) will be delivering water to the complex. As already discussed in the second chapter, the water tariff depends on the water consumption rate (refer to table 7 in the second chapter) [4]. The water tariff (2.10 Birr/m^3) was estimated on the monthly usage of water in the complex, consisting of water for hand washing, toilet cleaning and water vending, which amounts to about 20,5 m^3/month.

The beneficiaries of the project will be public toilet users, which will mainly consist of bus passengers that either arrive or leave the city of Arba Minch. The primary draft of the project

[32] Information from the OMFI
[33] 12,5 Birr=1€ or 9 Birr=1USD
[34] Estimation based on private e-mail correspondence with Addis Ababa

does not include showers, but they might be incorporated into the complex at a later point in time. The body of the toilets will have advertisement placement, for which 200 Birr will be charged per month[35].

The collected and sanitized urine as well as feces will be sold to farmers at a rate of 0.08 Birr/l of urine and 0.03 Birr/kg of dried feces. The way in which these prices were estimated will be given in detail further on in the section 5.5.2. The question directed at the members of the EcoSanRes forum group about the money charged for these products revealed different experience in various developing countries. In Kerala, one of dry compost toilet users has sold the product at a rate of 150 Rs per sack, which is about 3.0 to 3.5 USD for about 25 kg[36]. In Burkina Faso, the hypothetical value of urine is around 0.25 USD per 20-liter jerry can of urine[37]. In Uganda, it was charged about 3.0 USD per jerry can of urine and about 2.0 USD per bucket of feces[38].

The visitors of the toilet complex will be charged a fee of 0.2 Birr per toilet use. All the accessories such as toilet paper, ashes for covering of feces, water and soap for hand washing will be provided. The Ethiopian Electric Light and Power Authority (EELPA) will be providing electricity to the toilet complex at a rate of 0.65 Birr/kWh[39].

5.3. Population served

The users of the toilet complex will be mainly passengers traveling from and arriving in Arba Minch. The number of visitors expected every day was estimated on the three-month data that involved the number of people traveling from Arba Minch by bus. There are different buses leaving Arba Minch and their seat capacity ranges from 24 to 62. Some of these buses travel over long distances, e.g. to Addis Ababa (about 500 km), whilst others only 20 km. In the estimation, it was assumed that the same number of people leaving Arba Minch would also arrive in the city. The sum of the passengers traveling from Arba Minch by bus for a three-month period amounted to 155,080 people. Thus, the double equals 310,160 people. It was assumed that only 10% of the passengers would be willing to use the restroom. In consequence, it is expected that 341 people will be using the toilet complex every day. However, for simplicity reasons as well as allowance for deviation from the assumptions made, it was estimated that *300 people* would use the toilet complex daily. Each toilet unit is designed to serve 60 visitors every day, so the complex will consist of 5 toilet units.

5.4. Detailed description of the toilet units and the operational concept

Each toilet unit will have a corrugated iron sheet cover as a roof, a bamboo mat wall lined with a plastic sheet, a masonry wall at the basement and wooden stairs. There will be five toilet units built for the public toilet complex, three of which will be designated for female, and the two remaining for male visitors. Each toilet unit will be fitted with a squatting pan, urinary and hand-washing basin. One toilet unit will have the following dimensions: 1.11 m wide, 1.66 m long and 2.07 m high. The basement will be 1.2 m high, where a half-cut

[35] Based on the DMT Nigeria, private e-mail correspondence with Mr. Moyin, General Manager of DMT
[36] Paul Calvert
[37] Linus Dagerskog, CREPA HQ
[38] Michael Oketch Omwodo, Ecosan Coordinator, Uganda
[39] Based on private correspondence with the EELPA

collecting barrel for feces and a 1000-liter collecting tank for urine will be placed. The bottom of the basement will consist of a concrete layer, a layer of thick material and compacted soil. Outside of the toilet, there will be a composting unit placed, where primarily dried feces and waste material from the buckets placed in the cubicles together with other organic material will be further composted before being sold to farmers. The toilets will be provided with a lock and so they will stay closed and locked at the time between 21 p.m. and 5 a.m. The caretaker will be locking and unlocking the toilet units. Also, the caretaker's responsibility will be cleaning of the toilets twice per shift. Moreover, they will be responsible for collecting of ashes for covering of feces from neighboring households. The experience from Arba Minch shows that at first ashes will be collected free of charge, however, when people notice that they have a value and are necessary for the toilets' operation, they might be willing to charge a fee. Also, the caretakers will be in charge of emptying of the containers with urine and feces and further handling of the excreta. Feces from the collecting barrel will be mixed with other organic material and left for composting in the composting unit situated in the vicinity of the toilet complex. Caretakers will be also collecting the user's charge as well as ordering and changing accessories such as toilet paper, soap, etc. They will be also giving instructions to users as well as making sure that user's instructions are legible and shown on the interior wall of every toilet cubicle. Moreover, they will also perform some small repairs in the complex, if needed. Also, their duties will include selling of sanitized urine and composted feces to farmers.

5.5. Cost analysis of the project

5.5.1. Investment calculation

Based on the estimations of the number of visitors per day, it was decided that five toilet units would be built. The cost of building one toilet unit amounts to around *6,200 Birr*. The general cost estimate for building one urine-diverting toilet unit is presented in table 19 below. The detailed calculation is shown in appendix 3.

Item No	Description	Unit	No. of Units	Amount (Birr)
COST ESTIMATE OF URINE DIVERSION TOILET UNIT (12,5 Birr=1 € or 9 Birr=1 USD)				
	A. SUB STRUCTURE			
1	Excavation and Earth Works	Birr	1.00	11
	Total A	**Birr**		**11**
	B. SUPPER - STRUCTURE			
1	Concrete Work	Birr	1.00	1,848
	Total B	**Birr**		**1,848**
	C- ARCHITECTURAL WORK			
1	Walling Work	Birr	1.00	291
2	Roofing	Birr	1.00	246
3	Carpentry & Joinery	Birr	1.00	20
4	Wooden Stair	Birr	1.00	140
5	Sanitary and Other Fixtures	Birr	1.00	3,106
	Total C			**3,803**
	SUBTOTAL A + B + C			**5,662**
	D- ALLOWANCES FOR ADDITIONAL WORK (Design and Planning)	**Birr**	**0.05**[40]	**283**
	E- OVERHEADS & ADMINISTRATION	**Birr**	**0,05**[41]	**283**
	GRAND TOTAL A + B + C + D + E	**Birr**		**6,228**

Table 19: General cost estimate for building of one urine-diverting toilet

Taking into account that five toilet units need to be built, the total investment will amount to *31,140 Birr*, which will be provided on a loan basis from the already mentioned OMFI. The building of the toilet complex should take up to two weeks, before it will be ready for service. Thus, the income will start being generated two weeks after the loan has been granted and the complex already built. The 31,140 Birr investment costs also include the cost of building a composting unit. It was estimated that each toilet unit would contribute to building of the overall composting unit (750 Birr for each toilet unit was calculated). As already mentioned, it was assumed that land would not have to be purchased and the municipality would allow

[40] 5% of the Subtotal A+B+C
[41] 5% of the Subtotal A+B+C

for construction of the toilet for the company's own profit. In case the municipality obliged the company to purchase land for the public toilet complex, the costs incurred would have to be added to the initial investment costs.

5.5.2. Operation and maintenance costs and generated revenues

Table 20 presents operation and maintenance costs for the whole toilet complex. Also, different variables are presented in table 21. The variables include assumptions that have been made while calculating the operation and maintenance costs. In a nutshell, the assumptions include the fact that the toilet complex will stay open throughout the year (12 months with 30.5 days in a month). Moreover, toilet paper, soap and detergents use have been estimated in order to calculate the usage of these throughout a month. Furthermore, the estimations have been based on 5 toilet units with 300 visitors per day, which makes 60 visitors per toilet unit a day. For the calculation of the amount of soil conditioner that later will be sold to farmers, it was assumed that only half of the users would defecate. Also, it was assumed that light would be needed four hours per day due to the fact that there is no need for lighting of the complex between 6 a.m. and 6 p.m. What is more, water usage was based on the estimation that each visitor will wash hands for maximum of 20 seconds, with the water use of 0.95 l/min. Also, the toilet complex will be cleaned four times per day, and for each cleaning 4 l of water will be used. Operation and maintenance costs per one visitor were estimated to be about 0.10 Birr.

Operation & Maintenance costs for 5 toilet units							
Description	**Unit**	**Qty/ month**	**No. of toilet units**	**Total Qty**	**Unit rate (Birr)**	**Amount (Birr/month)**	**Amount (Birr/year)**
Cleaning agents (detergents) & material (sponge, gloves)	Bottle, piece	3.00	5	15.00	15.0000	225.00	2,700.000
Toilet tissue	Roll	18.30	5	91.50	4.0000	366.00	4,392.000
Soap	Bar	6.10	5	30.50	5.0000	152.50	1,830.000
Ashes	Kg	3.00	5	15.00	0.0000	0.00	0.000
Water for toilet cleaning	L	488.00	5	2,440.00	0.0021	5.12	61.488
Water for hand washing	L	579.50	5	2,897.50	0.0021	6.08	73.017
Electricity	KWh	3.05	5	15.25	0.6500	9.91	118.950
Light-bulb 25W	Piece	0.08	5	0.42	2.5000	1.04	12.500
Caretaker	People	2.00	5	2.00	13.5000	823.50	9,882.000
TOTAL CARRIED TO						**1,589**	**19,070**

Table 20: Operation and Maintenance cost calculation for five urine-diverting toilet units

Variables	Amount	Unit
Opening days per month	30.500	Days
Opening months per year	12.000	Months
Use of electricity of a 25 W light-bulb	0.025	KWh
Light bulb life time	12.000	Months
Toilet paper roll use	100.000	Uses/roll
Soap bar use	300.000	Uses/bar
Cleaning agent use/month	3.000	Bottles/month
No of caretakers	2.000	People
No of toilet cleanings per day	4.000	Clean. /day
No of toilet units under supervision of both caretakers	5.000	Toilet units
No of users per day	300.000	People
No of users per unit	60.000	Users/unit, day
No of defecations	30.000	Def. /unit, day
No of hours when light is needed	4.000	Hours
Time needed for 1 hand washing	0.330	Min
Water use for hand washing	0.950	L/min
Water use for toilet cleaning	4.000	L/clean.
Amount of ash used after 1 defecation	0.100	Kg

Table 21: Variables for operation and maintenance cost calculation

The prices for accessories were estimated through an e-mail correspondence with people working or living in Ethiopia[42]. Generated revenues together with variables explaining the assumptions made are presented in tables 22 and 23. For the calculation of collected urine and feces, it was estimated that one visitor would produce 0.25 l of urine and 0.20 kg of feces[43]. For the calculation of the price of urine sold as a fertilizer, it was assumed that nitrogen concentration in urine is 5 g N/ l (and 1 l of urine weighs 1kg). Also the price of urea was estimated at 300 Birr/quintal. Data from the year 2006 showed that in Tigray 100 kg of urea was sold for 318 Birr, in Amhara for 345.5 Birr and in Oromia for 356 Birr[44]. The comparison of concentration of nitrogen in urea and urine showed that an equivalent commercial nitrogen fertilizer could be sold at 32.6 Birr/quintal and it was further assumed that the price of urine sold as a fertilizer would be a quarter of it. The equation for the calculation of the price of an equivalent commercial nitrogen fertilizer can be seen below:

$$\frac{300Birr/QUINTAL}{\dfrac{46gN/1kgurea}{5gN/1kgurine}} = 32.6Birr/QUINTAL = 0.33Birr/kg$$

The harvested and sanitized urine would be sold for one quarter of the calculated price for an equivalent commercial nitrogen fertilizer (ca. 0.08 Birr/l). The price of composted feces would make 40% of the price of urine (ca. 0.03 Birr/kg).

[42] Courtesy of the ROSA team in Addis Ababa and Mrs. M. Simpson Hebert
[43] Based on the amounts: 1.5 l urine/p,d and 0.15 kg feces/p,d [41]
[44]http://www.addisfortune.com/Vol%207%20No%20356%20%20Archive/Fertilizer%20Market%20Suffers%20 Souring%20Prices,%20Limited%20Suppliers.htm

Also, water will be sold in the toilet complex and it was estimated that each toilet unit would sell 100 l of water per day (purchased for 0.0021 Birr/l and sold for 0.0025 Birr/l). Another source of income will be advertisements, which will be placed on the body of the toilets. It was assumed that each toilet would carry one advertisement.

GENERATED REVENUES FROM OPERATION OF 5 TOILET UNITS			
No of toilet units	**Fee charged (Birr)**	**Money collected/month (Birr)**	**Money collected/year (Birr)**
5	0.2000	1,830.00	2,1960.00
	Money earned on water vending (Birr/l)	**Money collected/month (Birr)**	**Money collected/year (Birr)**
5	0.0004	6.10	73.20
	Price of ad/month (Birr)	**Money collected/month (Birr)**	**Money collected/year (Birr)**
5	200.0000	1,000.00	12,000.00
	Price of urine (Birr/l)	**Money collected/month (Birr)**	**Money collected/year (Birr)**
5	0.0800	186.48	2,237.77
	Price of dried feces (Birr/kg)	**Money collected/month (Birr)**	**Money collected/year (Birr)**
5	0.0300	29.84	358.04
TOTAL CARRIED TO		**3,052**	**36,629**

Table 22: Generated revenues from operation of the public toilet complex

Variables	Amount	Unit
Opening days per month	30.5000	Day
Opening months per year	12.0000	Month
Amount of urine per one visitor	0.2500	L/person
Amount of feces per visitor	0.2000	Kg/person
Cost of water	0.0021	Birr/l
Concentration of N in urine	5.0000	g N/1kg urine
Concentration of N in urea	46.0000	g N/1kg urea
No of visitors per day	300.0000	People/day
No of visitors per toilet unit	60.0000	People/day
Amount of water sold by 1 toilet unit	100.0000	L/day
Price of water	0.0025	Birr/l
Price of urea	300.0000	Birr/quintal
No of advertisements on 1 toilet unit	1.0000	Advertisement
No of defecations in 1 toilet unit	30.0000	Defecation/toilet unit, day
Price of equivalent commercial fertilizer with the N concentration the same as urine's	32.6100	Birr/quintal
	0.3300	Birr/kg
Price of urine as a factor of equivalent commercial N fertilizer	0.2500	
Price of dried feces as a factor of the price of urine	0.4000	

Table 23: Variables for revenues calculation

Comparing the annually generated revenues with annual operation and maintenance costs, it is clear that the public toilet facility will be making a profit. However, the loan together with its interest rate and service charge needs to be paid back to the OMFI, and a corporate income tax must also be paid. After the first year of operation (with all the estimations that have been made), the toilet complex will make a profit (after tax) of 8,878 Birr. The next tables present financial statements for the first three years of operation, including a plan of paying back liabilities within a four-year time frame.

5.5.3. Financial statements of the company

For the convenience of the reader, explanation of the financial statements and what they actually refer to, will be given. The explanations are based on the course material "Business Tools for Innovation", prepared by the Management Consulting GmbH, Stuttgart 2002.

A balance sheet is a comparative listing of all assets, equity, and borrowed capital at a certain day. The asset side of the balance sheet contains the current and fixed assets. This side shows how money was invested and spent; it is the capital expenditure side. The fixed assets might include land, building, machines, etc. They stay within the company for years and they are to be used for a longer period of time (in this case it is the building, the public toilet complex that belongs to fixed assets). Fixed assets also need to be depreciated. Depreciation reflects the loss of value of assets. It distributes the cost of purchase over the duration of the asset's working life. In this case, the building will be depreciated 4% every year, with the so-called straight-line method. In this method, the yearly depreciation depends on the anticipated average working life expectancy of the asset. In the case of the public toilet complex, it was assumed that its working life expectancy would be 25 years. The current assets "move" through the company at a relatively fast rate. These include for instance cash and cash in bank. The liability side of the balance sheet consists of equity and borrowed capital, capital that is owned by outside parties. This side shows how the company is financed. In a nutshell, balance sheet informs about the size, type and composition of company's assets at a given time. It further shows the capital structure of a company and how the assets are financed.

A profit and loss statement (P&L statement) is a periodic accounting procedure, in which the revenues are opposed to the costs of accounting period. The P&L account shows the success of an accounting period. Thus, operating results as well as the after-tax-results are more closely regarded. The Operating Profit or Earnings before Interest and Tax (EbIT) shows the results of the production/providing of service (depending on what the company sells, delivers) as well as operative activities while the after-tax-results express the success of the whole company after considering finance costs and other outstanding returns and taxes. When this is positive (revenues>costs) the company has made a profit. When speaking of a loss or an annual shortfall, then the total of the P&L account will be negative.

A company's ability to do business is determined by its ability to pay its liabilities on the date of maturity. This ability is referred to as "liquidity". Liquid financial means are primarily cash and cash in bank. Successful companies monitor and direct the movements of liquidity with the indicator called *cash flow*. Cash flow is the balance between inflow and outflow of liquidity within a specific period. One can calculate the cash flow and its variations over time. It becomes clear how much cash is or was available to be invested, how much is on hand to pay debts with or how much is available to distribute a dividend during the period of analysis. One can also get information about the sources and use of liquidity in a company.

In the calculations, it was assumed that liabilities would be paid back starting from the second year of operation. As long as all the above-mentioned estimations are fulfilled, the loan will be paid back within the first four years of operation. For the calculations, it was assumed that the building would be depreciated using the straight-line method; with 4% each year, the corporate income tax in Ethiopia is 30%, revenues, operation and maintenance as well as personnel costs are as in tables in the section 5.5.2. It was assumed that no other taxes would have to be paid. The company will take a loan of 33,000 Birr to cover the building costs of the public toilet complex (31,141 Birr) and to buy first supplies of accessories needed for the complex to operate. In the financial statements, it was assumed that revenues will be the same each year, and the same applies for operation and maintenance as well as personnel costs. The interest rate needs to be paid until the loan will be paid back, and the service charge needs to be paid only once.

OPENING BALANCE SHEET YEAR 1 (Birr)			
ASSETS		***LIABILITIES***	
Fixed assets		**Equity**	
Building	0	Share capital	0
Accumulated depreciation	0	Profit/loss carry forward	0
		Income of the period	0
		Loan	33,000
Total fixed assets	**0**	**Total equity and returned earning**	**33,000**
Current assets		**Short term debt**	
Cash	33,000	Other liabilities	0
		Accruals	0
Total current assets	**33,000**	**Total short term debt**	**0**
Total assets	***33,000***	***Total liabilities***	***33,000***

PROFIT AND LOSS STATEMENT YEAR 1 (Birr)		Notes
Revenues	36,629	Generated revenues from operation of 5 toilet units. Refer to table 22
+ Other income	0	
- Cost of service sold (O&M)	9,188	Yearly O&M costs of running 5 toilet units, without personnel costs (19,070-9,882 = 9,188). Refer to table 20
Gross Profit	***27,441***	
- Personnel expenses	9,882	19,070-9,188 = 9,882
- Depreciation	1,246	Depreciation of 4% from the total construction cost
- Interest rate	3,300	Interest rate – 10% of the loan
- Service charge	330	Service charge – 1% of the loan
Profit or loss from operation	***12,683***	
- Income tax	3,805	Income tax in Ethiopia: 30% of Income (30%*12,683=3,805)
- Other taxes	0	
Profit/Loss after tax	***8,878***	Company made a profit of 8,878 Birr

CASH FLOW STATEMENT YEAR 1 (Birr)		Notes
Profit/loss after tax	8,878	From the P& L Statement year 1
+/- Non cash expenses	0	
+ Depreciation	1,246	
Operating cash flow	***10,124***	
+/- Changes in working capital		
- Capital expenditures	31,141	Construction costs of the toilet complex
Cash flow	***-21,017***	
Source of funds		
+ OMFI debt	33,000	The loan taken from the OMFI
Total source of funds	***33,000***	
Financing balance	11,983	
+ Balance of last year	0	
Financing balance	***11,983***	Change in liquid means >0; the company is doing well financially

Table 24: Financial statements for the first year of operation of the public toilet complex

YEAR END BALANCE SHEET YEAR 1/ OPENING BALANCE SHEET YEAR 2 (Birr)			
ASSETS		***LIABILITIES***	
Fixed assets		***Equity***	
Building	31,141	Share capital	0
Accumulated depreciation	1,246	Profit/loss carry forward	0
		Annual result	8,878
		Income of the period	0
		Loan	33,000
Total fixed assets	***29,895***	***Total equity and returned earning***	***41,878***
Current assets			
		Short term debt	
Cash	11,983	Other liabilities	0
		Accruals	0
Total current assets	***11,983***	***Total short term debt***	***0***
Total assets	***41,878***	***Total liabilities***	***41,878***

Construction costs of the toilet complex

Building – accumulated depreciation = Total fixed assets

From the Cash Flow Statement year 1

From the P & L Statement Year 1

PROFIT AND LOSS STATEMENT YEAR 2 (Birr)	
Revenues	36,629
+ Other income	0
- Cost of service sold (O&M)	9,188
Gross Profit	***27,441***
- Personnel expenses	9,882
- Depreciation	1,246
- Interest rate	3,300
Profit or loss from operation	***13,013***
- Income tax	3,904
- Other taxes	0
Profit/Loss after tax	***9,109***

CASH FLOW STATEMENT YEAR 2 (Birr)	
Profit/loss after tax	9,109
+/- Non cash expenses	
+Depreciation	1,246
Operating cash flow	***10,355***
+/- Changes in working capital	
- Loan payback	11,983
- Capital expenditures	0
Cash flow	***-1,628***
Source of funds	
+ OMFI debt	0
Total source of funds	***0***
Financing balance	-1,628
+ Balance of last year	11,983
Financing balance	***10,355***

Loan paid back with the cash resources from the first year

The result of the Cash Flow Statement from year 1

Table 25: Financial statements for the second year of operation of the public toilet complex

YEAR END BALANCE SHEET YEAR 2/ OPENING BALANCE SHEET YEAR 3 (Birr)			
ASSETS		***LIABILITIES***	
Fixed assets		***Equity***	
Building	31,141	Share capital	0
Accumulated depreciation	2,491	Profit/loss carry forward	8,878
		Annual result	9,109
		Income of the period	0
		Loan	21,017
Total fixed assets	***28,650***	***Total equity and returned earning***	***39,005***
Current assets		***Short term debt***	
Cash	10,355	Other liabilities	0
		Accruals	0
Total current assets	***10,355***	***Total short term debt***	***0***
Total assets	***39,005***	***Total liabilities***	***39,005***

Sum of the depreciation from two years (→ Accumulated depreciation)

From the Cash Flow Statement year 2 (→ Cash)

From the Profit and Loss Statement year 1 (→ Profit/loss carry forward)

From the Profit and Loss Statement year 2 (→ Annual result)

33,000-11,983 = 21,017 (→ Loan)

PROFIT AND LOSS STATEMENT YEAR 3 (Birr)	
Revenues	36,629
+ Other income	0
- Cost of service sold (O&M)	9,882
Gross Profit	***26,747***
- Personnel expenses	9,882
- Depreciation	1,246
- Interest rate	2,102
Profit or loss from operation	***13,518***
- Income tax	4,055
- Other taxes	0
Profit/Loss after tax	***9,462***

10%*21,017 = 2,102 (→ Interest rate)

CASH FLOW STATEMENT YEAR 3 (Birr)	
Profit/loss after tax	9,462
+/- Non cash expenses	
+Depreciation	1,246
Operating cash flow	***10,708***
+/- Changes in working capital	
- Loan payback	10,355
- Capital expenditures	0
Cash flow	***353***
Source of funds	
+ OMFI debt	0
Total source of funds	***0***
Financing balance	353
+ Balance of last year	10,355
Financing balance	***10,708***

Table 26: Financial statements for the third year of operation of the public toilet complex

YEAR END BALANCE SHEET YEAR 3/ OPENING BALANCE SHEET YEAR 4 (Birr)			
ASSETS		***LIABILITIES***	
Fixed assets		***Equity***	
Building	31,141	Share capital	0
Accumulated depreciation	3,737	Profit/loss carry forward	17,988
		Annual result	9,462
		Income of the period	0
		Loan	10,662
Total fixed assets	***27,404***	***Total equity and returned earning***	***38,112***
Current assets		***Short term debt***	
Cash	10,708	Other liabilities	0
		Accruals	0
Total current assets	***10,708***	***Total short term debt***	***0***
Total assets	***38,112***	***Total liabilities***	***38,112***

Sum of the depreciation from 3 years (→ Accumulated depreciation)

From the Cash Flow Statement Year 3 (→ Cash)

From the P&L Statement year 1 and 2 (→ Profit/loss carry forward)

From the P&L Statement 3 (→ Annual result)

21,017-10,355 = 10,662 (→ Loan)

PROFIT AND LOSS STATEMENT YEAR 4	
Revenues	36,629
+ Other income	0
- Cost of service sold (O&M)	9,188
Gross Profit	***27,441***
- Personnel expenses	9,882
- Depreciation	1,246
- Interest rate	1,066
Profit or loss from operation	***15,247***
- Income tax	4,574
- Other taxes	0
Profit/Loss after tax	***10,673***

10%*10,662 = 1,066 (→ Interest rate)

CASH FLOW STATEMENT YEAR 4	
Profit/loss after tax	10,673
+/- Non cash expenses	
+Depreciation	1,246
Operating cash flow	***11,919***
+/- Changes in working capital	
- Loan payback	10,662
- Capital expenditures	0
Cash flow	***1,257***
Source of funds	
+OMFI debt	0
Total source of funds	***0***
Financing balance	1,257
+ Balance of last year	10,708
Financing balance	***11,965***

33,000 – (11,983+10,355) = 10,662 (→ Loan payback)

CLOSING BALANCE SHEET YEAR 4 (Birr)			
ASSETS		***LIABILITIES***	
Fixed assets		***Equity***	
Building	31,141	Share capital	0
Accumulated depreciation	4,983	Profit/loss carry forward	27,450
		Annual result	10,673
		Income of the period	0
		Loan	0
Total fixed assets	***26,158***	***Total equity and returned earning***	***38,123***
Current assets		***Short term debt***	
Cash	11,965	Other liabilities	0
		Accruals	0
Total current assets	***11,965***	***Total short term debt***	***0***
Total assets	***38,123***	***Total liabilities***	***38,123***

Sum of the depreciation from 4 years

From the Cash Flow Statement Year 4

From the P&L Statement year 1, 2 & 3

From the P&L Statement 4

Table 27: Financial statements for the fourth year of operation of the public toilet complex

As it can be seen in the Profit and Loss Statements, the company will be making a profit every year (8,878 Birr- in the first year, 9,109 Birr- in the second year, 9,462 Birr- in the third year and 10,673 Birr in the fourth year). This profit shows money that the company is left with after covering the operation and maintenance costs, personnel costs, depreciation, the interest rate on the loan and the income tax. The results are quite similar for each year due to the fact that revenues, operation and maintenance and personnel costs were assumed to be the same each year. Of course, this is the easiest assumption and the company upon starting to make a profit every year might involve itself in other profit-generating activities, e.g. provide a showering facility. The financial statements for the first years of operation show how the company would do in financial terms if all the estimations proved to be correct. In such a case, the loan owned to the OMFI would be paid back in rates (11,983 Birr; 10,355 Birr and 10,662 Birr) starting from the second year of operation, as it can be seen in the cash flow statement for the year 2, 3 and 4. Being able to pay back the loan so early is for sure a good result. The company might even start thinking about building another complex next to the market place. Also, the financing balance from cash flow statements looks well, due to the fact that changes in liquid means are always positive (financing balance of each cash flow statement, after addition of the balance of the previous year cash flow statement). Liquidity refers to the ability to meet all required payments in a timely fashion and this is exactly what the company is striving for and manages to achieve.

5.5.4. Sensitivity analysis

The above-mentioned plan of paying back the loan together with the interest rate and service charge within the first four years of operation may be fulfilled if the estimations made are fulfilled. However, it might be that fewer visitors will appear daily, or farmers will not buy sanitized urine and feces or companies will not be willing to post advertisements on the toilet cubicles. Thus, a sensitivity analysis needs to be made in order to allow for an unexpected turn of events and calculate financial risks involved.

The assumption about the estimated *number of visitors* per day states that 300 people will be visiting the public toilet complex daily. In case only half of them is going to use the restrooms, the financial result of it will be quite significant as it can be seen in the table below. The difference would be huge, and at the end of the fourth year of operation the company would still owe as much as 29,649 Birr to the OMFI (see the closing balance sheet for the year 4). The amount still owed to the OMFI is very big, compared to the first analysis, when everything went as planned. From the loss carry forward (-2,245 Birr), it is clear that the company is not able to make a real profit (also shown by the annual result). On the assets side, cash shows as little as 799 Birr, the amount that will be used to pay back the loan in the coming year. It makes it easy to understand that the loan will take many years to be paid back, if the financial result continues to be like this.

CLOSING BALANCE SHEET YEAR 4 (Birr)			
ASSETS		***LIABILITIES***	
Fixed assets		***Equity***	
Building	31,141	Share capital	0
Accumulated depreciation	4,983	Profit/loss carry forward	-2,245
		Annual result	-446
		Income of the period	0
		Loan	29,649
Total fixed assets	***26,158***	***Total equity and returned earning***	***26,958***
Current assets		***Short term debt***	
Cash	799	Other liabilities	0
		Accruals	0
Total current assets	***799***	***Total short term debt***	***0***
Total assets	***26,958***	***Total liabilities***	***26,958***

Table 28: Closing balance sheet for the fourth year of operation with the estimation of 150 visitors/day

However, it might be that only in the first few months of operation visitors will appear in a fewer number than expected. When calculating that only in the first 3 months of operation the facility will be visited by 150 people per day, and starting from the fourth month already 300 people will be using the public toilet complex daily, the difference will not be as huge as in the first scenario. However, the loan will not be paid back within the first four years of operation (with 2,037 Birr still owed to the OMFI at the end of the fourth year of operation). In the first year, revenues would be lower (32,050 Birr), with operation and maintenance costs also slightly lower (8,039 Birr), but in the second year it would be already the same as in the first scenario analysis, namely 36,629 Birr and 9,188 Birr, accordingly. Looking at the closing balance sheet year 4, one can see that the loan would not be paid back completely; still 2,037 Birr would be owed to the OMFI. However, the profit carry forward from the first 3 years of operation (25,367 Birr) is positive and so is the annual result (10,505 Birr). Also, cash on the assets side is 11,751 Birr. One can see that this scenario does not have as drastic financial impact on the company as the previous one.

CLOSING BALANCE SHEET YEAR 4 (Birr)			
ASSETS		***LIABILITIES***	
Fixed assets		**Equity**	
Building	31,141	Share capital	0
Accumulated depreciation	4,983	Profit/loss carry forward	25,367
		Annual result	10,505
		Income of the period	0
		Loan	2,037
Total fixed assets	***26,158***	***Total equity and returned earning***	***37,9094***
Current assets		***Short term debt***	
Cash	11,751	Other liabilities	0
		Accruals	0
Total current assets	***11,751***	***Total short term debt***	***0***
Total assets	***37,909***	***Total liabilities***	***37,909***

Table 29: Closing balance sheet for the fourth year of operation with the estimation of 150 visitors/day in the first 3 months of operation

This scenario analysis highlights the fact that was already well known from the beginning, namely that visitors are crucial for the successful operation of the public toilet complex. In case in the first few months less visitors used the toilets, the financial impact would not be as significant as in case the projected number of visitors appeared to be overestimated and only 50% of the projected number would use the provided service. In such a case, only two or three toilets should be built so that the investment on building additional toilet units would not be made without purpose. This analysis shows how important the estimation of the number of users is, and what a significant financial impact it might have on the project if it appears to be overestimated. Thus, even though it was calculated that 341 people would be willing to use restrooms, it was decided that 300 people would be chosen as the expected number of users, in order to allow for some deviation from the assumption that 10% of the passengers would be willing to use the public toilet facility.

Another problem that could appear might involve farmers and their unwillingness to pay for sanitized urine and composted feces. They might be willing to collect it and further use it on their farmlands, however, they could be unwilling to pay for it. Thus, the next analysis shows the financial impact in case *no sanitized excreta were sold to farmers*. As it can be derived from the table, the difference is not as significant as in case of overestimating the number of users. Obviously, the profit would be lower since revenues from selling of the fertilizer to farmers would not be included. Also, the loan would not be paid back within the first four years of operation (refer to the closing balance sheet for the year 4). However, comparing the result with the overestimation of the number of users, this scenario is not as financially dangerous for the company as the first scenario. In case of the overestimation of the number of users, the closing balance sheet for the fourth year of operation shows the amount of 29,649 Birr still owed to the OMFI. In case no sanitized excreta were sold, the company would still owe money to the OMFI after the fourth year of operation, but as little as 5,046 Birr. Thus, it can be stated that the project is not highly sensitive to the fact whether sanitized urine and feces are going to be sold to farmers or not. However, it would achieve a better financial result if it were the case.

CLOSING BALANCE SHEET YEAR 4 (Birr)			
ASSETS		***LIABILITIES***	
Fixed assets		***Equity***	
Building	31,141	Share capital	0
Accumulated depreciation	4,983	Profit/loss carry forward	22,358
		Annual result	8,602
		Income of the period	0
		Loan	5,046
Total fixed assets	***26,158***	***Total equity and returned earning***	***36,006***
Current assets		***Short term debt***	
Cash	9,847	Other liabilities	0
		Accruals	0
Total current assets	***9,847***	***Total short term debt***	***0***
Total assets	***36,006***	***Total liabilities***	***36,006***

Table 30: Closing balance sheet for the fourth year of operation with the assumption of no sanitized excreta being sold

Another consideration that might influence financial performance of the project is the willingness of companies to post their *advertisements* on the toilet cubicles. Kebele eleven is the one where most business activities take place, so there is a high potential for companies to be willing to post advertisements. Also, the estimated price is much lower than the one asked for by the operators of the already mentioned Dignified Mobile Toilets in Nigeria (refer to the fourth chapter). There, the price of putting an advertisement on the body of a toilet is equivalent to around 350 Birr per month[45]. Revenues estimations for the toilet complex in Arba Minch assume the price of 200 Birr per month and advertisement. However, the worst-case scenario needs to be analyzed. Thus, the financial result in case no advertisements were posted on the toilet units are presented in table 31. In such a case, revenues would be down from 36,629 Birr/year to 24,629 Birr/year with operation and maintenance as well as personnel costs remaining the same. The closing balance sheet for the fourth year of operation shows that the company would still owe as much as 25,256 Birr in case companies were reluctant to post their advertisements on the toilet cubicles. Thus, it can be stated that the financial performance of the public toilet complex is dependent on additional sources of income (other than a user's charge), e.g. from allowing for advertising on the toilet bodies. In case it does not take place, there needs to be another source of income such as selling of travel accessories, e.g. tissues, drinks, etc. Also, in order to assure that companies will be putting their advertisements on the toilet cubicles, contracts should be signed in advance for a specific period of time. Well in advance of the expiry date of the contract a new agreement should be signed with the same company or, in case they do not want to continue advertising, new companies should be contracted. Also, the size of the advertisements should be regulated so that it would fit on the body of the toilet.

[45] Information gathered from correspondence with Mr. Moyin (General Manager of the DMT)

OPENING BALANCE SHEET YEAR 4 (Birr)			
ASSETS		***LIABILITIES***	
Fixed assets		***Equity***	
Building	31,141	Share capital	0
Accumulated depreciation	4,983	Profit/loss carry forward	2,148
		Annual result	1,567
		Income of the period	0
		Loan	25,256
Total fixed assets	***26,158***	***Total equity and returned earning***	***28,971***
Current assets		***Short term debt***	
Cash	2,813	Other liabilities	0
		Accruals	0
Total current assets	***2,813***	***Total short term debt***	***0***
Total assets	***28,971***	***Total liabilities***	***28,971***

Table 31: Closing balance sheet for the fourth year of operation with the assumption of no advertisements being posted on the toilet cubicles

It can be derived from the analysis that the facility would not make much profit if it were only based on providing service of public toilets. What is considerable is that without a significant source of other income, the facility will not be making enough profit to pay the loan back within the first few years of operation. If the loan is to be paid back quite soon, there needs to be another way of generating an extra income. For instance, a showering facility could be incorporated. Then, visitors could be charged for using it and would have to buy water for this purpose. In case showers were added to the service, greywater treatment would need to be incorporated, as already discussed in the third chapter. Depending on the financial performance of the public toilet complex, there might be other services offered with time. If the complex is going to make enough profit and the loan will be paid back, there might be another investment made, e.g. showers or a baby-changing and breast-feeding room, lockers, etc. Further investments are highly dependent on the financial performance of the project within the first years of its operation. Also, after paying back the loan, the public toilet complex might start generating more profit that could be spent on building another facility, e.g. in the vicinity of the market places. Then, gained experience and lessons learnt from building, operating and maintaining of the first facility could be efficiently used for the next one and allow for substantial savings. In such a way, everyone would benefit, the company – financially, the municipality and the beneficiaries – health and convenience, and the environment – through prevention of its degradation.

5.6. Why not pour-flush with anaerobic digestion?

In the second chapter, there were two toilet types described, namely a urine-diverting toilet and a pour-flush toilet with anaerobic digestion. The project and all the resulting calculations are based on the choice of a urine-diverting toilet. The main reason for this choice is the simplicity of its construction and operation as well as appropriateness to the location in the city of Arba Minch. As a toilet built above ground, it is suitable for application in flood-prone regions. As it was already discussed in the second chapter, Arba Minch faces flooding problems. In the case of a pour-flush toilet combined with anaerobic digestion, great care needs to be given to the construction of a biogas digester. It needs to be very well designed, precise and involve skilled labor, which might be difficult to organize. Precision is of great importance due to the fact that no leakages of gas can be allowed, which is also related to the security issue. In case of a public toilet complex visited by 300 users per day, an additional feed would be required, such as animal manure, cow dung, etc. One of the main problems related to the choice of this technology is related to the issue of sludge that accumulates as a by-product. This material needs to be disposed of and the city of Arba Minch is already facing a problem related to the management and disposal of solid waste (refer to the second chapter). Therefore, it might be assumed that sludge would not be disposed of without affecting the environmental health. The choice of the toilet technology needs to be based on the overall estimation of the impact of the project. With a urine-diverting toilet, there is no generation of by-products, as sanitized urine and feces can be used on farmlands. Sludge should undergo treatment, as it cannot be used directly on land in the form as it leaves the biogas digester. The Sulabh organization estimates the volume of digester sludge per user to be 0.00021 m^3, which would mean around 2 m^3 of sludge, accumulated every month [33]. With desludging being performed every half a year, approximately 12 m^3 of sludge would have to undergo treatment and be safely disposed of. The effluent after being treated can be used as a fertilizer, however, a treatment process in a wetland or drain field is absolutely necessary prior to its agricultural application. In such a case, there would need to be a bigger spatial requirement for incorporation of the post-treatment facility. Another problem with this technology would include the danger of clogging and system failure when the number of users was overestimated. The system with a biogas digester requires a constant feed in order to work well and generate biogas. The Sulabh organization suggests that the use of biogas technology combined with pour-flush toilets is feasible when the number of users is more than 100 [68]. One of the most significant advantages of this technology is generation of biogas that can be later used for cooking, generating electricity, etc. Without assurance that a required feed will be available on a daily basis, the system could not succeed. Due to little use, the biogas digester would dry out and the investment would prove unsuccessful. It might be that for bigger investments, with a clearly defined number of users (e.g. in hotels in Arba Minch) this technology would be preferred. Then, the generated biogas could be used in the facility, e.g. for cooking of meals in a hotel. However, without a clear definition of the number of users, the risk of the system to fail is too high to be taken.

It is interesting from the financial point of view to discuss differences to present calculations if the pour-flush toilet with a biogas digester was chosen. First of all, the toilet construction would be much cheaper, due to the fact that the unit could be built on the ground, so no stairs would be needed, no masonry work and no concrete slab. However, with this technology there is a need for water for flushing (1-2 l per each flush), so the water tariff would be higher due to a higher water consumption (from 2,10 Birr to 2,70 Birr/m^3). Also, the investment for building of a biogas digester would have to be included. The price is estimated at around 500 Birr/m^3 of the digester. For the estimated number of users (300 per day), the minimum volume would be 24 m^3 (300 people x 2l/person x 40days[46]=24,000 l/day), so for the safety reasons it should be built bigger, e.g. 30 m^3. Thus, the investment cost for the biogas digester would be around 15,000 Birr. As already mentioned, construction of such a digester needs to be very precise and trained labor needs to be involved in building not to allow for any fractures or leakages. Thus, labor costs would be quite high, compared to the ones employed in the construction of a urine-diverting toilet. On the other hand, revenues could be higher due

[46] Hydraulic retention time is about 30-40 days [68]

to savings on electricity. However, in the case of the discussed project the cost of electricity is not a significant part of operation costs due to the fact that electricity is needed only four hours per day. Also, the biogas digester would have to be protected against amplitudes in temperature and resulting cooling, which would influence the rate of biogas production. Therefore, special protective material would have to be coated on the biogas digester or a protective structure would have to be built around it, also increasing the investment costs. Maintenance of such a system requires frequent checking for gas leakages. Normally, one person should be employed for supervision of the digester and performance of unplanned work. This would increase personnel costs. Daily maintenance work does not require much input, however, regular oil changes, digester clean out, etc. are necessary. In the case of a biogas digester, running costs with a professional supervision and management are as important as the construction costs and cannot be neglected. In calculating depreciation, normally 15 years of economic life span are assumed [40]. Certain parts of the plant have to be replaced, e.g. a steel gasholder. Also, all the steel parts need to be repainted every year or every second year [40]. These activities add up to the running costs of such a facility.

Both of the toilet types described in detail in the second chapter have their pros and cons. Having verified the local situation, it has been opted for the urine-diverting toilet as a better choice for the location and circumstances. However, pour-flush toilets with anaerobic digestion have great potential for implementation in developing countries. In case of the city of Arba Minch, one could see their usefulness in big complexes such as hotels or a university, where the number of users is quite big and rather constant as well as the generated biogas will find its utilization in the complex itself, saving on the investment on the gas distribution network.

Chapter 6: Conclusions

Sanitation as a method of containment and sanitization of human excreta serves an important role of preventing the spread of diseases and protecting both human and environmental health. Thus, the provision of sanitation services is one of the main focuses worldwide, with a particular emphasis on the developing part of the world. The conventional sanitation approach discussed in the first chapter, be it ”drop and store” or “flush and discharge” systems, have many drawbacks and should not be considered as a feasible solution to sanitary problems facing the developing world. In order to meet the sanitation United Nations Millennium Development Goal, sustainable sanitation solutions should be considered. Ecological sanitation presents a variety of sanitary options, which contain, sanitize and allow for reuse of nutrients present in human excreta. This approach prevents from pollution, on the contrary to end-of-pipe solutions. In developing countries, the latter options are mostly doomed to failure due to a lack of the infrastructure, huge costs of sewerage as well as of operation and maintenance of wastewater treatment plants. In most cases “flush and discharge” systems in developing countries do not work properly due to a lack of treatment, and raw sewage makes its way to receiving water bodies, which causes environmental pollution. Also, costs of the conventional sanitation approach are too high to be borne by developing countries. Therefore, the alternative approach such as ecological sanitation or low-cost sanitation systems should become a feasible option there.

The city of Arba Minch, which is situated in Ethiopia, like many other cities in developing countries, is facing a number of environmental problems coupled with the population growth and poor infrastructure. One of the most burning problems deals with the provision of public toilets in such places as markets and a bus station. The city has two ventilated improved pit latrines that serve the role of public toilets. They are obviously not enough to serve the public in Arba Minch. The lack of public toilets in the vicinity of markets and the bus station makes merchants and clients use the riverside for defecation and urination. Passengers use the nearby tearooms or hotels or urinate next to the bus station. Thus, it was recognized that the municipality needed help in designing appropriate public toilet system. The bus station was chosen as the first location for a public toilet complex. Two technologies were considered for this purpose: a dry toilet with urine-diversion and a pour-flush toilet with anaerobic digestion. Having considered the local conditions, with an emphasis on problematic effluent sludge treatment and disposal in case of anaerobic digestion, urine-diverting toilets were chosen as a better option. Based on bus timetables and passenger numbers, it was estimated that the public toilet complex should consist of six urine-diverting toilet units serving 300 users on a daily basis. The business plan presented in the fifth chapter shows the feasibility of the project and proves that the loan taken for the initial investment on the public toilet complex would be paid back after the fourth year of operation. The public toilet facility located next to the bus stop would allow for collection of urine and feces, which after sanitization could be sold to farmers. From financial point of view, it is necessary to highlight the fact that the complex will be making a profit providing that other income generating activities than provision of toilets would also be performed. These activities may include selling of advertisement space on the toilet cubicles, selling of travel accessories, etc. The risk analysis revealed that if no companies were going to post their advertisements on the toilet cubicles, the project would not be as financially successful as expected. Therefore, another profit generating activity could involve selling of water of better quality that would not have to be boiled prior to consumption. Water supplied by the Arba Minch Town Water Service could be treated in a simple treatment step and sold for a much higher price. As a comparison, bottled water can be purchased in Arba Minch at around 4 Birr/l[47]. For the company to make a profit equal to the one generated from allowing for advertisements on the body of the toilets, around 1,500 l of water sold at a rate of 0.25 Birr/l would have to be vended by the toilet complex on a daily basis. The price would involve a tenfold rise from the one without an extra purification step and a small investment would have to be made on the provision of the treatment method. However, the inhabitants of the city, who are not connected to the water supply, are forced to buy their water from neighbors or public taps at a higher rate. Vending of water of two qualities (one would require boiling prior to consumption, whilst the other not) could be an alternative with a potential of an equal financial impact to generating income from selling of advertisement space. Providing that all the estimations and assumptions are true, a micro enterprise responsible for building, operation and maintenance of the public toilet facility, could also extend the area of operation to other sites in Arba Minch, e.g. the vicinity of market places. Having gathered experience with urine-diverting toilet units, it is possible to either continue with the same technology or switch to pour-flush toilets with anaerobic digestion, due to the potential of using generated biogas and energy savings involved. However, the city of Arba Minch is facing problems related to disposal of sludge from pit latrines and solid waste. Therefore, prior to employment of anaerobic digestion, a detailed plan of treatment and reuse or safe disposal of effluent sludge from an anaerobic digester should be drafted. Also, careful design and skilled labor should be provided for the erection of a biogas digester. Moreover, the estimation of number of users plays an important role in case the toilet complex is to be coupled with an anaerobic digester. Generation of biogas from public toilet complexes requires constant feed of material for anaerobic digestion, otherwise the system would dry out and it would no longer function properly.

The alternative sanitation approach has a huge potential for implementation and successful operation in countries like Ethiopia. Thus, it should be explored and effectively implemented, providing that local conditions and user's preferences match the chosen technology. Ecological sanitation with its huge variety of sanitary solutions, either based on dehydration or decomposition processes, provides many different options that can be efficiently chosen for different locations, climate, culture, geographical conditions, etc. With the sanitation coverage still lagging behind the water supply coverage, the alternative sanitation approach should play a significant role in sanitation provision in the developing world.

[47] 12,5 Birr=1 € or 9 Birr=1 USD

Appendix 1

Table 32: Summary of local conditions in kebeles in Arba Minch, Ethiopia

Kebele No	Kebele 1	Kebele 2	Kebele 3	Kebele 4	Kebele 5	Kebele 6	Kebele 7	Kebele 8
Public toilets	No	1 communal built by Red Cross	No	No	No	No	No	No
Open defecation	In 2 gorges	In 1 gorge	In 3 gorges	On 1 side of the market	N/A	N/A	N/A	N/A
Household sanitation issues	Dry pit latrines, no desludging for last 3 yrs, septic tank overflows, pits collapse due to soil structure	N/A[48]	N/A	N/A	Pit latrines dug by daily laborers	Pits fail due to soil condition	Toilet built near a gorge with excreta drained to it, flooding of toilets observed	Shallow pits due to rocky soil nature
Water and wastewater issues	Yard connection, no WC, showers & hand basins in use, no GW[49] reuse	Hotels with toilets with cemented floors and a septic tank, high GW generation, no GW reuse, people living next to the gorge drain GW there	No GW reuse, low-cost houses drain wastewater to 1 of the gorges	No GW reuse	Most households connected to the town water supply line, no storage or treatment of GW, reuse of GW for plants and garden watering	The best tourist hotel with a septic tank and effluent treatment facilities	Most of the households-yard tap users	Some households not connected to water supply, only 3 water points, clothes washing, bathing in Kulfo River, GW reuse

48 N/A- not available

49 GW- greywater

Kebele No	Kebele 1	Kebele 2	Kebele 3	Kebele 4	Kebele 5	Kebele 6	Kebele 7	Kebele 8
Solid waste disposal	Gorges, open areas, in low-cost neighborhoods SW collection	Gorge, high SW[50] generation	Gorges	N/A	Plastic waste on the road side	2 donkeys for transport of SW to a municipality designated site	N/A	N/A
Houses	"Tukul" houses at the periphery, poor housing condition, condominium houses under construction	No "tukul" houses	Low-cost houses made of hollow concrete blocks, "tukul" houses at the periphery	N/A	Households have additional houses built for rent	Newly built houses	Stretched settlement	All houses residential, illegal settlers at the periphery
Hotels	Small number	Many	N/A	N/A	Yes	Many, best tourist hotel	N/A	N/A
Institutions, organizations	Educational institutions, Catholic Mission	Governmental offices, ROSA project office	Model school, clinic, court office	Second largest market	Beverage houses, shops, churches	Coffee mill, Teachers Training College, Commercial Bank, School, Health College, MSE Production Center, Mosque, Town Water Service Office	Many churches, Governmental offices, e.g. Tele-communication Corporation, City administration	N/A

[50] SW- solid waste

Kebele No	Kebele 1	Kebele 2	Kebele 3	Kebele 4	Kebele 5	Kebele 6	Kebele 7	Kebele 8
Income generation	Animal husbandry	Mixed employment: civil servants, merchants, retired people	Many civil servants and retired people	Many farmers, second largest market	N/A	Maids, civil servants	N/A	Daily laborers for pit digging and emptying, petty traders, masonry workers
Space for expansion	Abundant space	No open plots, densely populated	N/A	N/A	Densely populated	N/A	Wide areas undeveloped- rocky ground	N/A
Kebele	**Kebele 9**	**Kebele 10**	**Kebele 11**	**Kebele 12**	**Kebele 13**	**Kebele 14 Kebele 15 Kebele 16**		
Public toilets	No	No	No	1 communal built by Red Cross	No	No		
Open defecation	1 gorge	Suspended latrine using gorge as a pit	Urinating next to the bus station	N/A	N/A	Gorge, area at the periphery & university campus		

Kebele	Kebele 9	Kebele 10	Kebele 11	Kebele 12	Kebele 13	Kebele 14 Kebele 15 Kebele 16
Household sanitation issues	Failure & collapse of pits observed, people living around the gorge- no toilets	High costs for pit digging due to rocky nature of ground	High-income households with good quality of toilets	N/A	Some don't have toilets due to economic problems and lack of space, many households live in clusters and share a single toilet, most toilets in bad condition	Management bodies force households to have their own toilet + provide materials for the poorest, NGO fought against open defecation with Community Led Total Sanitation and out of 215 households without toilet 190 dug pits for toilets
Water and wastewater issues	Problem of potable water supply, very few yard connections, Kulfo River used for all purposes, 2 water points	Some households use Kulfo River for bathing and clothes washing, GW collected in a pit	N/A	Common practice of draining GW outside compounds, wastewater from garages not properly managed & disposed, Kulfo River used for bathing & clothes washing	Kulfo River used for washing clothes	AMU- well-established sewerage system & 2 waste stabilization ponds, wastewater effluent used for irrigation by farmers, deep water wells at the university + town water supply, water supply problem: not sufficient number of water points, some use water from irrigation canal from Kulfo River for clothes washing and cooking

Kebele	Kebele 9	Kebele 10	Kebele 11	Kebele 12	Kebele 13	Kebele 14 Kebele 15 Kebele 16
Solid waste disposal	Gorge	Special waste from abattoir burnt, septic tank for wastewater contaminated with blood, waste from the market not properly managed	SW collected by the municipality, complaints about SW collection tariffs	SW from the market not managed, SW disposal site near the Kulfo River + 2 other dumping sites	SW collection organized by the municipality running well	N/A
Houses	"Tukul" houses	N/A	High rise buildings	Some slums around the market	Constructed at the time of town establishment	"Tukul" houses at the periphery, "chika" houses with corrugated iron sheet roof
Hotels	N/A	N/A	Many	N/A	N/A	N/A

Kebele	Kebele 9	Kebele 10	Kebele 11	Kebele 12	Kebele 13	Kebele 14 Kebele 15 Kebele 16
Institutions, organizations	2 schools	Technical & Vocational Training College, 4 floor mills, Abattoir, Prison, sitting place of the football pitch, small local market, daily laborers transporting SW to the gorge	Bus station, boutiques, stationary shops	Boarding School, Health Station, old and new airport, textile factory, Paramedical College, Teachers Training College, floor mills, grain stores, main market	Mosque, 2 police stations, stadium, shops	Arba Minch University (AMU), Arba Minch state farm, primary school, health post
Income generation	The poorest kebele	N/A	Businessmen	N/A	Petty traders, prostitutes	Daily laborers, fuel wood collectors, significant urban agriculture
Space for expansion	N/A	N/A	N/A	N/A	N/A	No problem with space

Appendix 2

Table 33: Summary of public toilet projects in different developing countries

Location	Kitui Nairobi	Mukuru Nairobi	Mathare 4B Nairobi	India, Sulabh toilets	Kibera slum, Nairobi	Kano, Nigeria	Lagos, Nigeria
Number of toilet blocks	5 blocks: – 1 with 20 cubicles – 4 with 12 cubicles	2 toilet blocks with eight door each for two clusters of 506 and 466 households	1 block with 12 cubicles	Various number 1. Pay-and-use community toilets 2. Toilets in slum areas	Three blocks: 1. 105 latrines 2. 24 latrines 3. 6 latrines	Various number, located in public places, around main markets and in congested areas Two units type: 1. 16 cubicles. (5t[51], 3b-male, 7t, 1b-female) 2. 10 cubicles. (4t, 2b-male, 3t, 1b-female)	Mobile toilets, various number
Community/public toilet	Community	Community	Community	Community/Public	Community	Public	Public
Toilet type	1 block- flush toilet 4 other blocks- dry pit latrine	Manually flushed toilets from a central point	Flush toilets	Twin pit pour-flush latrine with/out biogas digester plant	1. Pit latrine or pour-flush 2. Pit latrine 3. Pour-flush toilets	N/A[52]	Flush toilets
Sewer connection	1 block with 20 cubicles from Nairobi City Council Water Supply free of charge	2 blocks	Yes	No	1. No 2. No 3. Yes	Yes	No, waste holding tank

[51] t- toilet, b- bathroom
[52] N/A- not available

Location	Kitui Nairobi	Mukuru Nairobi	Mathare 4B Nairobi	India, Sulabh toilets	Kibera slum, Nairobi	Kano, Nigeria	Lagos, Nigeria
Water in latrines	For sale by jerricans in water kiosks, no water taps in the latrines	For sale from an outside tap and by jerricans	For sale by jerricans to cover the maintenance costs	Yes	1. Water connection with tank 2. Water connection with tank 3. Water kiosk with tank	Supplied by Kano State Water Board, if not: private boreholes, wells	Yes, with/out wash-hand basin
Operation and Maintenance	1 block- 20 households clean in turn 4 other blocks- problematic, too many users	2 women from each area elected by the community, attendants	2 members	1. Where lease period is 1-2 yrs public agency responsible for maintenance, Sulabh- only day-to-day operations 2. Sulabh appoints caretakers, charged fee covers mainten. costs	1. Volunteer 2. Employee 3. Employee	Management by individual operators, staff for fee collection and maintenance work employed	Individuals to whom the toilet is leased
Inspection	Committee (all 5 blocks)	Committee	N/A	Sulabh's internal monitoring system	N/A	N/A	Individuals to whom the toilet is leased

Location	Kitui Nairobi	Mukuru Nairobi	Mathare 4B Nairobi	India, Sulabh toilets	Kibera slum, Nairobi	Kano, Nigeria	Lagos, Nigeria
Emptying	Committee arranges, households join funds for desludging truck	Not needed	Not needed	Not needed	1. Yes 2. Yes 3. No	N/A	Company providing the toilets
Investment/ Funding sources	UNICEF	Donor (material cost), community-landlords (labor cost)	City council	1. Municipality (construction cost, service charge paid to Sulabh, water and electricity) 2. Additionally corporations provide a block grant to the private operator	1. Grant 2. Grant 3. Private sector and micro finance institution	1. Private investors 2. Municipality and leased to individuals	Private sector rented on a lease basis to individuals
Users	1 cubicle-20 households Visitors	Household membership through fee payment Visitors	Household membership through fee payment	Households, visitors	1. Subscribers, visitors 2. Visitors 3. Visitors	Visitors	Visitors
Membership fee per household [USD]	N/A	0.82/month	0.41/month	Toilets in slum areas: free of charge	1. 1.3/month 2. No 3. No	Public toilet	Public toilet
Passer-by/visitor fee [USD]	N/A	N/A	0.08/use	Pay-and-use toilets: 0.02/use of toilet and bath, urinal free of charge	1. 0.025-0.064 2. 0.025 3. 0.038	0.3-0.5	0.15

Location	Kitui Nairobi	Mukuru Nairobi	Mathare 4B Nairobi	India, Sulabh toilets	Kibera slum, Nairobi	Kano, Nigeria	Lagos, Nigeria
Additional facilities	None	Used for showering but not prepared for it	Showers	Showers, washing clothes, lockers, babysitting, dressing	Showers, lending of sandals, showers	Showers	Movable showers, urinal on the side of the toilet

Appendix 3

Table 34: Detailed cost estimate of a urine diversion toilet unit

Item No	Description	Unit	Qty	No. of Units	Total Quantity	Unit Rate (Birr)	Amount (Birr)
	A - SUB STRUCTURE						
	1 - EXCAVATION & EARTH WORK						
1.01	Site clearing and removing of the top 200 mm thick soil.	m^2	1.84	1	1.84	2.00	3.69
1.02	Bulk excavation in ordinary soil to a depth not exceeding 200mm	m^3	0.50	1	0.50	15.00	7.48
	TOTAL CARRIED TO						**11.16**
	B - SUPER STRUCTURE						
	1 - BASEMENT SLAB WORK						
1.01	Masonry wall at the basement	m^3	3.32	1	3.32	450.00	1,495.80
1.02	Provide. cut and fix in position Diameter 10 cm eucalyptus wood formwork						
	a) To floor slab	Pcs	7.33	1	7.33	12.00	88.00
1.03	Mass concrete quality C-20.360 kg of cement / m^3 filled in to form work and vibrated						
	a) In 3 cm thick Floor slab	m^3	0.18	1	0.18	716.76	132.07
	b) In 3 cm thick Floor slab (Top slab)	m^4	0.18	1	0.18	716.76	132.07
	TOTAL CARRIED TO						**1,847.94**
	C- ARCHITECTURAL WORK						
	1 - WALLING						
1.01	Provide. cut and fix in position Diameter 12 cm eucalyptus for walling	Pcs	8	1	11,634	15.00	174.51

1.02	Supply and construct bamboo mat lined with plastic sheet walling.	m^2	11.63	1	11,634	10.00	116.34
	TOTAL CARRIED TO						**290.85**
	2 - ROOFING						
2.01	Provide. cut and fix in position Diameter 8 cm eucalyptus for walling	Pcs	5.00	1	5.00	10.00	50.00
2.02	Supply and fix Corrugated Iron Sheet (G-32). for roof cover including all posts & the necessary fixing accessories.	m^2	3.52	1	3.52	55.62	195.78
	TOTAL CARRIED TO						**245.78**
	3 - CARPENTRY & JOINERY						
3.01	Supply and fix plywood door for fecal chamber and urine chamber opening.						
	D1 = 600 x 100mm	No.	1.00	1	1.00	20.00	20.00
	TOTAL CARRIED TO						**20.00**
	4 - STAIR						
4.01	Wooden stair	No.	1.00	2	2.00	70.00	140.00
	TOTAL CARRIED TO						**140.00**
	5 - SANITARY AND OTHER FIXTURES						
5.01	Pedestal Toilet (China Model)	Pcs	1.0	1.00	1.00	90.00	90.00
5.02	Urinary	Pcs	1.0	1.00	1.00	15.00	15.00
5.03	Collecting Tank (1000 liter plastic)	Pcs	1.0	1.00	1.00	1,230.00	1,230.00
5.04	Collecting barrel (half-cut) for feces	Pcs	4.0	1.00	4.00	125.00	500.00
5.05	Hand wash depot fixed with tap	Pcs	1.0	1.00	1.00	40.00	40.00
5.06	50 mm PVC pipe	Mt.	3.0	1.00	3.00	6.67	20.00

5.07	75 mm PVC pipe	Mt.	3.0	1.00	3.00	17.50	52.50
5.08	Elbow 90 degree Diameter 50mm	Pcs	4.0	1.00	4.00	7.00	28.00
5.09	Elbow 90 degree Diameter 75mm	Pcs	1.0	1.00	1.00	7.00	7.00
5.10	75 mm Vent Cap	Pcs	1.0	1.00	1.00	25.00	25.00
5.11	1/4 lit black paint	can	1.0	1.00	1.00	10.00	10.00
5.12	Bucket with a scoop for ashes	Pcs	1.0	1.00	1.00	20.00	20.00
5.13	Bucket for waste	Pcs	1.0	1.00	1.00	20.00	20.00
5.14	Toilet roll paper holder	Pcs	1.0	1.00	1.00	28.75	28.75
5.15	Door lock	Pcs	1.0	1.00	1.00	20.00	20.00
5.16	Electricity connection fixtures	Pcs	1.0	1.00	1.00	100.00	100.00
5.17	Composting unit	Pcs	1.0	1.00	1.00	750.00	750.00
5.18	Transportation costs	%				0.05	150.00
	TOTAL CARRIED TO						**3,106.25**

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