Pre-Feasibility Assessment of Onsite and Decentralised Sanitation Systems for New Satellite Settlements in Abuja, Nigeria

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List of Abbreviations

AEPB	Abuja Environmental Protection Board
AGIS	Abuja Geographic Information Systems
BOD	Biological Oxygen Demand
DALY	Disability-Adjusted Life Years
DFID	Department for International Development
EIA	Environmental Impact Assessment
FCC	Federal Capital City
FCDA	Federal Capital Development Authority
FCT	Federal Capital Territory
FMA	Federal Ministry of Aviation
FMEnv	Federal Ministry of Environment
FMWR	Federal Ministry of Water Resources
FWS	Free Water Surface
HLR	Hydraulic Loading Rate
IMF	International Monetary Fund
LGA	Local Government Authorities
MDG	Millennium Development Goals
NGN	Nigerian Naira
NUWSRP	National Urban Water Sector Reform Project
NWSSP	National Water Supply and Sanitation Policy
O&M	Operation and Maintenance
PC	Personal Computer
PF	Pour Flush
PPP	Public – Private Partnership
SF	Subsurface flow (SF) wetland
SMWR	State Ministry of Water Resources
SWA	State Water Agencies
UD	Urine Diversion
UfW	Unaccounted for Water
UN	United Nations
UNEP	United Nations Environment Programme
UNESCO	United Nations educational, Scientific and Cultural Organization
UNICEF	United Nations Children's Fund
USACE	United States Army Corps of Engineers
USEPA	United States Environmental Protection Agency
UV	Ultraviolet
VIP	Ventilated Improved Pit
WC	Water Closet
WECD	Water, Engineering and Development Centre
WHO	World Health Organisation
WRI	World Resources Institute
WSP	Waste Stabilisation Pond
WTP	Wastewater Treatment Plant

Abstract

Poor sanitation degrades the environment; even worse it causes deaths especially among children in developing countries. Conversely, good sanitation saves lives. The answer to the sanitation problems for most developing countries has been the linear conventional systems: 'do nothing', 'drop and store', 'flush and discharge', these approaches come with drawbacks that have potentially grim consequences for human and environmental health.

Abuja the new capital city of Nigeria and focus area of this study is a young, newly developed city that has seen huge amounts of capital invested in sanitation infrastructure and services. Wastewater management in Abuja employs these conventional approaches, which this study has found to be problematic. The main city has reticulated transport system but treatment facilities are non-functional; in some cases as a result of non availability of spare parts for plant maintenance, in other cases lack of funds for operation and maintenance. In the peri-urban settlements, existing sanitation systems are such that the pollution of soil and water sources is rampant; among the indigenous population, lack of access to sanitation facilities was common as such open defecation is practiced.

Conventional sewerage sanitation is expensive; it is not affordable to most communities in the developing world for various reasons and the Abuja case is no exception especially considering the costs of upkeep and expanding the existing infrastructure. Are there alternatives that protect human and environmental health while being technically and economically feasible as well as socially acceptable?

This study involved carrying out a pre-feasibility assessment (technical, institutional and socioeconomic) of potential alternative sanitation systems, which may be implemented in place of current conventional systems, which have been identified in this study to be unsustainable in the local context.

A field study was conducted using participatory methods, which analysed the current wastewater management situation, identified the problems associated with current management practices in the study area, needs and preferences of the residents in the study areas. Following this, the feasibility of potentially sustainable alternatives to current technologies was evaluated, and scenarios based on selected technologies are developed; the technical, institutional and socioeconomic feasibility of these scenarios in the local context are assessed.

This study found that the current conventional waterborne system was failing to achieve proper treatment of wastewater within the main city; it was expensive and heavily reliant on external input in terms of technology and funds; the system also failed to achieve coverage requirements especially for peri-urban residents. For the conventional onsite systems, the most significant problem was environmental pollution resulting from improper management practices and non regulation of such systems by the responsible authorities.

Kuje Satellite Town was taken as the design example for the scenario development; simplified sewerage, waste stabilisation ponds, constructed wetlands, dry urine diversion systems and composting were found to be feasible for the area, and were used in the scenarios. Economic and qualitative comparisons indicate the simplified sewerage and pond system, the dry toilet with urine diversion and the rottebehaelter with solids composting were the most promising.

In conclusion, sanitation systems in developing countries modelled after those of industrialised countries are resource intensive and unsustainable in developing countries in terms of capital and O&M costs, environmental impacts, long term maintenance, and fee recovery, even for new cities such as Abuja. Other conventional approaches are also not sustainable as impacts on human and environmental health are rather high. Locally suitable alternative (costs, maintenance requirements, local availability of installation, operation and maintenance materials, resources and skills as well as adequate institutional capabilities and social acceptance) technologies, which suit the purpose and local conditions of intended users such as those examined in this study, must thus be the focus for developing countries.

Chapter 1: Introduction

Poor sanitation has serious consequences for health (WHO/UNICEF, 2000), a fact easily seen in the impacts of water and sanitation related diseases on human health. For example, diarrhoeal diseases alone cause over two million deaths every year (Parry-Jones and Kolsky, 2005), most of these in children (WHO, 2006). 21% of all mortality in children under five in developing countries is attributable to diarrhoea (Kosek, 2003), equivalent to one child dying every twelve seconds (Parry-Jones and Kolsky, 2005). Other health issues such as intestinal helminths infections affect 133 million people with 9400 deaths every year (WHO, 2004), while an estimated 160 million people are infected with schistosomiasis, causing tens of thousands of deaths every year, in sub-Saharan Africa (WHO, 2004).

Although grievous the situation is not without hope. Improved sanitation alone reportedly reduces diarrhoea morbidity by 32% and schistosomiasis by up to 77%, with even higher rates in combination with improved water supply and hygiene (WHO, 2004).

What is sanitation? The term 'sanitation' has been given various definitions by different authors and researchers most of which generally encompass all conditions that affect health – water, wastewater, personal and food hygiene, public health, etc. this description though right is rather broad. For the purpose of this work the term sanitation will refer specifically to wastewater management i.e. the treatment and disposal of sewage from domestic sources and is used interchangeably with 'wastewater management' unless indicated otherwise.

1.1 Urban Sanitation

Sanitation as we know it in the developed world today has its origins in the public health disasters of the 1800s when people died of diseases caused by exposure to faecal contamination e.g. the cholera epidemics that swept across Europe. The first major epidemic in Europe reportedly killed over a million people between 1830 and 1832 (Wyn-Jones, 2000). In some cities, public streets were awash with (excrement) as many homes discharged their waste into overflowing cesspits and in some cases onto streets. When in 1854 John Snow's connection between the cholera deaths in London and sewage-polluted water sources, was established (Cooper, 2001), the focus of the intervention measures then was to transport the waste material away from people and dwellings, which in essence gave birth to modern sewers. However the sewage collected was simply dumped into water bodies, the idea was that the sewage would be diluted and dissipated. However, problems arose when the rivers also became polluted due to very high sewage loads. This occurrence and attempts at water pollution control eventually led to the development of treatment systems for sewage which has consequently grown into the conventional sanitation approach as we know it today.

"There are hundreds, I may say thousands, of houses in this metropolis which have no drainage whatever, and the greater part of them have stinking, overflowing cesspools, and there are also hundreds of streets, courts and alleys that have no sewers; and how the drainage and filth are cleaned away and how the miserable inhabitants live in such places it is hard to tell... I have visited very many places where filth was lying scattered about the rooms, vaults, cellars, areas, and yards, so thick and so deep that it was hardly possible to move for it. I have also seen in such places human beings living and sleeping in sunk rooms with filth from overflowing cesspools exuding through and running down the walls and over the floors... the effects of the effluvia, stench and poisonous gases constantly evolving from these foul accumulations were apparent in the haggard, wan and swarthy countenances and enfeebled limbs of the poor creatures whom I found residing over and amongst these dens of pollution and wretchedness…Morality, and the whole economy of domestic existence is outraged and deranged by so much suffering and misery." (Phillips, 1847)

This quote depicting living conditions in the city of London in the not too distant past could easily fit the situation in many of the world's developing countries today. Life especially for the urban poor can be very hard. It is common knowledge that the rate at which urbanisation is occurring throughout the developing world is not commensurate with that at which housing, infrastructure and services - all basic necessities, are being provided. Rapid urban population growth and the inability and in some cases unwillingness of developing country governments to provide improved housing and basic services has hitherto intensified the development of slums (peri-urban /squatter settlements) in and around many urban centres. These settlements are known to be among the worst of polluted places in the world (Hardoy et al., 2001) as a result of inadequate sanitation services stemming from factors such as inadequate financial resources, insufficient water, lack of space, difficult soil conditions, and limited institutional capabilities (Esrey et al. 1998) and the situation is expected to worsen as population increases.

However these problems are not limited to squatter settlements; indeed when one considers the scale of problems that exist in planned 'legal' settlements one can only wonder at what the "illegal" slum settlers who often live outside government recognition, on land no one else wants, and in amazingly appalling conditions, must face on a daily basis, as they struggle to take their place on this earth we all call home.

The situation in most developing countries as regards sanitation has been in the best case scenario to adopt the same approach as obtains in the developed world – conventional sewerage sanitation with the hope of replicating similar benefits. The problem with this approach is that many developing countries simply end up importing technologies for which they lack the required finances, technical expertise or institutional capabilities to operate and sustain. The implications of such decisions are negative for both human and environmental health. Examples abound of situations where such systems have been implemented and have failed. In other cases the 'do nothing' or 'drop and store' approaches are common. In addition to examining sanitation conditions in the peri urban areas, this study will relate the experience of the new capital city of Nigeria, Abuja with the conventional sanitation approach.

1.2 The Role of Sanitation in Sustainable Development

In recognition of the importance of sanitation to the objectives of sustainable development which the Brundtland Commission in its 1987 report defined as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs", the MDG goals on sustainable developments has as one of its targets (goal 7) 'to **reduce** by **half** the proportion of people without **sustainable** access to safe drinking **water** and **sanitation** by **2015'**, a laudable ambition no doubt. However, according to the mid-term assessment of progress on reaching the MDGs – 'Meeting the Millennium Development Goals (MDG) drinking water and sanitation target', more than 2.6 billion people - over 40 per cent of the world's population - do not have access to basic sanitation and more than one billion people still use unsafe sources of drinking water (WHO, UNICEF, 2004).

The majority of these people reportedly live in the developing world particularly in sub-Saharan Africa, in countries with annual per capita incomes as low as 107 USD (IMF, 2006), where many live on less than one dollar a day, in places rife with poverty, disease.

According to the same report, which details the progress of countries, regions, and the world between 1990 and 2002, sub-Saharan Africa "has the lowest percentage of people with access to basic sanitation facilities – 36%, an increase of just four percent since 1990". Worldwide only 49% are reported to have access to adequate sanitation facilities in developing countries in comparison with 98% for the developed countries.

The report further asserts that based on the current pace of advancements, global sanitation targets will be missed by about "half a billion people - most of them in Africa and Asia - allowing waste and disease to spread, killing millions of children and leaving millions more on the brink of survival" (WHO,UNICEF, 2004). The situation is obviously dire and discouraging.

Even if the conventional sanitation approach worked in developing countries, the challenge of meeting the sanitation target of the MDG goal 7 requires providing adequate sanitation access to an estimated 95,000 people per day worldwide (Rockström et al., 2005), this of course requires huge amounts of investment if conventional sanitation is considered. Simply put, for most developing countries installing conventional sanitation means debt, more debt than they already have and certainly more than they can afford. It means paying great prices for systems that are almost bound to fail or that at best will not be sustainable in the long term due to costs among a variety of factors further discussed in Chapter 2. The implication of this is that eventually more people will lack access to sanitation with even greater negative impact on human and environmental health as populations grow and untreated wastewater is discharged into the environment.

For the rural and urban poor who often lack services and have to rely on water sources (rivers and streams) that serve as sinks for wastewater, the consequences are potentially disastrous – ill health, inhibited productivity or inability to work and consequent poverty. There is a cycle in motion in the lives of the urban poor. They are poor so they live in unhealthy conditions (slums and squatter settlements) and get sick and being sick means they cannot work to earn enough to improve their living conditions or move to better places as such they remain poor and in these environments all their lives and many never break out of the grip of poverty. To people in this situation sustainable development remains an incomprehensible and unrealistic concept.

1.3 Goal Seven and the Urban Poor

Lack of access to adequate sanitation is a huge problem, with a potential for causing extensive damage to health, environmental, economic and social aspects of life, particularly in urban areas as many cities in the developing world are over-populated resulting mostly from extensive rural–urban migration and unbridled population growth.

The UN-Habitat's report *The Challenge of Slums: Global Report on Human Settlements 2003,* estimates about 900 million people – approximately one in three of the world's urban population – live in slums. The situation appears to be most grave in sub-Saharan Africa where the proportion of urban slum dwellers is highest at 71.9% (UN-Habitat, 2003).

To say that the living conditions for the urban poor are unhealthy is not only stating the obvious but also a gross understatement. In most of these places, the lack of means to dispose of human waste, household sullage and solid waste (Sinnamtaby, 1990), means there is often a presence of pathogenic microorganisms (especially from excreta) in the living environment. This coupled with a lack of basic services such as access to good quality drinking water, basic health care, malnutrition and a lack of knowledge of basic disease prevention strategies, means many of the diseases that result in a high death rate are endemic in these areas.

The health problems prevalent in most developing countries according to the WHO, are infectious and parasitic diseases, which according to the World Health report of 1998 represented the highest cause of death in developing countries, 43% of all deaths in 1997 alone (WHO, 1992, 1998). UNICEF (2004) child mortality figures indicate, *Infant Mortality* rates of 101 babies per 1000 live births in Nigeria compared to 4 in Germany, while *Under Five Mortality* is an estimated 197 deaths in Nigeria and 5 in Germany. Other sources on child mortality also indicate that poverty plays a role in the observed mortality figures – a twenty-fold difference between rich and poor (DFID, 2005).

Following the epidemics in Europe, links between living conditions, infrastructure, services and disease were made by experts of the time. Edwin Chadwick, strongly advocating improving the lot of the urban poor in the city of London, called for strong executive bodies to solve the problems of sanitation in his report to the United Kingdom parliament on the dastardly living conditions of the urban poor at that time. In the report, he recommended intervention strategies to improve the health of the urban poor such as water supply and sewage collection systems (Chadwick, 1842 *at http://www.victorianweb.org/history/chadwick2.html*). Even today, the provision of infrastructure, basic services, sanitation systems, which meet the requirements of users technically, socio-culturally and economically alongside the promotion of good hygiene practices, is proving to be one of the most effective ways to improve health by preventing or limiting communicable diseases (Sarmento, 2001).

1.4 Conventional Sanitation vs. Sustainable Sanitation

One of the ways the sanitation problem has been addressed in developed countries is through the use of conventional sewerage; one of the main impacts of this on the environment is the over exploitation of natural resources. The operation of these systems is simply too resource intensive for them to be the sustainable choice for all. The abuse resulting from improper operation and use will ultimately lead to irreversible degradation of natural resources such as soil and water. There are some who believe future wars will be fought over natural resources such as water as the world supply of water becomes limited due to overuse and degradation of quality (Segerfeldt, 2005).

The fact is that the shortcomings of the conventional approach are coming to the fore even in the developed countries, and experts are beginning to acknowledge that the approach of using huge amounts of water of drinking quality to transport small fractions of waste to a treatment facility only to expend huge amounts of energy and effort in an attempt to separate the waste mixed into the water in the first place may not be the best at all; further, treatment is not always guaranteed. In many cases where conventional sewer systems are available, there are no treatment facilities and wastewater is discharged untreated into water bodies, a situation that many researchers agree is prevalent in most developing countries; 95% of the total amount of sewage in developing countries is discharged untreated (WRI, 1998). The same scenario is found even in some European cities, according to a 2001 press release from the EU Commission on Environment, 37 European cities still discharged wastewater untreated into the environment; the statement further asserts that many other cities discharged only partially treated effluents *(http://ec.europa.eu/environment/nsf/city_sevage.htm)*. The implication of this practice is of course the pollution of water bodies with consequent degradation of water quality.

With the advancement of science and technology, research gives evidence of some potentially severe consequences arising from conventional sanitation. An example is the release of recalcitrant substances among which are those that acts as endocrine disruptors into water bodies, which as shown by some studies is causing feminisation of some aquatic species, (Blaise et al, 2003 and Cone 1998).

The question is with knowledge of all these, should developing countries follow the same path knowing they might face the same issues in future without the capabilities developed countries have at their disposal? Indeed sanitation bears rethinking in both developed and developing countries, with issues of costs, resource availability/ consumption and potential for environmental degradation, conventional sanitation is not a one stop solution to the world's needs.

Sustainable technologies must be the focus for developing countries in the bid to provide access to sanitation. It is understood that prestige, convenience and affordability are among the most significant factors in people's choice of sanitation systems, there are non conventional technologies already available that will meet the conditions of the most discerning of users. However, there is not enough information disseminated about such technologies and this must be rectified. Adopting locally sustainable sanitation technologies requires the dissemination of information to local decision-makers as well as developing the technical capacities required for installation, operation and maintenance of such technologies in local conditions.

Many authors have given various definitions to sustainable sanitation. In general however, sustainable sanitation may be described as that which is most appropriate to the purpose and local conditions (institutional, socio-cultural, economic, and technical) of its intended users. Factors such as low costs, low maintenance requirements, local availability of installation, operation and maintenance materials, resources and skills as well as adequate institutional capabilities and social acceptance among others determine the appropriateness hence sustainability of a technology.

Non conventional sanitation alternatives (low cost, low tech) exist that are likely to be more suited to the situations in most developing countries. Examples of these include 'ecological sanitation' (EcoSan) systems and those that could be termed 'low cost conventional' systems (discussed in Chapter 2).

Ecological sanitation may be described as a closed-loop system, which views human waste as a resource rather than a waste and recognizes that it is essential to sanitize human excreta before its reuse. 'Low cost conventional' sanitation systems have also been applied in many developing countries. Proponents of low-cost conventional sanitation have put forward their case on the benefits of installing such systems in terms of health improvements, low cost (construction, operation, maintenance, and water consumption) and their applicability especially in urban areas even in high-density conditions.

1.5 Meeting the Sanitation Target

Projections and statistics regarding the MDG sanitation targets imply that with the status quo these targets will not be met unless some very radical measures are taken. Currently global efforts are neither meeting the needs of the present population, as only 36% of the population in sub-Saharan Africa are currently served with sanitation services, and the needs of future generations is unlikely to be met if the present trends continue (UNICEF/WHO, 2004).

The challenge presented by lack of access to sanitation is not new, but it is huge and growing. Its impact on the dignity and quality of life especially of the urban poor can be debilitating – a gripping cycle of disease, poor health and poverty from which escape seems almost impossible.

The combination of poverty and poor health is a problem not only for the affected individuals but also for whole countries. No country is able to achieve significant growth and development with a huge proportion of its productive workforce enervated by disease. The direct costs associated with disease both to individuals, who when poor are unlikely to be able to afford appropriate or effective treatments, and to governments who may lack the resources to deal adequately with the large-scale public health problems resulting from or exacerbated by water and sanitation related issues. As the UN Secretary-General, Kofi Annan, correctly observed "we shall not finally defeat AIDS, tuberculosis, malaria, or any other infectious diseases until we have also won the battle for safe drinking water, sanitation and basic health care" (WHO, 2004).

1.6 The case of Abuja, Nigeria

Abuja the new capital city of Nigeria has a huge and growing population due to massive and continuous rural–urban migration of people coming into the city in search of a 'better' life. These people are not catered for in the original plan and due to the city's exorbitant living costs, are forced to live outside the "mainstream" community in unplanned and illegal peri-urban settlements. The result is that slums are fast developing around the once pristine city, which is now a source of concern for the authorities.

After trying the usual strong arm tactics of dealing with squatter settlements the local authorities have begun to acknowledge that the situation needs to be handled in a better, more constructive way, which will present beneficial possibilities to both the populace and the authorities. This has led to discussions about possible intervention strategies to create opportunities for the development of areas outside the main city, thereby encouraging a spread rather than the current concentration of development in and around the main city; plans are focused on resettlement rather than legalising existing illegal settlements through introducing various land /home ownership schemes and providing basic infrastructure and services to the people in these areas.

Conventional sanitation is not a sustainable option for most communities in the developing world for various reasons (discussed in Chapter 2); the Abuja case is no exception especially considering the costs of expanding the existing infrastructure to include those without access as in this situation.

Considering the dangers of lack of access to sanitation facilities, improper wastewater management practices, and the drawbacks of conventional sanitation, it is imperative that locally appropriate strategies (technology and management) be adopted for the case of Abuja and not simply a replication of unsustainable solutions from the developed world.
To reiterate an earlier point, the MDG 7 points to sanitation as a key element in sustainable development. In the context of sanitation, sustainable development would mean, access to sanitation for all that does not withdraw more fresh water resources than necessary if at all, and which does not pollute soil, surface or groundwater, and also allows for the essential nutrients in human waste to be recycled back into the environment in a way that will not adversely affect human health.

Abuja is currently served by various conventional systems, the main ones being: centralised sewage transport and offsite treatment, or onsite collection and storage, all of which have local human and environmental implications. In this research work, wastewater management practices in Abuja and its peri urban settlements will be examined; non conventional alternatives - 'ecological sanitation' (EcoSan) systems and 'low cost conventional' systems will also be examined for their suitability and feasibility in the local context. A field study carried out in Abuja is incorporated into this study, with the findings (current local issues, impacts, user preferences, etc.) inputted into the selection of potentially feasible sanitation technologies and from these, sanitation scenarios were developed; costs for each scenario are estimated to determine its economic feasibility.

1.7 Outline of the Report

Details of the work done during this research study are presented in this thesis as follows: **Chapter 1**, the current chapter, presents an introduction to the subject of the research. An overview of sanitation its role in development, its problems and impacts are briefly discussed. **Chapter 2** presents a review of the research issues discussing sanitation and related issues (importance, approaches, impacts, technologies); background information about the study area and an overview of the water and sanitation sector in Nigeria are presented; the problem of squatter settlements in the study area is also discussed. **Chapter 3** discusses the significance of the study, its purpose, objectives and limitations. In **Chapter 4**, the methods applied in the fieldwork and other parts of the research study are described. **Chapter 5** presents and discusses the results of the research focussing on the findings of the fieldwork. The proposed sanitation scenarios and associated costs are presented in **Chapter 6.** The conclusions of the study and recommendations are discussed in **Chapter 7**.

Chapter 2: Review of Research Issues

This chapter presents a review of the research issues, discussing sanitation – its importance, approaches in sanitation, and impacts of lack of sanitation; it gives a brief overview of sanitation technologies as well as other related issues. Background details of Nigeria and in particular the study area are also presented.

2.1 The Importance of Sanitation

Access to sanitation is an important indicator of development as denoted by its inclusion in the MDGs for sustainable development. At the local or community levels, sanitation or a lack of it has direct and concrete impact on people and the environment in which they live. Appropriate and safe management (collection, treatment and disposal) of wastewater (excreta and sullage) is essential for the protection of human and environmental health, and also offers important social benefits to communities (Scott et al., 2003). Some of these benefits include:

Human health: the impact of lack of sanitation is seen primarily in the area of health. Links between sanitation and health have long been established; a host of debilitating and deadly diseases are associated with lack of sanitation and may be reduced or prevented with sanitation interventions; health benefits of sanitation can be seen in the reduction of diseases in communities where sanitation facilities are present. WHO figures assert that while improved water supply reduces diarrhoea morbidity by between 6% and 25%, improved sanitation reduces diarrhoea morbidity by 32% with the reduction levels rising up to 45% when hygiene interventions are provided (WHO 2004). Myint and Aye (1988) in a study of nine villages in Myanmar, report a 60% reduction in diarrhoea attributed to the provision and use of latrines. As Dr Jong-wook Lee, aptly puts it, "*Water and Sanitation is one of the primary drivers of public health. I often refer to it as "Health 101", which means that once we can secure access to clean water and to adequate sanitation facilities for all people, irrespective of the difference in their living conditions, a huge battle against all kinds of diseases will be won*" (WHO, 2004).

Environmental health: as noted in chapter one, the Cholera epidemics in Europe led to links being made between living conditions and disease prompting the development of intervention measures first to transport the waste away from the living environment and subsequently to treat the wastewater before disposal. According to the WHO Expert Committee on Environmental Sanitation in 1954, the provision of sanitation is among the first basic steps that should be taken towards ensuring a safe environment (WHO, 1954). The release of untreated excreta into the environment is a significant factor in the pollution and degradation of both water and soil quality. The effects of this can be seen in developing countries as most of the generated raw wastewater is discharged into surface water bodies; an example is Lagos, Nigeria where many of the water bodies have either become acrid due to organic pollutant overload, or as reported by Iwugo et al. (2003) polluted by pathogenic organisms and heavy metals from industrial discharges.

The discharge of raw wastewater allows the build up of polluting materials in the receiving bodies with the capacity for assimilation eventually becoming exceeded. This in turn may result in potentially irreversible environmental problems as is usually the case for groundwater pollution.

Poverty and economy: the link between poor health and poverty is obvious and logical as only healthy people are strong enough to work and earn a living to take care of their needs and those of their families. Prüss et al. (2002), estimated the disease burden from water, sanitation, and hygiene to be 4.0% of all deaths and 5.7% of the total disease burden (in DALYs) occurring worldwide, taking into account diarrhoeal diseases, schistosomiasis, trachoma, ascariasis, trichuriasis, and hookworm disease. From these estimates it is clear that sanitation related diseases exert a significant toll on the lives of people globally, it thus stands to reason that sanitation and related interventions will lead to an improvement in health, consequently productivity and ultimately poverty reduction. In addition to these positive effects of improved sanitation on individual livelihood, there are indirect potential (communal and national) economic benefits as well.

Convenience, privacy and safety: sanitation practitioners have been surprised to find that these factors are of tremendous importance even more than health to people in some communities. Safety is a vital issue particularly in communities that lack sanitation facilities where women and girls have to defecate in the open. Most often this is done before dawn or after dusk when they are most likely to be exposed to physical dangers such as rape, assault, animal attack, etc. In many places the whole issue of relieving oneself is a very private matter for a variety of reasons, even among men. Pickford (1995), citing Mwayanugba (1991) relates the example of men in Zambia who relieve themselves on the lake over the edge of a canoe but make a point of catching a fish to conceal their reason for going out on the lake. Women in some cultures are particularly opposed to being seen during times of menstruation or when dealing with postnatal discharges. Convenience is potentially an issue for all toilet users – men, women, old and young children. Young children are often afraid to go out alone at night to relieve themselves, the elderly and sick (men and women) might simply be too weak. Availability of sanitation facilities providing privacy and dignity has been cited by many authors and researchers as a factor in school attendance by girls as they reach puberty.

Justice and Equity: equity and justice are fundamental principles underlining a sustainable society and development. The 2002 report of the United Nations Economic and Social Council on Economic, Cultural and Social Rights states that "the right to drinking water and sanitation is an integral part of officially recognized human rights and may be considered as a basic requirement for the implementation of several other human rights". It basically recognises the right to water and sanitation as a human right, which when lacking negatively affects life, and as such is a vital component of the right to life, health, housing and education among other rights. Simply put, sanitation is important because it is not a luxury but a basic need and even a right (Guisse, 2002). The points highlighted above give an overview of the importance of sanitation to public and environmental wellbeing; the following section examines the link between sanitation and disease.

2.1.1 Sanitation and Diseases

To reiterate an earlier assertion, one of the primary purposes of sanitation provision is the protection of human and environmental health. The links between sanitation and health have been established, and sanitation is widely accepted as one of the most effective barriers against the transmission and spread of disease. A host of diseases (of bacterial, viral, and helminth origins) are excreta related and are transmitted through diverse routes from an infected person to others. Knowledge of these diseases is essential to the design of sanitation systems targeted at interrupting their transmission as well as protection of human health by aiding and ensuring their destruction, classifying these diseases is a means of understanding them. Excreta related diseases may be classified based on their environmental transmission routes (Feachem et al., 1983; Mara, 1996), they may also be classified according to causative agents and consequent effects on infected persons. The environmental classification system is presented in table 2.1

Table 2. 1: Environmental classification of excreta-related diseases (Mara, 2003)

Category	Environmental Transmission Features	Major Examples of Infection	Environmental Transmission Focus
I. *Non-bacterial faeco-oral diseases*	Non-latent Low to medium persistence Unable to multiply High infectivity No intermediate host	*Viral*: Hepatitis A and E; Rotavirus diarrhoea; Norovirus diarrhoea. *Protozoan*: Amoebiasis Crystosporidiasis, Giardiasis. *Helminthic*: Enterobiasis, Hymenolepiasis	Personal, Domestic Wastewater
II. *Bacterial faeco-oral diseases*	Non-latent Medium to high persistence Able to multiply Medium to low infectivity No intermediate host	Campylobacteriosis, Cholera, Pathogenic Escherichia coli infection, Salmonellosis Shigellosis Typhoid Yersiniosis	Personal, Domestic Wastewater, Crops
III. *Geo-helminthiases*	Latent Very persistent Unable to multiply No intermediate host Very high infectivity	Ascariasis, Hookworm infection, Strongyloidiasis, Trichuriasis	Peri-domestic wastewater, Crops
IV. *Taeniases*	Latent Persistent Able to multiply Very high infectivity Cow or pig intermediate host	Taeniases	Peri-domestic Wastewater Fodder Crops
V. *Water-based helminthiases*	Latent Persistent Able to multiply High infectivity Intermediate aquatic host(s)	Schistosomiasis, Clonorchiasis, Fasciolopsiasis,	Wastewater Fish, aquatic species or aquatic vegetables
VI. *Excreta-related insect vector disease*		Bancroftian filariasis transmitted by Culex quinquefasciatus	Wastewater
VII. *Excreta-related rodent – vector disease*		Leptosporosis	Wastewater

Of all possible transmission routes those of greatest importance for the spread of excreta-related diseases according to many researchers are those transmitted via the oral routes as illustrated in figure 2.1.

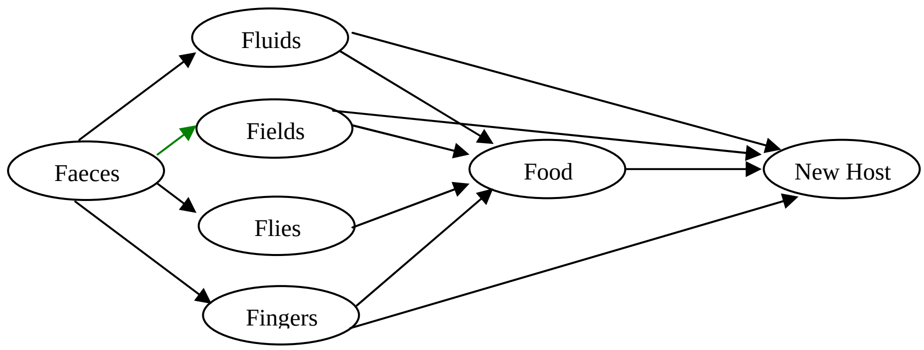


Figure 2. 1:Faeco-oral transmission routes (Wagner and Lanoix, 1958)

The F-Diagram from Wagner and Lanoix depicting the routes of transmission alludes to the importance of sanitation in breaking the pathway of infection by acting as a barrier against the spread of pathogens in excreta primarily through the containment and isolation of the material from humans and the environment. Further benefits are derived when containment is coupled with good hygiene practices such as hand washing with soap after defecation (Mara, 1996).

Based on the F-diagram, a lack of sanitation facilities then implies that all the pathogens in excreta that would have otherwise been contained are released into the environment with attendant risks of human exposure and environmental pollution. Disease transmission is determined by several pathogen-related factors in addition to host characteristics e.g. susceptibility, which according to Carr (2001) includes:

- The organism's ability to survive or multiply in the environment (some pathogens require the presence of specific intermediate hosts to complete their lifecycles).
- Latent periods (many pathogens are immediately infectious; others may require a period of time before they become infective).
- An organism's ability to infect the host (some pathogens can cause infections when present in small numbers e.g. Ascaris, others may require a million or more organisms to cause infection, Feachem et al., 1983).

These factors imply that sanitation provision efforts geared towards preventing excreta related diseases must take into account factors affecting disease transmission.

2.2 Approaches in Sanitation

Sanitation or wastewater management is a concept that is as old as man himself and one that is still crucial to man's wellbeing today.

> *"Designate a place outside the camp where you can go to relieve yourself. As part of your equipment have something to dig with, and when you relieve yourself, dig a hole and cover up your excrement For the LORD your God moves about in your camp … your camp must be holy,…", Deut 23:12-14.*

People through the ages have had to find solutions for managing the products of their bodily functions. Specific instructions addressing this issue can be found in the Bible, given to ensure the protection of the health of the Israelites as they travelled in great numbers for many years; it was considered serious enough to be included among instructions on issues extremely vital to their existence, clearly defecation is serious business.

Sanitation was practiced long before the modern day links between poor living conditions and diseases were understood. The ancient civilisations knew the importance of removing human excreta from their immediate environment. Historians tell of the Minoan civilisation (Corrigan, 1935) with its underground systems that transport wastewater away from dwellings dating back as far as 1700 B.C., buildings and palaces featuring sinks, lavatories, flushing water closet, and separate drainage systems that emptied into a sewer. Sewers were reportedly available in Rome since around 800 B.C.; some citizens also had water closets that drained into cesspools below their homes, and solid waste disposal and street cleaning service was carried out by designated administrators, who in some cases were quite proud of their sanitary achievements as a remark from Frontius an official in charge of the aqueduct indicates "*the results of the great number of reservoirs, works, fountains and water basins can be seen in the improved health of Rome. The city looks cleaner, and the causes of the unhealthy air which gave Rome a bad name amongst the people in the past are now removed. Compare such important engineering works with the idle pyramids and the useless though famous buildings of the Greeks.*" (Frontinus, "The Aqueducts of Rome" Rome A.D. 100.) *http://www.schoolhistory.co.uk/year7links/romans/sewers.pdf*

The above are but a few historical examples depicting man's efforts aimed at managing his waste which according to several authors was mainly to improve conditions in his living environments, control odour, and improve the appearance of cities rather an attempt to control disease.

However, historians recount that during the medieval period in Europe, cities grew into crowded and unsanitary places where homes were often infested with disease carrying rodents and insects, and human and animal excrement frequently contaminated drinking water; the results being the spate of deadly infectious diseases that killed many people.

Initially, "miasmas" (bad air) was blamed for the various outbreaks of diseases until a link was established between sanitary conditions, faecal contamination and disease, of note are the works of John Snow and Edwin Chadwick in this area that ultimately led to the development of sanitation as it obtains today. Modern approaches to sanitation or wastewater management can be classified into the conventional and alternative concepts.

2.2.1 Conventional Approach to Sanitation

The conventional approach developed largely in response to threats to public health and is focused on isolation and removal of human waste from the dwellings. Conventional sanitation technologies include those that either collect and store excrement - 'drop and store' or collect and transport the material away from human dwelling - 'flush and discharge' (Esrey et al., 1998). Systems that could be termed 'conventional' in sanitation can be grouped into three, they are:

'Do Nothing' Systems: in this system there is no defined method of wastewater management and no technologies utilised, people simply do what they see fit sometimes without due regard for environmental health, but surprisingly with consideration for the protection of human health, achieved by the removal of excreta from the immediate dwelling areas. Examples of this include the open defecation practice, and the 'wrap and throw' method of excreta disposal. There is no deliberate collection or treatment of the excreta and disposal is largely unregulated; the only similitude of regulation is enforced by people's perception of right or wrong, clean or unclean, and religious or cultural beliefs. These influences in some cultures make the practice seem quite well regulated and non problematic. However, it must be noted that while this may not be an urgent problem in a rural area but in a densely populated setting, wrapping and throwing excreta is very much an unacceptable practice. With the dangers associated with exposure to excreted pathogens, these types of systems are a threat to human health.

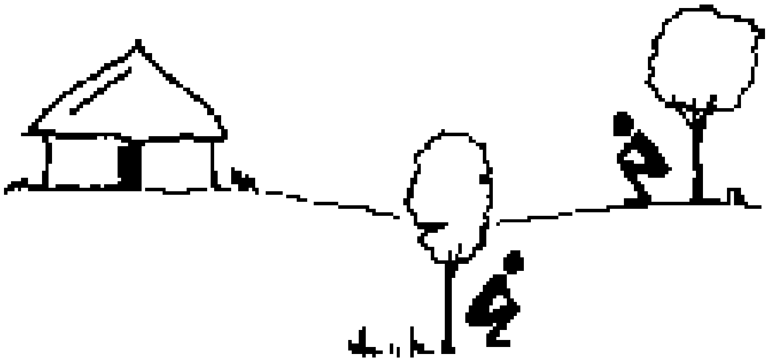


Figure 2. 2: The 'do nothing' approach – open defecation. (Franceys, 1992)

'**Drop and Store' Systems**: as the name implies, in this system the excreta is simply collected in a chamber out of sight and stored for an indefinite period. An example of this system is the pit latrine and its variants. The advantage of this system is that it is an improvement on the 'do nothing' approach in that it allows the removal and containment of pathogen laden excreta, and has successfully prevented disease in some places. However, its disadvantages are basically similar to those of the 'flush and discharge' (see next section) system in that it often does not allow for reuse of the nutrients contained in human waste, and is often accompanied by a nuisance of smells, pollution of water sources such as drinking water wells, and groundwater. There are also problems associated with installing this technology in densely populated areas as it requires the availability of adequate space. Also areas with high water table, difficult ground and soil conditions, mean that pits cannot be dug deep, in which case they will fill up too fast and have to be emptied often by hand at great risk to the workers or new ones have to be dug costing money to the home owner. Also installation may increase risk of destabilising foundations of nearby houses especially in densely populated areas.

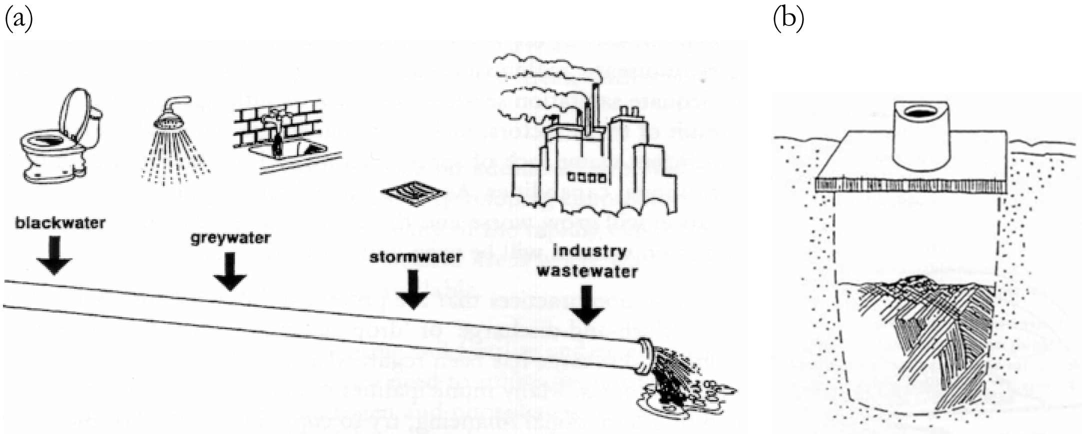


Figure 2. 3: (a) 'flush and discharge' and (b) 'drop and store' approaches (Esrey et al., 1998)

'Flush and Discharge' Systems: the flush and discharge type of conventional sanitation is very well established in the developed countries of the world. The system basically relies on the use of water to transport human excrement through underground sewers to treatment facilities where the 'pollutants' in the wastewater are removed using a combination of physical, biological and sometimes chemical processes before the treated water is discharged into the environment. This system overall has been very effective in the management of wastewater in the developed world with great success in protecting human health over the years as the public health disasters of the 1800s are no longer an issue in the developed world today. In many cases steps have also been taken to regulate discharge of harmful micro-pollutants into the environment, the success of this is however debatable as issues of the release of endocrine disruptors and pharmaceuticals into the environment even after high levels of treatment are now the focus of scientific research and discussions in these countries. Despite its obvious advantages in disrupting the spread of disease and convenience of use, the conventional 'flush and discharge' system has many disadvantages. In addition to the release of recalcitrant substances the 'flush and discharge' wastewater systems present a host of fundamental problems a few which are as follows:

- *Water consumption*: this is perhaps the most important disadvantage of this system considering the predictions of water scarcity expected to affect many countries of the world (UNEP, 2002). The system utilises a large amount of freshwater (drinking water quality), to transport a comparably minute quantity of excrement to treatment plants. According to Otterpohl (2001), approximately 25,000 – 100000 litres of wastewater is produced per person per year of which urine and faeces make up only about 500 litres and 50 litres respectively (see figure 2.4). An estimated 50 – 100 litres of water is used daily to flush away 1–1.5 litres of human excreta (Jönsson, 1997; Van der Ryn, 1995; Esrey, 2000) and this represents 50–100 litres of freshwater of drinking water quality! Considering available data on water scarcity – 48 countries expected to have chronic shortages of water by year 2025 (Hinrichsen et al., 1998), the flush system is obviously not sustainable.

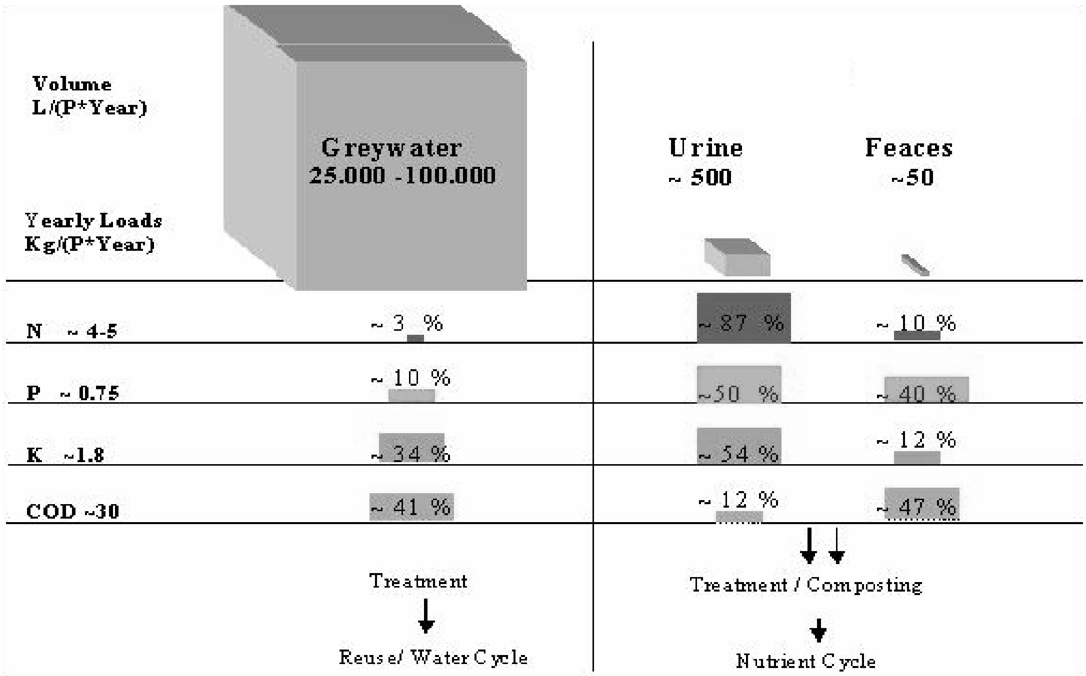


Figure 2. 4: Constituents of domestic wastewater (Otterpohl 2001)

- *Environmental degradation*: although there are regulations to ensure the treatment of wastewater, its composition at even after treatment will impact the receiving bodies in some way. When effluent quality is not properly monitored and nutrients are released into water bodies the ecological balance is disturbed and a mixing of the nutrient and water cycle occurs. Human health is put at risk when nutrients make their way into drinking water supply, a widely known example is the impact of nitrate contamination of drinking water – methemoglobinemia (blue baby syndrome). Esrey,

(2000) referring to a study by Grant et al., (1996) reports the occurrence of spontaneous abortion linked with nitrate contamination. Also of concern are pharmaceutical residues or metabolites that end up in water bodies (Raloff, 1998); Groundwater pollution is also a problem associated with this system. Experts concede that it is virtually impossible to operate a sewer system without incidences of leaks. Infiltration of groundwater into the sewer, and the much more serious problem of ex-filtration of wastewater into groundwater, are potential problems in this system, thus the "backbone" of the conventional system – the sewer, is a potential source of contamination of precious groundwater.

Though efficient, this system does not guarantee 100 % pathogen removal. This is especially a problem where the operation is such that disinfection is not carried out. As is often the case in many developing countries that have a semblance of this system, treatment sometimes does not go past the primary stage before effluent discharge. This represents a potential source of faecal–water related disease with an almost unending infection and excretion cycle.

Loss of biodiversity is another environmental problem that may result from the use of conventional wastewater management system. For example in ocean disposal of wastewater, nutrient pollution may damage fragile coral reefs. It is reported that nitrates are toxic to coral reefs and phosphates damage their skeletal growth (Hawkins and Roberts, 1994).

- *Installation, operation and maintenance cost*: the conventional 'flush and discharge' system is very expensive. The cost of constructing the sewer network may account for up to 80% of the total investment into the wastewater treatment system. Operation and maintaining the system also represents additional costs for example energy costs.

- *Dilution:* the indiscriminate mixing of wastewater streams, (yellow, brown, grey) results in very large, highly diluted amounts of wastewater to be processed, which in turn requires large-areas, expensive treatment plants, complex processes and high-energy input to achieve desired levels of treatment.

- *Nutrient loss:* valuable plant nutrients that could be recycled into food production are flushed away only to be removed again from the wastewater at high cost. This is a factor that greatly impacts food security in a world where malnutrition and famines are rife. Artificial fertilizers are currently considered answers to the problem of food production and poor or deteriorating soil quality but at great costs to the environment – depletion of non-renewable resources that accompany their production. Considering that excreta (see figure 2.4) not only contains similar nutrients as some of these chemical fertilisers but also organic matter a significant advantage over chemical fertilisers, recycling the nutrient content of human excreta would go a long way to alleviate the problems of food production and world hunger.

However, the conventional system severely limits the recovery and return of valuable nutrients back into the nutrient cycle where it is greatly needed.

- *Generation of problematic products:* sewage sludge, one of the end products of this system contains most of the unwanted substances e.g. heavy metals in the wastewater; its agricultural application is thus problematic in spite of the available nutrients it contains. It is therefore another waste to dispose of appropriately often at significant cost.

  Ability to accommodate growing demand: global population is rising. According to the United Nations Population Division, world population may reach 9 billion by the year 2050 (UN, 2004), with the growth occurring mostly in poor developing countries. As mentioned earlier the infrastructure required to provide and maintain conventional sanitation systems is expensive even in developed countries, how will sanitation be provided for all these people and who will pay for it? Even where infrastructure exists maintenance is a problem in many developing countries. It will simply be infeasible economically and technically to keep pace with the expansion of their sewer systems to accommodate the needs of their growing population.

The disadvantages of the 'do nothing' and 'drop and store' systems are primarily environmental degradation through soil and water (surface and ground) pollution and even more important the exposure of human and animals to the pathogenic organism in human excrement and the consequent spread of disease.

Summarily, although the conventional waterborne system as widely used in the industrialised world has apparently been effective, for developing countries who make up the highest proportion of world population and those most affected by the problems associated with lack of sanitation facilities, the disadvantages especially in terms of cost, operation, maintenance and environmental impact, it does not in the long term appear to be a sustainable solution for all.

2.2.2 Sanitation in Developing Countries

The 'do nothing' and 'drop and store' systems are the most common conventional sanitation systems available in the developing world. As can be imagined neither has been able to provide adequate human and environmental health protection as various vectors still have access to excrement, and faecal related diseases still rife with millions of people dying of diarrhoeal diseases yearly (WHO, 2004).

In places with waterborne system ('flush and discharge'), treatment plants often either do not exist or do not function very well; raw wastewater is simply discharged untreated or at best only partially treated into receiving bodies. According to the World Resources Institute, over 95% of sewage in developing countries is discharged without any treatment into receiving bodies of water in the environment (WRI 1998). Indeed sanitation practices in developing countries leave much to be desired. Without a doubt, none of the conventional systems discussed in previous sections is an appropriate solution to the sanitation needs in developing countries. They use too much valuable water and energy, and in most cases generate more waste than the environment can safely assimilate unassisted. Further, only the dry conventional systems are fairly affordable in most developing countries as the financial capability to install, operate and maintain the waterborne systems or the technical capabilities required for operation are not locally available. Thus, problems of pollution, failure of plants among others are associated with the use of these systems in developing countries. As such where they exist, they are most often limited to upscale sections (wealthy upper, middle class areas) of urban centres and treatment is incomplete at best.

In spite of the obvious problems, advantages exist in developing countries in that in many places investments have not been made in sewer systems, as such there are opportunities for implementing efficient, cheaper, non-sewer systems, which can fulfil the requirements of good sanitation systems. Thus alternative approaches that benefit rather than damage the environment must be the focus of attempts at solving the sanitation problems in these countries.

2.2.3 Alternative Approaches to Sanitation

Sanitation in most developing countries leaves much to be desired. According to WHO figures, sanitation coverage is only 49% for developing countries - 2.6 billion according to 2002 estimates lack access to sanitation facilities (WHO, 2004). Where sanitation systems exist, they are often mainly conventional systems such as those described previously. As already discussed, the conventional approach to sanitation with its linear wastewater management systems is not sustainable in terms of resource consumption, environmental pollution and above all cost. It is clear that in view of the drawbacks associated with the use of these systems new, better solutions are needed. These new solutions must offer human and environmental health protection, conservation of resources especially water, be affordable and acceptable to potential users. Alternative sanitation systems such as ecological sanitation and 'low cost' conventional systems that offer these qualities and more, discussed in the next section, have been developed and implemented in many parts of the world in both developed and developing countries.

2.2.4 Ecological Sanitation

Ecological Sanitation (EcoSan) is a new sanitation concept based on an ecosystem approach. While conventional systems function on the premise that excreta are waste, EcoSan is a closed-loop system (see figure 2.5) that treats human excreta as a resource to be recycled as such it promotes the separation and closure of both the water and nutrient cycles as opposed to the linear flow in conventional systems. The EcoSan approach to sanitation is based on three fundamental principles: rendering human excreta safe, preventing pollution rather than attempting to control it after the fact, and using the safe products of sanitized human excreta for agricultural purposes (Esrey et al. 1998).

EcoSan is not about promoting a particular sanitation technology but rather utilising technologies that achieve its aims of:

- reducing health risks related to sanitation, contaminated water and waste.
- improving the quality of surface and groundwater.
- improving soil fertility.
- optimising the management of nutrients and water resources.

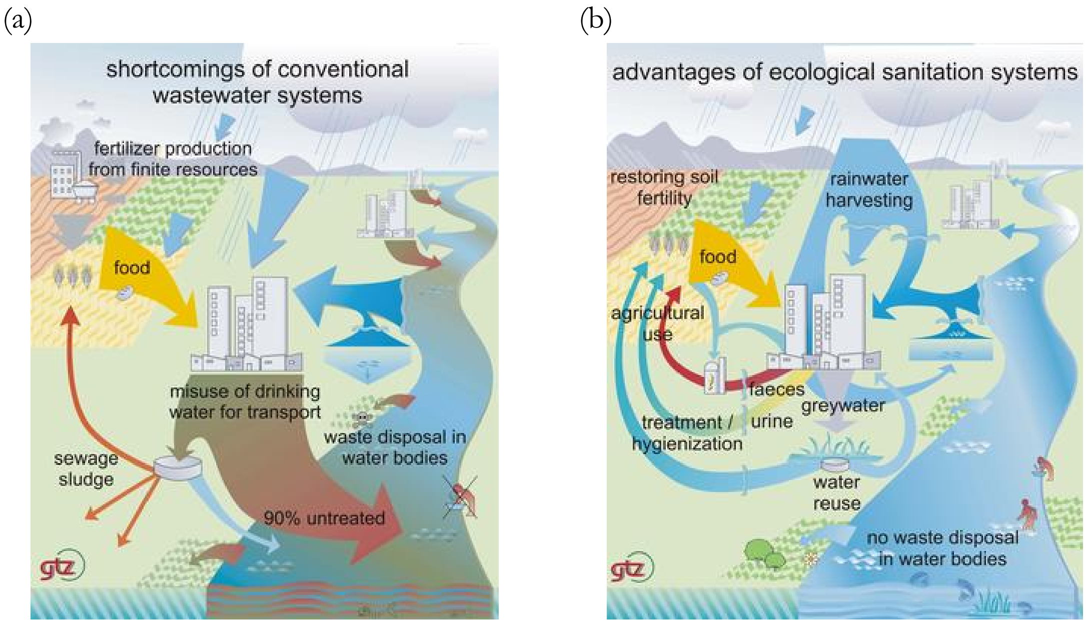


Figure 2. 5: (a) 'conventional' wastewater systems and (b) 'ecological sanitation' systems (GTZ, 2004)

2.2.4.1 Methods in ECOSAN

The primary strength of EcoSan systems is the separate collection of the different streams in wastewater and subsequent targeted treatment of the same. This is also the main difference between EcoSan and conventional systems. EcoSan recognizes that wastewater is made up of different components (figure 2.4) that have different characteristics and thus require different types and levels of treatment (figure 2.6).

Brown water

Brown water is water from the toilet, consisting of faecal matter, flush water with or without toilet paper. It is high in organic nutrients and exerts the highest amount of chemical oxygen demand. It is relatively small in quantity when collected separately an estimated 50 kg/p/year (see figure 2.4). It is however the source of most pathogens in wastewater, thus is a potentially hazardous material – one gram of faeces can contain

10,000,000 viruses; 1,000,000 bacteria; 1,000 parasite cysts; 100 parasite eggs (UNICEF, 2000); once sanitised however it yields valuable soil conditioners that can be applied in agriculture. Options for treating brown water in ecological sanitation systems include: composting and vermicomposting with or without other organic solid waste e.g. kitchen residues, dehydration and anaerobic digestion (Del Porto and Steinfeld, 1997; Gajurel, 2003).

Yellow water

Urine in ECOSAN is known as 'yellow water'. It is valuable due to its fertilising capacity. It is relatively sterile except when from a sick person (Feachem et al, 1983) or contaminated with faecal matter, and can be reused with minimal further treatment. Urine reuse is a valuable source of fertiliser, comparable in quality to commercial fertiliser but without the contaminating properties of commercial fertilisers (see figure 2.4). For maximum assurance of health protection, urine should be treated before application on crops. Simple storage for a period of time (about one to six months) in an airtight vessel, which serves to destroy pathogens that may be present in the urine, is all the treatment required to sanitise urine for reuse. The Ecosanres 'Guidelines for the Safe Use of Urine and Faeces in Ecological Sanitation Systems' recommends a storage time of one to six months for urine sanitisation at temperatures of 4 – 20°C, but states that no storage required for a single household reusing its own urine. (Ecosanres, 2005). Following this the sanitised product can then be applied directly on agricultural land or diluted if it is to be applied on plants. A mixture of brown and yellow water is known as black water.

Greywater

Greywater generally refers to wastewater from non-toilet sources such as kitchen sinks, baths/showers, laundry, or generally wastewater not containing excreta (brown or yellow water). Greywater varies from source to source; its characteristics are usually a reflection of the lifestyles, habits and customs of the people that generate it, and with great variations in volumes, constituents, chemical and microbiological characteristics.

Greywater represents a valuable source of reclaimed water for reuse especially in places with scarce freshwater resources where reclaimed water could relieve the pressure on freshwater. The reuse purpose often determines the type and level of treatment to which the greywater is subjected; generally the quality and the treatment requirements increase with increasing levels of human contact. Potential reuse possibilities for treated greywater may include: irrigation; car washing and similar outdoor uses; toilet / urinal flushing; and groundwater recharge when treated to very high degree. Various biological treatment processes for greywater are available; among these are very simple ones such as constructed wetlands (see section on sanitation technologies).

A summary of the streams, treatment and reuse possibilities in EcoSan is depicted in figure 2.6.

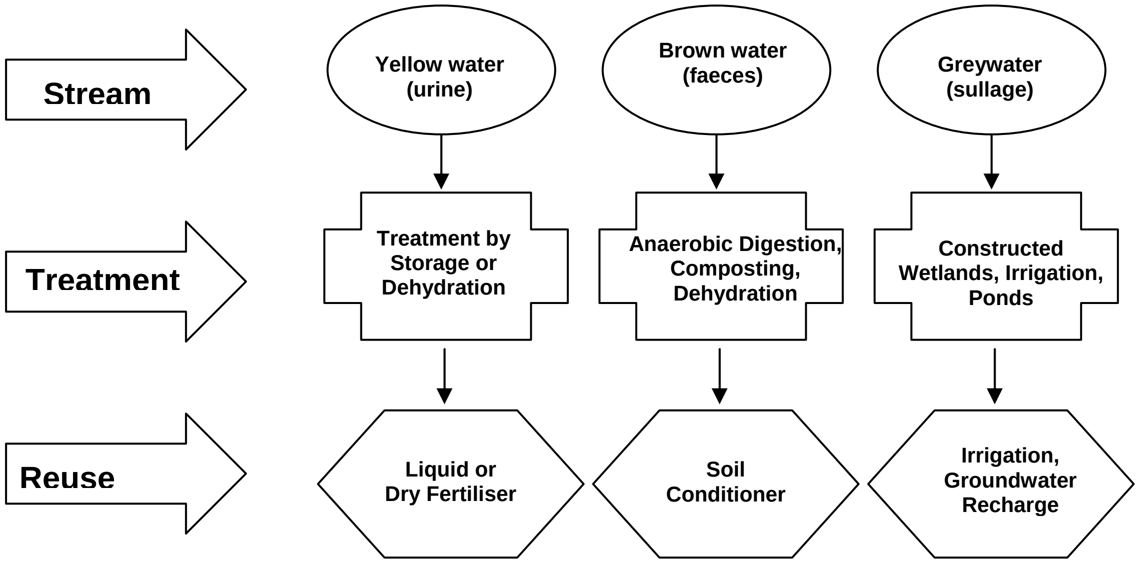


Figure 2. 6: Wastewater streams, treatment and reuse possibilities (adapted from GTZ, 2004)

2.2.4.2 Potential Benefits of EcoSan

Low cost and flexibility: EcoSan systems are mainly non centralised systems as such the need for sewers is all but eliminated, this means that the heavy investments in sewer networks can be avoided, which is a significant benefit to developing nations. There is a wide range of EcoSan technologies available in terms of operational and management complexity and cost, as such there is a potentially affordable option for everyone.

Targeted treatment: the separation of wastewater into constituent streams allows for targeted treatment of each stream thus lowering operation costs.

Pollution prevention: the separation limits dilution and the generation of large quantities of wastewater. It also allows the isolation of the brownwater stream, which is the pathogenic and problematic fraction.

Poverty alleviation: separation also allows for nutrient recovery and reuse in agriculture. This not only aids food production through the provision of access to cheap, sometimes free plant nutrient sources, it can also help in poverty alleviation through enhanced food production and job creation.

Resource management: EcoSan systems can be designed using technologies that are dry or utilise limited quantities of water thus limiting the consumption of this precious resource.

MDG target: Ecological sanitation systems for the poor enhance their dignity, quality of life and health.

Renewable energy: EcoSan technologies have the potential for the production of energy from wastewater for example biogas production during anaerobic treatment of black water.

2.2.4.3 Challenges of ecological sanitation and possible responses

Ecological Sanitation concepts are a radical departure from conventional systems. As such their implementation often requires change especially in the perception or behaviour of users and local authorities. Change is something people often do not welcome by nature even when it is for their good especially when it comes to issues of culture and behaviour. This resistance is one of the main challenges EcoSan faces today. Further, the favourable way in which conventional system especially flush technologies are viewed sometimes means dry EcoSan systems have a problem of acceptance by users who often consider non flush systems inferior alternatives. One of the principles of EcoSan is the reuse of sanitised excreta in agriculture; this is a problem for the adoption of the systems in places where there are religious or cultural taboos and attitudes restricting the use of excreta-derived fertilisers. Current legislations in many countries are still largely focused on conventional systems as such this often limits many sanitation practitioners in implementing EcoSan systems. In contrast to conventional sanitation, there is a limited experience of large scale implementation that can serve as examples of success to be replicated. EcoSan has all the potential characteristics for being a sustainable way of providing access to sanitation facilities to the over two billion people who still lack access today with other attendant benefits. However, tackling the issues identified above is a necessary step in ensuring that the promises EcoSan offers are actualised.

2.2.5 'Low cost conventional' Sanitation

These systems utilise technologies that are in many ways similar to the mainstream conventional technologies with the main difference being that they are designed in such a way that they can be installed, operated and maintained at significantly lower costs than their conventional counterparts. Examples of such technologies include the low cost sewerage systems, which are basically sewers of small diameter pipes designed to be laid at shallow depths (described in later sections), the waste stabilisation pond systems and planted filter beds.

Some of the main advantages of these systems are that they are mostly low tech systems and require limited or no energy input. They can be run by appropriately supervised operators with low skill levels. They are quite similar to some of the conventional systems as such they are usually not a problem for management bodies that already utilise conventional technologies. Low cost conventional systems utilise some technologies that users are already familiar with e.g. the WC as such they have potentially high user acceptance. Because they simply mimic natural systems having almost no mechanical input, availability of space is one of the primary requirements of these systems and about the most important limitation of many of the technologies in this group. However with good design, the systems are able to achieve the objectives of a good sanitation system and in many cases they also allow the reuse of treated wastewater, which in the author's opinion puts them at par with EcoSan systems. Selected sanitation technologies belonging to the systems already described will be presented in the following section.

2.3 Sanitation Technologies

A sanitation system is more than just the toilet fixture; it covers the toilet and the means by which the material that is deposited in the toilet is stored, transported, treated, etc. these represent the technical aspect of a sanitation system. Others include the social, institutional and even financial aspects. In this section a review of some of the available sanitation technologies is presented. They are differentiated into technologies that are receptacle units (toilet), technologies for storage/transport, treatment, disposal and reuse. This review is not intended to be an exposition an abundance of literature exists on the subject. The technologies presented here are either available in the study area or those considered as potentially applicable mostly those based on alternative concepts such as the ecological sanitation systems, selected low cost conventional systems and natural wastewater treatment systems.

2.3.1 Toilet Fixtures and Devices

Squat Holes/ Pans

A squat hole, pan or plate is a fixture of the dry pit toilet system, the pan is usually a part of or fixed to the slab placed over the latrine's pit. In the case of a squat hole it is simply a hole in the latrine slab. Squat holes are usually about 400mm long and 180–200 mm wide and may have either round, rectangular, square or key hole shapes depending on the user's preferences (Pickford, 1999 and Kalbermatten et. al, 1982); the dimensions of the hole must be such that children are not in danger of falling into the pit during use. Some squat holes are set in slabs that are movable and thus transferable from pit to pit e.g. SanPlat see figure 2.7. Squat holes may also have a footrest (www.sanplat.com). A variant of the squat hole/pan for the dry toilet system is the pedestal seat system.

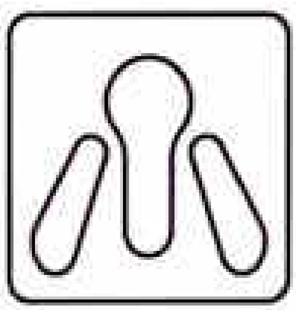


Figure 2. 7: VIP toilet (www.sanplat.com)

Pour Flush Pan

The pour flush pan shown in figure 2.8 is the toilet fixture in the wet pit toilet system suited to users who are washers. It consists of a pan with an integral water seal that provide odours and insect control. The toilet is manually flushed after use with 1-3 litres of water. The pan is connected to a pipe through which the flushed pan content is discharged into the pit. The pour flush toilet requires availability of water for proper functioning. This is a convenient low cost toilet fixture that has easily manageable operation and maintenance requirements. Its main disadvantages are its proneness to blockage by bulky material and the requirement for flush water albeit small especially where water is not easily available.

Figure 2. 9: VIP toilet (www.toiletsforall.org)

Urine Diversion pans

The urine diversion (UD) toilet (see figure 2.9) allows the separate collection of urine (diluted or undiluted) and subsequent reuse in agriculture. Urine diversion toilets are available in various forms – as squat pans and as pedestal seating toilets. They may also be used with dry (non flush) and wet (flush) sanitation systems. The unit usually has a partition in the toilet bowl that serves to isolate the urine from the faecal solids. The urine part is located in front to allow use by both men (requires men sitting while urinating) and women; the faecal solids are collected in the rear partition. In the dry UD toilet the urine is captured in the front partition connected to a simple pipe discharging into a storage canister or leach pit while the faeces is collected dry through a drop hole in the rear portion of the device. The flush UD toilet may be designed to allow for separate flushing of the urine and the faeces partition. The toilets may be made from porcelain, concrete, fibreglass or plastic. The

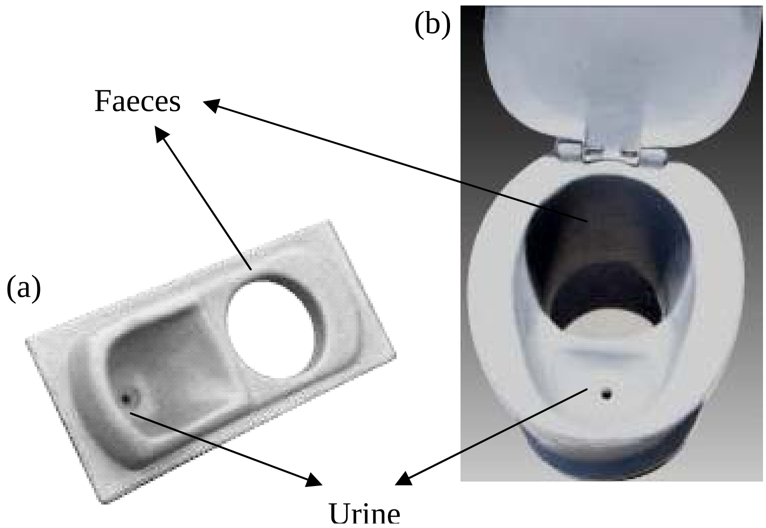


Figure 2. 12: UD squat pan (a) and pedestal (b); source: www.kentainer.com

whole purpose of a urine diversion system is to keep urine and faeces separate as such one of the main requirements of this fixture is that users are careful not to allow urine enter the faecal solids part during use. The main advantage of this fixture is that it allows the separation of excreta at source. However this fixture may require a change in user behaviour e.g. men sitting or squatting to urinate, which may be a potential problem in some cultures.

Conventional Flush Toilets (WC)

The conventional flush toilet also known as water closet (WC), disposes of excreta by washing them away with water into a connected drain pipe when the flush mechanism is activated. It consists of a pedestal unit (bowl and siphon) with a water seal and a tank that stores the water used for flushing. The tank is connected to a water supply source and has a valve that activates the refill system when the toilet is flushed in readiness for the next use. The main requirement of this fixture is water. It is convenient to use and has very high user acceptance. However, its disadvantages include the use of high quality water to flush away a relatively small amount of excreta. Recent variants developed to address water requirement of this fixture include, the low flush and vacuum toilets.

Vacuum Toilets

The vacuum toilet (see figure 2.10) is similar in appearance to the conventional flush toilet but functions differently in that it uses an active vacuum in place of a siphon. It utilises considerably low amounts of water about one litre per flush which is its main advantage compared to the WC. Activating the flush mechanism opens a valve in the sewer line, and the vacuum in the line sucks the contents out of the toilet bowl. The system requires constant electrical power supply for proper functioning. The main advantages of this system are: it uses very little water, and is efficient in cleaning the toilet bowl after use even with very little water, and it offers the same convenience as a WC. It is however expensive to install, operate and maintain. Its dependence on constant electrical power supply means it is unsuitable for developing countries where electricity supply can be erratic.

Figure 2. 13: Vacuum toilet

2.3.2 Technologies for Collection /Storage

Urine Canisters

These may be simple polyethylene canisters similar to water cans and used in the collection of urine in a dry UD toilet system. They are relatively cheap and easily available.

Pit System

The pit toilet (see figure 2.11) consists of an underground chamber – the pit, over which a cover slab with a hole known as the squat hole is placed. The pit of the pit toilet system serves as a device for storage and minimal primary treatment of excreta. The whole unit may then be enclosed by a housing (superstructure), which is built primarily to provide privacy and protection to the user and the toilet from weather. The superstructure may as in the case of the VIP latrine (see description below) or may not be vented as in the case of the simple pit latrine. A wide variety of materials is often used for the superstructure ranging from grass, palm-thatch, bamboo, corrugated iron sheets, to concrete or bricks. The storage chamber or pit is usually about 3-5 m deep and depending on design factors lined, unlined, raised or below ground (Kalbermatten et al., 1982; Brikke and Bredero 2003; Franceys, 1992). Waste is deposited in the pit as the toilet is used and is stored in there until the pit is nearly full, it may then be emptied and its contents disposed of to prepare it for use. Sometime the full pit is simply sealed off and a new pit dug. The simple pit latrine is a classic example of this type of toilet; its variants include: the borehole latrine and the ventilated improved pit latrine. The Arborloo, is similar to the pit latrine but has a shallow pit which when full is covered with soil and planted with young trees (Morgan, 2000).

The pit system requires suitable ground conditions for installation (no underground rock, high water table, etc); it is also preferably suited to locations with adequate space as such rural and low density urban areas. Pit system is an improvement on no sanitation by providing a designated place for defecation, privacy and some level of convenience. No water is needed for its operation and a unit can be shared between households. However, the system has the potential for groundwater contamination through leaching of liquids from the pit. It must be emptied often at significant cost when full usually manually presenting a risk to workers as faecal matter is often still fresh.

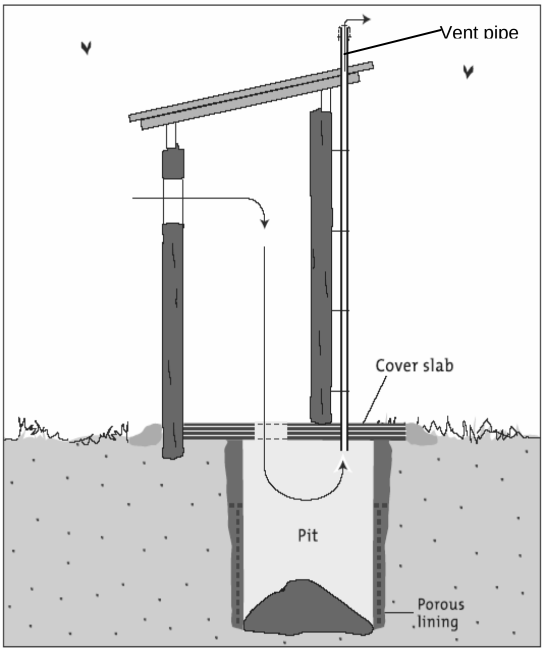


Figure 2. 15: VIP toilet, (Brikke and Bredero, 2003)

VIP Latrines: the VIP latrine is an improvement on the simple pit latrine. In addition to the features of the simple pit latrine, the VIP contains a vent pipe covered with a fly screen extending from within the underground chamber above the superstructure roof. As air flows over the top of the vent pipe, the air in the pit chamber is sucked out into the atmosphere and is replaced by fresh air flowing in through the superstructure openings into the pit.

Vaults

The vault system consists of a permanent watertight (retains both solids and liquids) receptacle used for the collection and storage of excreta. It may be designed for installation above or below ground and may be modified to function as a composting or dehydration system. It is commonly used in sanitation systems that allow for separation of waste at source and thus is applicable in systems designed to allow excreta reuse (see figure 2.12).

The vault may be made of concrete or polyethylene in which case it is movable. When it functions as a composting system, bulking material such as wood chips or bark is added to the excreta after each use. In the case of its function as a dehydration system, dry material such as ash, which enhances dehydration and sanitisation of the excreta, is added to the vault. Emptying the vault is usually done manually although this represents a health risk to the workers as such must be carefully carried out to limit associated risks. Hand operated pumps (manual pit emptying truck – MAPET, see figure 2.14) and vacuum trucks are not applicable for emptying as the vault contents are usually dry. In dry sanitation systems such as the urine diversion dry toilets, the period of storage

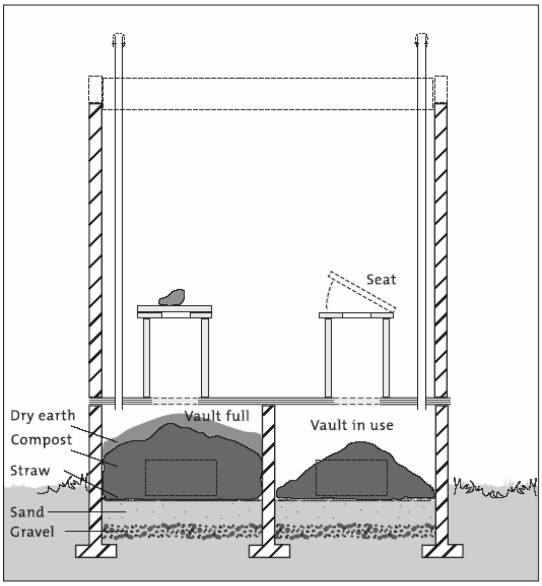


Figure 2. 18: Double vault composting toilet (Brikke and Bredero, 2003)

in the vault also serves to provide treatment such that risks associated with emptying vaults manually are significantly reduced. The water tightness of vaults and the possibility of above ground installation are advantages in pollution control. This system is flexible in its operation but requires a fairly well organized cartage system.

Septic Tanks

The system shown in figure 2.13, consists of a watertight underground tank, which receives and serves as a settling chamber for raw sewage. It acts as a solid-liquid separator and a partial solids decomposition chamber. As wastewater flows into the tank, the solids are separated from the liquid by settling and floatation. The settled solids form the sludge layer at the bottom of the tank, while the floating solids form the scum layer at the top of the tank. The layer in between the scum and sludge layer contains partially clarified water, which then flows out of the tank through the outlet positioned beneath the scum layer, to further treatment or disposal systems.

Appropriate design and construction is essential for the proper functioning of a septic tank. Some of the most important design considerations are the volume of wastewater received by the tank, temperature, maintenance requirements and frequency, number of compartments (may be single or multi-compartment), tank geometry and retention time. Retention time directly affects the performance of a septic tank as short retention times do not allow proper settling of solids resulting in re-suspension of solids in the tank and the discharge of such solids into the disposal fields, which may in turn cause clogging and outlet pipe blockage. Baffled or multi-compartment tanks generally perform better than single-compartment tanks of the same total capacity, as they provide better protection against solids carryover into discharge pipes during periods of surges or upsets due to rapid sludge digestion (USACE, 1999). They may be constructed out of concrete or prefabricated plastic material.

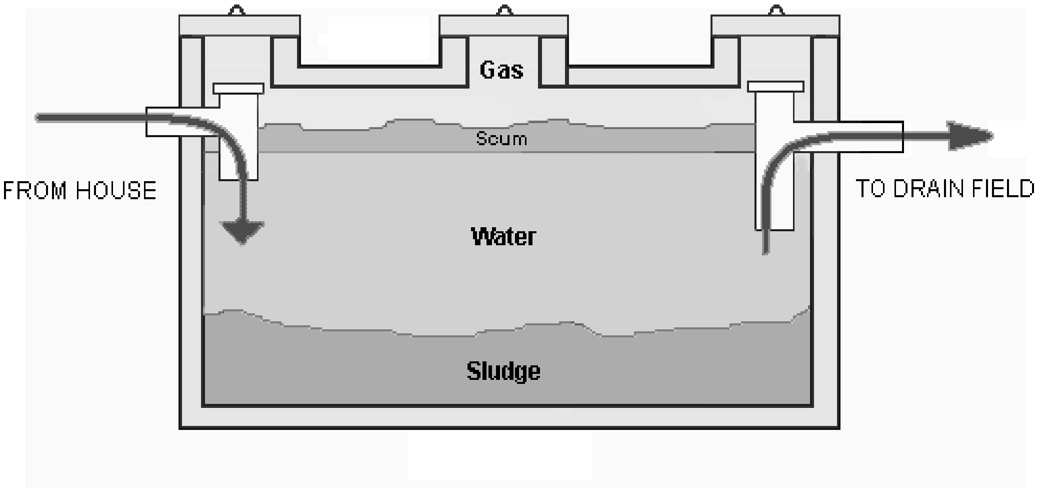


Figure 2. 19: Section view of a septic tank (source: www.septicinspection.com)

Septic tanks require an in house water supply, appropriate effluent treatment or disposal systems e.g. soil absorption field systems, mounds, lagoons, etc. and as such sufficient land. They are flexible and adaptable to a wide variety of household conditions and thus applicable as on site system for single homes, establishments, or clusters of homes in low density areas. The disadvantages of the septic tank system are: the treatment provided is only partial and effluents require further treatment, there is a high risk of pollution from leakage and poor functioning tanks, and they are expensive to construct and maintain. (Kalbermatten et al., 1982). Septic tanks must be emptied periodically by trucks, which may be a problem in high density areas with restricted vehicular access.

Interceptor Tanks

The interceptor tank is similar to and functions much like the septic tank. It is applicable in situations where there are no existing septic tanks especially for communities planning a solids free (settled) sewerage system. It is designed in the same way as a septic tank (Mara, 1996) and must be emptied of sludge regularly. Clusters of homes may be connected to an interceptor tank to reduce cost. For settled sewerage systems a single compartment tank is sufficient (Mara, 1996).

Rottebehaelter

The Rottebehaelter (pre-composting tank) refers to an underground concrete tank which either contains two filter bags hung side by side or two filter beds at its base (Gajurel, 2003). Wastewater discharged into the tank is separated into liquid and solid fractions by filtering through the filter bags or beds (see figure 2.14). The liquid fraction (filtrate) collects at the bottom of the Rottebehaelter and is drained via pipes where gradient allows or pumped out; the filtrate may be treated in a constructed wetlands and the solid fraction is collected for further treatment by digestion, composting, etc. The Rottebehaelter is designed with two filter bags or beds to allow for alternate usage. A bag or bed is first filled and then allowed to stand for a period which enables, dry decomposition (see section 2.3.1.4) while the other is filled. The system requires drainage by pumping where the gradient does not allow for drainage by pipe. Collecting of the solids must be properly managed for efficient operation of the system. The system allows for simple solid-liquid separation and reuse. It is most suitable where local post treatment and reuse are possible.

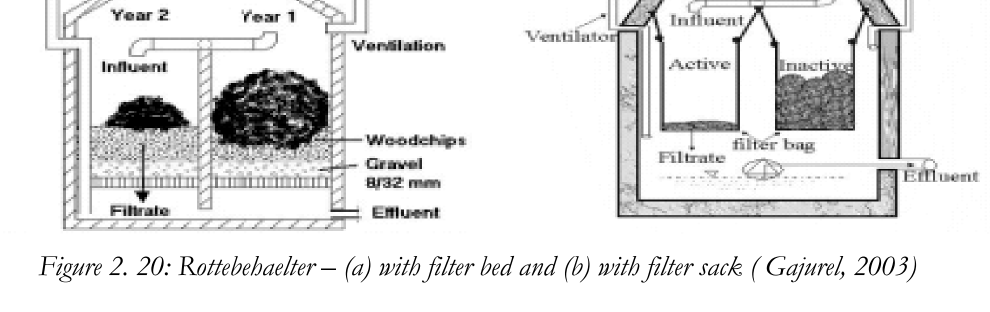


Figure 2. 20: Rottebehaelter – (a) with filter bed and (b) with filter sack (Gajurel, 2003)

2.3.3 Technologies for Transport

Cartage: manual or truck

Cartage is the most basic system of excreta haulage. It involves the transport of excreta from the point of generation to the point of treatment, reuse or disposal. A typical sanitation system involving cartage is the bucket latrine system, in which excreta are collected in small buckets placed under a squat hole and the bucket's contents emptied at regular intervals by a service provider and taken away for disposal. Cartage based systems are a great risk to the health of both users and collectors as exposure to disease pathogens is very high.

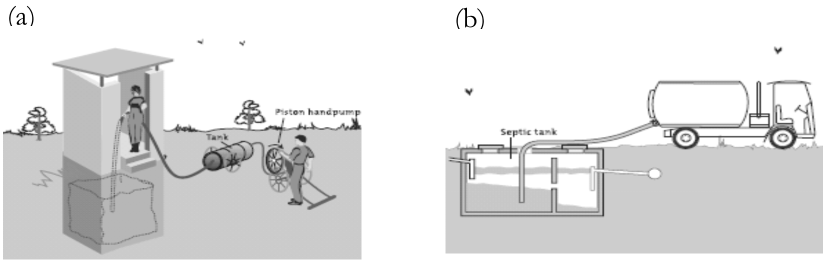


Figure 2. 21: (a) manual and (b) truck emptying devices (Brikke and Bredero, 2003)

Sewerage Systems

A sewerage system is a conveyance system that collects and transports wastewater from the point of generation to the point of treatment or disposal. Transport is usually and preferably (due to cost) by gravity with the network designed to follow the natural drainage pattern of the area. The system may be designed for the transport of wastewater and stormwater (separate) or both (combined). Separate sewers which require smaller pipes are preferred over combined as they are designed with large capacities only needed during intense rain, creating problems of excreta settling during dry weather flows. Further stormwater is largely less polluted than wastewater, and mixing both results in the dilution of wastewater, faecal contamination of stormwater and generation of very large quantities of combined wastewater which need treatment at high cost and where this is not possible discharge of untreated overflows. Sewerage systems may be classified into conventional and low cost sewerage.

Conventional sewerage: refers to a network of sewers laid deep in the ground and used for the transport of wastewater (see figure 2.16). The network consists of an in road system of pipes made of materials such as concrete, vitrified clay, etc., inspection units known as manholes, pumping stations and pumps. The minimum pipe diameter in conventional sewers is generally about 200 mm, laid at depths of more than 1 m. The network follows the natural gradient of the area but may require pumping where the land is flat. The conventional sewer system is a very reliable and convenient way of transporting wastewater. The system requires good design and the availability of water for proper functioning. The main disadvantages of the system are the cost – it is very expensive due to the scale of the installation, the depth of excavation required and operation and maintenance costs resulting from very conservative design parameters. Another disadvantage is the potential for groundwater contamination from ex-filtration of wastewater from pipes into the surrounding.

Low Cost Sewerage: low cost sewerage is a term describing alternatives to conventional sewerage systems that have the following characteristics in common: sewers consist of small diameter pipes made of easily available materials such as PVC, laid at shallow depth, with flow whenever possible by gravity. They are of two main types simplified and settled sewerage.

Simplified sewerage: is essentially conventional sewerage stripped down to its hydraulic basics i.e. without any of the conservative design features that have accrued over the last ~100 years (Mara, 1996). The simplified sewer system (see figure 2.16) is designed to transport unsettled wastewater via pipes of small diameter laid at shallow depths. In contrast to conventional sewers (in road) simplified sewers are laid inside the housing block (backyard or front yard) – this is known as condominial sewerage, they may also be laid outside the housing plot under pavements or sidewalks. The costs (installation, operation and maintenance) of this system are significantly lower than the conventional and are lower than onsite systems for population densities greater than 160 persons/ ha (Mara, 1996). This reduced cost is due to the shallow depths of excavation required – meaning excavation can be done without specialised equipment possibly by hand as in the case of the Bolivian system (Mara, personal communication), the use of small diameter pipes and simple inspection units in place of manholes (Mara, 1996).

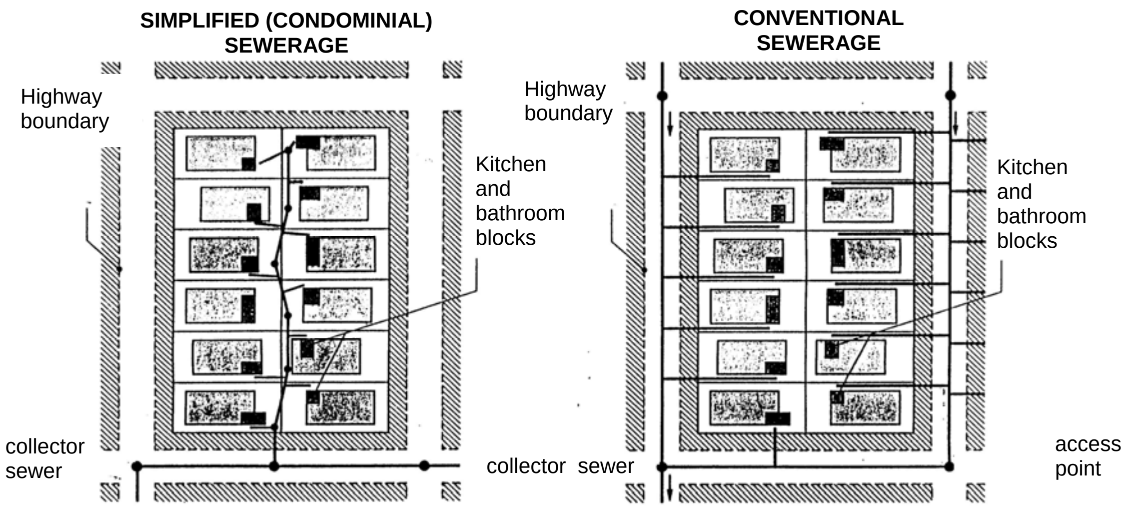


Figure 2. 22: Scheme of conventional and simplified sewerage system (D. Mara)

Accurate background information is needed for design and the system requires careful design and installation for proper functioning. Water is also essential for the proper operation of the system. The main advantages of the simplified sewerage system are the lower costs of installation, operation and maintenance for reasons previously stated. Cleaning is easier as manholes are replaced by inspection boxes due to shallow pipe depth. Installation can be participatory with user input for excavation and pipes-laying. Small maintenance activities may be carried out by users. Improper design will lead to system malfunction.

Settled sewerage: receives only the liquid portion of the wastewater i.e. after the solids have been removed hence the name 'settled' sewerage. The settling is usually done in an interceptor tank (see figure 2.17) similar to the septic tank where the scum and sludge are removed. Settled sewerage may be an appropriate solution for locations with existing septic tanks especially where the soil capacity to absorb the effluent is limited e.g. in cases of high groundwater table, low soil permeability, etc. and in cases where pollution of groundwater by septic effluent may occur, in this instance the effluent may be conveyed for off-site treatment and disposal. The design of the settled sewer is different from that of conventional sewers. As the transport is solids-free design based on self-cleansing velocity is not requirement. Similar to simplified sewers, small pipes and lower gradients can also be used. The system requires good design and adequate settling of solids. Its advantages are: it is cheaper than conventional sewerage and a good solution for situations where existing septic tanks may cause problems of pollution. An interceptor tank is used where septic tanks are not available. (Mara, personal communication)

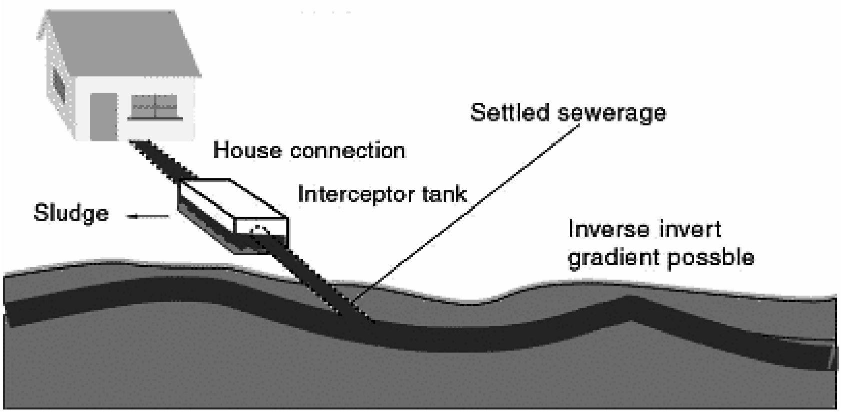


Figure 2. 23: Scheme of the settled sewerage system (source: www.unep.or.jp)

Vacuum Sewerage

In vacuum sewerage shown in figure 2.18, a central pumping station creates and maintains a vacuum in small diameter pipes, which generates a suction that draws and transports wastewater through the sewer to the treatment point. The force of the vacuum sucking the wastewater is usually enough to break up any solids in the wastewater, as such small-diameter plastic pipes can be used in vacuum sewerage. The suction also keeps the lines very clean, so manholes and cleanout points are often not necessary. The system depends on electricity and must be equipped with emergency backup generators in the event of a power outage as well as an operator. Vacuum sewers work with very little water thus are suitable for locations where water saving is a necessity. Pipes are constantly under negative pressure as such there is no leakage thus no associated pollution of groundwater by wastewater exfiltration. However installation, operation and maintenance costs make it unsuitable for many situations especially in developing countries.

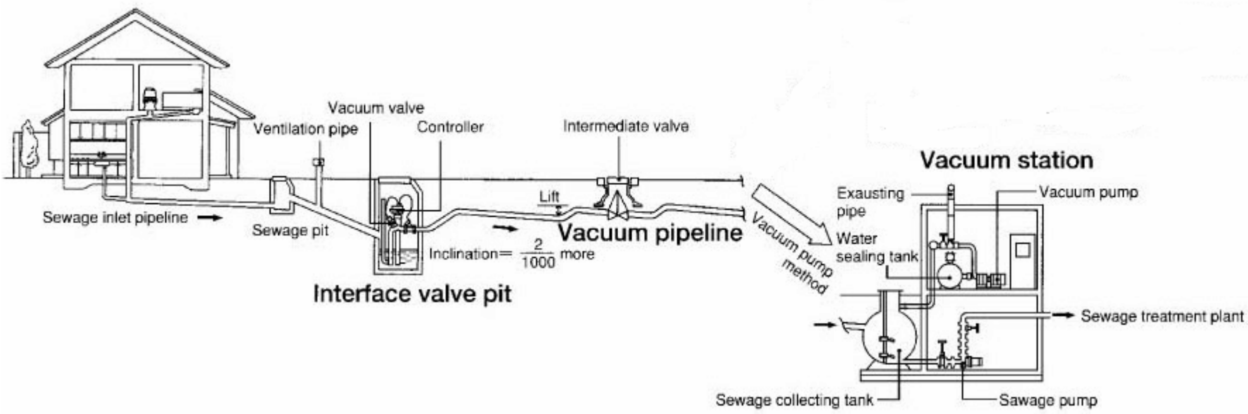


Figure 2. 24: Scheme of the vacuum sewerage system (source: www.gec.jp)

2.3.4 Treatment Technologies

Constructed Wetlands

Wetlands in general refer to naturally occurring areas of land where the water table is almost always at or very close to the ground surface as such saturated soil conditions occur most of the time, creating unique ecosystems where specially adapted plants and animals are found. The activities in a natural wetland may be simulated to some extent and even intensified in artificially created wetlands which are referred to as 'constructed wetlands'. Constructed wetlands are often expressly created for the treatment of wastewater and have been successfully employed in the treatment of wastewaters from various sources e.g. domestic, industrial, etc., with significant treatment efficiency in the removal of various pollutants. In some cases they are used to create wildlife habitats. They have emergent aquatic vegetation, and are similar in appearance to marshes and preferably situated at locations other than existing natural wetlands (USEPA Manual, 1993).

Two basic types exist:

- Free water surface (FWS) wetland: refers to wetlands that typically consist of a lined basin with emergent aquatic vegetation through which water flows horizontally and openly at a shallow depth.

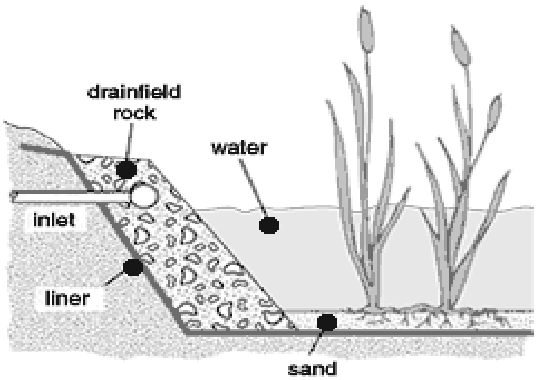


Figure 2. 25: Free Water Surface (FWS) Wetland (Gustafson et al., 2002)

- Subsurface flow (SF) wetland: typically consists of a lined basin containing layers of porous media bed e.g. gravel or sand, which supports the roots of emergent vegetation typically reeds. The water level unlike the FWS remains beneath the media layer surface. The SF wetland may be designed to have vertical or horizontal flow.

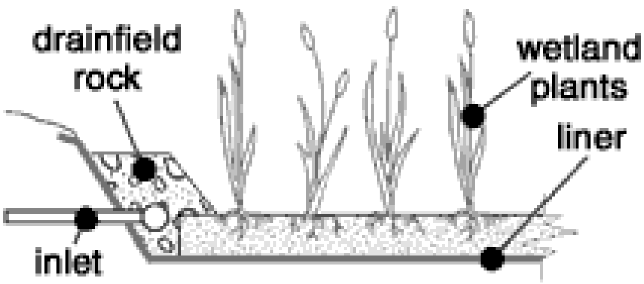


Figure 2. 26: Subsurface Flow (SF) Wetland (Gustafson et al., 2002)

According to Reed et al., (1995), the SF wetland has several advantages over the FWS, a few of which are as follows:

- in the SF water flows below media surface as such risks of odours, human or animal exposure to wastewater are limited.
- occurrence of insect vectors e.g. mosquitoes are also reduced.
- the presence of the media layer serves to increase the surface area available for treatment which may likely mean that treatment processes occur faster in the SF

than the FWS as such land area required to treat wastewater with similar characteristics will be smaller for the SF.

There are two types of SF wetlands based on the direction of water flow through the media, the vertical flow and horizontal flow wetlands.

Horizontal Flow SF wetland: typically consists of a lined planted media bed of gravel and/or sand through which wastewater flows horizontally. Although the media bed is continually saturated, the water level remains below the media surface. Treatment processes include physical (filtration), chemical (adsorption) and biological (BOD removal and nutrient uptake). The main advantages of the horizontal flow system are: low construction costs as design is simple and construction can be done by unskilled labour with appropriate supervision, in some cases even users can do some of the construction involved. Operation and maintenance is simple as no electromechanical parts are required. Treatment efficiency for primary effluent is high and in addition it can be designed to give aesthetic value e.g. Devon Hotel, Kandy in Sri Lanka (Corea, 2001)., The main disadvantages of this system are its high land requirement compared to the vertical flow system which makes it unsuitable for installation in densely populated areas.

Vertical Flow SF wetland: typically consists of a lined planted media bed of gravel and/or sand through which wastewater flows vertically, other key features include the inlet and outlet structures. The influent wastewater must be evenly distributed intermittently over the media bed and this is done using a perforated inlet device e.g. pipe submerged in the media. Treatment processes include physical (filtration), chemical (adsorption) and biological (aerobic BOD removal). The main advantages of the vertical flow SF wetland system are its treatment efficiency and low land requirement due to the way in which the wastewater is fed into the wetland. Incidentally this is also a factor in the main disadvantages of the vertical flow system – its proneness to clogging. Other drawbacks include the complexity of the feeding and discharge systems meaning design and construction is more sophisticated than the horizontal flow system discussed earlier in this section, and the need for electricity to run wastewater distribution devices. These factors make it less suitable than horizontal flow system in developing country situation where the availability of parts and the supply of electricity cannot be constantly guaranteed. However in situations where gradient allows, it may be possible to do the intermittent feeding without pumps.

Pond Systems

Waste Stabilisation Ponds (WSPs) are shallow man made basins that serve as treatment facilities for wastewater from different sources. Wastewater flows into and is retained in the pond for a pre-determined retention time usually several days following which the effluent is discharged for further treatment, reuse or disposal. WSP technology has been successfully utilised worldwide in both developed and developing countries (Mara, 1996, 2006). The main advantages of the WSPs are:

- *Simplicity*: as mentioned earlier they are man made basins and their construction requires little more than the effort to excavate the site of the pond. Construction involves minimal civil works (mainly excavation and earthmoving activities), embankment protection, lining if necessary and all of these may be installed by low skilled personnel with supervision. Ponds are simple to operate and maintain, typical O&M tasks include sludge removal, clearing of embankment, removal of scum or floating objects and ensuring the inlet and outlet structures are kept clear.

- *Low Cost*: this attribute is due chiefly to the simplicity of construction, operation and maintenance of the WSP. No electromechanical parts are required as such electricity or skilled manpower is not needed for operation.

- *High Treatment Efficiency*: WSPs offer impressive levels of wastewater treatment. Mara (1997) reports BOD removal levels greater than 90 % for well designed ponds. According to Mara (1997), WSPs are also very suitable for the removal of excreted pathogens a fact that is very important considering the danger posed to human and environmental health by excreta-related disease pathogens.

- *Robustness*: they are able to withstand organic and hydraulic shock loads due to their long hydraulic retention times, which make them suitable for treating high strength wastewaters. Further, according to Moshe et al. (1972) in Mara (1997), they are able to cope with heavy metals and thus can be employed in treating industrial wastewaters. "They are also the only secondary treatment process that can readily and reliably produce effluents safe for reuse in agriculture and aquaculture" (Mara, 1997).

Availability of adequate land is a requirement for WSPs, this is also its most important disadvantage, especially where land prices are high. WSPs are preferably suited to areas where the soil is not too permeable and the water table is not high; good geo-textile lining would be required, which may increase costs significantly. Siting of the WSP should avoid steep slopes particularly where it tends towards water bodies, and areas prone to flooding.

There are three main types of WSPs:

Anaerobic: anaerobic ponds provide excellent removal of biological oxygen demand (BOD) and suspended solids (SS). They are commonly about 2-5 m deep receiving wastewaters with high BOD loading; they are anaerobic because they do not contain oxygen due to their depth and are similar to the septic tank in function. The main function of the anaerobic pond is BOD removal and a well designed pond can achieve up to 70% BOD removal (Mara, 1997). Efficiency is helped by temperature thus the anaerobic ponds work well in warm climates. Retention times are short, about 1 day at temperatures above 20°C (Mara, 1997). Problems with odour have been associated with anaerobic ponds due largely to the presence of hydrogen sulphide formed by the anaerobic reduction of sulphate in the wastewater rather than a shortcoming of the technology (Mara, 1997). Odour can be reduced with proper design, avoidance of overloading and ensuring the sulphate concentration in the influent wastewater does not exceed recommended levels – 300 mg/l (Mara, 1997). It is worth mentioning that hydrogen sulphide in small concentrations is beneficial to the processes in the pond as it is precipitated with the heavy metal ions in wastewater as insoluble sulphides; and it is lethal to some microbes especially *Vibrio cholerae* (Mara, 1997). Depth is more important to the functioning of the anaerobic pond than the surface area, this means a reduction in the land area required for the overall pond system, and it is therefore advisable to include anaerobic units in ponds systems sited where land availability is a limiting factor in design.

Facultative: these ponds are aerobic and of two types. The *Primary Facultative* –this receives and treats raw wastewater, and the *Secondary Facultative* – which receives and treats settled wastewater typically septic tank or anaerobic pond effluent. Facultative ponds are characterised by the presence of algae and this gives them a dark green appearance. The algae through photosynthesis provide the pond bacteria with the oxygen which they use in BOD removal and the bacteria in turn produce carbon dioxide which the algae use in photosynthetic activities. Some facultative ponds may have a red or pink colour due to the presence of purple sulphide oxidising photosynthetic bacteria. Mixing is important and is wind-induced, in the absence of wind aided agitation the pond may stratify resulting in fluctuations in effluent quality. As carbon dioxide is consumed by algae, especially if this occurs at a rate faster than it is replaced by bacteria or from the atmosphere, bicarbonate and carbonate ions dissociate in order to generate carbon dioxide and hydroxide ions form leading to an increase in pH to levels as high as 9–10. These high pH levels result in the kill off of faecal bacteria. According to Mara (personal communication), pH > 9.4 is rapidly lethal to faecal bacteria, including *E. coli,* the exception being *Vibrio cholerae,* which is killed off by sulphides in anaerobic ponds as mentioned in earlier sections. The depth of the facultative pond is typically about 1–2 m, it should not be less than 1 m or there will be problems with plants emerging out of the pond encouraging mosquito breeding.

Maturation: maturation ponds are primarily polishing ponds used for the removal of excreted pathogens. BOD removal in maturation ponds is reported to be poor but they achieve significant levels of nutrient removal (Mara, 1997). They are often about

1-1.5 m deep and may be in series (more than one maturation pond) depending on the effluent quality required.

Overall pre-treatment (screening, grit removal) is essential prior to wastewater treatment in WSPs. Ponds occur in series depending on the system design which is based on wastewater treatment objectives or final effluent quality requirements or use. Typical uses of WSP effluent include: restricted or unrestricted irrigation, aquaculture, or simply disposal into aquatic bodies (surface or ground).

Anaerobic Digestion Systems

Anaerobic digestion refers to the breakdown of organic material by micro-organisms such as bacteria in the absence of oxygen. It is one of the oldest processes for the stabilisation of solids and biosolids (Tchobanologous, 2003). Anaerobic digesters are technologies that take advantage of this process of anaerobic digestion in the treatment of waste and production of bio energy. Although septic tanks and anaerobic ponds are also based on the same biochemical principles as anaerobic digestion systems, they are not designed for biogas collection. Anaerobic digesters may be applied in the digestion of virtually all types of organic material and are commonly used for wastewater treatment (domestic, animal, etc). Four phases are involved in the process, namely:

- Hydrolysis: involving the breakdown of complex organic molecules into simple sugars, amino and fatty acids.
- Acidogenesis: involving further breakdown resulting in the production of ammonia, carbon dioxide and hydrogen sulphide.
- Acetogenesis: involving the further degradation of the products of the acidogenesis step into products such as carbon dioxide, hydrogen and acetates.
- Methanogenesis: involves the production of methane, carbon dioxide and water.

The principal products of the digestion process are:

- Biogas: a mixture of mainly methane and carbon dioxide. Biogas is combustible and can be used as fuel for cooking, lighting and production of electricity.
- Slurry: a plant nutrient rich liquid material that makes very good fertiliser source.
- Stabilised sludge: this is organic material that may be used as soil conditioners depending on the source of the input material e.g. non industrial wastewater.

Viability of this system requires a use and markets for the products generated e.g. biogas and slurry. Biogas has been used in homes as fuel for lighting and cooking for example in Vietnam, China, and South Africa.

Technologies based on Decomposition

Composting is a biological process in which organic materials are broken down and converted to humus. Humus is a rich organic substance consisting of decayed vegetable or animal matter that provides plants nutrients and acts as a soil conditioner, increasing the ability of soil to retain water. Composting requires a reasonable amount of care and process engineering. It requires a relatively high humidity, around 50–60% (Gajurel, 2003) and deviations from this must be minimal because significantly lower humidity may result in the active organisms being deprived of water thus halting the process. On the other hand much higher humidity results in oxygen deprivation and consequent disruption of the process. A carbon to nitrogen ratio of about 25:1 to 30:1 must be maintained, which sometimes means that carbonaceous material (e.g. kitchen or garden waste) must be added to the compost heap. Destruction of pathogens to acceptable levels is best achieved with high temperatures (40 to >60°C), however, this is practically difficult as in some situations not all parts of the compost heap reach the desired temperature, with the consequence being that some pathogens survive. Overall composting can be effective in sanitising faeces as other factors do contribute to the destruction of pathogens in faeces; examples are unfavourable pH value, and residence time. Examples of sanitation systems based on decomposition, cited and also described in detail in the publication of Esrey et al. (1998) include:

- The "Clivus Multrum" single-vault composting toilet in Sweden.
- The "Carousel" multiple-vault composting toilet in Norway.
- "Sirdo Seco" solar heated composting toilet in Mexico.
- The movable bin toilet in Kiribati.
- The CCD toilet in the South Pacific.
- The double-vault toilet in India.

Vermicomposting

Vermicomposting is the process by which earthworms convert organic materials into humus. Vermicomposting offers a wide range of advantages, the processing time shorter (Gajurel, 2003), odour free process, (Shalabi, 2006), and various researchers have demonstrated its applicability to a wide range of wastes resulting in a material rich in plant nutrients with superior plant growth characteristics and soil water holding capacity (Appelhof, 1997; Edwards, 1995). The process has been successfully applied in the composting of faecal material in the research by Shalabi (2006) and involves the transformation of faeces into a form of vermicompost that is homogenous and soil like in appearance.

Technologies based on Dehydration

Dehydration involves the reduction or removal of the water content of the excreta. Heat, ventilation and the addition of dry material (ash, sawdust, and husks) are factors that aid the drying process in dehydration systems. Dehydration works best with separation at source i.e. when the material is not mixed with urine, flush or wash water, at relatively warmer temperatures and low humidity. Dehydration is an effective way of destroying pathogenic organisms, particularly helminth eggs, because it deprives them of the moisture they need to survive and is considered more effective in killing pathogens than other commonly used methods, especially for the pathogens that live the longest (Esrey et al., 1998). The product of this process is a dry crumbly material, which is rich in nutrients, carbon and fibrous material but not considered compost i.e. it is not stabilised as it still contains some biodegradable organics and further it will allow the growth of microbes when it comes in contact with water and must be treated further. The dehydration system requires vaults designed with adequate storage space as the process results in only small reductions in solid volume due to the dry material added and minimal decomposition of organic material. This means bulky material e.g. toilet paper are not disintegrated thus the separate collection of the materials for disposal by burning should be considered. If water is used for anal cleaning, this must also be diverted away to a separate facility for treatment or disposal. These systems are particularly suitable for dry climates; however they will also work if simple solar heaters (e.g. blackened lids) are used to cover the processing vaults in humid climates. Many examples of toilets based on dehydration exist and are listed below. Detailed description of these are available in the book Ecological Sanitation by Esrey et al. (1998), examples include:

- The double-vault dehydrating toilet in Vietnam.
- The double-vault dehydrating toilet in Central America and Mexico.
- The "WM Ekologen" dehydrating toilet in Sweden.
- The "Tecpan" solar heated toilet in El Salvador.
- The double-vault solar heated toilet in Ecuador.
- The indoor, long-drop dehydrating toilet in Yemen.
- The indoor, dehydrating toilet in Ladakh, India.

When applied correctly, both dehydration and decomposition will achieve sanitisation of faecal material. Systems based on both technologies have been successfully implemented in various parts of the world with very encouraging but varying degrees of success. Successful implementation of these systems involves careful planning, construction, use, management and care. It is important that users understand the functioning of the systems and be willing to play their part in maintenance activities or pay the charge for such services. Giving due consideration to factors such as users preference and local conditions is vital to the success of the systems e.g. a below ground dehydrating toilet built in an area prone to floods is already doomed to fail.

An EcoSan Example: Double Vault Dehydration Toilet

The double vault dehydration toilet is an archetypal ecological sanitation system. The system has been widely used in many parts of the world particularly in northern Vietnam and adapted for use in China, Central America, Mexico and other parts of the world.

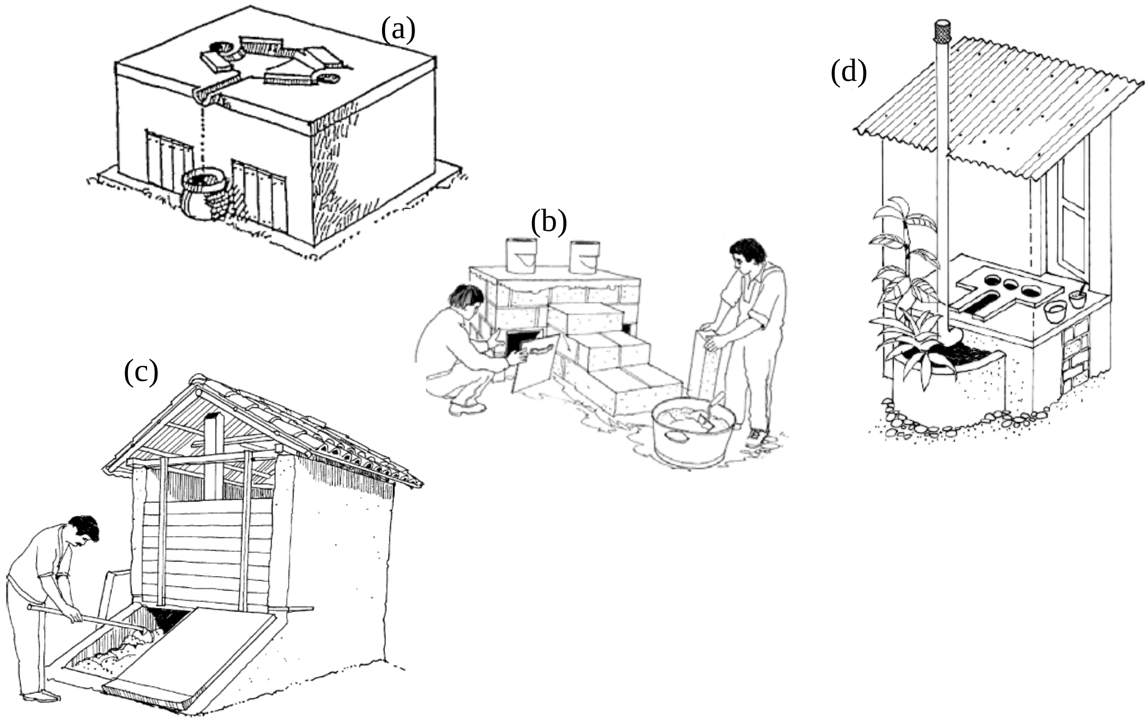


Figure 2. 27: Examples of Double Vault Dehydration (DV) Toilets – (a) Vietnamese DVD ; (b) Lasf toilet ; (c) DVD with solar heaters in Ecuador; (d) Kerala DV toilet. (Source: Esrey et al., 1998)

2.3.5 Systems for Disposal / Reuse

The availability and quality of water is a key issue for development and poverty eradication in Africa. With high rates of population growth and increased demand of fresh water resources, some regions of Africa already face water scarcity or are under water stress. Figure 2.22 shows countries that are expected to experience water scarcity or water stress by the year 2025. The imminent threat of water scarcity (quality and quantity), has meant that the value of treated wastewater as a resource for non potable uses is being realised especially in arid and semi arid areas of the world. Some of the many ways in which wastewater has been and is being used are: agriculture, aquaculture, horticulture, groundwater recharge, direct reuse e.g. for washing, etc.

Figure 2. 28: Countries expected to experience water stress or scarcity in 2025 (Source: UNEP,2002)

Irrigation: wastewater is a valuable source of irrigation water whether for agriculture or horticulture. It does not only provide the much needed water but also the valuable plant nutrients it contains such as nitrogen, phosphorus, potassium, etc.. Wastewater has been used to irrigate crops in many parts of the world in both developing and developed countries; Israel for example (only one of many – US, Australia, Mexico) uses over 65% of its wastewater to irrigate crops, with plans to use even more, over 90% by 2010 (Mara, 2004). Many farmers worldwide are aware of the value of wastewater for irrigation, however many use untreated wastewater; this practice carries risks not only to the health of the farmers but the eventual consumers of the crop. The WHO guidelines for the safe reuse of wastewater, distinguishes between the reuse of wastewater for directly edible crops such as salads (u*nrestricted irrigation*:) and those cooked prior to consumption irrigation (r*estricted irrigation* restricted).

The WHO ‘guidelines for the microbiological quality of wastewaters used for crop irrigation’ is presented in table 2.2; these guidelines are recommended for the protection of both the farmer (nematode) and the consumer (faecal coliform).

Table 2. 2: Guidelines for the microbiological quality of wastewaters used for crop irrigation (WHO 2004)

	Intestinal Nematode	Faecal coliform
Restricted Irrigation	≤ 1 egg/litre*	$\leq 10^5$/100 ml
Unrestricted Irrigation	≤ 1 egg/litre*	≤1000/100 ml
Aquaculture	0 egg/litre	$\leq 10^4$/100 ml

*<0.1 egg/litre for children under 15

Several measures can be employed in ensuring that these standards can be achieved (Mara, 2004), these include: wastewater treatment method and level, method of application (drip instead of flood or furrow irrigation), crop restriction and human exposure control e.g. simply using gloves and boots when working on the farm can be effective in protecting the farmers from exposure to pathogens.

Aquaculture: this refers to the production (farming) of fish and aquatic vegetables. Many species of fish notably carp and tilapia, reportedly grow well in sewage fertilised fish ponds (Mara, 1996). Aquaculture has been practiced for a long time in countries such as China, India and Indonesia (Bunting, 2004). As in the case for agriculture, the WHO has guidelines for wastewater fed aquaculture also given in table 2.2.

Aquatic discharge: this is a method of disposal of treated wastewater involving simply discharging the wastewater into the nearest water body; it is sometimes the only means of handling treated wastewater. It is essential that wastewater discharged into an aquatic body be treated to recommended standards, which often vary from place to place depending on local factors. It is important that treatment be designed with the final destination of the wastewater in mind, just as it is that guidelines and standards be developed that do not inhibit or defeat the very purpose for which they were set. Standards that are set unreasonably high may mean that treatment becomes unaffordable and in some cases lead to situations where raw wastewater is discharged into water bodies without treatment. Unfortunately in most developing countries the means to set and effectively enforce and monitor locally appropriate and beneficial standards are lacking and many simply adopt standards from developed countries for which they lack both the wastewater treatment technology and monitoring capability to achieve.

Summarily, the technologies presented in this section represent some of the technologies that are either available in the study area or that may be potentially suitable for conditions in many developing countries and especially in the case of Nigeria.

2.4 Nigeria

The Federal Republic of Nigeria is situated on the west coast of Africa and lies within latitudes 4° N and 14° N and longitudes 3° E and 14° E. Nigeria has a total area of 923,768 km^2 and shares its borders with the Republic of Niger (1497 km) to the north; northeast with Chad (Lake Chad – 87 km); with Cameroon to the east (1,690 km); with the Republic of Benin to the West (773 km); and coastal south by the Gulf of Guinea (~850km).

Climate: Nigeria has a humid tropical climate due to its location just north of the equator, and can be broadly divided into the following climatic regions: the humid sub-equatorial, in the southern lowlands; the hot tropical continental, in the far north; the moderate sub-temperate in the high Plateau and mountains; and the hot, wet tropical, in the hinterland (the middle-belt), with consistently high temperatures all year round ranging from 25°C to well above 40°C with only slight variations.

There are generally two distinct seasons depending on rainfall occurrence and distribution, which in turn depend on the prevalent air masses. The tropical maritime (TM) or south-westerly wind blowing in from the Atlantic Ocean, is moisture-laden and brings with it clouds and rain; and the tropical continental (TC) or easterly wind, which blows in from the Sahara Desert brings with it dryness and dust. Nigeria, therefore, has two major seasons, the dry season (harmattan) and the wet season (rainy), the lengths of these seasons vary from north to south.

Geophysical characteristics: the main geophysical features of Nigeria are the southern lowlands; the central hills and plateaus; the hills in the southeast and plains in the north. The lowest elevation point in Nigeria is at sea level (0 m) to and the highest (2,419 m) at the Chappal Waddi.

Geographically, Nigeria can be divided into the Northern region, comprised of the Sokoto Plains to the west, the Hausa High Plains in the centre, the Lake Chad basin to the northeast. The Middle Belt region covers the region between the southern rainforest and the northern Guinea Savannah. Administratively, the middle belt region is home to eight states and the Federal Capital Territory (FCT) of Nigeria (the study area of this research). The main drainage systems are the Niger-Benue, the Chad, and the Coastal river system. Nigeria has two major rivers: the Niger and Benue rivers both found in the middle belt region. The Niger flows across several West African countries; within Nigeria it flows from Jebba to Lokoja (~300 km); the Benue River flows from Makurdi to Lokoja (~200 km) and both meet at Lokoja (confluence), from where the Niger flows southwards forming a delta with many tributaries and estuaries, on its way to the Atlantic Ocean. The delta sprawls across the area known as the Niger Delta, which comprises of Delta, Bayelsa, Imo, Rivers, and Akwa Ibom States, (Encarta® Online Encyclopedia, 2006).

Nigeria's ecosystems: rainfall is the most important factor in the Nigeria's ecological (plant and animal) makeup. The main ecological zones in Nigeria are as follows: *freshwater swamp forest; lowland rainforest; mangrove forest; montane savanna; sudan savanna; guinea savanna; jos plateau; derived savanna; sahel savanna* (Olaleye, 1991).

Demography: Nigeria is Africa's most populous nation. According to World Bank (2004) estimates, the population of Nigeria is approximately, 140 million (World Development Indicators database, August 2005), although forecast figures put the population at 150 million, which makes Nigeria the largest country by population, in Africa. The country is composed of more than 250 ethnic groups, with the Hausa, Igbo and Yoruba representing the major ethnic groups. Religious groups include Muslims, Christians and indigenous beliefs. While English is the official language, a variety of indigenous languages are spoken throughout the country

Population growth and urbanisation: the importance of the demographic data presented in this section is that Nigeria has both a large population and one of the highest rates of population growth in the world, both factors having significant implications for the consumption of natural resources and environmental management. One projection estimates that Nigeria's population will reach 338 million by the year 2050. If correct, Nigeria would move from being the 10th most populous country in the world to the 4th in a span of under 50 years; table 2.3 places Nigeria's forecasted growth in global perspective.

Table 2. 3: Population projections for selected countries

Ranking in 2000	Country	Population (millions)		Ranking in 2050	Country	Population (millions)	Growth rates (2005)	Growth rates (2025)
1	China	1,256		1	India	1,707	0.6	0.2
2	India	1,017		2	China	1,322	1.4	0.9
3	United States	275		3	United States	394	0.9	0.8
4	Indonesia	219		4	Nigeria	338	1.4	0.8
5	Brazil	174		5	Indonesia	331	1.1	0.5
6	Russia	146		6	Pakistan	260	-0.4	-0.6
7	Pakistan	141		7	Brazil	228	2.0	1.4
8	Bangladesh	129		8	Bangladesh	211	2.1	1.4
9	Japan	126		9	Congo (Kinshasa)	184	0.1	-0.6
10	Nigeria	123		10	Mexico	167	2.4	2.3

Source: National Water and Sanitation Policy data and US Census Bureau data, April 2005 version

Rural - urban migration has been an important factor in the growth of cities in Nigeria in recent years. The urban and rural population is estimated to be approximately 48.3% and 51.7 % of the total population respectively (see table 2.4). Of the urban population, 68.8% are considered to be low income earners (Monday, 2004). The implication of this is that a huge proportion of urban dwellers in Nigeria live on income insufficient for their needs and in conditions unsuitable for good health. This reality has forced changes in urbanization patterns, for instance, giving rise to a significant increase in peri-urban settlements, as migrants who pour daily into the cities to work can only afford to live in peri-urban areas outside these cities, often with very poor basic infrastructure and social services. As table 2.4 shows the figures of urban residents are set to rise even higher if the population projections hold true.

Table 2. 4: Nigeria – population density, rural and urban population for years 2005-2030

Year	Population density (per sq. km)	Percentage rural (%)	Percentage urban (%)
2005	142	51.7	48.3
2015	174	44.5	55.5
2025	206	37.9	62.1

Source: Population Division, Department of Economic and Social Affairs, United Nations Secretariat, World Population Prospects: The 2004 Revision and World Urbanization Prospects: The 2003 Revision.

2.4.1 Status of Water Supply and Sanitation in Nigeria

Unfortunately rapid population growth has not been accompanied by a commensurate increase in the delivery of essential services such as water supply, sanitation, and collection – disposal of solid wastes.

2.4.1.1 Water Supply

According to the National Urban Water Sector Reform Project (NUWSRP) report of January 2004, it is estimated that currently only about 50% of the urban and 20% of the semi-urban population have access to reliable water supply of drinking quality from non traditional sources (Monday, 2004). The same report submits that the overall effective urban water supply coverage may be as low as 30% of the total population due to poor maintenance and unreliability of supplies, with rural coverage being an estimated 35%. Table 2.5 shows the percentage of dwelling units and their sources of water.

Table 2. 5: Water sources in Nigeria

Type/ Source of Water	1994/95	1995/96	1996/97	1997/98	1998/99
Pipe-borne	24.23	26.70	24.74	27.51	24.38
Borehole	9.61	10.40	15.41	32.24	11.83
Well	27.25	30.70	27.62	10.74	28.27
Stream/ Pond	38.91	32.10	32.23	n/a	33.82
Tanker/Truck	n/a	29.49	28.38	27.68	1.70

n/a: not available *Source: Federal Office of Statistics, Nigeria*

Water supply in Nigeria is managed at three levels:

1. National – Federal Ministry of Water Resources (FMWR): The Federal Ministry of Water Resources (FMWR) is responsible for formulating and coordinating national water policies, management of water resources including allocation between states, and approving development projects.
2. State – State Water Agencies (SWA): these have the responsibility of providing urban, semi- urban and, in some cases, rural water supply; they develop and manage water supply facilities within respective states in accordance with established financial objectives. Each SWA is responsible to the State government generally through the State Ministry of Water Resources (SMWR).
3. Local Government – Local Government Authorities (LGA): there are 774 in total, and they are responsible for the provision of rural water supplies and sanitation facilities in their respective areas, however according to the NUWSRP report (2004) only a reported few have the resources and skills to do this.

The State Water Agencies (SWA) manage water utilities in each state; they are responsible for the extraction, treatment, distribution of water, and cost recovery. However, operational efficiency of the SWAs is reportedly "unacceptably low". For example in 1998, non-revenue or unaccounted for water (UfW) was estimated at up to 63%

(Monday, 2004), meaning most operate at a loss and are not self sustaining. Factors contributing to the observed inefficiencies in the water supply system include:

- *Institutional*: insufficient financial resources; highly politicized tariff setting system and poorly motivated staff.
- *Technical*: aging pipes with frequent breaks and treatment works in poor condition are said to be common to most systems.
- *O&M issues*: unstable thus unreliable supply of electricity, fuel and treatment chemicals; irregular or almost non-existent preventive maintenance.
- *Financial*: under-investment in both supply capacity expansion and periodic replacement of aging components at existing facilities.

The report asserts that the SWAs are currently unable to meet the existing demand for safe water in cities within their jurisdiction. Rural water supply is still mainly from traditional sources (wells, standpipes, streams, rivers) in most parts of Nigeria. The inclusion of peri-urban areas in the jurisdiction of most utilities represents an added burden on these SWAs and their facilities as such piped water supply to peri-urban residents is limited where existent. Sources in peri-urban areas include public standpipes that belong to the utility, wells, private boreholes, or private water vendors who sell at rates much higher than the SWAs.

Impacts of the current water situation

The immediate impact of this situation is insufficient supply of water to the general population. Socially, this results in pressure on certain sectors of society mainly women and children who have the responsibility of collecting water for the family's use. Health wise, vulnerability of consumers to water related diseases are higher; economically, time spent in collecting water is time lost to economic productivity and education – it is not uncommon to have absenteeism in schools due to water collection responsibilities or in some cases inability to concentrate when children do get to class due to physical exhaustion.

2.4.1.2 Sanitation in Nigeria

In general, all three ('do nothing', 'drop and store', and 'flush and discharge') conventional systems discussed in previous sections are employed in wastewater management in Nigeria, and may be found in both rural and urban settings. Residents and home owners in Nigeria are responsible for the provision of their own sanitation facilities and the preferred type is often a matter of affordability as there is no regulation of sanitary facilities in Nigeria in general, the only exception being the cartage (bucket) system which has been banned in parts of Nigeria e.g. Lagos State (Iwugo et al., 2003).

Most parts of Nigeria with the exception of Abuja and limited areas of Lagos have no sewerage system. Wastewater management is accomplished in a variety of unregulated ways employing conventional technologies such as pit latrines, septic tank systems with or without soak-away. In most cases where pit latrines are used, there is usually no provision made for sullage. The result is that sullage and sometimes raw sewage either lie stagnant or end up being disposed of through the storm water drainage systems where these exist.

Overall according to the NUWSRP report (2004) the proportion of the total population with access to facilities for disposal of excreta and wastewater is lower than for water supply, no figures are however given for this. A reason the report cites for this is that "many of the states have been unable to provide statistics because of a lack of reliable management information systems". However data covering the period from 1994 – 1999 (see table 2.6) shows the percentage of households with access to different types of sanitation facilities; the pit system is the most common type of sanitation facility.

Table 2. 6: Types of sanitation facilities in Nigeria

Type of Toilet	Year				
	1994/95	1995/96	1996/97	1997/98	1998/99
Pit	61.36	61.60	56.97	56.57	54.56
Bucket	0.96	1.00	1.40	1.07	0.58
Water Closet	8.58	8.50	10.30	13.41	13.71
Others	29.10	28.90	31.33	28.97	31.16

Source: Federal Office of Statistics, Nigeria

2.4.1.3 Environmental Management in Nigeria

Environmental management in Nigeria is the responsibility of the Federal Ministry of Environment (FMEnv). Its mandates include the establishment of federal water quality standards and effluent limitations, protection of air and atmospheric quality, protection of the ozone layer, control and discharge of hazardous substances, etc., (Monday, 2004).

2.4.1.4 Water and Sanitation Policy in Nigeria

A National Water Supply and Sanitation Policy (NWSSP) was adopted in January 2000 with its main focus being the provision of sufficient potable water and adequate sanitation to all Nigerians in an affordable and sustainable way through participatory investment by the three tiers of government, the private sector and the beneficiary. Policy targets highlights are as follows:

- to meet the national economic target of improving service coverage from 40% to 60% by the year 2003.
- extension of service coverage to 80% of the population by the year 2007.
- extension of service coverage to 100% of the population in the year 2011.
- sustain 100% full coverage of water supply and wastewater services for the growing population beyond the year 2011.

Although the policy states free access to basic water supply and sanitation services for the poor as one of its objectives, and in addition recommends the following water supply standards for various settlement types in Nigeria, no specific details are available for peri-urban areas.

Table 2. 7: Water consumption estimates in Nigeria

	Population	L/cap/ day
Urban	>20,000	120
Small Towns	5,000 - 20,000	90

Source: NUWSRP, NWSSP (2004)

According to the NUWSRP report (2004), the main objectives and strategies of the policy are as follows:

- increase service coverage for water supply and sanitation nationwide to meet the level of the socio-economic demand of the nation on the sector.
- ensure good water quality standards are maintained by water supply agencies. The WHO drinking water quality standards shall be the baseline for the national drinking water quality standard.
- ensure affordability of water supply and sanitation services for the citizens.
- guarantee free access for the poor to basic human need level of water supply and sanitation services.
- enhance national capacity in the operation and management of water supply and sanitation facilities.
- privatize water supply and wastewater services (where feasible) with adequate protection for the poor.
- monitor the performance of the sector for sound policy adjustment and development for water supply and sanitation through legislation, regulations, standards and laws for water supply and sanitation.
- reform of the water supply and sanitation sector to attain and maintain internationally acceptable standards.

2.4.1.5 Problems facing the Water Sector in Nigeria

The Water Sector in Nigeria faces uphill challenges in the discharge of its duties. A significant and potentially damaging one especially in regard to water quality and health is that of contamination of water sources. Some of the factors identified by responsible agencies and in this study are:

- poor sanitation and inadequate wastewater treatment followed by discharge.
- inadequate solid waste disposal and storm drainage.
- poorly located water supply intakes.
- poor institutional capability.

These factors affect Nigeria as whole and parts of the study area Abuja in particular.

2.5 Abuja: Creation and Development

Abuja is the new capital city of Nigeria. Until 1976, the city of Lagos had served as Nigeria's capital city from 1914. Nigeria's adoption of a twelve State structure in 1967 made Lagos not just the capital of Nigeria but also the capital of the State of Lagos similar to the status of Berlin, Germany. In addition to its role as an administrative centre, Lagos being on the coastal line of Nigeria is a hub of commercial and industrial activities, with both the busiest air and sea ports in Nigeria.

Population figures for Lagos have been quite difficult to establish (Aina, 1990), as growth (birth and migration) has been high and uncontrolled with an estimated 18% population growth rate given by Ola (1977). This growth of course means increased pressure on the city's infrastructure and services – housing, road networks, water supply, communication, sanitation, etc. Residents and visitors alike acclaim the chaotic congested traffic situation in Lagos. It is not uncommon to spend two hours to cover a distance of 20 km in some parts of the city (personal experience). On the housing front the development of slums and squatter settlements due to acute housing shortages and high rents were then a problem today in spite of governmental efforts to alleviate the conditions and is still largely the same today.

The overall constraining issue with the physical growth of Lagos is the availability of land for expansion and further development. The total land area of Lagos is about 3 568.61 square kilometre (Lagos State Government website); according to Iwugo et al., (2003), 40% of the total land area in the state is covered by water and wetlands. Consequently, even with the best intention and effort on the government's part, an ever increasing population means infrastructure development was and is still much slower than population growth. Hence these among many other pressures necessitated the creation of the new capital of Abuja.

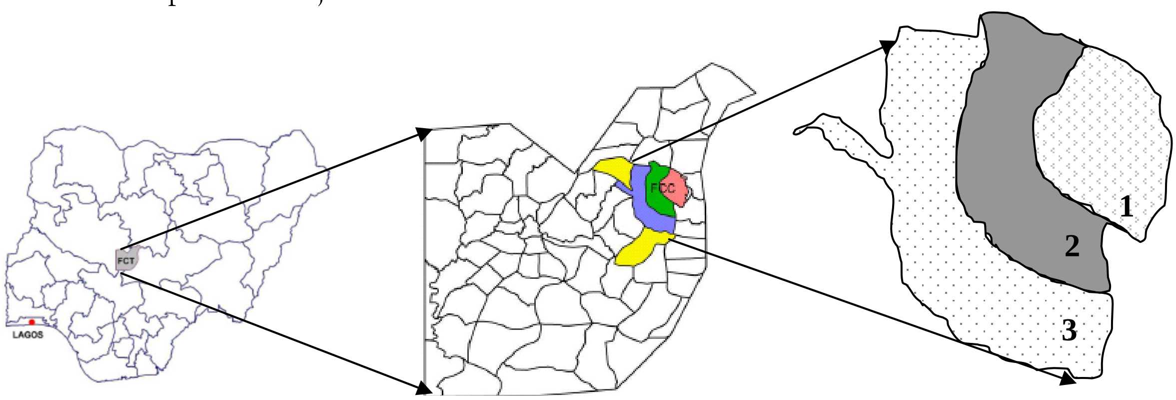


Figure 2. 29: Maps of Nigeria, FCT and FCC phases 1, 2, 3

In August 1975, the Akinola Aguda Panel was set up by the then military government of General Murtala Muhammed to: review the dual role of Lagos as capital of Nigeria as

well as Lagos State; recommend suitable alternative location if the panel's conclusion is that the capital be relocated from Lagos.
The Panel's findings highlighted the inadequacies of Lagos in its function as the nation's capital, the main ones summarised below are:

- the inadequate land area for expansion makes Lagos an unsuitable site for Nigeria's capital.
- Lagos is located within a region that belongs predominantly to a particular ethnic group in Nigeria; this may generate geopolitical issues as regards other ethnic groups.

It therefore recommended that the capital be relocated to a new site. The site for this new capital should have the following characteristics: be apolitical in nature; centrally located and thus easily accessible from all parts of Nigeria; have enough land area for development, and natural resources. The panel's choice for Abuja as the location of the new capital city was thus mainly based on the area's centrality, easy accessibility, good climate and low population density (Umeh, 1993).

The Panel's recommendations were accepted by the then administration and the Federal Capital Territory (FCT) was created in 1976. The Federal Capital Development Authority (FCDA) established by decree No 6 of 1976, was given the responsibility of preparing the Abuja Master Plan, the physical development of the main capital city (FCC), and the provision of municipal services.

Located in the middle belt of Nigeria; Abuja is carved out of several states such as Niger, Kwara, Nasarawa formerly Plateau. It covers a land area of about 8,000 km², and lies between latitude 8.25° and 9.20° N and longitude 6.45° and 7.39° E falling within the geographical centre of the country.

Abuja officially replaced Lagos as capital in December 1991, with the official relocation of the administrative organs of the Federal Government following 15 years (1976 – 1991) of planning, development and construction.

2.5.1 Physical Development

Following the creation of the new Capital Territory, a development Master Plan was prepared for the territory and physical development of the FCT commenced in 1979. A part of the territory (the North Eastern Quadrant) designated the Federal Capital City (FCC), houses the seat of government; the FCC was designed for a maximum population of 3.1 million, see figure 2.23.

According to the Master Plan, physical development of the FCC was to proceed in Phases see figure 2.22. Phase 1: consists of

- The 3–Arms Zone: Administrative Centre of the government
    - The Presidency, National Assembly, Supreme Court complexes

- The Business District
    - Transport Terminal, Ministries and Diplomatic zones, Central Market
- Six residential Districts
    - Maitama, Asokoro, Wuse I, Wuse II, Garki I, Garki II

Status: Development in Phase I is extensive, infrastructure has been provided

Phase 2: consists of

- National Park
- 4 Sector Centres
- 14 Residential Areas
    - Katampe, Mabushi, Utako, Wuye, Durumi,Gudu, Jabi, Kado, Dakibiyu, Kaura, Duboyi, Gaduwa, Dutse, Jahi.

Status: Development and infrastructure provision in Phase II is only partial.

Phase 3: will have 16 Districts. The site appraisal and conceptual design were completed in 1998, the general land use plan in 2001, while work on the development plan and the preliminary engineering design are currently in progress.

In summary, the seat of government officially moved from Lagos to Abuja on the 12th of August 1991. This has meant that Phase I, which as stated above contains the national administrative zones, has received and continues to receive priority attention in infrastructural development. Construction of roads, drainage/ sewer and water supply lines, have been completed in Phase I. The rest of the FCT consists of the Area Councils, which are equivalent to the Local Government Areas existing in the rest of the country. The following are the Area Councils in the FCT: Abaji, Bwari, Gwagwalada, Kuje, and Kwali Area Councils. Embedded in some of these Area Councils are Satellite Towns and Development Zones. These satellite towns were to cater for the larger majority of the inhabitants of the FCT and as such it was hoped that Abuja would not face the problems that Lagos faced and still faces. But events of the last 6 or 7 years have shown that proactive and creative measures need to be taken to avoid a similar scenario. The selected peri-urban study settlements are all located within or around the FCC; the factors affecting their development are discussed in Chapter 5.

2.5.2 The Development of Squatter Settlements in the FCT

Movement of people can either be forced or voluntary. Disasters, such as wars, floods and earthquakes, among others, are some of the reasons that could force man to move out of an area that he is familiar with, to resettle in an entirely new area (Jibril, 2006). The creation of Abuja resulted in the movement of the local inhabitants. The search for a better life (rural–urban migration) and government acquisition of land for development are both significant causes of human movement in the case of Abuja. As in most cases involving government policy, affected people often have little choice in the matter, and the FCT resettlement program is no exception.

As indicated earlier, the decision to relocate to Abuja is consequent to the Aguda panel's recommendations regarding the inadequacies of Lagos as the Nation's capital. The new capital was to be *"with easy accessibility from all parts of the country by road, rail and air which would facilitate the administration of the country… from the view point of national security, be less vulnerable to external aggression as it would be practically immune to sea-borne attack…"*(Murtala, 1976 in Jibril, 2006).

The creation of Abuja came with the problem of what to do about the people who were living in the area at the time. The government policy was to resettle local inhabitants "…*the few local inhabitants in the area, who needed to be moved out of the territory for planning purposes, will be resettled outside the area in places of their choice at Government expense*…"(Murtala,1976 in Jibril 2006)

This first major governmental policy (1976) was the complete relocation of the entire inhabitant population outside the new FCT. The primary aim of this policy was to free the territory from any primordial claims, and to allow the planning and development of the new city without any hindrance; these were the main reasons for the displacement and resettlement of the indigenous population. An initial assessment put the number of affected inhabitants at about 25000 – 50000 (Umeh, 1993), but the correct estimate was later discovered to be about 150000 – 300000 (Jibril, 2006). The extremely high costs of compensating this number of people led the government to reconsider and change its relocation and compensation policy.

This change in policy effectively meant "only those affected by the actual siting of the city were to be evacuated" and the decision then was to allow the inhabitants to remain, and be resettled within the territory, should their places of abode be affected by city development projects. This change in policy can be regarded as one of the core causes of the squatter or slum settlements problems within the FCT. Two categories of resettlement were intended:

- complete relocation outside the FCT
- remaining and resettlement within the FCT

The problems with land administration and squatter settlements in the FCT arise mainly from the second resettlement category. According to Jibril (2000), four policy changes have been made regarding this second resettlement category between 1978 and 2003.

The first policy states *"…those not affected by the first phase of resettlement, but wish to move out of the territory may do so, but such people will have no claims on the FCDA, as they have not been forced to leave. This in effect means that inhabitants (indigenes) not moved out during the present exercise who decide to stay will now be deemed to be citizens of the FCT and FCDA will soon appoint an administrator to administer them and look after their welfare. The present land area gazetted as FCT will remain. The site cleared for the building of the capital itself will be evacuated and resettlement of the* *people so evacuated can take place within or outside the territory. The meagre funds available now should be spent more on development of infrastructure rather than on payment of compensation…"* (Obasanjo, 1978 in Jibril 2006).

The second policy change of 1992 adopted "Integration" for those who chose to remain in the FCT over relocation. The third policy change in 1999 involved a reversal of the "Integration Policy" in favour of complete resettlement. However, according to Jibril (2006), houses (Jibi resettlement town) provided for this purpose completed and ready for occupation in 2002 were taken over by government agencies instead. The fourth and current policy stance – 2003, recognises the impossibility of implementing the original provisions of the Abuja Master Plan (which the current FCT administration has embarked upon) without a well articulated resettlement policy on the displaced inhabitants; a cardinal principle of which is complete resettlement.

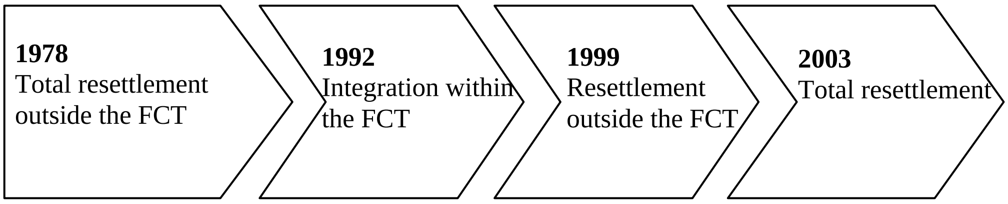


Figure 2. 30: Progression of resettlement policy for the FCT

These inconsistencies in government policy have had serious impact on the implementation of the provisions of both the Abuja Master Plan and the Regional Development Plan of the FCT; most importantly it has led to the creation, growth and proliferation of squatter settlements in the FCC and FCT (see table 2.8 adapted from Jibril, 2006).

Table 2. 8: List of some Squatter Settlements in the FCT based on AGIS report (adapted from Jibril, 2006)

Name	**Type**	**Area ha.**	**District**
Durumi	Squatter	32.3	Durumi
Mabushi	Squatter / Market	15.5	Mabushi
Mada	Squatter	165.4	Outside FCC
Kurbo	Squatter / Market	54.5	Outside FCC
Kuchigoro Ext	Squatter	59.9	Kukwaba
Karmajiji	Squatter	37.9	Kukwaba
Wuye	Squatter	2.4	Wuye
Jabi 1 & 2	Squatter	18.3	Jabi
Dakibiyu	Squatter	51.6	Jabi/ Dakibiyu
Utako	Squatter	11.9	Utako
Karmo	Squatter	524	Karmo
Gwarinpa	Squatter	408	Gwarinpa I
Dape	Squatter	455	Dape

The government initially took up the responsibility of housing provision, this proved inadequate for the number of people that moved to the FCC. With the reluctance on the part of private developers to invest in the FCT, the consequence was acute shortage of housing in the FCC leading to astronomical rents. The few private developers investing in the area focussed on building mansions and office complexes that promise higher returns rather than affordable housing for low – middle income earners, a fact that further compounded the housing problems. The only solution open to most people in this group especially people working outside the formal sector (civil service), who are not entitled to government housing provisions was to resort to living in squatter settlements either as tenants or home owners building on land purchased illegally from indigenous people.

Although illegal, the land market thrives and has been hitherto the easiest way to land acquisition by a large proportion of the resident migrant population of Abuja. In some cases as a result of the complexities involved in land acquisition and development, legitimate developers also turn to these illegal land markets. The local traditional rulers involved in the operations of the illegal land 'markets' rather than wait for compensation from government for their land found it more expedient and lucrative to sell outside government regulatory bodies, Jibril, (2006) also confirms this observation. Developers of the squatter settlements also exploited the situation (weakness of the government control system; demand for and shortage of housing) on the basis of the 'ease' with which money is made from the trade resulting in the flourishing of squatter settlements.

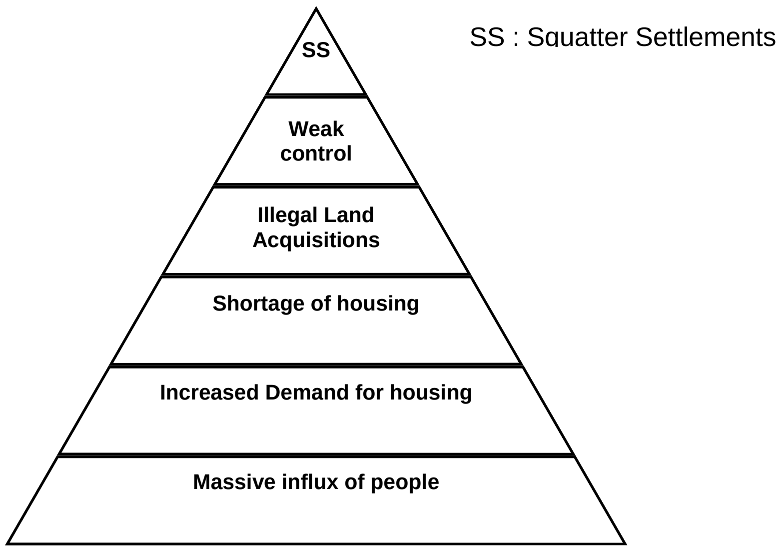


Figure 2. 31: Causes of squatter settlement development

Problems associated with the squatter settlements

As is often the case with squatter settlements, most of these settlements lack the most basics amenities. Some of the problems with the existence of these squatter settlements in the FCC and its environs as gathered during the field study and supported by Jibril (2006), are as follows:

Developmental:

- the distortion of the provisions of the Master Plan for the FCC and the FCT Regional Development Plan.
- the constraints placed on the meaningful implementation of the provisions of the Master Plan.
- the development of urban slums in a once pristine city.

Socio-economic:

- the health hazards associated with the squalid living conditions in the settlements both to people living within the settlements and other inhabitants of the FCT.
- the loss of revenue to government e.g. water charges go to vendors (rather than to the Water Board) who take their supply illegally from government piped supply; and since the land market is illegal it is informal and thus no taxes are collected from transactions by government agencies.
- the increase in crime rate as these settlements are becoming breeding grounds and hideouts for criminals and unemployed youth – a particularly sad development as Abuja was reputed to be one of the safest places in Nigeria.
- the breakdown of the traditional social/ leadership structure due to the now multi-ethnic nature of these settlements.
- substandard services e.g. educational and health institutions and facilities within these areas are largely unregulated, with potential risks to residents.

Summarily, the development of squatter settlements in the FCT is obviously a problem that can no longer be ignored. Abuja was created to avoid the problems of Lagos, with the current state of things concerted efforts are needed to forestall a repeat of the Lagos scenario. The conditions especially as regards water and sanitation (discussed in Chapter 5) in many of these settlements pose risks to the health of both the inhabitants and the FCT as a whole; measures that can be taken regarding sanitation are the focus of this work.

Chapter 3: Purpose of the Study

3.1 Background

Housing, water supply and good sanitation are not just necessities for a decent life but basic human rights and an integral component of sustainable development. The situation in most developing countries as regards sanitation is that it has a far lower priority compared to water supply, health and other development issues, as reflected by the focus of most programmes and expenditure aimed at development. This approach sadly is counterproductive to the very purpose of development as wastewater management can simply not be divorced from water supply and health.

This study takes place in Abuja, which is the new Federal Capital Territory (FCT) of Nigeria. According to details from the Master Plan (Abuja Master Plan, 1978), conventional sewerage system (network of sewers – separate for wastewater and storm water and biological treatment) was planned for the FCT, although these types of systems from experience in both developing and industrialised countries worldwide are expensive to install, operate and maintain relying heavily on sustained injection of funds and high operator skills. Are these types of systems suitable and sustainable for Abuja?

3.2 Scope of Study

Following official definitions of the municipalities within the FCT, the study area is differentiated into the federal capital city (FCC) and the rest of the territory, with the FCC being the main area of study. The peri-urban settlements studied are located within and around the area defined as FCC. This study investigated water, sanitation issues and their impact on human and environmental health in both planned sections of the FCC and the informal peri-urban settlements.

3.3 Aims and Objectives of the study

The main aim of this study is to carry out a pre-feasibility assessment (technical, social and economic) of selected wastewater management systems in order to determine those that are potentially feasible for the study areas.

Thus the main objectives are to analyse the current wastewater management situation and highlight the problems associated with current practices in the study area (FCC and its peri-urban areas); evaluate the feasibility of potentially appropriate alternatives to current technologies, how these might work as well as the associated economic implications. Further the implications of current practices for health (human and environmental), as well as factors influencing human dynamics, are examined. Based on local conditions and needs, potentially feasible wastewater management scenarios will be developed with a focus on the 'ecological sanitation' and 'low cost' technological alternatives to conventional sanitation. These scenarios must address the problems and needs identified, the preferences expressed by the target users and their economic capability.

To this end this study will attempt to answer the following questions:

- *What sanitary conditions currently exist in the study areas, proportion of people with and type of access to sanitation?*
- *What are the current disposal/management practices of wastewater generated?*
- *What are the problems with the current management practices and what impacts have these practices had on human and environmental health?*
- *Are there alternatives to existing wastewater management practices and how will they work?*
- *What pulls people to the FCT and what factors drive the development of slums and why?*
- *What opportunities and challenges are likely to affect addressing the slum and sanitation problems?*

Obtaining answers to these questions will contribute to the overall objectives of:

- Evaluating and documenting existing sanitary conditions, current wastewater management practices and their impact on the health of the people and environment in Abuja, Nigeria.
- Evaluating the problems associated with slum settlements around the city.
- Develop wastewater management scenarios for the peri-urban settlements of the FCT based on locally appropriate technologies.

Tools employed in this study include: review of existing and accessible literature, field study with visits to sites and facilities relevant to the study, discussions with relevant local professionals as deemed appropriate for the different aspects investigated. Details of the methods applied in this research work are presented in Chapter 4.

It is expected that this study will result in recommending feasible alternative wastewater management strategies particularly based on local needs and conditions. The findings of this research work will be shared with the municipal authorities in the study area and it is hoped that there will be interest in implementing the study's recommendations. Also, as no information of the nature this study will yield currently exists for this area, it is expected that the study will provide a foundation for further work in this area, in implementing the proposed solutions, and as a starting point for further study or providing further data on the subject.

3.4 Limitations of the Study

The main factors that were limitations in this research work include: availability of and access to data; limited time and resources for the field study; tensions in the study areas; cultural sensitivities; respondents' expectations; and unresponsive agencies. All of these points are discussed in detail in Chapter 5 (5.3.8).

Chapter 4: Research Methods

4.1 Overview of the Methods

This section presents an overview of the methods applied in the field study, technology selection, scenario development, design and cost estimation, and scenario comparison. This work was carried out as outlined in the table 4.1.

Table 4. 1: Overview of the research methodology

Phase	Activities	Outcome
Preparation	Literature search and review; discussions with supervisors, etc. Field study preparation	Definition of: study objectives; scope of research; data needs
Field Study	Field work / data collection	Primary and secondary data; data analysis; fieldwork report and results presentation
Technology Selection	Identification of problem areas based on field study results; definition of criteria for technology selection	Compilation of potential technologies
Scenario Development	Definition of criteria for sanitation systems scenarios; systems / boundary definition; scenario creation from technologies shortlist	Scenario schemes and details
Design /Cost Calculation	Design and cost estimations for each scenario	Design details and related costs
Scenario Comparison	Definition of criteria for comparison	Feasibility of each scenario
Report writing	Compilation of literature, results, bibliography	Dissertation

4.2 Methods for the Field Study

This field research is qualitative and descriptive in nature and considering the objectives of the study stated in Chapter 3, it was necessary to collect both secondary and primary data. The following methods were applied during the fieldwork: review of existing documents, observation, largely informal key-informant interviews (municipal authorities and agencies, residents, landlords, tenants, and service providers), and survey; to obtain the data used in answering the research questions.

Peri-Urban Study Site Selection: the specific peri-urban settlements were selected after familiarisation visits to potential study sites. There are about three major roads going out of the main city linking nearby States; the study sites had to meet the following criteria: be along one of the major roads linking the main city to neighbouring states; have developed informally and not have a legally recognised status by the authorities; have no government provided infrastructure. The following sites were selected based on the above listed criteria: Chika, Kuchigoro, Mpape, Karmo, Idu, and Gwagwa.

4.2.1 Collection of Secondary and Primary Data

For this work, secondary data was collected from governmental and private sources. Follow up calls and visits were made to the agencies already contacted before arrival at the study site; written requests for access to existing documents were also made to the respective agencies, however, verbal requests sufficed in some cases where a good rapport had been established with officials. The following are the agencies that provided secondary data: Abuja Environmental Protection Board (AEPB), various departments of the Federal Capital Development Authority (FCDA) namely: Engineering Services, Health Services, Lands and Planning, Satellite Town Development Authority, and Resettlement Services.

The documents obtained were reviewed to gather information on the existing situation concerning the areas of activities and coverage of the respective agencies. These included informational brochures, project reports, situational reports, impact assessment reports, and journal articles written by officials of some of the agencies; private sources included newspaper articles.

Primary data may be described as first hand data and in this study primary data collection activities involved: site visits (walks and observation), interviews, and surveys.

4.2.1.1 Site Visits

Site visits involved familiarisation (transect) walks and observation, the purpose of which was to observe existing situation, select potential study sites and validate some of the data obtained from documents and informal key informant interviews. Initial visits were made to potential sites prior to study site selection. These first sets of visits served to ascertain if the sites met the study site selection criteria listed previously, and involved simply taking walks (guided and unguided) around the area, observing the people, environment and conditions. Further visits were made to selected study sites for more detailed qualitative data collection. The second round of visits involved observations, informal key informant interviews and documentation (written and visual) of existing situation or conditions. Subsequent visits were carried out during the survey part of the study. Although specific rounds of visits made to the study sites are as described above, visits were made outside of these as deemed necessary.

4.2.1.2 Interviews

Interviews (formal and informal) were carried out at various stages of the study with key informants who included residents (tenants, landlords, homeowners) of the selected study sites, staff of the governmental agencies covered during the study, local artisans and traders among others. The purpose of these key informant interviews was to obtain an insight into the perspective of interviewees about the existing situation, problems and areas of need.

The first round of interviews were informal utilising the *informal conversational approach* described by Johnson and Christensen (2003), no schedule was employed at this stage; questions were spontaneous and open ended allowing for respondents to not only answer the questions asked but further give information they were willing to share or deemed important sometimes directly related to the study and sometimes not. The responses were recorded using a voice recorder sometimes openly other times covertly depending on the situation and ease of respondents towards expressing their opinions on record. The recorded responses were later transcribed into text.

The informal interview part of this study was important as it facilitated the development of a rapport with the study subjects and their familiarisation with the study. They were also able to express their opinion freely in a way that they would not if they were responding to questions on a formal questionnaire as observed during the survey stage. This approach was used with residents, artisans, traders and lower cadre agency officials.

The formal key informant interview focussed mainly on the higher cadre agency officials (decision maker level) and employed the *interview guide approach* (Johnson and Christensen, 2003); a list of open ended questions drawn up based on information gathered from document review, observations and informal interviews was utilised. This part of the study served to gain the governmental perspective of the issues this study examined, and questions were directed at the concerned respondents in random order allowing for a blend of spontaneity and structure in addressing the issues of concern. Responses were recorded manually in case notes and in some cases covertly using a voice recorder and later transcribed. Whatever interview method is employed it is recommended that such information be further investigated to ensure validity. This was done using methods such as observation and survey.

4.2.1.3 Survey

In addition to the above primary data collection methods, a survey was also carried out in each of the following settlements (selected study sites): Chika, Kuchigoro, Mpape, Karmo, Idu, Gwagwa. The data collection instrument (see appendix A) utilised in this segment of the study is based on the defined objectives of the research as highlighted in Chapter 3. Prior to the visits, the survey was to be carried out using structured questionnaires to be filled out by the study subjects, this was however reconsidered and changed due to observations made following site visits and pre-testing of the initial questionnaires. The questionnaires were subsequently adapted to interview protocols due to demographic, cultural, and logistic factors related to the study subjects and settlements. The change was that the researcher would ask the questions as listed in the protocol and the researcher (not the study participant) would also record the answers given by the respondents on the data collection instrument. This change had to be made for ease of administration and to obtain a good number of responses as some respondents were illiterate.

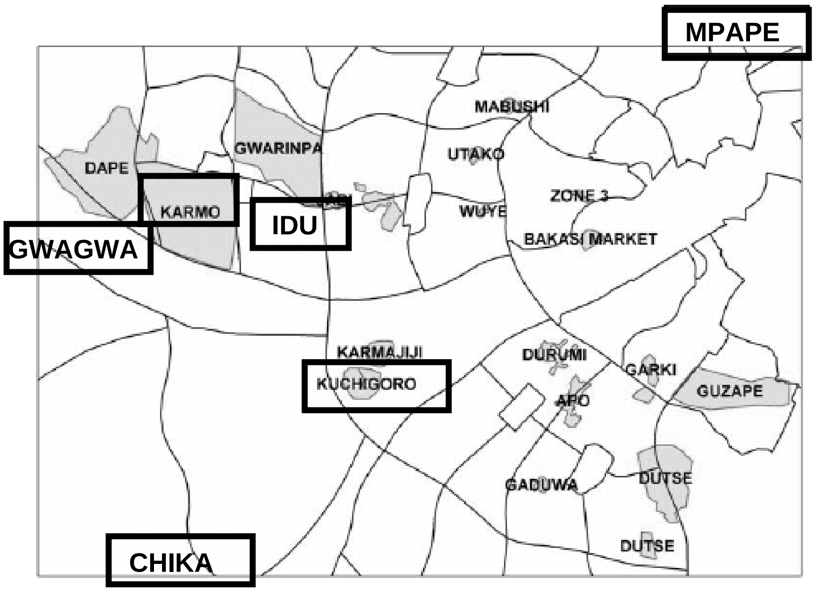


Figure 4. 1: Some squatter settlements in the FCC (approximate location of study sites in boxes) Jibril, 2006

4.2.2 Sampling of Respondents

Qualitative sampling methods, which due to the peculiar nature of the study sites and subjects, involved strategies that combined different (mixed purposeful) sampling techniques were applied in this study. For this work non-probability sampling methods, in particular, convenience sampling using the mixed purposeful approach with maximum variation (best case, worst case) as described by Johnson and Christensen, (2003) was employed.

4.2.3 Data Analysis

The information/data gathered during this field research were analysed and a description of the research findings and its interpretation are presented in Chapter 5. This process included analysing survey data using the spreadsheet software MS Excel, transcribing recorded interviews, organising and documenting information from observation notes and the processing and presentation of visual data.

Summarily, in view of the nature and objectives of this field study, the most important of which was to provide a picture of the water supply and sanitation situation for Abuja in general and specifically the peri-urban study settlements, different research approaches were applied for the different aspects investigated. These are outlined in the table 4.2 and brief descriptions of some of the methods listed are given in appendix A.

Table 4. 2: Summary of data collection methods employed in the field study

Specific Investigation Area	**Data Collection Method Applied**
Overall situation of study settlements	Observation; Walks; Informal interviews
Demographics	Survey by questionnaire/interview schedule
Water Supply coverage	Document Review; Survey by questionnaire/interview schedule; Key informant interview
Sanitation Provision	Document Review; Survey by questionnaire/interview schedule; Key informant interview
Wastewater Management	Document Review; Survey by questionnaire/interview schedule; Key informant interview; Observation
Acceptability /satisfaction	Survey by questionnaire/interview schedule
Social/health	Document review; Key informant interview; Survey by questionnaire/interview schedule;

4.3 Technology Selection

A wide range of methods and suggestions are available in the literature regarding sanitation technology selection methods. The procedure applied in the technology selection part of this study was adapted from recommendations from a variety of sources in the literature (Kalbermatten, et al. 1982; Cotton and Franceys, 1991; EHP, 1997; Brikke and Bredero, 2003, etc). The primary input into the process was however the findings of the field study. First a list of criteria was defined for the sanitation technologies based on predefined scenario objectives, in order to compile a shortlist of potential technologies to be inputted into the scenario development stage. The criteria potential technologies had to meet were based on the literature and issues identified from field study results and are as follows:

- *Human and Environmental health protection*: technologies must protect human health by acting as barrier against disease causing organisms (safe excreta handling, disposal or reuse); protect environmental health (no pollution of water sources or soil – onsite or downstream); should have minimal environmental impact i.e. low resource consumption e.g. water input.
- *Appropriate technology*: technologies must be relevant to local conditions e.g. site characteristics; they should use locally available resources (materials and skills) for construction, operation and maintenance.
- *Technical feasibility*: they must be appropriate as regards: physical site conditions, operational and maintenance requirements e.g. energy input; low maintenance requirements e.g. no or limited mechanical parts, and low operator skill.
- *Technology performance*: technologies must be robust (able to adapt to variations in hydraulic and compositional loads) and reliable under varying operational conditions.

- *Institutionally manageable*: technologies must be manageable by local infrastructure without requiring highly skilled personnel, high level or extensive training for staff. It is preferable that it can be accommodated in existing management capabilities.
- *Socially feasible*: technologies should encompass user preferences – desires, practices of potential users. An idea of this can be obtained by gathering information on existing, known or preferred technologies and cultural beliefs.
- *Affordable/low cost*: technologies must be affordable to users in terms of capital and recurrent costs. These should ideally not require external funding sources. Some technologies stand out as being typically low cost in comparison to others as such these are preferred.
- *Reuse possibilities*: technologies that allow or offer opportunities for the reuse of the treated wastewater are also preferred.

A review of sanitation technologies available in the literature was carried out and an initial shortlist of potentially applicable options was then drawn up. The requirements of the technologies from the initial selection shortlist were assessed against local conditions resulting in the exclusion of some technologies from the final options' list. The technologies were then grouped into sanitation system components i.e. technologies for collection, storage or transportation, treatment, and disposal or reuse.

4.4 Scenario Development

The purpose of the scenario development was to create a number of potentially feasible sanitation systems that are locally appropriate and sustainable from which users may select. The scenarios were developed using information gathered from the field study data (*problems; existing sanitation facilities; culture, attitudes and preferences; geology and climate; water supply; managerial resources; settlement characteristics*) and the result of the technology selection process. The process involved is as outlined in figure 4.2.

Based on the problems identified from the results of the field study, a set of objectives was defined for the sanitation systems scenarios, which were inputted into the criteria for technology choice and a technology options list was drafted, this was then used to develop the scenarios. The scenario objectives were as follows:

- *Human and environmental health protection*
- *Appropriate technology: Low tech; Low maintenance; socially acceptable*
- *Affordable: Low capital and recurrent cost*
- *Reuse possibilities where applicable*

The starting point in creating the scenarios was to define system conditions – determining the type of wastewater treatment technology (onsite, offsite, wet, dry, decentralised, centralised) to be applied in each potential scenario. This was followed by a decision on whether the treated wastewater will be reused or discharged into the environment and finally if the wastewater is to be separated at source or collected combined. Once these systems conditions were clarified, the system components were chosen and technologies appropriate for each system component was selected from the technologies options list resulting in each scenario.

The scenarios were then checked to confirm if they met the overall objectives previously defined for potentially sustainable sanitation solutions for the study area. Design and cost estimations were then carried out for selected scenarios.

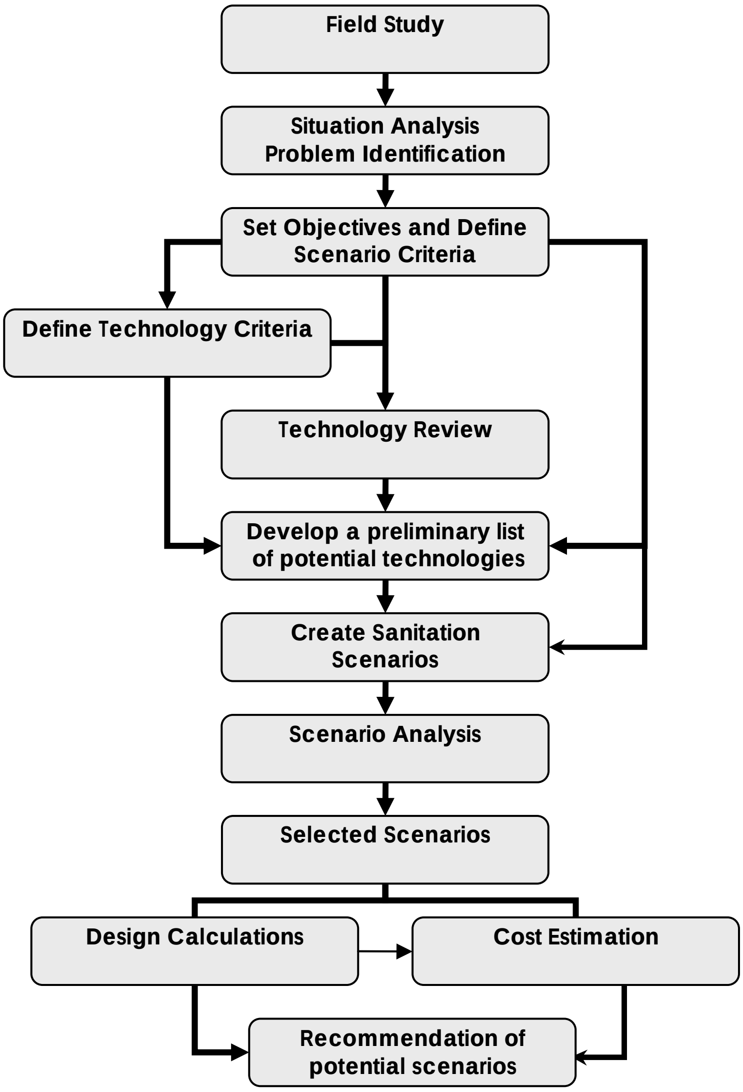


Figure 4. 2: Flowchart of scenario development process

4.5 Design Calculations

The design calculations for selected technologies are based on methods described in the literature, and are summarised in table 4.3. Due to limitations imposed by a lack of data, some assumptions were made in the design as such they are simple estimates rather than precise models.

Table 4. 3: Summary of technologies and design methods followed

Technology	Sources
Simplified Sewerage	Mara, (1996); Mara et al., (2001)
Waste Stabilisation Ponds	Mara, (1997, 2003)
Constructed Wetlands	USEPA (1988, 1993) and Reed et al., (1995)
Interceptor Tank	Mara, (1996)
Settled Sewerage	Mara, (1996); Bakalian et al. (1994)
Double Vault Toilet	Kalbermatten et al., (1982)
Urine Diversion Systems	Simple estimation was made for these systems following the design from Leal (2004), based on Oldenburg
Rottebehaelter	

4.5.1 Simplified Sewerage Design

Simplified sewerage system is utilised in one of the scenarios presented in Chapter 6. The design of the system is based on the method described by Mara (1996, 2001). Two methods are presented the self cleansing velocity method and the tractive tension method; both yield similar results but the tractive tension method leads to shallower sewer depths, thus lower costs as such this is preferred.

Tractive Tension Method – Hydraulics Design Steps:

1. Determine the Design Parameters
   a. *Design population:* average household size for the design area or a particular sewer section, multiplied by the number of households.

   b. *Total water consumption:* average per caput water consumption multiplied by the design population for the entire area or sewer leg.

   c. *Return factor*: refers to the percentage of total water consumption that ends up in the sewer. It is often assumed to be 85%.

   d. *Peak Factor*: reflects the variations in wastewater flow through the day. Taken as 1.8

   e. *Groundwater infiltration*: taken as negligible

2. Calculate Peak Wastewater Flow (q)

$$q = 1.8 \times 10^{-5} p \cdot w$$

p = contributing population
w = water consumed (l/c/d)
q is subject to a minimum value of 1.5 l/s

- Initial Flow (q_i): flow at the start of the design period
- Final Flow (q_f): flow at the end of the design period

3. Calculate minimum sewer gradient (I_{min})

$$I_{min} = 5.64 \times 10^{-3} q^{-6/13}$$

where $q = q_i$

4. To determine sewer diameter, calculate

$$q_f/I_{min}^{1/2}$$

5. Locate the value obtained in step 4 on the design table for simplified sewers based on Manning's equation for which the proportional depth of flow d/D is between **0.2 and 0.8**, (for table see Mara 1996, pg. 120).

6. Note the sewer diameter given at top of column where this value of $q_f/I_{min}^{1/2}$ is found.

7. Read off the $v/I^{1/2}$ value corresponding to the $q_f/I_{min}^{1/2}$ in step 6.

8. Estimate v (ms^{-1}) from $v/I^{1/2}$, should be greater than 0.5 ms^{-1}

Draft Sewer Layout

The sewer network (condominial and collector branches) was developed based on the following conditions: natural topography, network simplicity, low excavation depths, and avoiding crossing roads; each property will have an inspection box/grease trap and a junction box will be placed at every major turn in the sewer. The sewer routes were drawn and other parameters calculated using the Simplified Sewerage PC Design software.

4.5.2 Waste Stabilisation Pond Design

The pond system (anaerobic, facultative and maturation) design follows the method described by Mara, (1997, 2003) for pond systems in tropical conditions.

Design Input

- *Temperature*
- *BOD loading*
- *Wastewater flow*
- *Sludge Accumulation Rate: 0.04 m^3 /yr*

4.5.2.1 Anaerobic Pond Design

1. Calculate Residence Time (θ_a)

$$\theta_a = \frac{L_i}{\lambda_v}$$

where: L_i = influent BOD (mg/l)

λ_v = volumetric BOD loading (g/m^3)

2. Calculate Pond Volume (V_a)

$$V_a = Q * \theta_a$$

where: Q = wastewater flow (m^3d)

θ_a = as defined above

3. Calculate Pond Area (A_a)

$$A_a = \frac{V_a}{D}$$

where: D= pond depth (2 – 5 m)

4. Estimate BOD Removal

Temperature dependent design value table is presented in (Mara, 2003, pg. 109)

5. Estimate Sludge Accumulation Rate (V_s)

V_s = *accumulation rate (0.04 m³/yr) x contributing population*

6. Estimate Total Pond Volume (V_t)

$$V_t = V_a + V_s$$

7. Sludge Removal Frequency n (yrs) for Anaerobic Pond

$$n = \frac{(1/3 \times V_a)}{sludgeaccumulationrate \times population}$$

4.5.2.2 Facultative Pond Design

1. Calculate Area of Pond (A_f)

$$A_f = \frac{10 \cdot L_i \cdot Q}{\lambda_s}$$

where: L_i = influent BOD (mg/l)
Q = wastewater flow (m^3d)
λ_s = surface BOD loading (kg/ha d)

2. Calculate Residence Time (θ_f)

$$\theta_f = \frac{2 \cdot A_f \cdot D}{2Q_i - 0.001A_f \cdot e}$$

where: D = pond depth (m)
e = net evaporation rate (mm/d)

3. Estimate BOD Removal (L_e)

$$L_e = \frac{L_i}{1 + k_1 \cdot \theta_f}$$

where:
$k_{1(T)} = k_{1(20)}\ (1.05)^{T-20}$
$k_{1(20)}$ = 0.3 day^{-1} and 0.1 day^{-1} *for primary and secondary facultative ponds respectively*

4.5.2.3 Maturation Pond Design

1. Estimate helminth egg required removal (%)
   Determine % removal achieved in anaerobic pond
   Determine % removal achieved in facultative pond
   Required removal in Maturation Pond = 100[(eggs in fac pond effluent - 1)/(eggs in fac pond effluent)]

2. Determine required residence time in Maturation Pond θ_m (days) from design values for egg removal table (Mara, 1997)

3. Calculate Maturation Pond Area A_m (m^2)

$$A_m = \frac{2 \times Q_i \times \theta_m}{2D + 0.0001 \times e \times \theta_m}$$

4. Estimate BOD Removal
   Inf. BOD * Removal Factor

5. Estimate eggs in Maturation Pond effluent (E_e)

$$E_e = E_i \times (1 - removalfactor)$$

6. Estimate Faecal Coliform Removal (N_e)

$$N_e = \frac{N_i}{\left[(1 + k_T\theta_a)(1 + k_T\theta_f)(1 + k_T\theta_m)^n\right]}$$

4.5.3 Small Onsite Constructed Wetlands

The method presented here is based on constructed wetland design by Reed et al (1995) and the 'Plug Flow Model for Onsite Wetland Systems' USEPA (1993), recommended for single households or small communal systems. The plug' flow model presented here is a simplified design procedure for small scale onsite horizontal flow systems:

1. Determine the design flow

2. Define the influent and effluent: BOD_5 (mg/l), TSS (mg/l)

3. Select filter bed media type, size range, and depth. Define the effective water depth and temperature.

4. Select plant type - Reeds *(Phragmites), Cattail, Ornamental etc.*

5. Calculate bed surface area (As):

$$A_s = \frac{Q[\ln(C_o / C_e)]}{k_t \cdot d \cdot n}$$

Where: Q = wastewater flow (m³)
C_o =influent BOD (mg/l)
C_e = effluent BOD (mg/l)
k_t = rate constant
d = depth (m)
n = porosity

As a safety factor, use a rate constant k_{20} = 75% of the base value (1.104 d^{-1}); for design of small on-site systems k_{20} = 0.828 d^{-1}. For other temperatures estimate k_T using $k_T = k_{20} (1.06)^{T-20}$

6. Determine Retention Time: t (days)

$$t = \frac{\ln(C_o / C_e)}{k_T}$$

7. Determine the wetland dimensions

   Assume (L:W) = 2:1, and calculate bed length (L) and width (W) from previously determined surface area.

   Note: An aspect ratio of 2:1, and a bed depth of 0.6 m will satisfy Darcy's Law constraints on hydraulic design of the bed, so hydraulic calculations are not required. However hydraulic calculations are necessary if site conditions do not allow L:W = 2:1 and 0.6 m depth for the bed.

8. Estimate TSS Removal (mg/l)

   $$C_e = C_o \times (0.1058 + 0.0011(HLR))$$

   where: HLR = hydraulic loading rate (mg/l)

   $$HLR = \frac{Q}{A_s}$$

4.5.4 Settled Sewerage and Interceptor Tank Design

4.5.4.1 Interceptor Tank Design

The interceptor tank is required as a settling device for the wastewater prior to discharge into the settled sewer and the design is based on one compartment septic tank design by Mara (1996).

1. Calculate Sedimentation

   a. Hydraulic Retention Time (t_h) days

      $t_h = 1.5 - 0.3 \log (P \cdot q)$

      where P = contributing population

      q = wastewater volume (l/c/d)

   b. Volume V_h (m^3)

      $V_h = 10^{-3} \cdot P \cdot q \cdot t_h$

2. Calculate Sludge Digestion

   a. Time t_d (days)

      $t_d = 30\ (1.035)^{35-T}$

   b. Volume V_d (m^3)

      $V_h = 0.5 \times 10^{-3} \cdot P \cdot t_d$

3. Estimate

   a. Digested Sludge Storage Volume V_{sl} (m^3)

      $V_{sl} = r \cdot P \cdot n$

      where r = sludge accumulation rate (m^3)

      n = desludging interval (yrs)

   b. Scum Storage Volume V_{sc} (m^3)

      $V_{sc} = 0.4\ V_{sl}$

4. Estimate Total Tank Volume V_T (m^3)

   a. $V_T = V_h + V_d + V_{sl}$

4.5.4.2 Settled Sewerage Design

The method described by Mara (1996), and Otis and Mara (1985) is applicable for the design of the settled sewerage system and is as follows:

1. Determine the Design Parameters
   - *Design population:* average household size for the design area or a particular sewer section, multiplied by the number of households.
   - *Total water consumption:* average per caput water consumption multiplied by the design population for the entire area or sewer leg.
   - *Return factor*: refers to the percentage of total water consumption that ends up in the sewer. It is often assumed to be 80% or 85%.
   - *Peak Factor*: reflects the variations in wastewater flow through the day. Taken as 1.5

2. Calculate Peak Flow q_{h} - per household (l/s)

   $q_h = 1.5 \times 10^{-5} p \cdot w$

   where, p = household size

   w = water consumed (l/c/d)

3. Select sewer section for hydraulic analysis on the basis of each section having reasonably uniform gradients or flow

4. Create with table ten columns as follows:
    - *Column 1* = Station number: number assigned to point at which each section starts, commencing from <u>downstream</u> end of sewer
    - *Column 2* = Station elevation: elevation of each station above datum (taken here as elevation of Station 1) (m)
    - *Column 3* = Distance: <u>horizontal</u> distance of each station from Station 1 (m)
    - *Column 4* = Elevation difference over section: difference between elevation of adjacent stations (m)
    - *Column 5* = Section length: difference between station distances (Col. 3) of adjacent stations (m)
    - *Column 6* = Average section slope: column 4 ÷ column 5 (m/m)
    - *Column 7* = No. of connections served: cumulative no. of compounds connected upstream of downstream end of section
    - *Column 8* = Design flow: peak flow in section i.e. column 7 × peak flow per household (l/s)
    - *Column 9* = Sewer diameter: diameter (mm) selected by designer for each section (*note: may need to change if initial choice proves to be inadequate*)
    - *Column 10* = Flow at full pipe: estimate using $Q = 2.4 \times 10{-}4D^{8/3}i^{1/2}$

    Note: If Q for Column 10 > Column 8 then sewer diameter is ok if not then select larger diameter pipe

5. For critical sections i.e. sections with zero gradient, calculate the hydraulic gradient (i) for the section of sewer when flowing just full using:

    $$\mathbf{Q = 2.4 \times 10^{-4}\, D^{8/3}\ i^{1/2}}$$

    where, Q = flow (l/s)

    D = sewer diameter (mm)

6. Calculate max. elevation to which hydraulic gradient rises:

    $= i \times L$

    where, i = hydraulic gradient as calculated above

    L = length of sewer (m)

Note: hydraulic gradient must be below the invert of outlet of any interceptor tank to avoid backflow

Due to data limitations, assumptions will made based on the simplified sewer design for the settled sewerage.

4.5.5 Double Vault Systems

Vault volume designed assuming one year each for filling and resting.

$$V = \frac{4}{3} \times R \times P$$

where, R = accumulation rate and P = contributing population

4.5.6 Urine Collection Tanks

The volume of the urine tanks was based on the following assumptions:

- Urine production (l/c/d): 1.5
- Sanitisation time: 1 – 12 months (post filling)
- Household size: 6
- Collection intervals: 30 days

Holding Tank Capacity = *urine production (l/c/d) • contributing population • time (d)*

4.6 Scenario Comparison

The different scenarios were compared based on cost and other factors such as: complexity, social acceptance, resource consumption and reuse potential.

4.6.1 Cost Analysis

The cost analysis was done using the dynamic cost comparison method of the Laenderarbeitsgemienschaft Wasser (LAWA), and focused on the assessment of the scenarios based solely on costs. The NPV analysis is based on the concept that the value of a unit of currency today is worth more than the same in say five years i.e. the time value of money.

In this comparison all scenarios were assumed to have similar benefits, thus no benefits are included in the analysis (LAWA, 2005; Otterpohl and Meinzinger, 2005; Collier and Ledbetter, 1988). Costs, capital (construction, labour, material, etc.), annual operational costs and replacement costs were factored into the analyses based on the lifetime of the scenario component being considered.

The following procedure was applied:

- cost estimation: determination of capital, replacement and operating costs
- determination of lifetimes of the various scenario components
- selection of an appropriate discount rate

- calculation of the conversion factors
- determination of the net present value of costs (capital and O&M) by discounting them to the present time

Conversion of Costs into Net Present Values (NPV)

Once the costs had been compiled, the NPV of each alternative were determined using the following conversion factors:

- for one time costs (initial capital investment, and replacement costs)

$$PV = \left[\frac{1}{(1+i)^n}\right]$$

where:
PV = present value
n = time period
i = discount rate

- for annual costs (O&M costs)

$$PV = \left[\frac{(1+i)^n - 1}{i \times (1+i)^n}\right]$$

The sum of these present values of capital and operating costs then gave the net present value for each scenario; assumptions made include: unified component lifetime and evaluation time periods.

Cost Comparison

The NPV of all the scenarios are then compared within the following restrictions: NPV must never be negative and should be preferably greater than zero. The scenario with the least NPV is deemed the most preferable alternative economically.

A discount rate based sensitivity analysis was carried out to determine the influence of discount rates on the respective NPV. This was done by simply calculating the NPVs of each scenario at different discount rates (8%, 10% and 12%).

4.6.2 Overall Scenario Comparison

The scenarios were further compared using the following set of criteria, based on suggestions from the literature and previously stated scenario objectives: cost (capital and recurrent), simplicity (ease of construction, O&M), social acceptance, resource consumption (water, land, energy), and product reuse potential.

Chapter 5: Results of the Field Study

The findings emanating from the field study and other activities carried out as part of this research work are presented and discussed in this section.

The field study was conducted in Abuja, the new Federal Capital Territory (FCT) of Nigeria and covers the Federal Capital City (FCC) and selected informal peri-urban settlements around the FCC. The study commenced following the completion of logistic arrangements such as notifying and obtaining approvals for the field study from responsible authorities; and covered the period between January to June 2005, which falls between the end of the harmattan season (October to March) and the beginning of the rainy season (April to September) in Nigeria. Results obtained from review of secondary data sources, interviews with key informants, observations, and surveys carried out in the peri-urban settlements and the FCC are presented and discussed.

5.1 Environmental Profile of Abuja

5.1.1 Location

Abuja the new capital city of Nigeria is officially known as the Federal Capital Territory (FCT) and covers a land area about 8,000 km^2. It lies between latitude 8.25 N and 9.20 N and longitude 6.45 E and 7.39 E; it is bounded to the North by Kaduna State, to the East and South East by Nasarawa State, to the West by Niger State, and to the South by Kogi State; the FCT falls within the geographical centre of the country. The issues surrounding the creation and development of Abuja have been discussed in Section 2.5.

5.1.2 Administrative Boundaries

Following the creation of the Federal Capital Territory (FCT), a development Master Plan was prepared for the territory with a part (North Eastern Quadrant) of the territory designated as the Federal Capital City (FCC). The FCC is the administrative seat of government housing the Minister who is the administrative head of the FCT; the study areas comprise of the FCC and selected peri-urban areas. The FCT is made of several area councils, namely: Abaji, Abuja, Bwari, Gwagwalada, Kuje, and Kwali area councils, see figure 5.1.

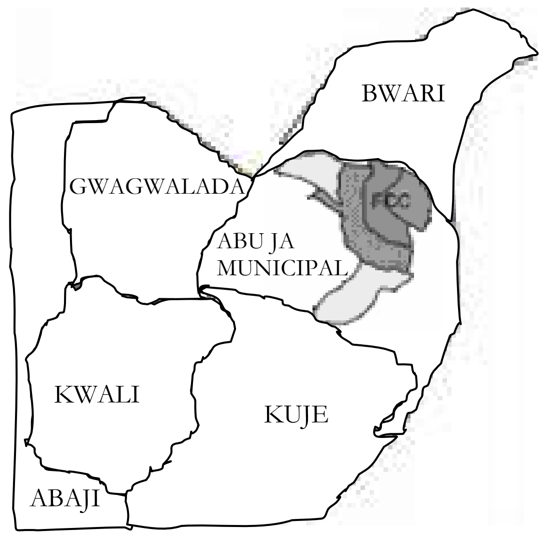


Figure 5. 1: Map showing area councils of the FCT of Nigeria and the location of the FCC

5.1.3 Geophysical Characteristics

The effects of weather and climate are important to various aspects of human and environmental life, they are particularly important in the selection and design of sanitation technologies as such climatic conditions prevalent in the FCT are discussed as follows based on meteorological records from the Federal Ministry of Aviation (FMA), Abuja. Two distinct seasons are experienced in the FCT: the rainy season and the dry season. The rainy season covers the period between April and October, while the dry season begins at the end of October and continues through to the end of March.

Rainfall: in general precipitation patterns delineate the seasons in Nigeria and in the study region as well. The rainy season is characterised by heavy and frequent rainfall, and the dry season characterised by little or no rainfall depending on the region – the frequency and intensity of rain events decreases as one moves northwards with the coastal regions in Nigeria experiencing rainfall all year, however, with reduced frequency in the dry season. In the FCT, average monthly rainfall in the rainy season (April – October) is between 107 mm and 1707 mm and less than 75 mm in the dry season (November – March), (see table 5.1 for data on the precipitation pattern in the study area). The high rainfall experienced represents an opportunity for augmenting water supply at the household or communal level in the FCT with rainwater harvesting. Currently there are shortages in many parts of the FCT during the dry season; if this abundant resource is tapped in the rainy season, stored rainwater can easily be used after treatment by filtration, boiling and/ or disinfection by UV irradiation (if for human consumption) at household or communal levels.

Table 5. 1: Average monthly rainfall (mm) for the FCT over a period of 11 years

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1990	0.0	8.0	0.0	68.1	177	214	349	234	176	142	29.9	38.5
1991	0.0	0.0	41.1	100	226	252	197	381	137	166	0.0	0.0
1992	0.0	0.0	9.8	104	152	187	177	261	298	134	53.1	0.0
1993	0.0	0.0	37.2	40.2	152	241	297	376	225	135	27.3	0.0
1994	0.0	0.0	0.8	90.7	177	199	1707	555	284	150	0.0	0.0
1995	0.0	0.0	26.7	58.3	117	115	221	417	199	154	1.4	0.0
1996	0.0	16.9	2.5	70.5	239	174	211	327	235	140	0.0	0.0
1997	0.0	0.0	27.0	76.7	167	194	187	225	247	198	9.5	5.3
1998	0.0	28.7	9.9	86.5	107	195	310	196	181	322	0.0	0.0
1999	0.0	0.0	20.6	81.9	228	162	345	345	283	0.0	0.0	0.0
2000	0.0	0.0	0.0	53.2	139	145	275	255	110	0.0	0.0	0.0

(*Source: Federal Ministry of Aviation, Abuja.)*

Temperature: the efficiency of most biological treatment processes (anaerobic digestion, compositing, dehydration, etc) employed in sanitation technologies are temperature dependent. Temperature is either required to enable the biochemical breakdown occur or assist in killing off pathogenic organisms, thus it is one of the factors that affects the sanitisation level of the end product. It is typically hot during the dry season and cooler during the rainy season in Nigeria. In the FCT region, the mean monthly temperature ranges from 27.7°C – 39.5°C. In the dry season (November to April) temperature ranges from 33.2°C – 39.5°C, and 28°C – 34°C for the rainy season (April to October). Table 5.2 shows temperature data for the study region.

Table 5. 2: Average monthly temperature for the FCT

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1990	35.2	35.7	36.3	33.9	34.5	30.8	29.2	30.0	30.0	31.5	33.8	33.3
1991	34.8	37.3	36.2	33.7	34.3	31.0	29.0	27.9	30.6	30.3	33.6	34.5
1992	34.5	37.7	37.0	34.7	32.5	29.8	28.1	27.7	29.1	31.5	33.4	35.5
1993	35.3	37.5	36.1	36.6	33.7	31.2	29.5	29.6	30.6	32.1	34.1	34.7
1994	35.1	37.5	39.5	35.1	32.5	31.2	29.5	28.7	29.8	31.5	34.3	35.1
1995	36.0	38.0	36.0	37.3	34.0	31.6	29.9	29.9	30.3	31.4	34.5	33.5
1996	36.3	37.9	37.7	36.6	32.5	30.7	29.5	28.8	29.4	31.5	35.2	36.2
1997	36.1	37.6	37.2	34.1	32.1	31.0	29.5	29.5	30.9	31.3	33.2	34.2
1998	35.3	38.0	30.1	37.6	33.4	31.3	29.1	28.3	29.9	31.1	34.5	35.2
1999	35.4	36.7	36.9	35.0	32.7	31.0	28.9	28.8	29.4	30.7	34.3	35.2
2000	35.9	35.8	38.2	35.3	33.7	30.6	29.0	28.9	30.1	31.2	35.0	35.0

(*Source: Federal Ministry of Aviation, Abuja.)*

Relative Humidity: humidity is at its highest, up to 90 % during the rainy season and lowest during the dry season. Humidity data obtained from the Federal Ministry of Aviation for the years 1990 – 2000 is presented in the table 5.3. Humidity is an important factor especially when waterless sanitation systems (e.g. dehydration based EcoSan systems) are considered as extremely high humidity may contribute to such systems malfunctioning unless this factor has been duly considered in the design.

Table 5. 3: Monthly averages of relative humidity data for the FCT

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1990	38	28	24	69	78	81	87	86	82	79	66	68
1991	35	54	60	73	81	82	89	90	86	80	57	66
1992	28	21	52	76	77	83	85	86	88	77	40	57
1993	29	38	55	65	67	80	85	84	81	77	50	45
1994	46	28	32	68	78	85	81	86	85	75	42	46
1995	41	28	38	66	85	79	84	85	83	77	50	43
1996	43	52	60	65	76	82	85	87	85	79	39	41
1997	40	22	45	72	78	81	87	87	81	79	66	45
1998	38	35	35	65	80	86	87	84	84	79	58	43
1999	43	50	62	62	76	81	86	87	83	78	64	36
2000	41	26	38	65	72	81	85	87	85	77	51	40

(*Source: Federal Ministry of Aviation, Abuja.)*

Soil and Geology: the soil profile of the FCT area is composed of mainly deep well drained Orthic Luvisol (Typic Paleustalfs) and deep well drained Chromic Luvisol (Typic Haplusstalfs), its characteristics are summarised in the table below. The geology of the FCT is composed of the basement complex (the oldest in Nigeria) generally regarded as Pre-Cambrian rocks (Wupa WTP EIA, 2004).

Table 5. 4: Characteristics of soils within the FCT

Depth (cm)	**Description**	**PSD %**			**pH**
		Sand	Silt	Clay	
0–30	Brown (10YR 5/3) coarse sand: structure-less; single-grained loose; common fine roots; gradual smooth boundary.	31	27	12	6.6
30–50	Brown (10YR 5/4) loamy coarse sand: structure-less loose; few fine roots; abrupt smooth boundary.	20	21	40	5.6
50–100	Red (2.5YR 4/6) fine gravelly sandy clay loam; massive few fine roots; abrupt smooth boundary common fine roots; gradual smooth boundary.	34	13	20	6.3
100–150	Red (2.5YR 4/6) fine gravelly sandy clay loam; massive few fine roots; fine quartz and pergmatic fragments.	21	16	42	6.0

(*Source: EIA for Wupa wastewater treatment plant, 2004)*

Vegetation and Wildlife: the FCT falls within the Guinea Savannah belt an ecological zone characterised by trees and shrubs scattered among open grassland (Federal Ministry of Aviation, 2001). A diverse range of wildlife can be found in the FCT. Monkeys, birds, a variety of reptiles (pythons and poisonous snakes, rainbow lizards, etc), the African giant snail and other snails are among the animals found in the FCT. The most common fishes found in the FCT are tilapia and catfish. A wide variety of insects and arthropods can also be found in the FCT.

Water Resources: two main sources of water exist in the FCT: surface and ground water. Studies by the FCDA reveal that no large scale groundwater resource is present in the FCT. Surface water is present in form of rivers and streams. Some of the main rivers are: Usuma, Wupa, Ushe, Wuye, Orozo. Although the availability of surface water is limited by seasonal factors, it is however found in greater abundance than groundwater (FCDA, 1979; Wupa EIA, 2004). These surface waters are the source of water for the water utility bodies from which they extract, treat and distribute to the consumers in the FCC.

5.1.4 Socio-economic Characteristics

The area now known as the FCT was occupied by the Gwaris. With the creation of the FCT came the displacement of the indigenous population who lived in the 845 villages found within the FCT some were resettled within their respective states of origin from which the FCT area was carved out, others chose to remain in new settlements within the FCT. The move to Abuja by the Federal Government has been accompanied by an influx of people from all parts of Nigeria. It can be assumed that most if not all ethnic groups now call the FCT home, as such it has become a melting pot of culture and diversity in Nigeria. Table 5.5 and figure 5.2 show the population statistics for the FCT in 1991, these are figures for the last census held in Nigeria (source: National Population Commission). A new census has just been concluded in March 2006 the results of which are not available as at the time of writing this report.

Table 5. 5: Population profile of the FCT (Wupa EIA, 2004)

Area Council	Male	Female	Total
Abaji	10833	10248	21081
AMAC	129388	97561	226949
Gwagwalada	42656	36650	79306
Kuje	22422	21916	44338
Total	**205299**	**166375**	**371674**

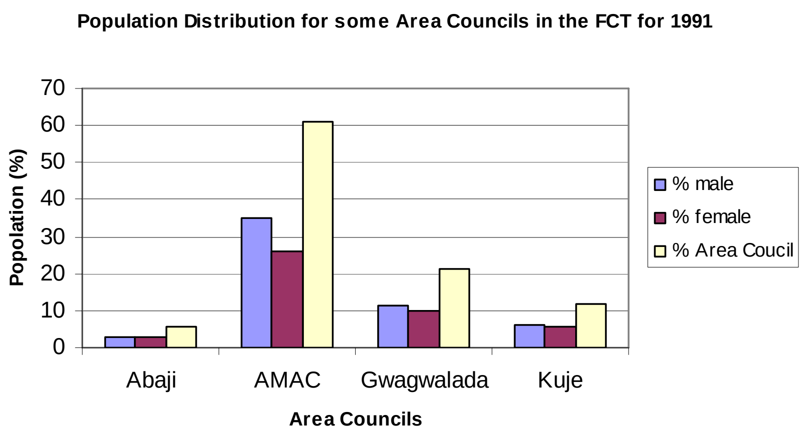


Figure 5. 2: Population distribution for some Area Councils in the FCT (Wupa EIA, 2004)

According to the Master plan the maximum population of the FCC should be about 3.1 million. Conflicting population figures were obtained during the course of the study ranging from 1 million to 6.7 million depending on source; according to a consultant's report (Citiserve, Report in 2003), the FCT currently has about 6.1 million inhabitants, however, the Abuja Environmental Protection Board (AEPB) in-house studies within the last one year, puts the current population of the FCT at 6.7 million. The result of the 2006 National Census should shed some light on the actual population of the FCT once it is available.

Economic Activity: the FCT is primarily administrative in function; economic activity is largely comprised of the construction and service sectors although there are several small to medium scale industries as well. Even with the relocation to Abuja, Lagos still remains the economic capital of Nigeria. Although the main occupation of the indigenous population is farming, in general the residents of the FCT are mainly civil servants and other government officials, artisans, construction workers, traders, etc.

5.1.5 Water Supply Infrastructure in the FCC

Management: water supply in the FCT has been the responsibility of the FCT Water Board since its creation in October 1989. Before this water supply was the responsibility of the Water and Sewage Division of the Engineering Department of the FCDA. In addition to extracting, treating and distributing treated water to its consumers, the Board was specifically created to:

- Control, manage, install, maintain all water works and services vested or to be vested on the Board by the Minister of the FCT.
- Ensure the supply of potable water of adequate quantity and quality for the FCT at economic rate.
- Encourage the conduct of research for the purpose of carrying out its functions.
- Provide such research result to the Minister of the FCT for input into policy formation processes relating to water management and pollution control. (Source: publication of the FCT Water Board information section)

The Board has five main sections in its organisational structure; they are as follows in table 5.6:

Table 5. 6: Organisation structure of the FCT Water Board

Department	Function
Personnel	General administration and human resources management.
Finance & Supply	Financial administrative duties.
Commerce	Billing, distribution of bills and revenue generation.
Planning & Operation	Water connections, distributions and maintenance of distribution pipelines and all water infrastructural facilities; planning and budget monitoring.
Rural Development	Rural water supply and mobilisation.

Source: Abuja Water Board, 2005

Water Sources and Capacity: the Jabi Dam with a reservoir capacity of 6 million m^3 and a treatment plant output of 340 m^3/hr was the source of water for the FCT from 1981–1987. Currently, the main source of potable water in the FCT is the Usuma Dam water works; located at about the area with the highest altitude in the FCT, the Usuma Dam has a maximum capacity of 100 million m^3. Due to the altitude of the dam's location the water treatment plants are fed mainly by gravitational flow, however, a pumping station allows transport of raw water to the water works in dry season when the reservoir level is low. There are two water treatment plants at the Usuma dam, both with capacities of 5000 m^3/hr. Two other treatment plants are located in Gwagwalada with capacities of 200 m^3/hr and 100 m^3/hr respectively.

Water Treatment and Quality: the water treatment processes in place at the water works are as follows: aeration, coagulation, flocculation, rapid sand filtration, chlorination and neutralisation. The onsite laboratory carries out quality assurance functions; water quality is checked before distribution and at various points along the distribution path and occasionally water samples is collected from homes for quality checks.
The quality team consists of three sections:

- *Physicochemical*: responsible for quality control analyses of physical and chemical properties of the raw and treated water.
- *Bacteriology*: carries out microbial analysis of the same.
- *Biology*: responsible for monitoring the aquatic ecosystem and ecology of the catchments' area as it affects raw water quality.

Water Distribution and Consumption: treated water is transported by gravity through steel pipes to storage tanks at various locations throughout the FCT and from there into the distribution network.

Table 5. 7: Water storage tanks and the area served. (Sources: FCT Water Board; Krohs, 2004)

Tank Number	Tank Location	Capacity (m^3,)	Target Area
3, 3.1, 3.2	Maitama	24000	Wuse, Gwarinpa, Maitama, Asokoro
4, 4.1, 4.1.1	Asokoro	24000	Garki, Central Area, Asokoro
Usuma	Kubwa	12000	Kubwa Satellite Town
4	Karu, Nyanya	10000	Karu, Nyanya
Usuma	Airport	10000	Airport and environs

According to official figures from the FCT Water Board, the Board supplies water to about 2.5 million people in the FCC. The rest of the territory especially the rural areas are served with water from boreholes.

For the FCC, information obtained from a review of existing documentation, key informant interviews and observations, reveals that the FCT Water Board serves the FCC and most homes have access to water piped directly into the homes. Most residents use this water for all their needs, however, informal discussions revealed that some people preferred bottled water as their drinking water source (especially for babies and young children) and the public water is used for all other needs; coverage for residents and offices is almost total.

As mentioned in earlier sections of this report, the FCC is divided into three developmental areas: Phases I, II, and III. Water supply infrastructure is fully developed with good service available for Phase I. Infrastructure and service is partial but almost complete for Phase II. As earlier stated Phase III of the FCC is still at the development plan and preliminary engineering design stage (Ike, 2004) as such no water supply infrastructure has been provided for this area as at the time of this study. Krohs (2004) reports that there are legal developments in parts of Phase III and that these areas are served by connections to the water supply system of Phase I.

Table 5. 8: Common sources of water in the FCT

Typical Sources of Water	**Use**	
	Urban /Peri-urban	**Rural**
Bottled water, Packet water	Drinking, Babies and Children	Drinking
Piped: Potable	All Needs	All needs
Well	Washing, Bathing	All needs
Borehole	All needs	All needs
Stream, Rivers	-	All needs
Rainwater	-	Washing, Bathing, Flushing
Vendors: Potable	All needs	All needs

Seasonal variation in demand for water affects water supply in the FCC especially in the dry season (Ozohu-Suleiman, 2003).. Some other factors affecting water availability and supply are as follows:

- The Usuma dam is fed by the Usuma River, which in turn is largely replenished by rainwater. In the dry season when there is no rain, extracting sufficient quantities of water for treatment and supply becomes quite difficult.
- Demand for water in the dry season is often high because of the high temperature and low humidity.

Interviews with officials of the FCT Water Board, reveal that at the time of this study (dry season), demand has been higher than the FCT Water Board is able to meet for the following reasons, climate induced increase in demand, population growth and seasonal reduction in the capacity of the Lower Usuma dam for example, as such, cases of shortages and irregularity in supply were reported in some areas of the FCC at the time of this field study.

Although data on consumption is not available from the FCT Water board as most homes are not metered, the Board assumes an average of 100 l/p/d. Metering of residences in the FCT is currently being introduced; two types are being considered, the conventional water meters and the pre-paid water or pay–as–you–use system, which will only supply the amount of water for the consumer has already paid; the system will be in operation in the near future.

Water Rate and Collection: while there may be some truth to the general perception in many cultures about water being free, its extraction, treatment and distribution is certainly not. As such water is not free in the FCT, its supply and enjoyment attracts a cost to the consumers. Two types of charges are applicable for water supply namely: Fixed Rate and Metered Rate. The metered rate is a recent development and is not widely available in most homes. Currently the most common billing system is the fixed rate based on the following factors:

- Type of building: domestic, commercial, public, private.
- Purpose of Building: residential, hospital, hotel, offices, etc.
- Ownership of building: government, individual, corporate, etc .
- Number of rooms in building: e.g. for flat rate - 1, 2, 5 etc bedrooms.

These rates are subsidised particularly for government owned residential quarters. Unlike in some western countries, the water rate does not include a charge for wastewater treatment. Collection of the water charge is through designated banks in the city.

Satisfaction with Water Supply service: although no specific survey was carried out on the issue of satisfaction with the water supply system within the FCC, discussion with a few residents of the FCC revealed a general satisfaction with the water supply services available. The convenience of simply turning the tap and having water was the most important factor for consumers from the discussions. Those who believed services were good were mostly those who lived in sections of the city where water supply is regular and piped water is always available. However in some sections of the city where supply is somewhat erratic, residents complained about the irregularity especially about having to be up at early hours of the day to collect water from the tap for storage and use through the day.

5.1.5.1 Challenges of Water Supply in the FCC

According to the sources interviewed at the FCT Water Board the following are some of the challenges facing the Board in the discharge of its duties:

- Funding.
- Seasonal shortages at extraction sources.
- Inability to keep up with demand for water.
- Non payment of charges by defaulting consumers and irregular payments by some paying consumers.
- Illegal connections to water distribution pipes by private residences.

- Vandalism of water distribution pipes by water vendors collecting water for sale.
- Illegal usage of water by small private business concerns such as roadside car washes and packet water producers and block moulding factories, most of whom operate from their homes and pay residential rates if at all while consuming water for business.

The problems highlighted above has meant that the FCT Water Board has been unable to fully meet the demands for water and as such supply has been irregular in some parts of the FCC as indicated by reports and some residents of these areas. This irregularity in supply has resulted in some residents particularly those outside of Phase I acquiring private supply systems such as boreholes and overhead storage tanks.

Water supply problems do exist in the FCC and the FCT in general. The main reasons as gathered in this field study are:

System Overload: the supply system is currently overloaded. There are simply many more people exerting a demand on the system than was originally planned for. The system supplies not only those living within the developed areas, but also partly those living in the peri-urban areas of the FCC. The demand exerted by non residential consumers often illegally, represents a high and unexpected burden on the system. Krohs (2004) reports that the Usuma dam reservoir was planned for 650,000 inhabitants but currently serves an unknown population several times in excess of the planned capacity, according to sources interviewed, 2.5 million are currently served (Lawal, FCT Water Board, personal communication) other sources give higher figures.

Undervaluation of Water by Consumers: observation on water use and attitude to water in some homes visited within the FCC suggests a lack of consciousness of the value of water among the consumers. This is reflected in the fact that many still have the cultural perception that 'water is free' and in addition to this, the belief that water is a right, it belongs to all and must be available at all times. One of the biggest challenges of the Board is getting people to pay for the water they consume. Instances were observed where people had showers for longer than 20–30 minutes several times daily, water lawns or wash cars daily with potable water, neglect to repair leaking taps which sometimes drip all day. All of these actions waste water and indicate a lack of consciousness that water is a precious commodity and must thus be used wisely.

Illegal connections: the scourge of illegal connections and tapping is exerting a heavy toll on the water supply system. Water vendors serving the peri-urban communities simply break supply pipes in order to collect water for sale to peri-urban consumers (see figure 5.3, 5.4, 5.5). It is not uncommon to find water continually leaking from these points even when not being used, this represents a big loss to the distribution systems, not to mention the degradation of water quality in the pipes as a result of the introduction of dirt and wastewater into the distribution pipes and its attendant risks to public health (typhoid fever is one of the diseases people suffer even in the city areas).

Non-paying commercial consumers: there is an innumerable amount of commercial water users who do not pay for water because they are not legally connected to the supply system. These are often heavy water consuming businesses, examples are car washes, block moulding factories, home based water / juice production industries, etc. The consumption of this group is unaccounted for and represents a loss to the distribution and revenue generation systems of the FCT Water Board.

Figure 5.3: Water vendors collecting water for sale (Krohs, 2004)

Figure 5.4: Illegal pipe connections to water mains (Krohs, 2004)

Figure 5.5: Losses due to pipe damage from illegal connections (Krohs, 2004)

5.1.5.2 Recommended Improvement Measures

So far the FCT Water Board has put some measures in place to alleviate the challenges facing water supply in the FCT. For example metering is employed as a means of discouraging wastage and managing water demand. Also gathered from key-informant interviews is that the Water Board is currently implementing plans to obtain water from sources outside the FCT, from the Gurara Falls in nearby Niger State to augment that which it obtains from the Usuma Dam. While metering should be effective in managing demand, it is the author's opinion that this alone is not enough to solve the current problems associated with water supply in the FCT. The following measures are recommended:

Public Enlightenment: there must be an enlightenment campaign to raise the awareness and consciousness of people on the value of water.

Water Pricing: there also needs to be an appropriate pricing system that takes the poor into consideration while it also reflects the cost of water better than the current one as this system places almost no value on the water supplied e.g. at present, the water prices are as follows:

- Metered Rates: Commercial– ₦100/m³ (0.60 Euro); Domestic – ₦ 50/m³ (0.30 Euro).
- Fixed Rates: ₦500 per room / month (3.30 euros) regardless of the number of inhabitants or consumption! (FCT Water Board data).

An appropriate pricing system in addition to metering will have an effect of consumer enforced control on demand for and use of water which encourages no wastage as is regularly the case among the poor who often to save water practice 'pinch technology' e.g. reusing water used for dishwashing until it can no longer be used then using this for flushing toilets. Ironically these poor pay more for their water than those with proper supply, indeed they more than anyone else perhaps due to the trouble they experience in getting water, by their actions place value on water.

Alternatives to Illegal Connection: better policing of the supply systems will help to control the problem of illegal connections to the network by vendors. In addition to this collection points should be set up for vendors where they can collect water at cheap rates (factoring in a profit margin for the vendors) for sale to the residents of peri-urban areas. This will help further to stem the problems of losses in the system; ensure that good quality water reaches the peri-urban residents; create an additional source of revenue for the Water Board as against the current situation where the vendors simply steal water from the Board.

Regulation of Commercial Activities: the regulation of commercial activities within the FCT though not the responsibility of the Water Board will help to check the activities of businesses that have a high water use such as those previously mentioned but that currently do not pay a water charge. There should be a regulation requiring such businesses to register with the local authority and receive a certificate of permit to operate in the FCT. This certificate should be given following the presentation of not only tax but also water charge payment records.

5.1.6 Wastewater Management

The idea of Abuja as the capital was to have a city that would be modern and comparable in terms of planning, development, infrastructure and services to major capital cities around the world. With this in mind and in recognition of the importance of proper management of wastewater, the primary and preferred method of wastewater management (collection, treatment and disposal) proposed for the FCT as contained in the Master Plan is the conventional system (central sewer network, treatment plants). Wastewater management in the FCT can be separated into that in place for the FCC and those for other areas of the FCT; a brief overview of the wastewater management in the FCC is presented in this section.

Sources: there are three principal wastewater sources in Abuja:

- Domestic: that from toilets, kitchen, bathing and washing in homes.
- Pseudo-domestic: other buildings with domestic functions such as schools, hotels, offices, hospitals, etc.
- Industrial: mainly spent process water.

Sewage Collection and Transport in Abuja: basically wastewater from buildings is collected and transported via tertiary sewer lines to district collectors, onward to trunk sewers and from there to the treatment plants. The network is designed to allow for gravitational flow. To date only the Phase I area of the FCC is completely served with sewers. Networks for Phase II and III are at different stages of completion. Transport of wastewater and storm is via separate sewer networks.

Wastewater sources and characteristics: wastewater generated within the FCC is largely domestic as there are currently no major industries within the FCC. There is however uncontrolled discharge into the sewer network by many small scale and home based industries; therefore the composition of wastewater from non-domestic sources is largely unknown. Hotels and industry are by regulation required to pre-treat their wastewater in-house before discharge into the public wastewater system.
The only easily identifiable industry discharge into the public wastewater system is the government owned and operated Security Printing facility. It is doubtful that the wastewater from this establishment is pre-treated before it enters the public domestic stream as suggested by the colour (various colours have been seen or reported) of the wastewater whenever discharge occurs, see figure 5.6 (a, b).

(a)

(b)

Figure 5.6: Wastewater discharge from the Security Printing facility in Abuja

Wastewater Characteristics: based on data from an official of the Water and Sewage division obtained from the Wuye treatment facility, the typical domestic wastewater characteristics in the FCC are presented in table 5.9:

Table 5. 9: Influent characteristics for Wuye Treatment Facility (Source: Abdullahi, 2005)

Period	**Flow rate (m^3/hr)**	**T °C**	**pH**	**TSS (mg/l)**	**COD (mg/l)**	**BOD (mg/l)**	**NO_3 (mg/l)**	**$NO_é$ (mg/l)**
Dec–Jun	340-390	31-35	6-8.5	225-240	800-895	480-512	1.2-1.8	0.8-1.4
Jul–Nov	340-380	31-32	6.3-8.4	225-235	840-893	472-490	1.3-1.8	0.9-1.3

Wastewater Treatment Systems: the FCC uses the conventional sanitation system – wastewater is transported through the public sewer network by gravity to the wastewater treatment facility that serves the area where the influent wastewater is treated and the effluent discharged into a receiving water body often rivers. The sludge is dewatered and transported to the solid waste dump and in the case of the Wupa Treatment plant currently under construction reuse in agriculture is planned. The treatment processes employed at the treatment facilities available in the FCC are aeration based and include: oxidation ditches, lagoons, extended aeration and activated sludge.

In the FCT's Master Plan, all the area councils of the FCT were to have central sewage schemes that fall within the six major sewage drainage basins in the FCT namely: Gwagwalada, Karu/Nyanya, Abaji, Wosika, Usuma and Wupa. Eleven treatment plants were proposed for the FCT but so far only one treatment plant is currently under construction at Wupa to serve the FCC and according to official sources the decision to begin work on the other plants has not yet been reached. In the interim, 13 aerators were constructed to treat the wastewater generated within the FCC pending the completion of the Wupa treatment plant; however, none of these 13 aerators were functional at the time of this study. Pictures of some of the plants visited are shown in figures 5.8, 5.9.

Table 5. 10: Wastewater treatment facilities in the FCC

Location	**PE**	**Area Served**	**Treatment System**	**Sink**	**Status**
Wuye	50,000	Phase 1	Aerated Lagoon	Wuye river	NF
Utako	100,000	Phase 2	Extended Aeration	Wupa river	NF
Wupa	700,000	FCC	Activated Sludge	Wupa river	UC
Gudu	6000	Legislative qtrs	Oxidation ditch	Wuye river	NF
All others	2000–10000	Various	Oxidation ditches		NF

NF= non functional; UC= under construction

Wupa Basin Sewage Treatment Plant

This is the new plant currently under construction, which when completed will serve the FCC area with a capacity of 700000 PE. The plant is designed based on the activated sludge system with UV tertiary treatment. The effluent is to be discharged into the Wupa River and the sludge dried for subsequent use in agriculture.

The proposed sewage treatment plant is to be situated in Wupa village within 20 km of the main city and about 14 km from the Wuye treatment plant. The Wupa plant will serve all phases of the FCC (Phases I, II, III) and will be the main sewage treatment plant. Sewage transport will be by gravity via a 14 km concrete sewer line to be constructed. The plant's treatment (see figure 5.7) is divided into primary (physical), secondary (biological) and tertiary (polishing) processes, these include:

- Screening / grit removal.
- Activated sludge process with simultaneous nitrification/denitrification.
- Secondary Clarification and sludge separation.
- Sludge thickening, dewatering, and evaporation in lagoons.
- UV treatment of both effluent and sludge.
- Effluent discharge into the Wupa river.
- Sludge drying on drying beds, caking, bagging. It is planned that the dried sludge be converted to manure or directly reused in agriculture.

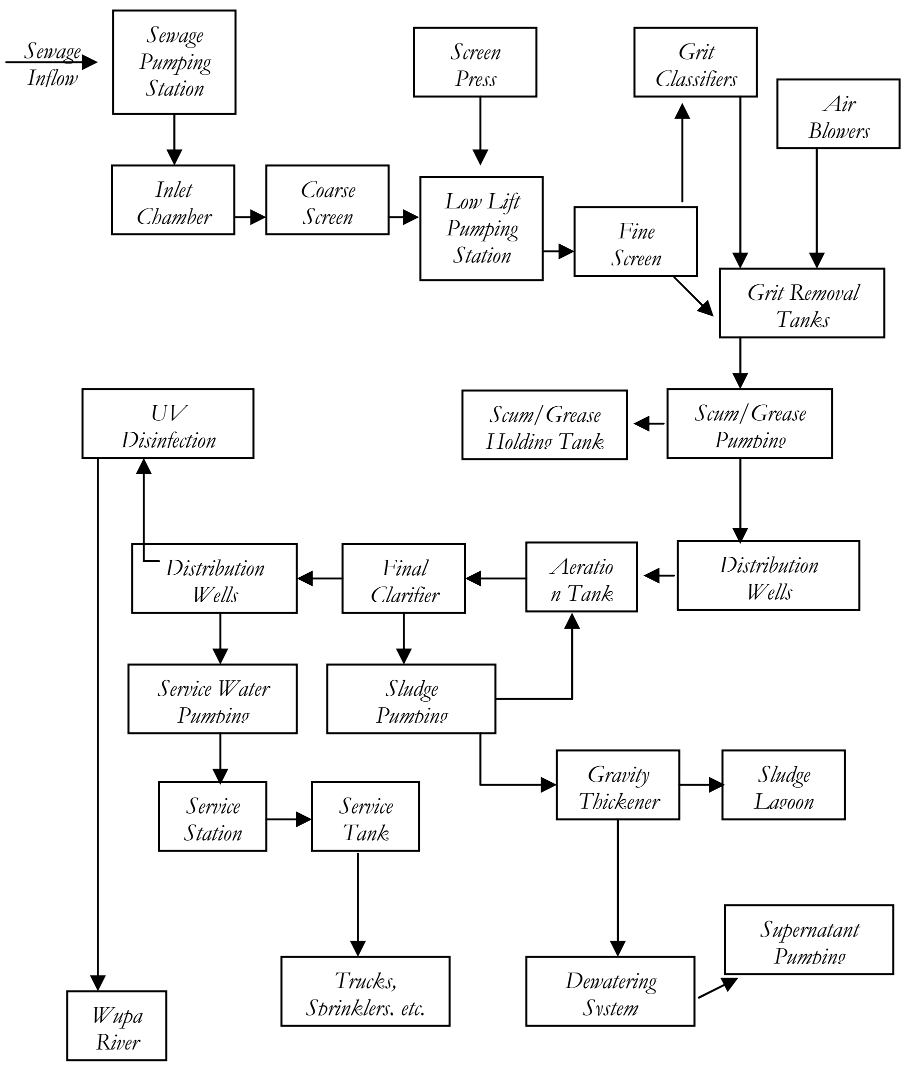


Figure 5. 7: Scheme of the Wupa Wastewater Treatment Plant

Pictures of some of the wastewater treatment plants visited

Aeration System at Wuye

Figure 5. 8: The Wuye Wastewater Treatment Plant in disuse, at Wuye FCC, Abuja.

Oxidation Ditch at Lungi

Figure 5. 9: The Lungi Wastewater Treatment Plant FCC, Abuja. (Picture shows oxidation ditches and faulty parts that have not been replaced for more than two years)

5.1.6.1 Challenges of Wastewater Management in the FCT

Wastewater management in the FCT has been riddled with problems. Interviews with some of the engineers in the Water & Sewage section of the Engineering Services Department of the FCDA revealed the following as the main problems they encounter in the discharge of their duties:

- *Lack of funds:*
  - for operation of treatment facilities.
  - for maintenance of existing sewers and treatment facilities.
  - for implementation of construction plans of sewer network and treatment plants.

  This has resulted in the some parts of the sewer network not being completed and has created a situation where most existing treatment facilities are non functional.

- *Bureaucracy:* the cumbersome and extremely slow process involved in obtaining required approval for maintenance (preventive or corrective) of the plants has meant that important decisions affecting the facilities cannot be taken urgently and in some cases the process has dragged on for years.

- *Availability of spare parts:* another factor as reported by some of the officials interviewed was that in some cases outdated equipment was used in the construction of the plants by the construction companies as such replacements for faulty parts are not easily available, thus creating an unnecessary dependence on these companies for the sourcing of spare parts.

- *Lack of consultation with local engineers*: some of the engineers interviewed cited non participatory decision making as a problem, some report that projects were sometimes undertaken without due consultation with resident engineers.

- *Poor fee recovery and high operation cost:* as is usual with conventional systems operation costs are high even when subsidised by government funds. Fee recovery for the FCC is at best poor and in most cases non existent. In the FCT, the Abuja Environmental Protection Board (AEPB) is responsible for the recovery of liquid waste disposal charge from consumers but has had very little success doing this so far (discussion with AEPB official), meaning the funds for operation which should at least in part be covered by the user is not available to the channelled into the running of the plants.

- *Overlap of functions*: several bodies have some role to play in wastewater management in the FCT and sometimes the roles are not properly defined as such there are conflicting efforts in the discharge of the duties involved in wastewater management. For example the AEPB is responsible for maintaining the sewer network but lacks the capability to do so. The AEPB collects the liquid waste treatment charge but does not remit this to the Water and Sewage unit (a subset of the FCDA Engineering

Services Department, not under the AEPB) which is responsible for the actual wastewater treatment activities and maintenance of treatment facilities.

- *Abuse of system by users:* many materials find their way into the sewer network that should not be there. Examples are polythene/ plastic bags and bottles, and other solid waste materials, which have in many parts of the city resulted in damaged sewers and bleeding manholes as shown in figure 5.10. Others are non degradable feminine hygiene products which get into the sewage and end up at treatment facilities. The pre-treatment stage at the plant is not always successful in removing these materials and they often end up in the systems.

Figure 5. 10: Bleeding manholes due to blockage in parts of the FCC

- *Low priority of wastewater treatment:* perhaps the most important factor is the low priority placed on dealing with wastewater issues by the authorities. There are simply more important and pressing needs than allocating funds required by facilities dealing with these "waste of the worst kind", material that is deemed of no value to anyone. On the part of users, the out of sight, out of mind scenario applies.

The uncertainty in the population figures for Abuja and the fact that many residents especially those outside of the FCC Phase I and II are not connected to the sewer network, makes the estimation of the actual wastewater generation difficult. However of the wastewater that is collected only a fraction ends up in the treatment systems. In general the following problems in addition to those specified by the officials were observed during this study:

- Low priority and under-funding for wastewater management on the part of the management of the FCT, which can be attributed to inadequate awareness of the links between improper wastewater management and public and environmental health on the part of the decision makers.
- Rapid population growth resulting in increased pressure on infrastructure including water resources, wastewater and solid waste disposal services.

- Inadequate number of functional sewage treatment plants in operation and poor operating conditions in existing plants.
- Non regulation of on-site/private facilities for sewage and industrial wastewater disposal which has been identified by most researchers as a cause of water pollution.
- Non-enforcement of existing regulations on polluters by responsible authorities.

5.1.6.2 Recommended Improvement Measures

Awareness raising: raising awareness of both the public and decision makers is central to solving the wastewater management problems of the FCT. Often users' awareness of wastewater management is limited to the toilet handle — flush and out of sight, it's gone and out of mind especially for people served by centralized systems. It is usually only those with onsite systems such as septic tanks that are once in a few years reminded of the necessity of dealing with wastewater when emptying their tanks and often when the tank fails. Yet the components (infrastructure, operation and maintenance) required in conventional waterborne wastewater systems are some of the most capital intensive endeavours any community will face. These systems are certainly not cost free. Many developed countries include in or collect alongside their water tariff a component for wastewater treatment based on water consumption, in the example of Germany this is higher than the charge for the potable water consumed – as it is more expensive to treat wastewater than it is to treat raw water. This system is based on the fact that all water consumed ends up as wastewater, which needs to be treated before being discharged into the environment. An advantage and by product of this system is that efficient consumption of water is encouraged on the part of the consumer.

On the part of the authorities there exists a low priority for wastewater management thus the sector is under-funded, a factor attributable to a lack of awareness of the impact of poor wastewater management on human and environmental health. A likely reason is that the effects of this are not immediately noticeable. With the exception of cases of blocked or overflowing sewer lines, pollution effects of wastewater such as pollution of surface water is hidden by the effects of dilution and motion; and in groundwater the effects are largely invisible, with the consequence that extensive damage often occurs before the effects of untreated wastewater discharge become easily noticeable, by which time the costs of remediation (where still possible) is far higher than the costs of preventive action. The Wuye Plant, which was non functional as at the time of this study acts more or less as a channel for wastewater discharges into the Wuye River, which is a source of water for downstream rural communities of indigenous people and also used by some people within the FCC for needs such as bathing, washing, fishing, etc. as observed during a visit to the site see figures 5.11.

(a) (b)

Figure 5. 11: (a) Wastewater discharge point into the Wuye River; (b) Man swimming in the Wuye River a few meters downstream of the discharge point.

According to Krohs (2004), the Wuye River flows into the Usuma River, used as a raw water source for water treatment facility that serves the Gwagwalada area. This presents risks to human health but perhaps because the costs are not directly borne by the government as people are in most cases responsible for their own health care, it is easy to overlook the costs in work days and productivity lost to the economy by wastewater related diseases such as typhoid, diarrhoea, etc which are common in the area (see table 5.14 for an overview of diseases of public health concern in the FCT).

There is indeed a need to raise awareness on the part of the authorities on the public and environmental risks associated with improper wastewater management such that it is given attention and funding commensurate to that provided to other services such as water supply, health care provision, solid waste management, etc.

However the responsibility (social and financial) for wastewater management should not be limited to government alone, users need to be aware of the health and environmental risks associated with the discharge of domestic wastewater without adequate treatment and of the use of such water in irrigation of crops for human consumption. Essentially users need to know the water they use in their homes end up as wastewater which must be treated and that the required treatment is a service available to them at a cost as with other utilities such as electricity and telephone. User awareness will also contribute to the solving the current problems with abuse of the system by users. People need to be aware that their actions may impact the operations at treatment plants and result in a situation where systems fail with consequent impacts on receiving bodies and downstream communities and eventually on the users themselves especially in cases where the receiving body flows into a raw water source as in the Wuye case.

Provision of adequate funds: a major reason for the non functioning state of the interim wastewater treatment facilities in the FCC so far was that the funds required for preventive maintenance was not provided and many plants gradually became unusable due to non-replacement of broken parts. The difficulty in obtaining funds for operation and maintenance is in part due to the bureaucracy involved (long chain of authorisation) and in some cases corruption prevention checks in the system. Other factors include again low priority as there are simply more important demands on the budget. Considering that funds for repair is several times more than that for preventive maintenance, the difficulties involved in sourcing for the funds can only be imagined. Operation and maintenance costs are important in the decision to implement conventional wastewater systems as such it is essential for the proper functioning of such facilities that adequate funds be available for the procurement of spare parts and resuscitation of plant operations.

Improved institutional arrangements: there is an overlap of functions in the whole wastewater management scenario. Currently several bodies have some role to play in wastewater management activities. It is the opinion of the author that these roles are not in many instances properly defined as such there are conflicts in efforts involved in wastewater management. An example is a fact that theoretically speaking the AEPB is responsible for maintaining the sewer network but it lacks the capacity to do so. However, the AEPB collects the liquid waste disposal fee, which according to officials it does not remit to the Water and Sewage unit responsible for the actual day to day operation and maintenance of wastewater treatment facilities.

Undoubtedly the whole system will benefit greatly if the structure and roles of agencies involved with wastewater management are clearly defined. A suggestion is to have an overall body which will be the parent of the agencies responsible for water supply, wastewater and solid waste management. Such a body would oversee the provision of operational funds to each of the agencies and be responsible for fee recovery for all these related services while the respective agencies will be more or less technical units of the parent body with a degree of autonomy in decision making processes related to operation and maintenance.

Having this kind of structure will promote better interaction between the agencies, limit overlap of functions, improve service provision, facilitate quick response to faults and complaints, and improve fee recovery processes. Also clearly defined roles and responsibilities for stakeholder agencies involved in wastewater management can help prevent fragmented and uncoordinated approaches and actions while improving linkages to other sectors such as public health and agriculture.

Use of sustainable technologies: one of the challenges associated with the use of conventional wastewater management systems is that they are quite expensive to install, operate and maintain. Such operation costs are quite high even when subsidised by government funds. This is one of the problems encountered in fee recovery. Even though people understand, they often do not accept that services are not free. As such it is difficult to recover fees for wastewater from users who do not see the necessity of paying for 'valuable' potable water. The fee recovery problem is not limited to wastewater but afflicts also the water supply, electricity and telephone utilities. Again raising awareness is key; people simply need to know that they must pay for what they consume.

Another factor is that selection and implementation of locally appropriate technologies that provide the intended level of service/ treatment while being conscious of the local capacity and willingness to pay.

The current scenario is based on wastewater management systems proposed in the original Master Plan. However, the existing situation is that these systems are failing for various reasons and it is unreasonable to continue to replicate the same types of systems considering the problems that are being encountered with those already in place. The effort of searching out what is possible from the compendium of low cost efficient technologies is in the author's opinion well worth it.

Management and treatment priorities must first be established and technologies that are cost and energy efficient such as waste stabilisation ponds, constructed wetlands, etc., and able to deliver on set target must be given due consideration as opposed to the current practice of importing conventional systems which are both cost and energy intensive, requiring highly skilled manpower, dependent on foreign input for construction, operation and maintenance; with significant human and environmental impacts when failures occur. One of the complaints of some of the staff of the plants visited during this study is that they are not duly involved in key decisions regarding selecting technologies and installing treatment facilities, it is essential that any efforts in this regard are made with due consultation with the engineers responsible for the day to day operations and management of wastewater facilities in the FCT.

Participatory selection and implementation of technologies: experiences in various fields have shown that user participation in projects encourages ownership which in turn contributes to sustainability. This implies that technology selection done in a participatory manner with involvement of various stakeholders has potential benefits for wastewater management in the FCT. For example users are aware of the costs involved and are better informed of the operational demands on them. Although this scenario is no longer possible in the established parts of the FCC, it is still possible to adopt such an approach for areas planned for future development such as the satellite towns.

Regulatory issues: the wastewater and sanitation sector must be prioritised by the FCT management system. Wastewater and sanitation activities must comply with the National Water Supply and Sanitation policies and regulations. Systems of monitoring must be established as a control measure for the protection of receiving water bodies in addition to regulation enforcement and penalty systems. This is particularly important for the many private onsite system users whose activities are currently largely uncontrolled and unmonitored.

Capacity development: if alternatives to conventional systems are to be implemented, appropriately trained wastewater professionals are needed for such projects at both the technical, managerial and community participation levels. Strengthened institutional capacities will support the selection of sustainable technology and the installation, operation and maintenance of such as well as the environmental and human health implications of having such systems, and promote research into cost-efficient technologies.

Affordability issues: currently it is not feasible to expect that operational cost recovery from residents of the city can be effected as obtains in the developed world where such systems are common. If the opinion of residents expressed during this study holds true, the demands on people are already high without the additional burden of paying the costs of conventional wastewater treatment in addition to the other utilities charges they already pay . It is a case of users not having a say in the choice of treatment system they are to use which further buttresses the importance of user cost acceptance input into the selection process. One wonders if with knowledge of cost implications, this conventional system would be the preferred option for the average user.

Public – Private Partnership (PPP): in line with the current government privatisation efforts PPPs may present a means of funding wastewater management systems that are efficient in both service provision and cost recovery. The involvement of private investors in service provision in Nigeria is not new and has been hugely successful in areas such as telephone and mobile phone services, and can be adapted to the wastewater service. However, there are potential risks to having PPPs involved in managing essential infrastructure and services such as water and sanitation, main ones include:

- *Loss of control by local government:* PPP require the sharing of risks, benefits and decision making between the partners when most of the input is private it becomes a case of 'he who pays the piper dictates the tune'.
- *Increased costs:* as pricing is often done or greatly influenced by the private partner, the result is increased cost to users.
- *Monopoly:* risk of monopoly means competition which could lead to innovation, efficiency and lower costs is absent, and consumers are at the mercy of the private partner.

An overview of the wastewater management situation in the FCC has been presented above. For the rest of the FCT comprising the area councils, no sewer network has been provided as yet. Pit Latrines, Septic Tanks/Soak Away Pits, cesspools are normal for these areas, also found is the practice of open defecation.

In summary sewerage systems principally collect wastewater for transport away from their sources (homes, office, industrial complexes) to a treatment and/or disposal point. The proper functioning of this system depends greatly on:

- the availability of water for flushing as this is the medium of waste transport.
- a sewage network, laid deep in the ground, this represents the bulk of the investment (about 80%) required for having such a system.
- a treatment plant that receives, cleans and disposes of the wastewater.
- well trained professional staff for operating the plants, maintaining the network and treatment facilities.
- cooperation on the part of users (abuse of systems by throwing problematic substances into it).

Indeed the conventional waterborne system is a high-cost sanitation option appropriate only where funds are available for operation and maintenance by trained staff, and where the wastewater is properly treated as its hazardous contents represent a public health risk. The adoption of integrated management of water resources, cost-efficient and sustainable technology, all contribute to the sustainability of wastewater systems.

5.1.7 Solid Waste

The Abuja Environmental Protection Board is vested with the responsibility of waste management services in the Federal Capital Territory (FCT).

It is estimated that about 2.745 tonnes of waste is generated daily by the inhabitants of the FCT. Of the problems affecting solid waste management, storage is of major concern for the AEPB. According to the AEPB, presently, only about 1 million of the FCC inhabitants have access to standard waste storage facilities (waste bins). This has invariably led to indiscriminate creation of illegal dumps, which constitute not only a nuisance but also an environmental pollution source, even more important a potential public health risk as these are breeding grounds for disease vectors and pests.

Waste Collection/Transportation: Phases I and II of the FCC enjoys well-developed infrastructures unlike the other parts of the FCT. Presently, the *Solid Waste Management Services* in the FCC has been contracted to private companies. These companies are charged with collecting waste generated from domestic and commercial buildings, transporting the same to waste dumpsites on a regular basis (several times per week, depending on the level of need as determined by the AEPB), however, the structure, implementation and monitoring of this approach is still in its infancy.

The less planned and averagely developed areas of the FCT especially the densely populated informal peri-urban settlements in which an estimated 80% of the inhabitants of the FCT live, are not yet covered by the AEPB's plans and do not have a structured waste management system. These areas pose the greatest challenge as the unplanned nature and lack of civil infrastructure facilities makes accessibility and waste collection very difficult.

In these areas waste is collected in push trucks by private operators who collect waste as required by the residents and transport the waste to nearby dumpsites most of which are illegal. The operators' charges depend on the amount of waste the household generated (visually estimated); price ranges between 10 – 60 naira. The Area Councils of the FCT with the exception of AMAC are responsible for managing the waste generated within their domain. It is however envisaged that in future the AEPB's Waste Management activities will include these areas as well.

Figure 5.12 Waste dump at Kuchigoro

Waste Treatment / Disposal: dumpsites serve as the main disposal sinks for waste generated in the FCT. According to sources at the AEPB, there are no transfer stations and landfills in the FCT. At present, the FCC is serviced by only one officially designated dumpsite situated along the Zuba – Asokoro expressway, at Mpape Junction (see figure 5.13). However there are many others existing in parts of the city. According to the Abuja Master Plan about 705 Hectares was earmarked off the Airport Road as a landfill site for the waste generated in AMAC; so far this is not yet in existence. The *Ajata site,* which had served Nyanya, Karu, Orozo, Karshi Axis, is currently out of use (see figure 5.14).

(a) (b)

Figure 5. 13: (a) the AEPB's waste dump Site at Mpape Junction; (b) scavengers at the site (source: AEPB)

(a) (b)

Figure 5. 14: (a) Landfill site turned waste dumpsite; (b) Ajata Landfill Site, in disuse.

The FCT presently does not have an incinerator for special and hazardous wastes. These wastes are presently being burnt in the open. There is however a composting plant at Ajata, which is not currently functional and is now in disuse.

Figure 5. 15: Composting Plant at Ajata overgrown with weeds

While there is no recycling plant in the FCT, recycling is widely practiced by residents in general for economic rather than environmental reasons. Paper and plastic waste are quite valuable and are often sold to small scale business owners and local artisans who reuse these materials. Scavengers also engage in this practice, scavenging not only at dumpsites but going through the city looking into waste bins in residences and receptacles on the streets and other public places.

Figure 5. 16: Scavenger rummaging through a bin in the FCC

5.1.7.1 Challenges of Solid Waste Management in the FCT

While conscious of its duties and responsibilities, the AEPB admits its inability to effectively handle the waste management demands of the FCT due to:

- Limited institutional capability.
- Inadequate funds and resources.
- Inadequate capacity building structure.
- Inadequate enforcement of existing regulations.
- Obsolete Rules & Regulations that are not adequate for present day realities.

In spite of efforts reportedly made by the AEPB for proper waste collection and disposal it is evident that these attempts are inadequate to cope with the volume of waste being generated currently as it is common to find waste dumped on roads, open drains and many other 'convenient' locations in parts of the city; a practice associated with the poor environmental management conditions of Lagos. Contracting out to small firms the waste collection and transportation to designated dumpsites; new streamlined billing and fee recovery system; represent some of the steps currently being taken to assuage the problems associated with solid waste management in the FCT and it is gratifying to note that strategies that have been adopted are beginning to yield positive results.

5.2 The Peri-Urban Study Settlements

The results of the field study carried out in the peri-urban settlements are presented and discussed in the following sections.

5.2.1 Description of the Settlements

Houses: the types of houses found in these areas depend largely on the age of the settlements. Those that are very old e.g. the Karmo and Gwagwa settlements, as old as the FCC, are characterised by old structures that are constructed using cheap materials (see figure 5.17 a – f). The newer settlements have a mixture of houses ranging from those of the indigenous people to very well constructed modern homes. It is not uncommon to find homes fitted with high security fencing and gates, satellite TV, telephones, electricity, boreholes, and other amenities for the comfort of the residents. Lower income houses are mostly the "face me face you" (similar to a hostel type of accommodation), and units of one to three room flats for rent and private houses.

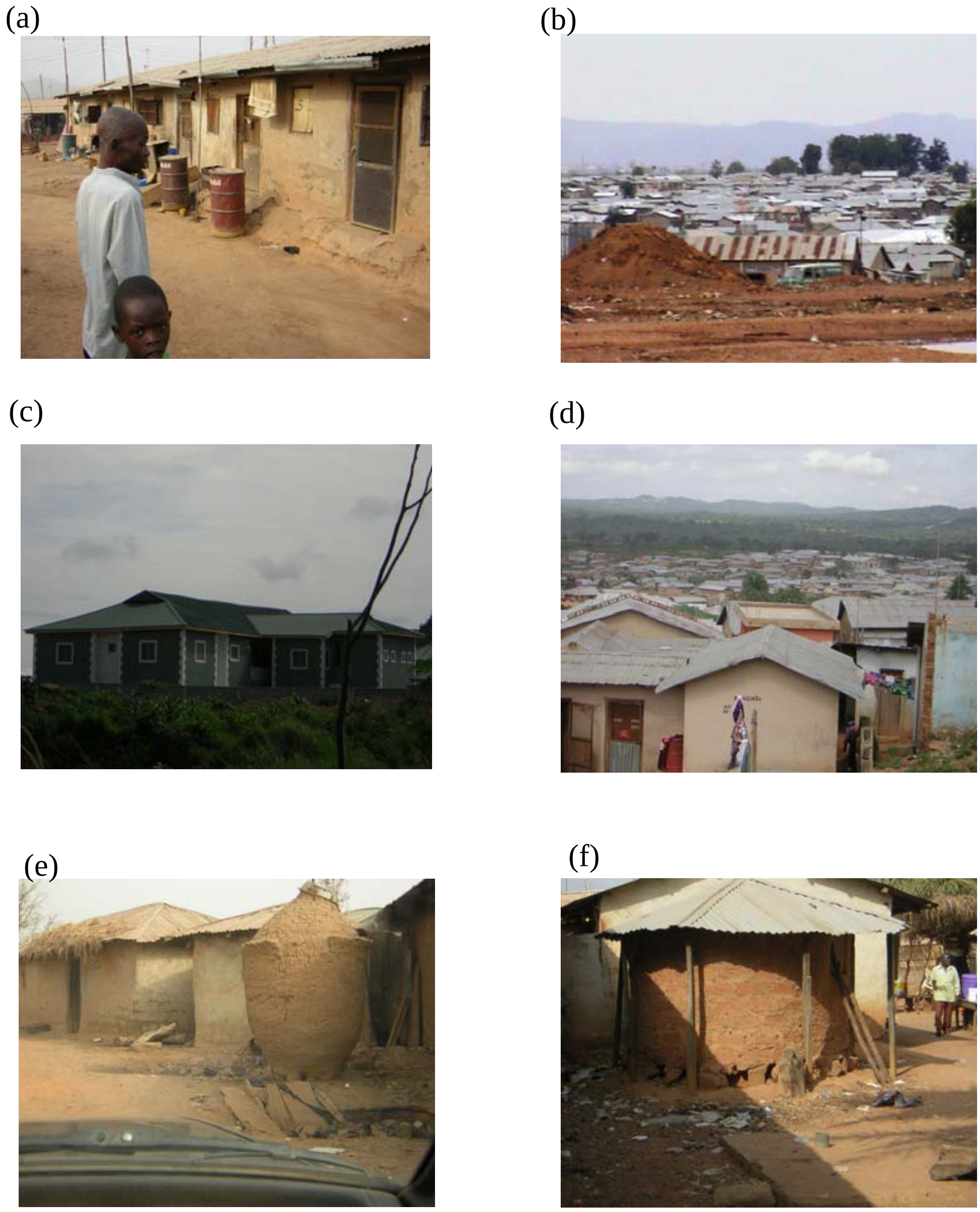


Figure 5. 17: Some houses in the settlements. (a) plastered mud brick 'face me face you' housing in Karmo; (b) houses in Chika; (c) nice looking modern homes in Mpape; (d) other houses also in Mpape (e) indigenous people's dwellings in Kuchigoro; (f) dwellings in Chika.

Roads: as with most slums or informal peri-urban areas the roads are unplanned, irregular and un-tarred, they are mostly only fairly passable during the dry season; during the rainy season the potholes in the roads collect water which form large deep pools; many of the roads are narrow and very close to the houses such that large vehicles e.g. waste trucks cannot pass through (see figure 5.18). As mentioned in Chapter 4 this field study was carried out between January and June 2004 (a period covering the end of the dry season and the beginning of the rainy season).

Figure 5. 18: Roads in Kuchigoro – typifying roads in the most of settlements

Residents: the residents in these settlements just like the houses are mixed, consisting of families from different walks of life. Some are very well educated people with white collar jobs in the city, who are unwilling or unable to pay the exorbitant rents in the main city but hope to someday be able to move from these settlements into 'better' places. In the meantime however they try to make life as comfortable as possible for themselves, sometimes forming associations that try to provide the basic amenities for their commune such as passable roads, security guards, electricity and cleaning the environment.

Water source: observations and informal discussions with residents revealed a variety of water sources are available in the settlements. The following are the main sources of water in the settlements: piped water (into personal house or compound) mainly from boreholes but sometimes from connections to public supply pipes intended for other locations (the legality of such connections could not be ascertained), privately owned public taps (private owners connected to public supply from which they sell water to the public) boreholes, wells, rainwater collection, bottled water, ponds, rivers or streams; tanker-truck, vendors. Results of the survey carried out in the settlements (presented in section 5.3.2) further confirm this. No government provided standpipes were observed in any of the settlements visited.

Sanitation: one thing common to all the settlements is poor sanitation, even in those that seem to be somewhat planned. Dirty streets, open waste dumpsites, water pools are quite common. Types of toilets available are mostly pit latrines, pour flush toilets with soak away, WC with septic tank and soak away. Most people have access to some kind of toilet, however many people practice open defecation. Most residents living in rented accommodation have shared (communal) toilet facilities while in the private homes only the immediate families use the available toilet facilities. It was observed that even in some of the private homes, the toilets were built outside the homes in spite of the fact that only the families used the facilities. Solid waste disposal is mostly by private removers who collect the waste at agreed intervals and at a charge based on the volume of the waste removed.

Health: Most residents sampled are aware of the links between poor quality environments and health. However, most feel there is very little that can be done to improve the general state of the settlements, so most focus improvement efforts on their immediate environment. There are no government provided hospitals or clinics in any of the peri-urban sites visited. They are mostly served by private health facilities or residents travel to the nearest government hospital in the FCC; the health department's service targets are primarily the FCC, and the indigenous population. It was not possible to obtain data on the impacts environmental conditions have had on the health of the residents as people for cultural reasons were reluctant to respond to questions on illnesses, and no data could be obtained from the Public Health unit on these areas as these were not available.

5.2.2 Factors affecting the location and development of the slums

Field study results indicate most of the squatter settlements did not develop as a result of land invasions as is sometimes the case in many parts of the world. The following are some of the ways the sites included in this study developed:

- influx of casual/construction workers and service providers (domestic and commercial) in response to the development of FCT resulting in the emergence of shanty-towns and squatter settlements which these workers occupy in such places as Karu, Nyanya, Karmo and Gwagwa.
- Some settlements grew around the indigenous people who sold off their customary rights to the land they occupy, and in some cases they encroach into surrounding areas which though they once had primordial rights to no longer own with the creation of the FCT.

See Section 2.5.2 for a detailed discussion of the squatter settlement issues.

Development pattern: the observations so far about the location of most of the squatter settlements suggest that they tend develop along the major roads leading into the city namely: the Giri–Garki stretch; Zuba– AYA junction stretch; the Nyanya–AYA stretch and the Karmo–Berger junction stretch. They are close to water sources and are close to or built around former indigenous people settlements (the local people displaced when the FCT was created); some chose to give up their land and be resettled in their states of origin, others chose to remain in the FCT and relocate to the new resettlement areas, while the rest remained in their original locations. It is these groups that remained who sold the land around them to the migrants; the situation now is such that the indigenous people are almost invisible in these places.

Availability of water: most of the slum settlements are located close to some kind of water source. This is because a lot of the settlements used to be small villages for indigenous people.

Availability of jobs: people come to the FCT for various reasons, some of which include – (a) the desire to have improved standards and quality of living; (b) the perception of Abuja as a land of promise essentially flowing with abundant riches; (c) a lack of gainful employment in their respective states of origin driving the economic migration to the FCT; (d) existing gaps in the labour force especially in the construction and service sector, waiting to be filled.

Proximity to the main city: most of these peri-urban settlements are close to the main city about 15 minutes to 1 hour's drive away. This is important for ease of access to the FCC and their jobs.

Availability of accommodation: availability of accommodation in these areas is a direct consequence of landlords and private developers seizing the opportunity presented by the scarcity of accommodation within the FCC to go into the surrounding settlements to acquire land from local chiefs on which they develop houses for rent. This means the settlements have grown around settlements that formerly belonged to the indigenous people, which is one of the primary reasons for the multi-ethnic nature of these settlements.

Cost of accommodation: cost is perhaps the most significant reason people choose to live in these peri-urban settlements. The cost of renting a room in the main city ranges from about 75000 NGN per annum to flats costing up to 800000 NGN and houses up to 1.5 million NGN (160 NGN = 1 Euro). Availability of land is an important factor in this issue; where land is available the problem is further aggravated by the fact that private developers choose to construct houses primarily for the extremely rich (most private developers go for mansions and office complexes rather than accommodation for rent which have longer return periods) who make up just a small portion of the population, the overwhelming majority of who are mostly government workers, people on their first jobs, and who get salaries that make it impossible for them to afford living within the FCC, as such they live in these peri-urban areas instead.
Constraint in choice: most residents live here because they can not afford available alternatives to the squatter settlements. Living in these settlements is the best they are

able to afford with their present income, while hoping to move higher as their financial status improves. This is a common view held by most of the residents.

Interest in moving: most residents are willing to move to other settlements if the conditions are right e.g. proximity to the main city; availability of jobs; good amenities and services; affordable accommodation or preferably home ownership options; possibility of still being part of the FCT, having secure rights to their own land and properties.

Authorities' views: there is currently a drive to restore the FCT back to the original Master Plan. This drive has been accompanied by a spate of demolition exercises and there are no sacred cows. It is clear from discussions with government officials that the presence of the squatter settlements is a problem they have thus far not being able to eradicate and are unable to effectively solve within the present development drives, unless concerted efforts are made to provide secure tenure to residents and a way found to include everyone in the Abuja dream. The efforts (policies and actions) made towards this has been discussed in previous sections of this report (see section 2.5.2). The authorities might be willing to accept plans to resettle the residents of these areas as long as they do not have to pay for this. This should not be a problem as people are willing to develop their homes if they have the land to do so.

5.3 Survey in the Peri Urban Settlements

A survey was conducted in the selected informal peri-urban settlements of the FCT as part of this field study. In this section the results of the survey are presented and discussed. These results except where specifically indicated as FCC are for the peri-urban settlements.

5.3.1 General Findings of the Survey

Survey Location and Response: a total of six study sites were to be covered in this study with a target of 50 respondents per settlement. It was not possible to achieve this due to time constraints and limitations discussed in section 5.3.8. The chart below shows the selected study settlements and the number of respondent that participated in the survey. A total of 251 respondents participated in this survey.

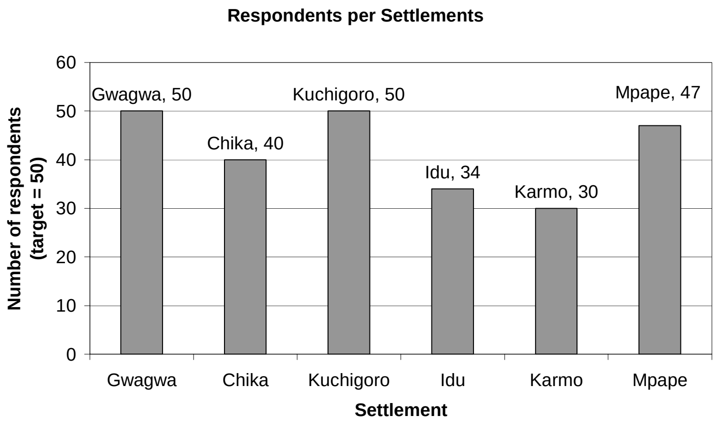


Figure 5. 19: Number of respondents for each of the selected peri-urban areas.

House Ownership: 14% of the total respondents from all the study settlements owned their homes, 70% lived in rented accommodation, 10% lived with family, 5% are squatters i.e. they do not have their own accommodation. Reasons given for this include inability to pay for a place to live, some are simply residents in transit to other parts of Nigeria, others recently arrived in the area and are just beginning the process of settling in, and 1% declined to answer. Being tenants often mean that people are not directly responsible for the choice of sanitation technologies installed in their dwelling. Their responsibility is thus restricted to the correct operation and household level maintenance of such systems. Anything beyond this is the responsibility of the landlord. The implication of this is that such systems especially where they are shared between tenants in the same building are abused as the caretaking for the systems becomes an issue where there is a lack of cooperation between users (see figure 5.21).

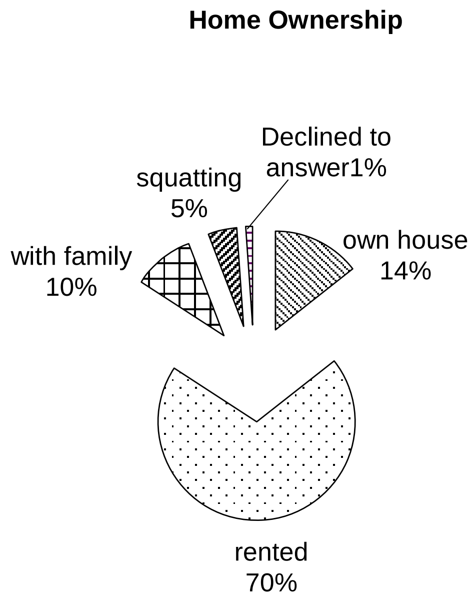


Figure 5. 20: Responses on home ownership in the selected peri-urban areas.

Figure 5. 21: Shared pour flush toilet in poor condition in Chika

Head of Household: heads of households play a significant role in the functioning of the family unit in many parts of the world especially so in most developing countries. They are often responsible for decision making in the family such as those involving capital expenditure in home improvements e.g. installation of sanitation facilities, ensuring compliance with operational requirements of such installations by other users within the household. Of the total number of respondents, 41% were heads of their households, 52% mostly female respondents were not, 7% declined to answer. The results indicate that the majority of heads of households among respondents were male.

Number of persons in Household: table 5.11 shows the average number of persons per household in five of the selected settlements. It was particularly difficult to obtain this data as many of the respondents preferred not to give this information, in fact some found the enquiry offensive. A possible explanation may be that some residents come from areas of Nigeria where the belief that "one does not count ones offspring" is held; another explanation might be concerns about security. The figures are particularly low for Mpape, this may be due to the nature of this settlement; it is a camp for construction workers many of whom are in the area solely for work and may not have come to the area with their families, choosing instead to commute between the work location and their home states. No logical reasons can be given for the other settlements with similar averages.

Table 5. 11: Number of residents per household

Location	**Average size of household**		
	Adult	**Children**	**Total**
Chika	2.6	2.7	5.3
Mpape	2.3	1.4	3.7
Kuchigoro	2.7	1.7	4.4
Karmo	2.4	1.5	3.9
Gwagwa	3.1	2.3	3.7

As the figures shown in table 5.11 may not truly reflect the actual number of inhabitants per household, an average household size of six persons is recommended for use in planning sanitation facilities for these areas – this figure is also used in the Master Plans obtained from the Planning Department of the FCDA, for some of the planned satellite towns.

5.3.2 Water Supply

Water Sources: the dominant sources of water as can be observed from figure 5.22 is supply by tanker-truck and vendors who often obtain their water by breaking and collecting water illegally from the FCC's piped network (see figures 5.2, 5.3, 5.4). As can be imagined the quality of water obtained this way cannot be guaranteed. The low availability of public stand pipes in most of the settlements can be taken as a further indication of the status of the settlements; a possible inference is that the settlements are not regarded as legal as such are not provided with public standpipes in spite of the fact that parts of the public water supply network is routed through areas quite close to some of the settlements. In some of such cases, vendors were observed either collecting water from broken pipes or residents made connections into their compounds where possible.

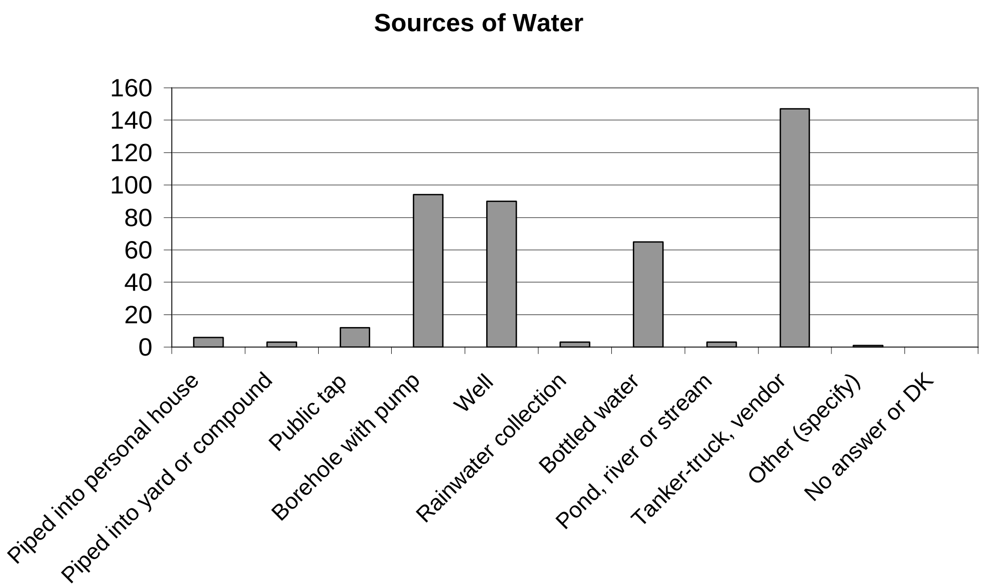


Figure 5. 22: Water sources in the selected peri-urban areas.

Perception of water quality: figure 5.23 shows the response of residents to the question "*do you think your water is good*?" 66% believed their water to be of good quality and 27% said NO. The responses are not based on any scientific knowledge but on the perception of good (good clarity, no sediments, no bad taste or smell) with deviations perceived as being bad. A few however indicated not trusting the sources even though the water appeared clean. There was also knowledge of home water treatment steps such as boiling, storage in clean and good locations in the house and being careful not to dip just any kind of utensil into the stored water. An interesting comment from one resident was that "bad water may sometimes be beneficial as it helps boost immunity against disease" as such the respondent would boil water for very young children but for not older ones to help them develop resistance to disease.

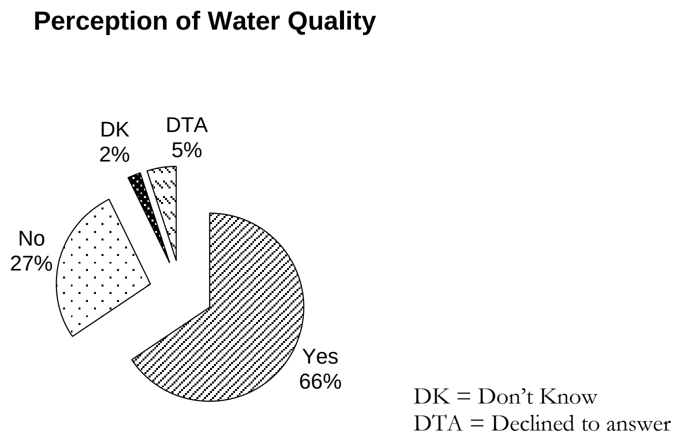


Figure 5. 23: Responses on perception of water quality in the selected peri-urban areas.

*Daily water consumption and cos*t: table 5.12 shows the average daily water consumption in some of the settlements and the cost per 20 litre jerry cans, which is the measure used to determine water prices in the settlements. The figures presented here are averages as they vary depending on location, proximity to the main city and water sources and population. The consumption for the Gwagwa settlement is higher than that for the others but no logical reason can be given for this observation (160 NGN = 1 Euro).

Table 5. 12: Average water consumption per day and cost of water in the selected peri-urban areas

Location	Average Consumption (l/c/d)	Average cost per 20L can (NGN)
Chika	29.6	26.0
Mpape	26.6	18.4
Kuchigoro	24.1	25.8
Karmo	24.6	22.5
Gwagwa	59.7	21.8

160 NGN = 1 Euro

Satisfaction with current water situation: a significant percentage 60% of respondents expressed dissatisfaction with their water supply, and 38% were satisfied with their water supply (see figure 5.24). Reasons for dissatisfaction include: uncertainty as regards quality, unreliability of sources, cost, insufficient quantity, distance and effort involved in obtaining water. In one area in particular, the water source was an open unprotected spring close to an area also used for open defecation (see figures 5.25–5.28). The nature of the area allows for access to the water by both humans and animals and some of the respondents indicated that their drinking water was sometimes obtained from this source.

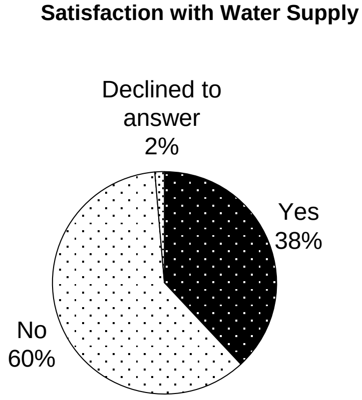


Figure 5. 24: Responses on satisfaction with water supply in the selected peri-urban areas.

Figure 5. 25: An unprotected water source

Figure 5. 26: People collecting water from the same unprotected source

Figure 5. 27: People collecting water

Figure 5. 28: The open defecation site close to the water source

5.3.3 Sanitation Facilities

Coverage: the term "coverage" as used here refers to the number of people or households or percentage of the population who have their own toilet facilities. While, the term "access" as used here refers to the right to use such available toilet facilities. Though no data exists about the level of coverage or access to sanitation facilities in the FCC, considering the peculiar characteristics of this city – it is a new city, planned with the aim of avoiding the environmental problems affecting Lagos; coverage within the planned sections of the main city can be assumed to be very high. However access even within the city is largely limited to residents. There are very limited numbers of public toilets, which are often only found in places like government owned public markets; most of the open markets do not have public toilets. Some people who come into the city to work, especially mobile traders and street hawkers, resort to using the green areas as open defecation sites. This action was observed in progress several times during the course of this study; the smell and presence of faecal matter is further evidence of this practice in these places as was observed. Private commercial premises, such as shops and offices even those in malls usually have toilets which are attached directly to them rather than general ones. This is to ensure that the toilets are properly managed by assigning responsibility of managing them to the occupiers of such shops or offices whether they are individuals or organisations. Public toilets (separate male and female) where available are operated by the Municipal Authority and users pay a fee of about ₦10–30 (0.06 – 0.18 Euro)

Results show a significant level of coverage in the settlements as 84% of respondents indicated they had access to some form of sanitation facility. 13% declined to answer, 3% had no access to sanitary facilities as shown in figure 5.29.

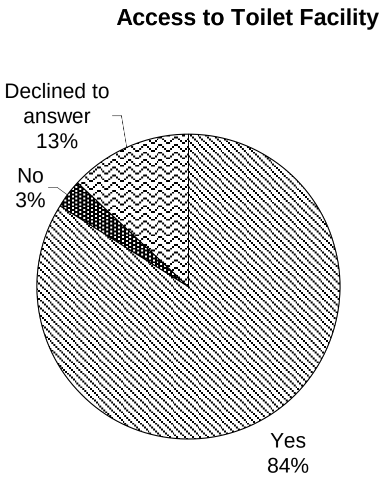


Figure 5. 29: Responses on questions on access to sanitation facility in the selected peri-urban areas.

Type of sanitation facility: the water closet (WC) is the prevalent type of toilets used within the FCC. In the peri-urban settlements however, a variety of facilities are available shown in figure 5.30 open defecation (2%), pit latrines (12%), and pour flush (PF) toilets (29%).

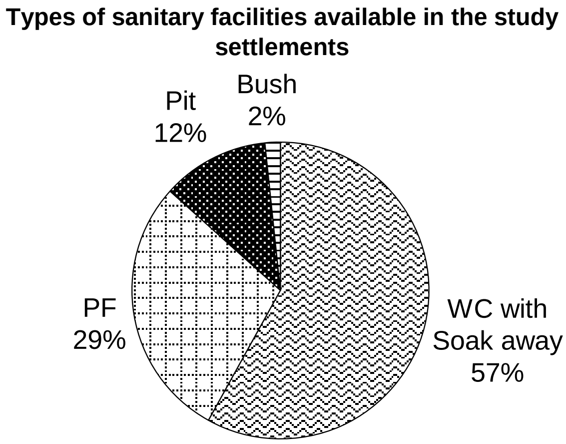


Figure 5. 30: Responses on types of sanitary facilities in the selected peri-urban areas.

Location of toilet facility: in contrast to the FCC where almost all toilets are located within the homes, in the study settlements, less than half of the toilets were reported to be located within the house as indicated by 46% of the respondents and in such cases use of the facility is restricted to the household occupying such houses. 49% had their toilet within their compound, this means the toilets are often shared with other tenant (see figure 5.31). The sharing of facilities between families in communal settings presents problems with managing such facilities unless there is cooperation among the users otherwise someone could be employed to provide this service for a fee agreed to by all affected users.

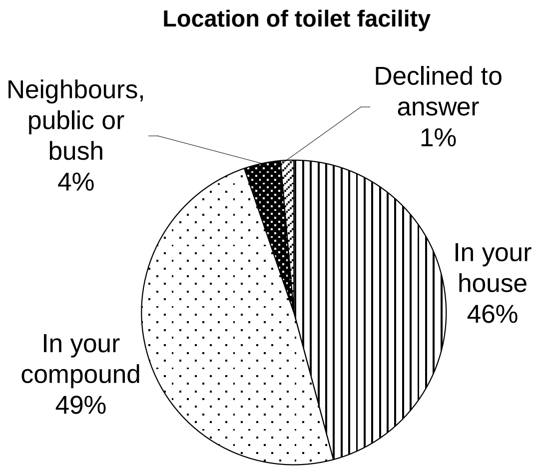


Figure 5. 31: Responses on the location of toilets in the selected peri-urban areas.

Toilet usage: the purpose of this question was to determine if any cultural reasons exist that discourage the sharing of sanitary facilities between men, women, young or old. The results (see figure 5.32) reveal that there are no such beliefs or practices among the users in all the settlements surveyed. A reason for this is likely to be the cosmopolitan nature of the settlements stemming from the fact that most residents are migrant workers from various parts of Nigeria. As such there exists a mix of cultures in the areas and no real rules exist that exclude any group from sharing facilities with anyone else.

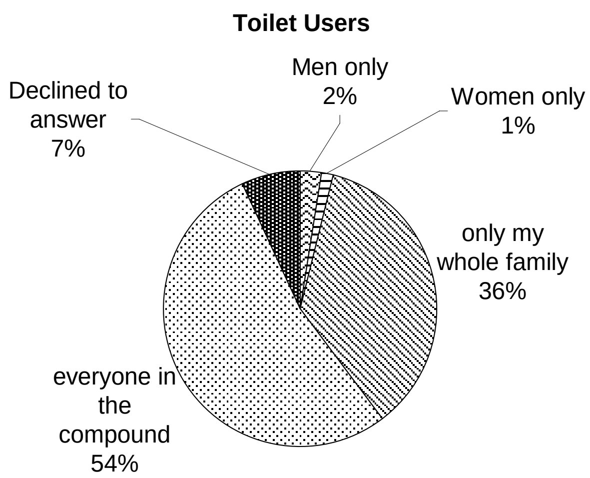


Figure 5. 32: Responses on toilet use in the selected peri-urban areas.

5.3.4 Preferences and Satisfaction

The survey tool included questions regarding the preferences of respondents on various factors pertinent to the selection of appropriate sanitation technologies. The results are presented in the following sections.

Anal cleansing material: expressed preferences from respondents about the choice of cleaning materials are presented in figure 5.33. Washers made up 19% of the surveyed population and 39% were wipers. This result implies that the population is a mix of washers and wipers meaning that care must be taken in the selection technologies particularly those relying on diversion of all waters away from the solids collection units.

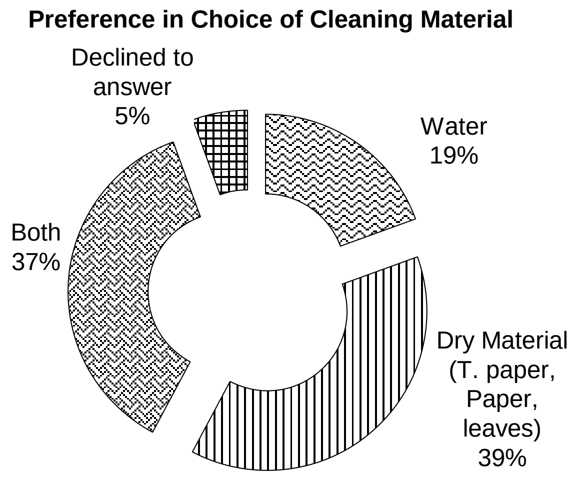


Figure 5. 33: Responses on choice of cleaning material from residents of the selected peri-urban areas.

Preferred position during use: this question was to determine user preference for sitting or squatting, this is shown in figure 5.34. The population is made up predominantly of 'sitters' (66%). This means technologies requiring squatting may not receive good acceptance among these groups of people as such the focus should be on technologies offering the possibility of sitting i.e. pedestals instead of squat pans.

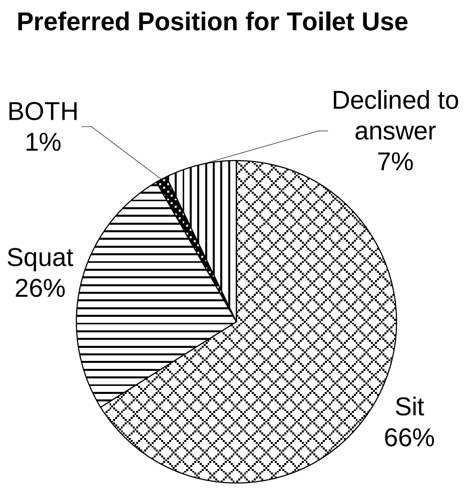


Figure 5. 34: Responses on preferences regarding position when using the toilet.

Preferred level of privacy: this question indicated the importance of privacy in the choice of sanitary facilities (see figure 5.35). The scale applied was from 1= least to 5= highest level of privacy. Privacy is rated quite high among respondents as indicated by the percentage of people (38%) who gave it a rating of 4 and 31 % that indicated an importance level of 3. While 12 % declined to answer and 5 % indicated privacy as a primary requirement mostly the mid income level educated residents, only 3 % of respondents thought privacy was not so important assigning a rating of 1. The remaining 11 % wanted at least some level of privacy.

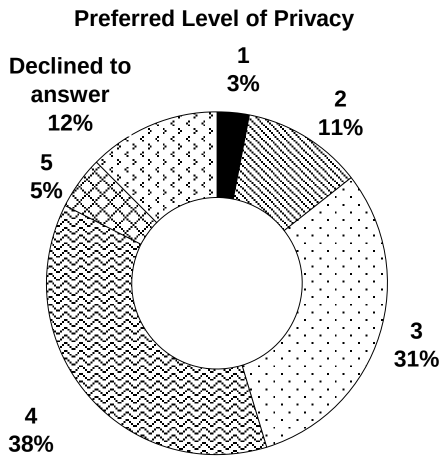


Figure 5. 35: Responses on importance of privacy to respondents.

The implication of these responses are far reaching, one is that most respondents preferred to have household level service not shared with anyone except direct members of their families. As such communal facilities are likely to be poorly received among the people.

Preferred location of toilet: according to figure 5.36, 64% of respondents preferred their toilets located within their houses. This would indicate that privacy and convenience, proximity and not having to share are very important issues for this group of respondents. Only 8% of respondents wanted their toilets outside of their homes. Possible reasons for this response include belief that a toilet while being necessary is dirty and should not be located close to other parts of the house; others 28% declined to answer. The responses here further indicate a preference for household level facilities.

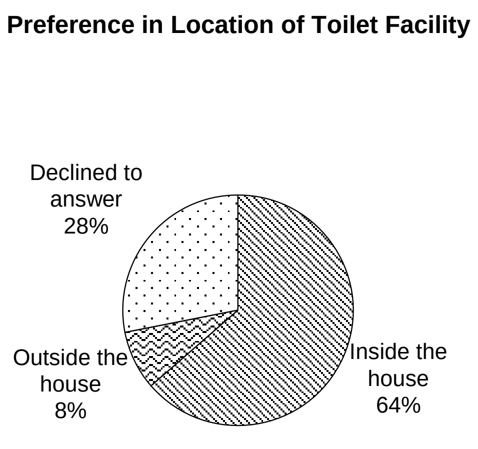


Figure 5. 36: Responses on preferences regarding location of sanitation facility.

Satisfaction with existing toilets: figure 5.37 shows that 56% of respondents expressed satisfaction with their toilets. Reasons for this response include the fact that many of these respondents already have WCs with septic tank; a common response from this group is "it doesn't get better than this". Some stated that their living in these settlements is temporary and are simply resigned to the fact that they must make do with whatever toilet is available until they can afford to move to better locations. The 37% of respondents who were dissatisfied with their toilets mostly had pit toilets or used the bush. Others were dissatisfied because their toilets were shared with others stating that it was inconvenient and difficult to keep shared facilities clean. Some especially female respondents in this category indicated that sharing toilets increased the possibility of contracting diseases from the toilets especially from being exposed to fumes emanating the pit while squatting over the hole.

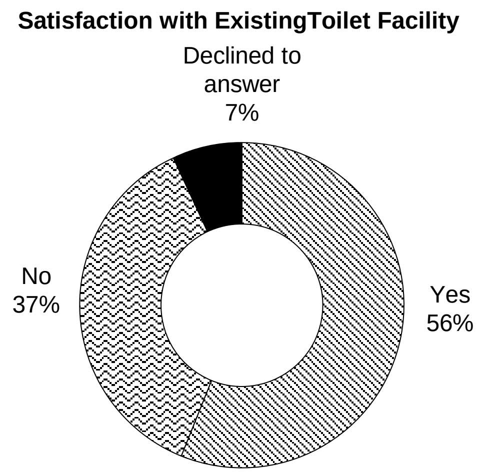


Figure 5. 37: Responses about satisfaction with existing sanitation facilities in the selected peri-urban areas.

5.3.5 Reuse of Treated Excreta in Agriculture

A section of the survey tool was devoted to sampling opinion on human waste reuse. This was particularly of interest because ecological sanitation systems, which promote safe reuse of treated excreta as one of its fundamental principles, are being considered for these areas. It is thus essential to be informed about perceptions (cultural, religious, etc.) regarding the handling or use of human waste in agriculture. The results are presented in the following section.

Assessing knowledge of fertilizer and manure use in agriculture: in general, with the exception of those who declined to answer among the respondents (3%), 95 % of respondents had some knowledge about the use of manure in agriculture claiming it increases soil fertility and improves crop yield (see figure 5.38). Among those who responded positively to the question of knowledge of manure use in agriculture, 91 % had knowledge of animal manure use in particular (see figure 5.39). This gives an indication of widespread knowledge of manure use in agriculture, however a somewhat interesting view especially in Nigeria (from personal discussions), though not directly covered in this study, is that crops grown with chemical fertilizers are not quite as tasty as those grown without. People tend to have a perception that mineral fertilising agent aided crops while being larger in size are of poorer quality as regards taste than those grown without these agents.

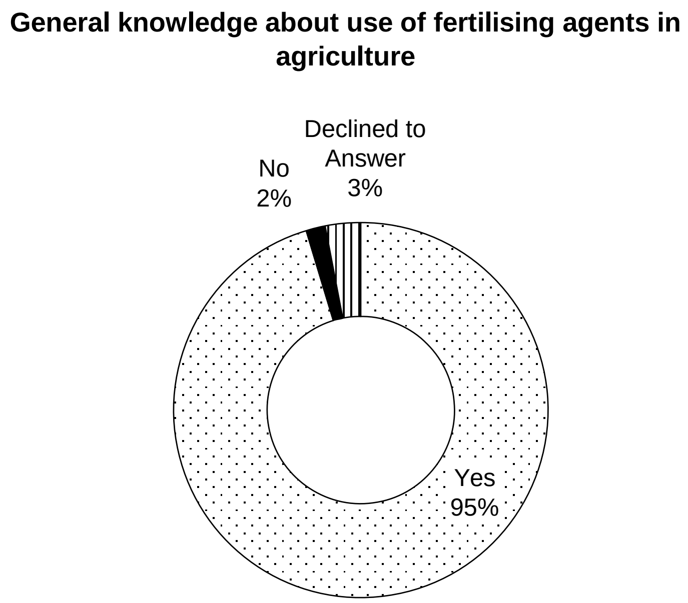


Figure 5. 38: Responses on knowledge about the use of fertilising agents in agriculture

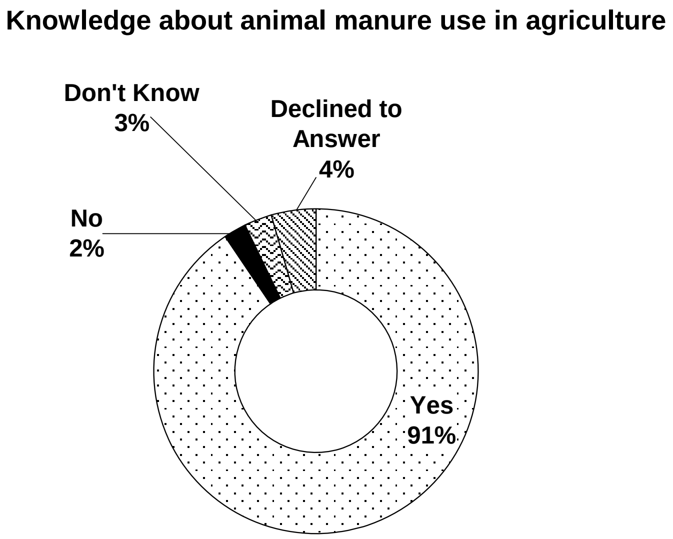


Figure 5. 39: Responses on knowledge of the use of animal manure in agriculture.

Assessing knowledge of human waste reuse in agriculture: on the question about knowledge of human waste reuse in agriculture, 52% answered indicated knowledge of human excreta use in agriculture, 39% did not know about human waste reuse in agriculture while 2% did not know and 7 % declined to answer (see figure 5.40). This indicates that although knowledge of animal manure use in agriculture was widespread, knowledge of human excreta use in agriculture was less common.

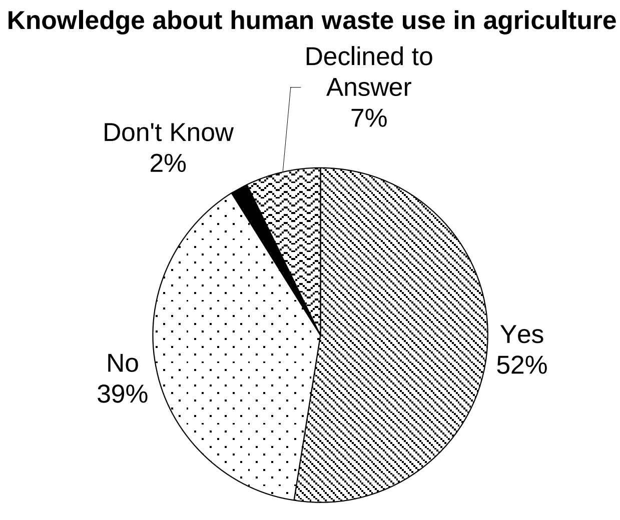


Figure 5. 40: Responses to questions on knowledge of the use of human waste in agriculture.

Acceptability of human excreta use in agriculture: regarding acceptance of human excreta reuse in agriculture (see figure 5.41), 42% of respondents thought the practice was acceptable and 51% thought it was not, 2% did not know and 5% declined to comment. Most of the respondents who thought human waste reuse in agriculture was acceptable were from the indigenous population who were predominantly farmers. The respondents from the settlement of Mpape had the highest percentage of objections to using human waste in agriculture. It was observed that majority of the residents of Mpape were migrant settlers who were mostly construction site workers, which may explain their response and attitude to human waste reuse in agriculture.

Figure 5. 41: Responses on acceptance of the use of human waste in agriculture

Regarding buying and eating food grown using human excreta as a fertilising agent, 51% of respondents would buy food grown using human excreta as fertilizer and 41% indicated they would not, (see figure 5.42). The positive responses indicate a good level of acceptance of food grown using treated human excreta, an interesting observation is that while people will not directly apply the material to their farms, they do not object to buying food on which the material was applied by others. This agrees with observations made in other regions of Nigeria where urban agriculture is practiced. It is widely acknowledged among people that farmers use septic tank effluents to grow vegetables and people purchase and consume the products nevertheless. The attitude seems to be one of 'I don't have a problem with it as long as I do not have to do it myself'.

The negative responses may be indicative of the influences of religious beliefs (although questions about religion were not included in the survey due to the sensitivity to such questions and the problems this is likely to cause) as the Islamic religion for instance has well defined stances on purity (clean, unclean, pure and defiled) especially regarding bodily discharges, and places significant restrictions on contact with excreta.

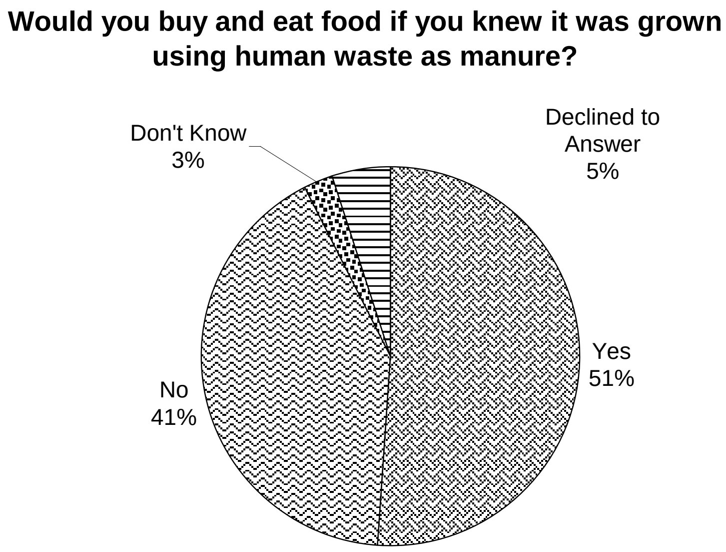


Figure 5. 42: Responses on acceptance of food grown using human waste

In general, knowledge of the value of excreta as manure is found even among those who object to the direct use of the material in agriculture. In some villages where open defecation is practiced in Nigeria for example, it is common for a particular site to be designated both for defecation and as a solid waste dump. The site is used for some time and abandoned for a new one. Often after a period of rest, edible plants such as vegetables appear on such sites and people acknowledge that crops allowed to grow or sometimes deliberately grown on such abandoned defecation sites grow better, with bigger leaves, etc. and many have no objections to eating such plants even though they will not deliberately apply human excreta.

Some farmers on the other hand consider human excreta a source of cheap fertilizing agents as they use septic tank effluent to irrigate their fields between planting seasons i.e. in the dry seasons, more for its nutrient value than for water. This practice of excreta application on fields during non planting seasons helps to limit exposure of farmers to potential pathogens while the high temperature during the dry seasons coupled with high solar radiation encourage high and fast die off of these pathogens, thus offering some limited level of safe reuse with current practices. It would however be better if the wastewater is treated prior to application to ensure that the practice is safe to both farm hands and consumers. Some farmers were observed irrigating their crops with water from the Wuye River taken very close to the point of sewage discharge into the river (see figure 5.43).

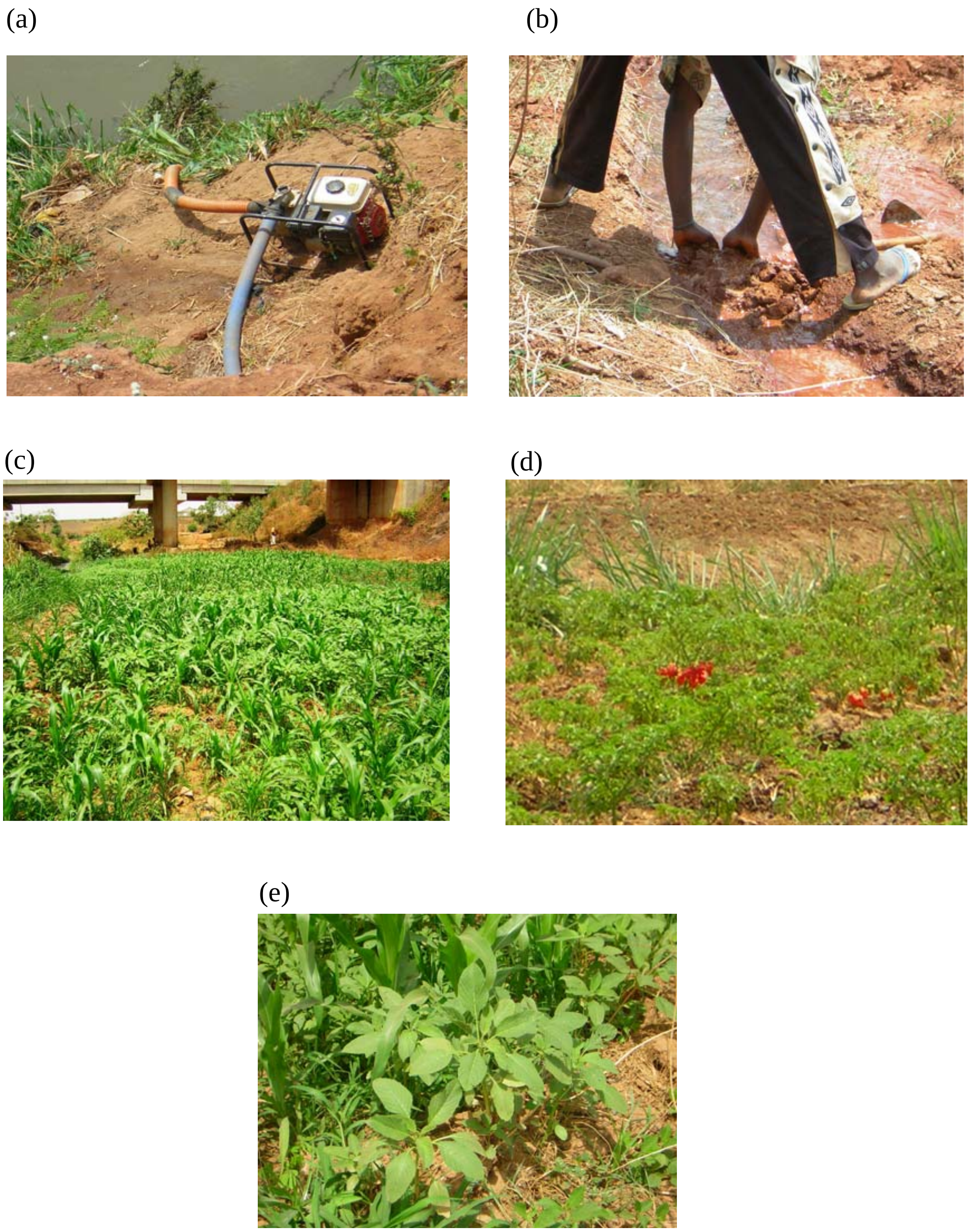


Figure 5. 43: (a, b) A farmer irrigating his crops with wastewater from the Wuye plant discharge point; (c) maize plants; (d) scotch bonnet peppers; (e) local spinach plant.

Handling human excreta: regarding beliefs about touching or handling human excreta, majority of the respondents 47 % did not have a problem with touching or handling human waste. This view was found particularly among female respondents as women are traditionally responsible for sanitation and hygiene in most communities in Nigeria.

Some respondents thought it was not allowed or hygienic, while others viewed the practice as a taboo or harmful (see figure 5.44).

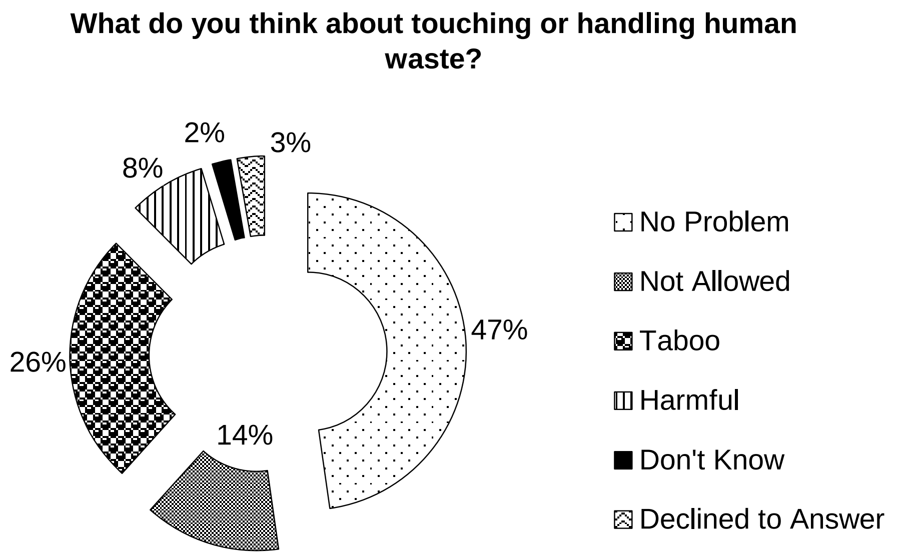


Figure 5. 44: Responses on attitudes to handling human waste in the selected peri-urban areas

5.3.6 Sanitation related health issues

Epidemiological data obtained from the Public Health department in the FCT are presented below and give an overview of health issues within the FCT. The data is representative of the FCT as a whole as data was not available for the peri-urban settlements in particular.

Infant and Under 5 Mortality Rate for the FCT in past years: data in table 5.13 shows the infant and under five mortality rates per 1000 live births; such data are significant as children are among the most vulnerable groups affected by water and excreta related diseases. Although the data is given for Nigeria as a whole, it is applicable to the FCT in particular.

Table 5. 13: Infant and Under 5 mortality rates for Nigeria

Year	Infant Mortality Rate / live 1000 births	Under five Mortality Rate / live 1000 births
1990	120	230
1995	73	141
1999	105	175
2002	110	183
2004	101	197

Source: UNICEF, World Health Organization, United Nations Population Division, World Bank and United Nations Statistics Division.

Table 5.14 shows data obtained from the Epidemiological unit of the Health Department of the Ministry for the FCT on the most prevalent diseases in the FCT. The significant issue here is that among vulnerable groups e.g. children, water and sanitation related diseases are next only to malaria and measles as causes of mortality in infants and children respectively.

Table 5. 14: The most significant diseases in the FCT

No	General	Children under 5	Children over 5	Adult	Water/ Sanitation related
1	Measles	Measles	Malaria	Malaria	Diarrhoea
2	Malaria	Diarrhoea	Diarrhoea	HIV/Aids	Dysentery
3	Pneumonia	Dysentery	Dysentery	Tuberculosis	
4	HIV/Aids	Poliomyelitis		Hepatitis B	
5	CSM	Malaria		CSM	
6	Tuberculosis				
7	Diarrhoea				
8	Dysentery				
9	Poliomyelitis				
10	Leprosy				

According to officials of the Epidemiological and Surveillance Unit of the Health Department, there have been outbreaks of diarrhoeal diseases said to be almost a yearly occurrence among the indigenous population people in some parts of the FCT particularly in a village near Gwagwalada where residents lack access to basic sanitation facilities and reportedly practice open defecation in their settlements. It was reported that as rain falls faecal matter is washed into their water sources resulting in the ingestion of pathogens that consequently cause diseases. In another instance villagers preferred to use stream water rather than the boreholes provided and were thus exposed to disease causing pathogens. Of the several episodes that were reported, several fatalities were recorded these are shown in table 5.15.

Table 5. 15: Reported cases of water and excreta related diseases and fatalities

Location	**2004**		**2005**	
	Reported Cases	**Deaths**	**Reported Cases**	**Deaths**
Kuje	-	-	-	3
Gwagwalada	55	7	60	12
Kwali	40	13	-	-
Mpape	10	3	-	-

The figures are limited to those that were reported at clinics and local health centres; many people due to issues of cost and lack of trust in modern medicine do not use such facilities preferring home remedies or local traditional healers as such occurrences and fatalities in these cases are hardly if ever reported.

Hygiene Knowledge: an overwhelming majority (95%) of the respondents had some knowledge of good hygiene practices as they responded that it was important to wash one's hands after defecating (see figure 5.45). When asked why, the overwhelming response was that hand washing was important to prevent the spread of disease. As seen from the chart only 5 % declined to answer. The level of knowledge of good hygiene practices is certainly an advantage for any sanitation provision program.

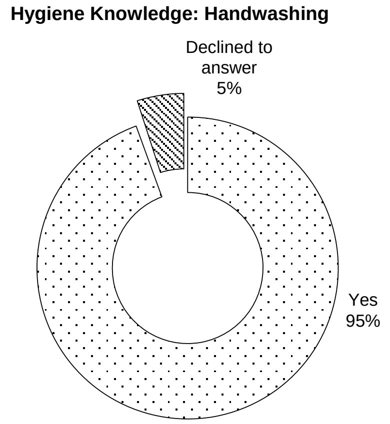


Figure 5. 45: Responses on knowledge about the importance of hand washing as a measure of hygiene and disease prevention in the selected peri-urban areas.

5.3.7 Solid Waste in the Peri-urban Settlements

Service providers and coverage: as opposed to the waste removal services provided mainly by the AEPB and its contractors in the FCC, in the peri-urban settlements, more than half of the respondents 61% used private removers, 30 % of the respondents disposed of their waste themselves usually simply throwing it on a heap by the roadside or in gutters and drains and only 1% use AEPB service (see figure 5.46). This practice of open dumping particularly around households represents a major health risk to residents from disease vectors living and breeding in such dumpsites. There is thus a need for improved solid waste disposal services in these settlements.

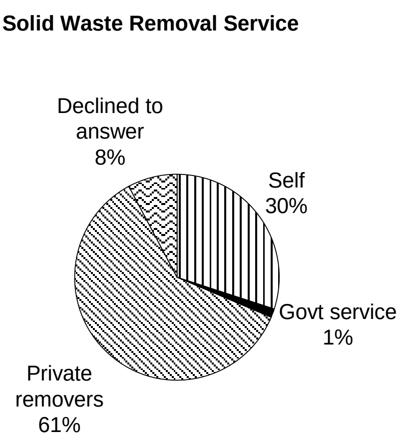


Figure 5. 46: Responses on solid waste service providers in the selected peri-urban areas

Satisfaction and willingness to pay for services

Figure 5.47 (a, b, c) shows the respondents answers to issues of satisfaction with the solid waste removal service, demand for improved services and willingness to pay. An overwhelming number of respondents were not satisfied with current state of service and would like solid waste service provided or improved. An even higher number were willing to pay for the services as according to these respondents they currently do.

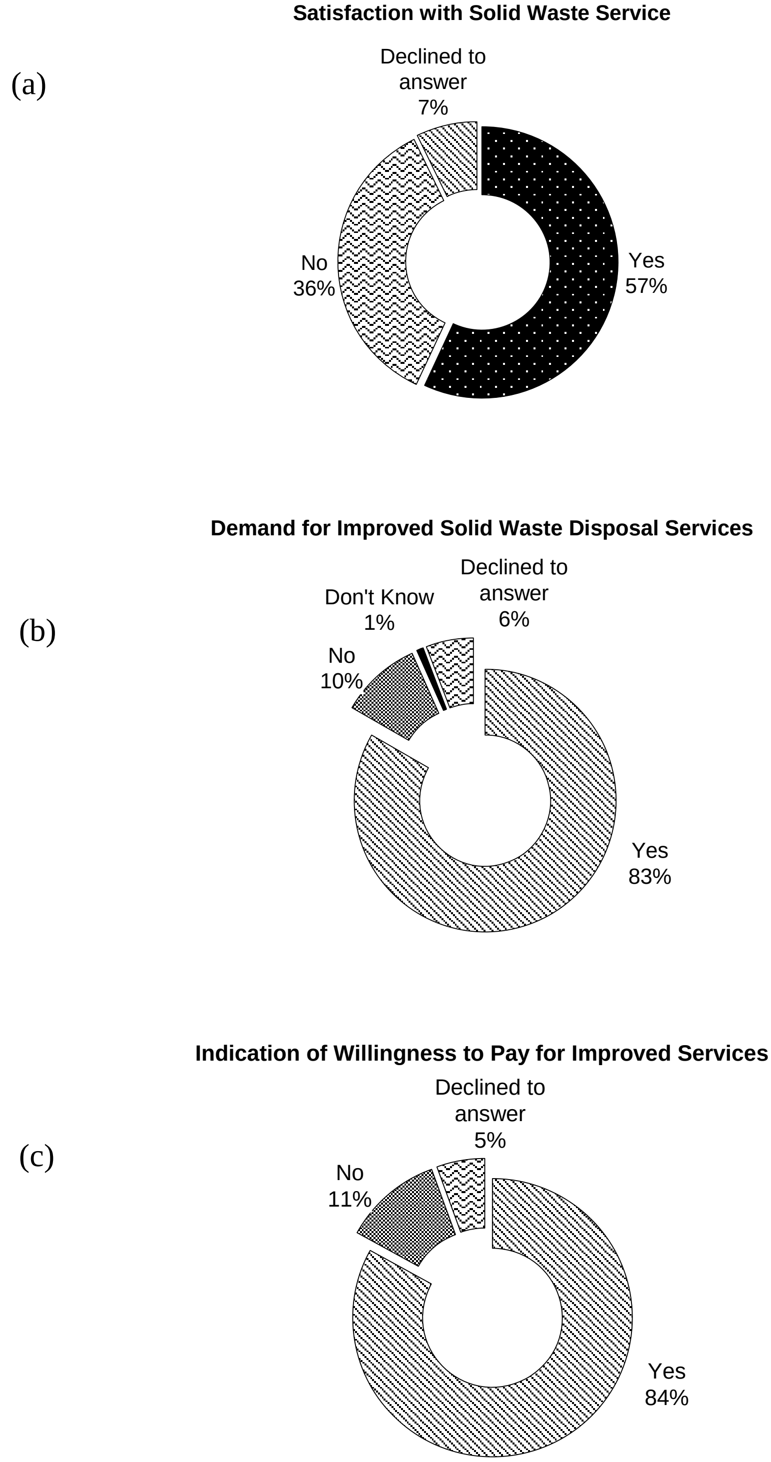


Figure 5. 47: Responses to various questions on solid waste management

Factors affecting general willingness to pay for service: the survey results shown in figure 5.48 revealed that people are very much interested in having access to better services. To the question *"under what conditions would they be willing to pay for better services"?* The options presented were, if it were their own house, if the accommodation was rented, if they would be willing to pay regardless of the ownership of the house as long as services were good. 65% of those interviewed said they would be willing to pay whether or not they owned the house as long as services were good. 8% indicated only if the house belonged to them, 13% declined to answer; this is probably because some of the respondents were not comfortable with discussing issues related to money and their having to pay for services. 14% would be willing to pay even if the accommodation was rented. These responses indicate both demand and willingness to pay for better water, sanitation and solid waste removal services.

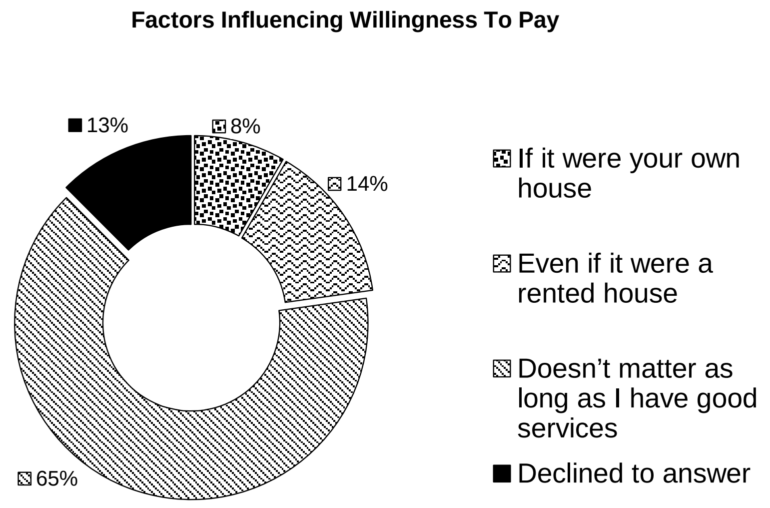


Figure 5. 48: responses on willingness to pay for services in the selected peri-urban areas

Preference for service providers: the respondents' preference regarding service providers (water, sanitation and solid waste) was also sought, responses were as follows: 49% preferred services to be provided by private concerns as in their opinion the companies are more efficient even if they are more expensive; they can also seek redress or switch providers if they are dissatisfied with their performance, unlike the municipal authorities who often hold the monopoly on service and usually do a poor job. 39% felt the government should be the provider of services. This group believed it is the duty of the government to provide things which they consider essential to the well being of the general populace. In figure 5.49 further details about preferences regarding service providers are given. Overall it can be inferred that people preferred private service to municipal, this is an indication of the potential for success should a private service agency be set up to serve these areas. This will not only meet the needs of users but also generate much needed employment in the areas.

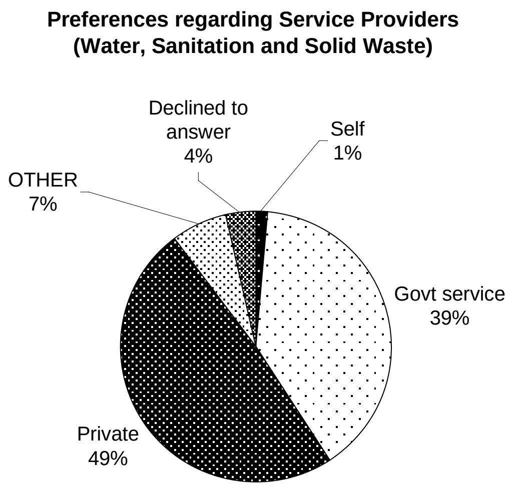


Figure 5. 49: Responses on preferences regarding service providers

5.3.8 Limitations of the Study

Many factors were limitations in this research work. The main ones are discussed in this section.

Access to Data: data from secondary sources such as the agencies responsible for the various issues addressed in this study was simply non-existent. Where data was available there was immense difficulties in obtaining access to such data. In some cases an official approval was required before data was released, the process of obtaining this was time consuming and tedious. The main reason for this was reluctance on the part of the lower cadre staff to be liable for unauthorised disclosure of information. For example it was not possible to obtain data regarding governmental expenditure on sanitation systems.

Time and resources: the nature of human dynamics and factors of efficiency are very different from place to place e.g. efficiency in Nigeria very much depends on social interaction skills, it is almost impossible to get things done by mail or phone, which often means personal presence is necessary as such considerable time is required to get things done. The ideal situation would have been to have made at least two to three visits to the study sites, however time and budget limitations made this impossible. German residency regulations also meant it was impossible to be outside of Germany for longer than six months; and severely limited funds meant that only one field visit could be carried out, the consequence of this is that not all necessary information could be collected for this work and in such instances assumptions have been made to supplement available data.

Communal tensions in the study areas: this study (January to June 2005) incidentally took place at a time the governing authorities began intensive squatter settlement clearance activities that involved demolitions of some settlements. As a result there was a lot of tension in the study communities during the time of this field study, largely from speculations that they might be next. This factor affected the survey part of the field work to a large extent with experience and response of residents of the study communities being mixed, some of the respondents were quite accommodating and willing to talk while some were very negative in their reception of the survey exercise, which in the author's opinion is a spin off of the squatter settlement demolition drive. Even those who responded positively were all too often interested not in the subject matter at hand but more in discussing their perception of the government's action. Many times people assumed or hoped the study was for newspapers and that their views and frustrations would be broadcasted to a wide audience. The climax of the prevalent tensions came when a student engaged to assist in data collection was attacked and seriously beaten by a potential respondent for reasons unknown, but probably because the respondent either found some questions objectionable or assumed that the student assistant was a government agent scoping the location for demolition. The physical assault was such that medical attention at the local hospital emergency unit and several days of follow up treatment were required.

Cultural sensitivities: due to the cosmopolitan nature of the study areas, it was impossible to gauge the cultural barometer of the respondents accurately. The impact of this is that some of the questions asked in the survey were culturally off limits for some people e.g. 'number of people in your household', as there is a belief in some parts of Nigeria that one should not count his offspring! The impact of such belief was highlighted again during the recent national census in Nigeria where census officials were reportedly attacked in some communities as they attempted to do their work (BBC News, 2006). Data collection exercises are almost always embroiled in cultural, political and religious hitches. This study experienced a small scale version of this scenario, as such care was taken not to offend the sensibilities of people a fact that affected the sampling process of the respondents. Income was another issue people were simply not willing to discuss thus it is uncertain that information given regarding willingness to pay expressed the reality of the respondents' situations.

Respondents' expectations: ideally this study should have been fully participatory; however this was not possible because of the potential of raising the expectations of people falsely. Many respondents cooperated because they thought or hoped their views would be addressed in a way that would be of immediate benefit to them. To avoid this, data collection methods were partially participatory or as participatory as possible given the circumstances.

Unresponsive agencies: many of the agencies covered in the course of this study were simply unresponsive. The police for example did not help when the incident where the student assistant was attacked was reported to them. They claimed that their approval should have being sought before the study commenced, whether their stand is right or not is unsure but it is doubtful if academic field studies require Police permission especially as approval was obtained in writing from the Abuja Environmental Protection Board prior to the commencement of the study. Other agencies such as the Water Aid office in

Nigeria did not respond to repeated requests (written, verbal) and follow ups for information on their activities, projects and experiences on water supply and sanitation in Nigeria.

5.4 Analysis of Existing Sanitation Systems in the Study Areas

The existing sanitation systems in the study area fall into two categories: the conventional waterless sanitation systems and the conventional waterborne systems.

5.4.1 Conventional Waterless Sanitation

1) The 'Do Nothing' Scenario *(Open Defecation; Wrap and Throw (Shot-Put); Disposal by Animal)*

Open defecation: refers to the practice of defecating in places other than built toilet usually out in the open, and either indiscriminately or in specially designated places such as defecation fields, waste dumpsites etc., (see Section 2.2.1). Reasons for this practice in the area include a lack of toilets or that available toilets are not satisfactory for reasons such as cleanliness, proximity, etc. In Nigeria there are differences in open defecation practice between residents of rural and urban areas and this is often due to traditional beliefs about excreta. In the rural areas, it is common to have a designated defecation place that is recognised and used by the community as such faecal matter is generally restricted from dwelling areas. The exceptions to this are the case of very young children, and in such cases the mothers or older siblings are responsible for ensuring that the excreta of the child is removed and disposed of appropriately; another exception is at night especially where the defecation site is far removed from the dwelling, many generally then resort to the "wrap and throw" method. In urban areas, open defecation is practiced indiscriminately. The control over the practice observed in rural areas is totally absent perhaps due to the limited sense of community in the urban as opposed to rural areas, which is also due to the fact that the residents of most urban centres come from different areas, background, etc.

Wrap and Throw: as the name implies people simply wrap their faeces and throw it out of their dwelling in the case of rural areas usually in a designated place but in urban areas wherever possible, sometimes on the streets, at the back of home, in neighbours' yard, in open canals, ditches, etc.

Disposal by Animal: another method of excreta management that fits under this scenario is the use of animals especially dogs and pigs to dispose of their excreta. These animals are summoned to eat up the excrement especially that of children.

Local Advantages

The only advantage of any of these practices is that people relieve themselves and remove the excreta from their immediate dwellings. However amazingly people have come up with advantages for these practices, its free food for the animals, they can examine the faecal matter to determine if they have intestinal worms, good fertilizer source for home gardens, and no need for expensive latrine construction therefore a cheap way to achieve the same objectives.

Disadvantages

For very obvious reasons open defecation, wrap & throw and disposal by animal are not practices to be encouraged. The potential of these practices for human and environmental health damage is enormous. Some of the specific disadvantages include:

- Encouraging flies thus providing good conditions for the spread excreta-related diseases.
- Given the right conditions, (moisture, temperature) intestinal parasite larvae e.g. hookworm, easily develop and are transmitted; people and animals may pick them up and may be directly infected or act as carriers for the different stages of the parasites life.
- Having animals eat human excreta is at best an unfair even cruel practice. Also eating meat from these animals represents a potential disease transmission risk unless proper cooked before consumption; however these animals (pigs, dogs) are not common traditional meat sources for human consumption in most parts of Nigeria.
- Run-off from such defecation may get into streams and other surface waters which are water sources for humans, which is an easy pathway for the spread excreta-related diseases as reported in some of the disease outbreaks in parts of the FCT (see Section 5.3.6).
- Lack of privacy for users during daylight hours
- Distance to dwelling may pose a problem for users at night or during rainfall especially the vulnerable groups such as women, young children, the old, or sick.
- Aesthetically it is a nuisance especially in large dense urban communities

In summary, all of the above named practices cause or have the potential to cause serious harm to both the environment and especially humans, and as such are not acceptable as bona fide excreta management practices.

2) Simple Pit Latrine

Description: simple pit latrines are another type of sanitation facility encountered in the study area. They basically consist of a pit with a squat hole through which excreta falls directly into the pit beneath the user, and a superstructure (please see Chapter 2 for a description of the technology). The superstructure is constructed using materials such as cement blocks, zinc sheets, and mud brick covered with plaster. The main determinant in the choice of the superstructure material for people is affordability (how much does the owner want to spend on the toilet) and target users (is the toilet to be used by the owner or tenants or visitors, etc), it is common to use good durable materials such as cement blocks where the toilet is used by the house owner as a good looking toilet is viewed as an indicator of social status. The pits are usually unlined as this is cheaper for the owner to construct. The pits are used until they are full and are then either abandoned for newly built ones or emptied manually. Some of the latrines visited were dirty, as there were faecal matter littering the interior of the toilet, bit most did not have a problem with flies, which may be an indication that the pits are not inundated with moisture and as such good soil drainage is indicated. On the other hand, the study was carried out in the dry season when there is no rainfall and most of the water wells were dry as such the no-fly and good drainage observation could also have been due to the effects of harmattan – lack of precipitation, high temperature and evaporation.

Figure 5. 50: Superstructure of a pit latrine in Karmo

Figure 5. 51: Inside a pit latrine in Karmo

Local Advantages

Pit latrines represent an improvement on no sanitation.

- They provide a designated place for defecation.
- They provide privacy and some level of convenience.
- They require no water for operation and the contribution of this factor to total household water cost is eliminated.
- Facilities can be shared between households.

Disadvantages

- Most of the pit latrines seen in the study areas were located close to water well for convenience this presents a potential for pollution of nearby water wells, which are sources of fresh water for households.

- Emptying of pits is usually done manually, this presents a risk to workers as faecal matter is often still fresh.
- Emptied pit content are often dumped in rivers or waste dumps without due consideration for the effects on the environment receiving the products.
- Latrines located outside homes, this is a convenience issue for users especially women and girls at night.
- No sense of ownership for shared latrines; it is therefore difficult to properly organise cleaning and other maintenance activities (see figure 5.21).
- Risks of collapse for substandard designs, designs are usually not regulated by the authorities as such a lot depends on the skill level and experience of the builder.

5.4.2 Conventional Waterborne Sanitation

1) Septic Tank System - *with Pour Flush (PF)/Water Closet (WC)/adapted WC; PF with Pit*
Septic tanks are arguably one of the most widely used onsite wastewater treatment system worldwide. This system was also widely found in the study area especially in the more upscale parts (see Section 2.3.1.2 for description of technology). In almost all cases the effluent is not given any treatment other than that accomplished during infiltration into surrounding areas. Where systems malfunction the sewage simply overflows into the surrounding and the tank is then emptied by environmental services which provide pit emptying services by truck. Regulations or construction standards if existing are not enforced and owners can simply employ the services of artisans skilled in septic tank construction who then constructs the tank based on experience. The method described by one local artisan for installing septic tanks is that they are constructed using bricks and a gap is deliberately left in one of the walls so that the water infiltrates into the surrounding areas, this serves as a means of limiting or totally eliminating the need for emptying the tanks or constructing a leach field or soak-away; this account if true or widespread is alarming. Most homes with a septic tank usually have one of the following types of toilet facilities: WC, Pour flush (see Section 2.3.1.1 for descriptions) or adapted WC.

Adapted WC: refers to the normal flush toilet, which due to limited water availability is flushed by pouring water into the toilet bowl by hand rather than by pressing the flush handle. It is very common in situations where there is no in-house water supply.

Advantages
In addition to the health benefits of having an improved sanitation system such as this one, the main advantage of the septic tank – WC, PF, adapted WC scenario is that

- it gives users the convenience of flushing and forgetting at least until the tank needs to be emptied;
- it is also associated with high social status in the peri-urban areas and considered much better than the pit latrine.

Disadvantages

Although this system is favoured and quite common in many of the houses in the peri-urban areas, it does have a number of disadvantages, some of these are:

- it is relatively expensive to construct and especially to empty, emptying costs range from 6000–10000 NGN (37 – 65 Euros) as such it is often left to overflow before it is emptied.
- it requires adequate water, which in the peri-urban areas is usually bought at high prices (see table 5.12), people usually resort to flushing with wash water from kitchen or laundry.
- it requires ample space thus is not suitable in high-density housing situations;
- it requires regular emptying of sludge, which often does not happen in these situations (Coker et al., 2003).
- emptied sludge is simply dumped at solid waste disposal sites and in rivers polluting the receiving bodies.
- many times the capacity of the infiltration field is exceeded due to the fact that many houses within the same area all have septic tanks discharging to the same field, in these cases there are puddles of wastewater around the houses – presenting a breeding ground for disease vectors.
- because there is usually no regulation of the construction, no attention is paid to whether or not the soil has the capacity to receive the tank effluent and you therefore have many systems that fail simply due to errors in design.
- some tanks as in the case of pit latrines are situated close to water wells, resulting in high possibility of polluting these wells.

2) Conventional Sewerage with WC

This system consists of the WC and a conveyance network, which carries the wastewater leaving the houses to a treatment facility if one exists or a disposal site in this case a river. The sewerage system in the study area is the separate (storm and wastewater) sewer system and is found only in the FCC, the peri-urban areas do not have sewers.

Advantages

The following are the advantages of the sewerage system in the FCC:

- *convenience*: unlike the onsite systems, this system allows the user to simply flush and forget what happens afterwards.
- *performance*: unlike the latrines there are no smells or fly nuisance as a result of having and using this toilet system.
- *reuse*: effluent is sometimes used for irrigation by farmers growing crops around the treatment facility at Wuye (see figure 5.43).
- *reliability*: unless there is abuse, the system is overall very reliable as far as the users are concerned.

Disadvantages

In addition to the general disadvantages of sewerage systems, some of the other disadvantages found regarding this system in the FCC include:

- high construction costs which has meant that the network has not been completed and many places even within the FCC currently do not have sewers;
- difficulties in regulating connections to the sewer lines means people sometimes connect to sewage pipes to stormwater networks;
- misuse of the systems by users who throw waste into the network casuing blockages and overflow onto streets in some parts of the city, (see figure 5.10);
- functioning treatment facilities are a required part of the whole system and when they are lacking or non functional as in the case of the FCC area? raw wastewater is often discharged into surrounding water bodies, as observed during this field study;
- reliable water supply is essential for proper functioning;
- maintenance must be adequate to prevent breakdown of systems – this was not the case with the study area as none of the 13 facilities within the area was functional at the time of this study;

Table 5. 16: Summary of the sanitation technologies and treatment available in the study area

	Technology	Indigenous Population	Peri-Urban	FCC	Treatment
Conventional Dry Systems	Open	✓	✓	✓	Open air drying, decomposition
	Wrap and Throw	–	✓	×	None
	Animal Disposal	✓	✓	×	None; consumption by animals
	Pit	✓	✓	×	None; storage
Conventional Wet Systems	Pour Flush + Pit	×	✓	×	None
	Pour Flush + Septic Tank	×	✓	×	Settling, decomposition, infiltration
	Adapted WC + Septic Tank	×	✓	✓	Settling, decomposition, infiltration
	WC + Septic Tank	×	✓	✓	Settling, decomposition, infiltration
	WC + Sewerage	×	×	✓	Treatment plant, river disposal
	Public Facilities	×	×	✓	Sewerage, treatment plant, river disposal

Shaded cells: indicate areas having both household and communal facilities

5.5 Addressing the need for sanitation services in the FCT

In summary, although the sanitation coverage in the study areas was not total, the use of inappropriate sanitation technologies was found to be more of a problem than a lack of access. In the FCC the treatment systems are failing for the many reasons discussed in previous sections, of these one that stands out in particular is that the treatment technologies currently in place in the FCC are non sustainable in that they are dependent on external inputs (imported spare parts, energy, highly skilled operators) for proper and sustained function. In the author's opinion technologies that have limited or no-mechanical parts especially imported ones, low or no energy requirements would be more beneficial in terms of sustainability.

For the squatter settlements whose residents represent the primary target of this study, pollution resulting from non regulated private onsite sanitation facilities was the most common problem among the migrant population. People simply install what they wish without due regard of the impact such systems may pose to human health or the environment. As such there is largely a careless attitude towards excreta and sullage handling.

Among the indigenous population on the other hand, access was the major problem. Any solution proposed for these groups of people must take into consideration their cultural practices and preferences and also include an element of hygiene education. Although this group of people were not originally included in the study target population, they also were in the study areas. As such possible sanitation systems have been developed that could be potentially feasible among this group as well.

The current situation with the squatter settlements is that resident will be assigned plots of land in the satellite towns, which they are expected to develop and move to in the near future. As most of these satellite towns are currently only existing on paper, there is a good opportunity to influence development and encourage the adoption of environmentally sound sanitation technologies that are low cost and efficient. However for any such measures to be successful it is essential that there be some major changes made in the way sanitation infrastructure is developed.

- *Appropriate policy/regulation:* currently people do what they deem fit. There is no control on what people consume or discharge into the environment and how this is done. This is not a good way to develop sanitation infrastructure that enable sustainable development. First there must be regulations in place based on the National Environmental Policies that tells people what they can and cannot do as regards the toilets they install in their homes. There must also be a system put in place by the environmental bodies in charge of the FCT that enforces these regulations. The current situation is that outside of conventional systems, the authorities are not involved in any other kind of sanitation infrastructure management and this must be changed because overall when problems arise it will eventually become the problem of the authorities so better to get it right before problems occur than deal with them after the fact.

- *Provision of options*: the authorities must be educated on the sanitations options available besides the age-old conventional sanitation systems they are used to. This will require openness on the part of the officials, training and some research (pilot testing) into how these alternative technologies might work in their particular situation. A catalogue of possible options should be created and these established for each area. In essence anyone wishing to develop a home in the area would be presented with this catalogue of options with standards, from which to choose and deviations from these not permitted. The range of options should be such that will cover a wide spectrum of preferences within the boundaries of established environmental and resource consumption goals and management capabilities of the sanitation regulatory body. Appropriate penalties should be applied to defaulters.

- *Institutional capacity building*: there should be capacity building drives that target both the officials of the environmental departments and local artisans that do the actual construction of the toilets, such that they are familiar with the technologies, operation and maintenance issues. This will enable them provide decision making and maintenance support to users as required.

- *Enforcement and monitoring*: regulations are not of much use without a system of enforcement and regular monitoring as such there needs to be such a system in place. There is an agency for development control and building regulations and the sanitation regulatory unit could work with this agency. They basically would require that people submit with their house plans details of their choice of sanitation facilities selected from the list of option provided by the sanitation regulatory body. They could also maintain a list of trained artisans or small companies that are certified to replicate these technologies (producing parts, providing installation and maintenance services) to the homeowners. Upon the completion of construction, the inspectors would be invited to see the facility and give their approval, in which case the development control agency would only approve a building as fit for occupation if the owner presents a certificate of approval of his or her sanitation system issued by the sanitation regulatory body.

- *Public-Private Partnerships in management*: small onsite systems management companies could be created with private individuals responsible for the management of the onsite facilities in cooperation with the authorities in much the same way the current solid waste collection system operates in the main city (FCC).

This study began with a search for possible sanitation solutions for the peri-urban squatter settlements. However since it is more or less certain according to official sources that the settlements will all be demolished, it is unwise to promote the installation of expensive sanitation facilities in these areas only for these to be destroyed in the future. The new governmental approach of resettlement of these peri-urban residents in satellite towns around the FCT will provide opportunities for the development of areas outside of the main city, thereby encouraging a spread rather than the current concentration of development in and around the main city. This also presents a good opportunity to get the sanitation scenario right from the inception and planning stage. It must be reiterated that conventional waterborne solutions are simply too expensive for most people to afford and the provision of subsidies for operation of such facilities is essentially an unnecessary burden on government. Installing conventional systems such as those in the FCC will be by and large a mistake.

A more appropriate approach will be to examine locally appropriate low cost options that provide similar public and environmental health benefits to residents, which they want and are willing, and able to pay for. Such systems must be low cost, require low maintenance and skills in installation and operation to ensure sustainability. Where such systems allow for reuse of treated waste, this will be an added and welcome bonus.

Considering the dangers of lack of access to sanitation facilities and improper wastewater management practices, high cost of sewerage systems and its requirement of a piped water supply, which preclude its adoption in many communities in developing countries, there must be a shift from the innate preference for centralized conventional sanitation, with due consideration given to decentralised and on-site approaches to wastewater management in the planned satellite towns. The selected technologies are presented in table 5.17 and the scenarios developed from them in Chapter 6; these scenarios are based the points highlighted above.

Table 5. 17: List of potentially feasible sanitation technologies

Collection	**Storage**	**Transport**	**Treatment**	**Disposal**	**Reuse**
- Low flush toilets - Pour flush toilets -Squat pans - Dry UD toilets	- Canisters - Interceptor tanks -Rottebehaelter - Double vault systems	- Simplified sewerage - Settled sewerage - Cartage	-Pond systems -Constructed wetlands -Anaerobic systems - Composting - Dehydration	- Aquatic discharge - Infiltration	- Irrigation - Fertilisers - Soil conditioners

Chapter 6: Proposed Sanitation Scenarios

6.1 The Design Area

Kuje with a total land area of 1800 km², one of the area councils of the FCT has an area (93.16 km²) designated for development as a satellite town settlement (Kuje Master Plan). According to the master plan for Kuje, this area is intended to serve as a centre for absorbing migrants, and as the agricultural centre of the FCT, as such it is divided into two major zones – residential and farming. The area's soil type (well drained soil consisting of loamy sand to sandy clay loam, with low to moderate erodibility), and land characteristics make it one of the most fertile agricultural areas in the FCT. Sectors 4 (see figure 6.1) and 5 are the new development areas in Kuje, which may likely house those to be moved from some of the squatter settlements. Plots sizes in the area range from 300 m² to 1000 m² with an average household size of six persons. Water supply in the inhabited parts of Kuje is currently from boreholes, wells and streams; piped supply is planned for future use. The master plan does not indicate how wastewater is to be managed, which is the primary reason Kuje was selected as the design area in this study. As no concrete plan currently exists for wastewater management, opportunities exist to introduce and encourage the adoption of environmentally sound sanitation technologies that are low cost and efficient, rather than the resource intensive conventional systems that are not sustainable in the long term.

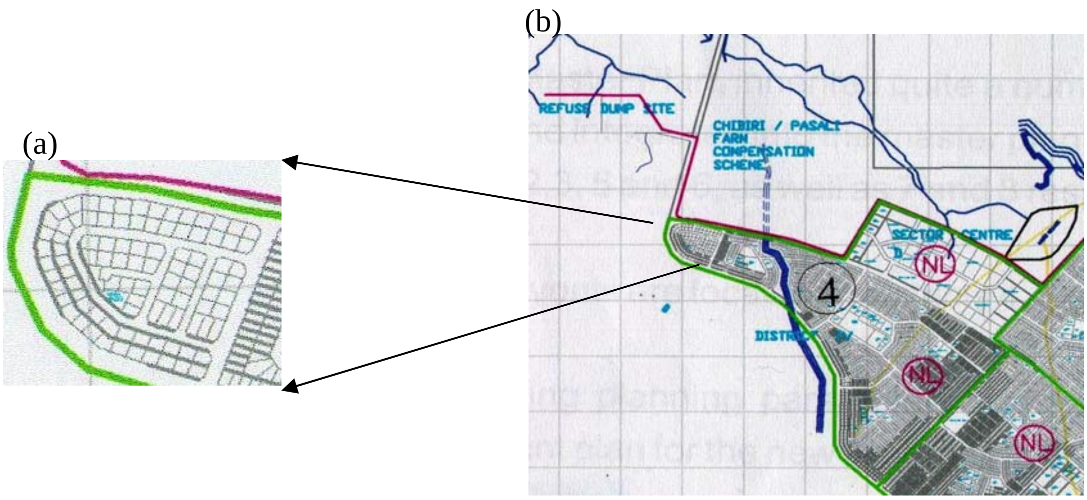


Figure 6. 1: Maps of the (a) design area; (b) Sector 4 of Kuje, FCT

6.2 Sanitation Systems

The sanitation scenarios proposed for settlements in Kuje are presented and discussed in the following sections. Considering the requirements and issues associated with centralised systems, the scenarios presented are either onsite or decentralised systems. The technologies represented in the scenarios were selected from a compendium of low cost sanitation technologies that have been successfully employed in conditions (physical, technical) similar to those prevalent in the area. The design area for these scenarios is a segment of Sector 4 representative of the Kuje area (see figure 6.1 a).

6.2 Semi-Central or Decentralised Systems

6.2.1 Combined Sewage Collection with Offsite Treatment

Description: this scenario is based on the wet sanitation concept and offers benefits similar to conventional waterborne sanitation with similar ease of use. It includes a low flush toilet as the in-house toilet unit for water conservation; both the black water and grey water streams are collected together; and the total wastewater is conveyed via simplified sewerage for treatment in ponds located outside the area.

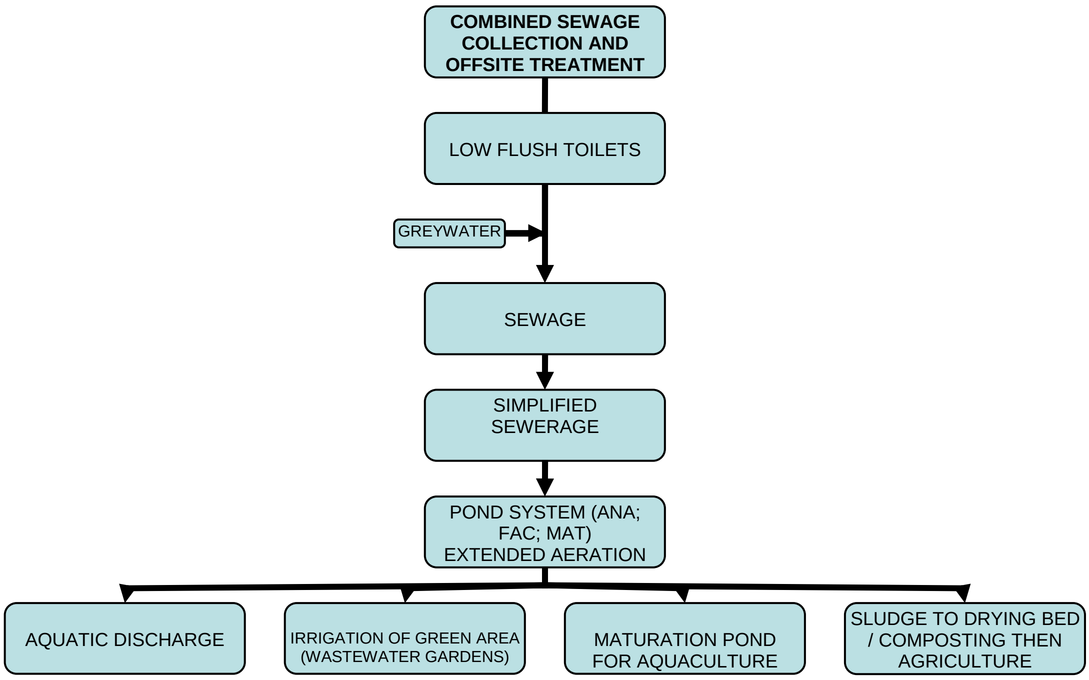


Figure 6. 2: Semi-centralised sanitation with waterborne sewage collection and offsite treatment

The pond system consists of anaerobic, facultative and where necessary maturation ponds, depending on the effluent quality requirement of the final reuse or disposal point of the treated wastewater. In this case effluent from the pond system may be reused in irrigation (agriculture or horticulture), aquaculture or discharged into an aquatic environment. The system is suitable as a semi-centralised system for a cluster of homes or an entire settlement; it is proposed in this case for a cluster of 97 households with an average population of six persons.

Installation, Operational and Maintenance Requirements: a primary operational requirement of this system is the availability of adequate water supply in the target area without which the system is bound to malfunction severely. For installation adequate data is essential as input into detailed design of simplified sewerage systems (see Chapter 4 for simplified sewerage and pond design methods). Typical data requirements include water consumption and wastewater generation, maps of catchments and topographical data, data on demographics – number of households to be served – two possibilities can be considered: full settlement i.e. no more houses will be added in which case increase in wastewater can only be due to increase in water consumption; or partial development i.e. there will be a difference in wastewater generation at the beginning and at the end of the design period. For sewer installation it is essential to ensure adherence to good construction practices e.g. follow the design parameters; correct application of inspection facilities, selection of good pipe materials, etc. Another vital requirement which may seem obvious but sometimes overlooked is that the intended users must want the systems –many projects have failed simply because this factor was not considered. As such the decision to install this system must be made in consultation with the stakeholders: intended users, municipal authority, after they must have been presented with other alternatives and know the advantages and potential drawbacks of each option, this instils a sense of ownership and responsibility, both of which are vital for sustainability of the system. For example users may not be able to dispose of bulky materials such as feminine hygiene products in the systems as is sometimes the case with normal flush toilets and conventional sewerage; this is a rule no one except the user can successfully enforce. There must also be an agreement as to which parts of O&M activities are to be carried out by the users and the municipal authorities respectively see figure 6.3.

Availability of maintenance equipments such as water jet units for sewer flushing is a necessity as well. This system requires treatment of the wastewater collected and transported from the households and this will be in pond systems. All the requirements outlined above apply to the successful installation and operation of the pond system as well. Typical maintenance requirements include:

For simplified sewerage

- Regular inspection of household connection point by the user.
- Keep bulky materials out of the system and prompt removal of such.
- Reporting blockages to municipal authorities, with prompt response to blockage report by municipal authorities.
- Occasional flushing of sewers with water jets to clear sediments and prevent blockage.

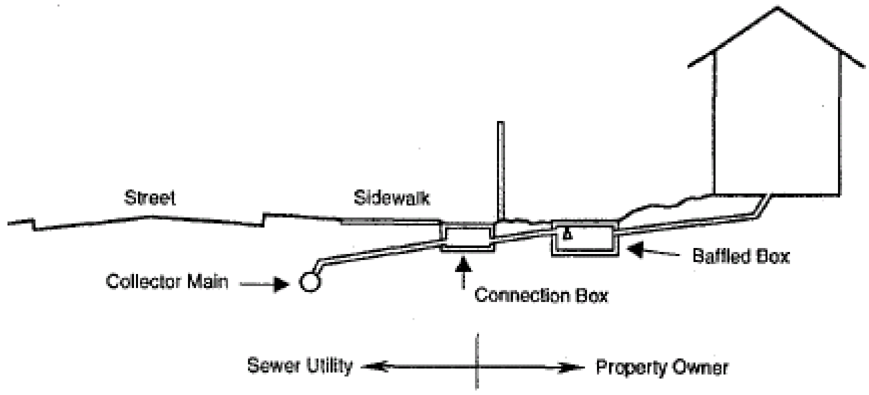


Figure 6. 3: O&M jurisdiction of property owner and sewer authority (Bakalian et al., 1994)

For the pond systems

- Regular scum removal from facultative and maturation ponds to ensure that sunlight reaches the algae in the ponds.
- Regular sludge removal is essential for the proper functioning of the ponds.
- Ensure that any damage to pond embankment is repaired promptly.
- Ensure that inlet and outlet devices are kept free of blockages.
- To prevent fly breeding, Mara (personal communication) suggests spraying scum layer on anaerobic ponds with suitable larvicides.

Advantages of this option:

- The convenience of having a flush toilet for which many users have a high preference as indicated by the survey results is one of the strongest points of this system.
- Lower costs of both the simplified sewerage and pond treatment systems compared to other conventional sanitation system.
- Low flush toilets represent a water saving opportunity in the scheme.
- Maintenance requirements of various components are manageable to both users and municipal authorities; users can also be easily trained to carry out simple onsite maintenance.
- Construction of both the simplified sewers and pond systems may be carried out using unskilled labour with skilled supervision. In some cases e.g. in the Bolivia simplified sewerage example (Foster, 2001), the community provided the manpower required for installing the pipes; this serves to lower costs.
- Opportunities exist for the reuse of the treated wastewater for horticulture, agriculture or aquaculture.

Disadvantages

- The mixing of the wastewater i.e. black and grey streams together is similar to that which occurs in the conventional wastewater management, which makes nutrient recovery difficult.
- Considerable land areas required for the pond system.

Opportunities

- Existing knowledge and management capabilities with conventional sewerage is an advantage for O&M requirements of the simplified sewerage.
- Lower costs of simplified in comparison to conventional sewerage means lower investment requirements for the authorities.

Technical Details and Implementation

The following key assumptions are considered: availability of sufficient water; no industrial wastewater discharge as there are no industries in the design area; user preference of flush toilets; adequate space for pond system installation; non-problematic ground conditions; user willingness to carry out required O&M operations and pay service charges as applicable; availability of local materials for construction; and availability of skilled manpower and materials for installation and operation/maintenance; possibilities for treated wastewater reuse.

From the hydraulic design of the simplified sewer system, 100 mm diameter pipes laid at depths of 0.5 m (upstream) and 0.48 m to 0.75 m (downstream) are required to transport wastewater from the houses to the collector and onwards to the pond systems for treatment. The natural gradient of the design area allows for transport by gravity, thus no pumps are required. For ease of construction and resistance to corrosion PVC pipes will be used; these are easily jointed, and minimise or prevent wastewater exfiltration or groundwater infiltration. A grease trap will be placed on the user property and a brick junction box at the point of connection to the sewer (see figure 6.3). Inspection/access chambers used in place of manholes will be placed at intervals of 50 m in the condominial sections and 100 m intervals in the main collector section of the network respectively. For the design area, a total of 2991 m of PVC pipes are required with an additional 500 m for further transport of wastewater to the ponds.

The pond system consists of one each of anaerobic, facultative and maturation ponds, and should be sited about 500 m downwind from the settlement following the recommendation of Mara (1997). The site is close to a solid waste treatment site and a nearby farm settlement. The soil is well drained with low water table as indicated by minimum borehole depth of 18 m (Ibrahim, personal discussion); impermeable plastic liners are used for the ponds. Mara (1997) states no grit removal is necessary for systems serving <1000 people, none is included in this system. The expected wastewater flow based on a per capita water consumption of 120 l is approximately 70 m^3 per day, with a

BOD of 333 mg/l based on a daily BOD contribution of 40 grams per caput (Mara, 2003). The estimated total pond area required based on these parameters is 329 m^2 (anaerobic – 30 m^2; facultative – 159 m^2; maturation – 140 m^2); the pond system was designed for restricted irrigation or aquatic discharge. Sludge treatment is in a drying bed. Details are presented in appendix B.

Scenario Feasibility

Technical: the simplified network consists of small diameter pipes laid at shallow depths as such no specialised machinery is required for installation of sewers. Excavation can be done by hand using simple digging equipment and possibly with householders contributing the labour for both excavation and laying of pipes. Various pipe materials can be used; in this case PVC is suitable and locally available. PVC is light, easily laid with easy to fit joints and immune to sewer corrosion (Mara, 1996) thus contributing to lower maintenance requirements and sustainability. The construction of ponds requires minimal civil works – mainly earthmoving, pond lining, inlets and outlets parts and embankment protection. They are simple to operate and maintain thus unskilled, but supervised, labour is all that is necessary. Routine O&M tasks include clearing embankment and floating vegetation this helps with insect control; sludge and scum removal, keeping the inlets and outlets clear, and repairing any damage to the embankments. In comparison with other wastewater treatment processes such as activated sludge or aerated lagoons, ponds require no electromechanical equipment or electrical energy input (Mara, 1997), thus the pond system in this scenario also has low requirements. These factors indicate that this scenario is potentially technically feasible in the study area.

The technologies in this scenario are not available in the study area; however they are similar to some that exist in the area. The skills required for the installation, operation and maintenance can thus be assumed to exist. However some level of training and supervision may still be necessary and it is not certain whether the design skills are locally available.

Institutional: a 'joint management' approach in which both the user and the municipal authorities have O&M responsibilities is efficient and recommended for this scenario. It is cost effective and allows for user involvement in O&M activities thus fostering a sense of ownership while reducing the burden of service charges. The municipal or environmental management authority must be responsible for the sewer network outside the user's property (see figure 6.3) and the wastewater treatment facilities to which the collected sewage is transported. The management authority must assess operation and maintenance costs and determine in consultation with the user, the charges applicable for services provided; the shared maintenance responsibility should be reflected appropriately in the service charges applied. Users are responsible for the maintenance of the sewer infrastructure within the boundaries of their property i.e. the user will carry out clean outs as appropriate and report blockages to the responsible authority. The management authorities must respond to complaints of blockages promptly, and ensure all required O&M equipment are available and functioning as required.

The user must also pay for services (water supply, sewage treatment, sewer maintenance) provided as jointly determined by the user and the authorities. It is essential that the users are trained by the authorities in the operation and maintenance of the network section within their jurisdiction. Requests for new connections should be made to the authorities and users should inform the authorities of unauthorised connections to aid proper monitoring of the network; the authorities on the other hand must provide connections to new users promptly.

Socio-economic: data gathered on user preferences suggest this scenario is likely to have high acceptance. The in-house and transport components are similar to existing ones with which users are already familiar and in some cases already use. The treatment technologies though different from those existing in the study areas have lower maintenance and possibly cost implications than other conventional treatment systems for both user and wastewater management authorities. The reuse of the treated wastewater as irrigation water for green areas is also desirable as this practice is already established in the region with current water sources being mainly rivers or sometimes potable water, particularly in the harmattan season when tanker trucks belonging to the Environmental Board can be seen daily watering plants in various public places in the main city.

6.2.1.2 Wet Sanitation with Separation of Solids

Description: in this scenario the total household wastewater collected using low/pour flush toilets for water conservation goes into either a communal or household interceptor tank in which the wastewater is separated into liquid and solid fractions by settling. The settling tank effluent (liquid) is then transported via settled sewerage for treatment in constructed wetlands. The wetland effluent may be used either in irrigation or simply discharged into an aquatic body. The solids are mechanically removed from the settling tank and transported by truck to a communal facility for composting or vermi-composting, with the resulting compost used in nearby agricultural areas as soil conditioners. The system is suitable as a decentralised system for a cluster of homes or a semi-centralised system for an entire settlement; in this case it is proposed for a cluster of 97 households with an average population of six persons.

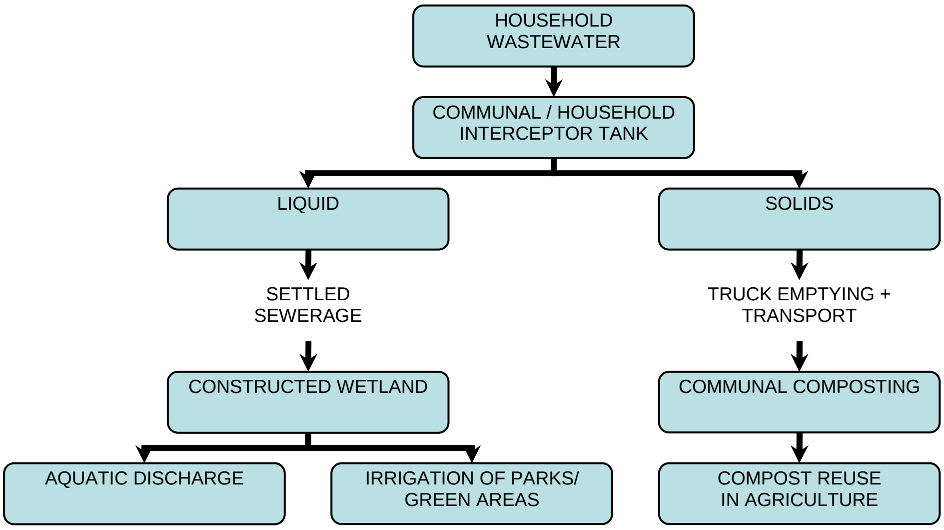


Figure 6. 4: Decentralised system with low flush toilet, separation, composting, and wetland treatment

Installation, Operational and Management Requirements: this scenario has similar requirements with those already discussed for the previous scenario (simplified sewerage and pond system). In addition, the accumulated sludge in the interceptor tank requires regular removal and further treatment by composting, thus a communal facility for composting is needed. An existing composting facility (Ajata composting plant) may provide this service meaning that no extra expenditure is needed to construct a new facility. As before a clear definition of the roles of both users and the municipal authorities in O&M activities is required and must be adhered to by all parties. Removal of blockages and sludge from interceptor tanks should not be left to the user but preferably undertaken by the municipal authorities or a designated service provider. Typical operational requirements include:

Settled sewerage

- vigilance to ensure no illegal connections are made to the settled sewers especially those discharging solids into the network.
- regular sludge removal of settled solid in the interceptor tanks.

Constructed Wetlands (horizontal flow):

Adequate space is required for the installation of the wetland system in this scenario. Adequate care must be taken to ensure that there is no seepage into the underground as such site must be lined appropriately. Public access to the site must be limited (particularly in the case of children); fences could be erected around the wetland for safety. Local plants are preferable as wetland vegetation e.g. thatch grass for example spear grass (*Imperata cylindrica)* and elephant grass (*Pennisetum purpureum*). Regular wetland vegetation and weed maintenance (removal) must be carried out after the initial planting to aid the establishment of wetland plants. It is essential that care is taken to ensure that no puddles collect in the wetland that provides breeding grounds for mosquitoes; and the settling tank should be cleaned out periodically.

Advantages of this Scenario

Some of the advantages of this scenario are:

- The scenario supports the preference many users have for flush toilets mainly because of the convenience the flush system offers.
- Both the settled sewerage and constructed wetland systems have lower costs than conventional sewerage and other biological treatment such as activated sludge systems.
- Significant quantities of flush water can be saved by the use of low flush and pour flush toilets in this scenario.
- This scenario presents an opportunity for the reuse of the treated wastewater.
- The technologies in this scenario generally have low maintenance requirements important for both users and municipal authorities who have the responsibility of O&M for the system.
- Construction of both the sewers and wetland may be carried out using unskilled labour; however skilled supervision is needed.

Disadvantages of this Scenario

Potential disadvantages are:

- The mixing of wastewater streams i.e. black and grey streams together is similar to that which occurs in the conventional wastewater management.
- The system requires availability of water for operation and will not be suitable where this requirement cannot be met.

Technical Details and Implementation

The following key assumptions are considered: availability of sufficient water; no industrial wastewater discharge as there are no industries in the design area; user preference of flush toilets; adequate space for wetland installation; non-problematic ground conditions; user willingness to carry out required O&M operations and pay service charges as applicable; availability of local materials for construction; and availability of skilled manpower and materials for installation and operation/maintenance; possibilities for treated wastewater reuse.

The technical requirements of this system are similar to those of the simplified sewerage network however since the settled sewer will transport liquid fractions only (no solids), the hydraulic design of the system requires 75 – 100 mm diameter pipes to transport settled wastewater from the house to the constructed wetland for treatment. Based on details from simplified sewerage design such as sewer depth and total length, which are adapted for the settled sewerage. Cleanouts are provided in place of manholes at all upstream ends, major intersections along the route and at 150 m interval along long or flat sections of the network. An interceptor tank will be placed on the user property estimated volume of 1.3 m^3 based on a per capita water consumption of 120 l and 85% wastewater return factor. A cluster of homes may also share an interceptor tank. The interceptor tank sludge will be transported by truck to the communal composting facility for treatment. Based on the wastewater flow of ~60 m^3, and an influent BOD of 333 mg/l, a wetland area of ~1033 m^2 is required to achieve BOD reduction to 20 mg/l. The treated effluent may be reused for irrigation at the nearby farm settlement or discharged into an aquatic body. The interceptor tank are to be emptied mechanically and the sludge treated by composting at the existing municipal composting plant. Please see appendix B for details.

The municipal authority will be responsible for fee recovery, operating and maintaining the street sewers, constructed wetland, composting facility and emptying interceptor tanks. However, they may engage the services of a private contractor to perform these tasks should they lack the capacity to do this, similar to what currently obtains with solid waste management in the FCC. The wastewater charge incorporated into the water bill should be levied based on freshwater consumption.

Scenario Feasibility

Technical: similar to simplified sewerage the settled sewerage network consists of small diameter pipes laid at shallow depths; no specialised machinery is required for installation of sewers and excavation can thus be done using simple digging equipment; householders may also contribute the labour for both excavation and laying of pipes. The pipe material to be used – PVC, is locally available. It is light, easy to install, meaning it can be done by unskilled labour with appropriate supervision thus contributing to lower costs, maintenance requirements and sustainability. Settled sewerage technology has been employed in parts of Nigeria such as New Bussa (Mara, 1996); the skills required for the installation, operation and maintenance of both interceptor tanks and sewer network exist and can be further replicated through training of local artisans; it is however not certain whether design skills are locally available.

A horizontal sub-surface flow wetland is chosen for this scenario even though the space requirement is higher than for the vertical flow wetland; one reason is that horizontal flow wetlands are likely to be less hospitable to mosquitoes, although vertical flow wetlands may also not encourage mosquitoes when flow is subsurface. An added advantage for horizontal flow wetlands is that pumps are not required thus the need for electrical energy is eliminated. It is estimated that space requirements for the vertical flow is about 1–2 m² per capita, however based on the design calculation, the space required for the horizontal wetlands in this scenario is not significantly higher than the theoretical space requirements for vertical flow wetlands. This may be attributed to the effect of high temperatures in the area.

For the wetland, construction involves mainly earthmoving, lining, inlets and outlets parts and vegetation planting; all of these tasks are simple and can be done by supervised unskilled personnel. Plants native to the region e.g. thatch grass is proposed as the wetland vegetation as these have economic benefit, and are locally used as roofing material and stuffing for bedding in rural areas and may be used in the farm settlements located in this area. The O&M requirements for wetlands are simple and do not require skilled labour. They include: inspecting the embankment and inlet/outlet structures for damage and carrying out repairs as necessary; examining and removing debris from inlet and outlet structures; clearing of unwanted plants; removing litter and debris from banks, soil surface, and harvesting plant species as required. The installation, operation and maintenance requirements of this scenario indicate that this scenario is potentially technically feasible in the study area.

Institutional: management of this is preferably carried out by the municipal authority however, a qualified service agency may also be contracted to provide these services. The municipal or environmental management authority must be responsible for the sewer network and the wastewater treatment facilities to which the collected sewage is carried. They are also to carry out the collection and transport of the solid fraction of the wastewater to the composting facility and subsequent treatment and distribution of the treated material. This will require investment in trucks and associated operational costs – this is already available in the area as this system is currently used for the desludging of septic tanks by the AEPB. Contracting these services to private providers may ensure greater efficiency but perhaps more cost to the user. The municipal authority must provide connections to new users, respond to complaints promptly; the responsibility of fee recovery also lies with the municipal authority.

Users have the responsibility of making requests for new connections to the authorities, and reporting blockages or faults to the responsible authority. Their vigilance and efforts in informing the authorities of unauthorised connections will aid proper monitoring of the network. The user must also pay for services (water supply, sewage treatment, and sewer maintenance) provided.

Socio-economic: inferences from survey data suggest this scenario is likely to have high acceptance. The in-house and transport components are similar to ones with which users are familiar (septic tanks and mechanical desludging) and some knowledge of composting already exists in the area as indicated by the abandoned composting facility in Ajata. This facility can be revived and used for solids treatment meaning no extra investment costs are needed for a composting facility. The treatment technologies for the liquid stream though different from those existing in the study areas is low tech and has lower maintenance and possibly cost implications than conventional treatment systems for both user and wastewater management authorities. The reuse of the treated wastewater as irrigation water for green areas is also desirable; the practice of irrigated horticulture is established in the area particularly in the dry season and the treated effluent can replace current water sources (rivers or sometimes potable water). Where local river grass vegetation are used in the wetlands these may be harvested and used for producing roofing or bed stuffing material or basket weaving thus generating both income and jobs.

6.2.1.3 Separation at Source and Onsite/Offsite Treatment

Description: figure 6.5 depicts a sanitation system based on separation of the wastewater streams at source. The grey water is transported into onsite settling tanks; the settled effluent is then transported via settled sewerage for treatment in an offsite communal wetland. The treated greywater may be reused in irrigation or discharged into the aquatic environment; the solids from the settling tanks may be composted with the faecal solids. The yellow water is collected separately in canisters at the household level; these canisters will be regularly collected by a designated service agency and stored for six months after which it may be used in agriculture as a fertiliser.

The brown water is collected using low flush toilets (pour flush toilets may be used where water is hand carried), once flushed the brown water goes into the Rottebehaelter (pre-composting tank) using a filter bed or filter bag where it is separated into solid and liquid fractions. The solid fraction is collected by a service agency for treatment by composting at communal composting centres with the compost reused in agriculture. The liquid fraction is transported into the settling tank along with the greywater then into the communal constructed wetland for treatment. Alternatively the grey water and Rottebehaelter effluent may be conveyed into onsite wetland systems with ornamental plants (Belmont and Metcalfe, 2002), that provide treatment while enhancing the aesthetic quality of the home environment.

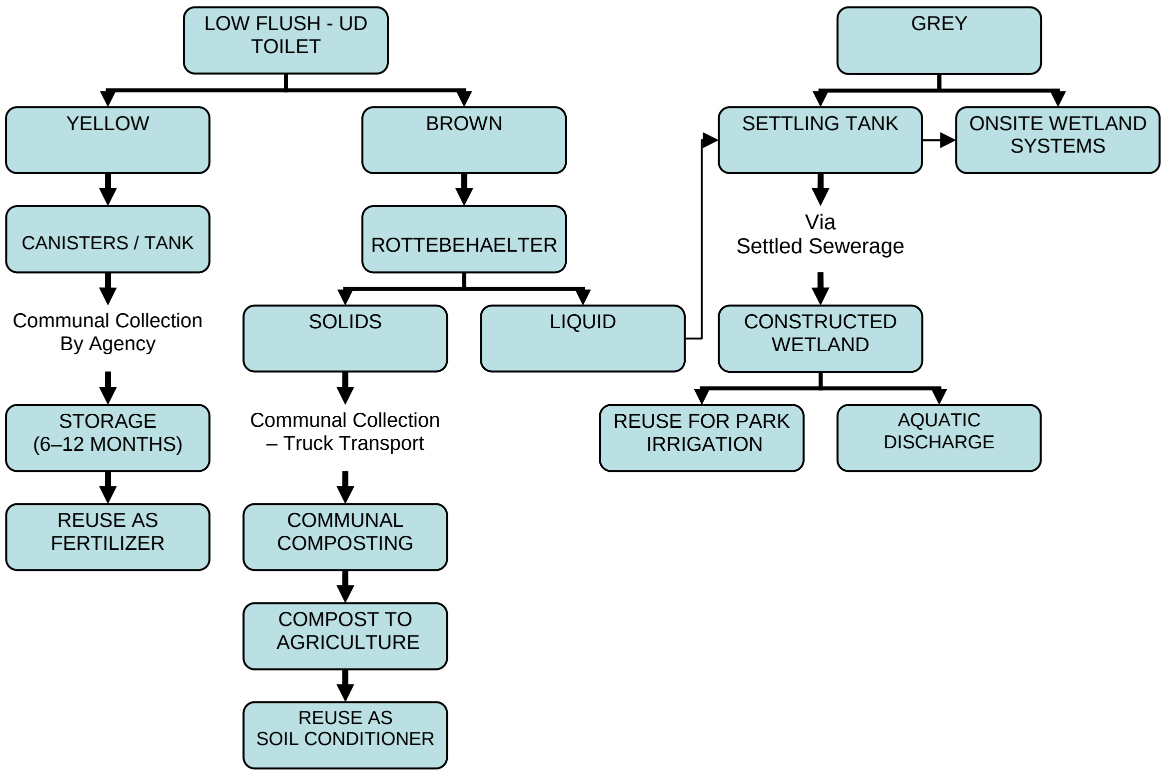


Figure 6. 5: Decentralised sanitation scenario with source separation and urine diversion

Installation, Operational and Maintenance Requirements: in addition to the requirements described for the previous system (see section 6.2.1.2), adequate space is one of the most important requirements for this system considering wetlands are the greywater treatment units; similar to other scenarios based on wet sanitation concepts, water availability is also essential in this system. As before user input in the selection and implementation of this system is vital for operation and maintenance of the systems as such the decision to install this system as in all cases must be made in consultation with the intended users. Roles and responsibilities of users and service providers in system O&M must be clearly outlined and adhered to by the users and the service agencies respectively. Efficient collection and transport systems for both yellow and brown water are operational necessities for the system. The recovery of charges for this system will contribute to ensuring sustainability of the system. Typical maintenance requirements for both the settled sewerage and the constructed wetlands components of this scenario are as discussed previously (see section 6.2.1.2).

Advantages of this Scenario

Some of the advantages of this scenario are:

- separation at source i.e. urine, faeces and greywater are collected separately thereby minimising the volume of the problematic streams e.g. yellow and brown water.

- brown water collection using low flush toilets offers convenience to users and is a significant attribute affecting acceptance; in addition low flush toilets offer opportunities for conserving water.
- system can be adapted to use pour flush toilets where water is hand carried.
- the scenario offers the opportunity of reusing treated streams (yellow, brown, grey) as fertiliser, soil conditioner and for irrigation respectively.
- the components of the scenario are largely low tech and thus offering some level of ease in carrying out O&M activities.

Issues to consider:

Potential issues that may affect the implementation of this system are:

- Further treatment is required for the liquid fraction of the Rottebehaelter; also adding the Rottebehaelter effluent to the greywater means higher nutrient and pathogen content of greywater to be treated.
- Risk of mosquitoes breeding and rodents, snakes taking up residence in the wetlands.
- Social acceptance of the urine diversion component of the toilet, which is new to Nigeria.
- Energy demand for yellow water cartage if this is not used onsite.

Technical Details and Implementation

The following key assumptions are considered: availability of sufficient water; adequate space for wetland installation; user willingness to carry out required O&M operations or pay service charges as applicable; availability of local materials for construction; and availability of skilled manpower and materials for installation, possibilities for treated wastewater reuse; in addition to this sufficient gradient for wastewater flow into the wetland system are necessary.

The technical requirements of this system are similar to those of the system described section 6.2.1.2, except that a Rottebehaelter is included rather than an interceptor tank. The settled sewer will transport grey water and the Rottebehaelter effluent to the offsite wetland system. A Rottebehaelter (1 m^3) is used for solids collection, these solids are then either composted onsite or collected by a service agency and transported by truck for composting at a communal facility.

As in 6.2.1.2, a communal wetland area of ~1033 m^2 is required to achieve BOD reduction to 20 mg/l. The treated effluent may be reused for irrigation at the nearby farm settlement or discharged into an aquatic body. In case onsite wetlands are preferred, assuming a daily wastewater flow of 0.8 m^3 is assumed and an influent BOD of 333 mg/l, the area required for BOD reduction to 20 mg/l is ~15 m² with a retention time of 3.4 days. Ornamental plants are used for aesthetics.

For urine collection, a volume of 1.5 l/day per capita generation with 65% capture rate is assumed as such collected volume per month is thus 176 l. 30 l jerry cans (plastic) are proposed for onsite urine collection and six will be required per month. The collection may be done once a week alongside the weekly solid waste collection rounds.

This system is best solely managed by the municipal authority or a service agency. The municipal authority or a designated service agency will be responsible for collection of both yellow and brown water, and the subsequent treatment; the O&M of both the settled sewer and wetland system, and fee recovery. The wastewater charge should be incorporated into the water bill and should be based on freshwater consumption. Users will be responsible for the cost of the in-house sanitation units, connection charges to the settled sewer network or the cost for the entire network infrastructure may be borne by the users in which case no connection charge is necessary; the O&M costs may then be included in the monthly water bill.

Scenario Feasibility

The feasibility requirements for this scenario are similar to those discussed earlier in section 6.2.1.2 due to similarities in the technological components of both scenarios. This scenario is also likely to have high acceptance. The in-house and transport components are familiar; a composting facility already exists in the area. The reuse of the treated wastewater as irrigation water for green areas is desirable as irrigated horticulture is well established in the area. Local river grass vegetation may be used for the communal wetlands to be harvested and used in the production of roofing or bed stuffing material thus generating both income and jobs.

6.2.2 Onsite Systems

6.2.2.1 Dry System with Urine Diversion

Description: this onsite scenario is based on separation of the waste streams at source. The greywater is collected in a settling tank then treated in an onsite wetland system planted with ornamental vegetation for aesthetics. Wetland effluent may be used for irrigating the family garden. The urine is diverted and collected in plastic canisters (jerry-cans), which once filled is removed and replaced with a new canister. The urine is stored for about one month by which time it is sufficiently sanitised and can be used as fertiliser in the family's garden or farm. Faecal solids are collected in double vault systems for composting or dehydrating. The first vault is filled until it is nearly full, soil or bulky garden material may be added to the toilet after each use if the planned secondary brown water treatment is composting (ash, if dehydration); the anal cleansing material can also be added to the vault except for the case of wash water in dehydrating systems; in this case a piping system may be installed in the toilet to direct the flow of wash water to the onsite wetland. Once the active vault is full it is allowed to rest while the second is put to use. In the case of composting systems this fallow period is the secondary treatment step which yields finished compost under the right conditions. Further treatment is required with dehydration systems, a possibility is composting with kitchen or garden waste or incineration.

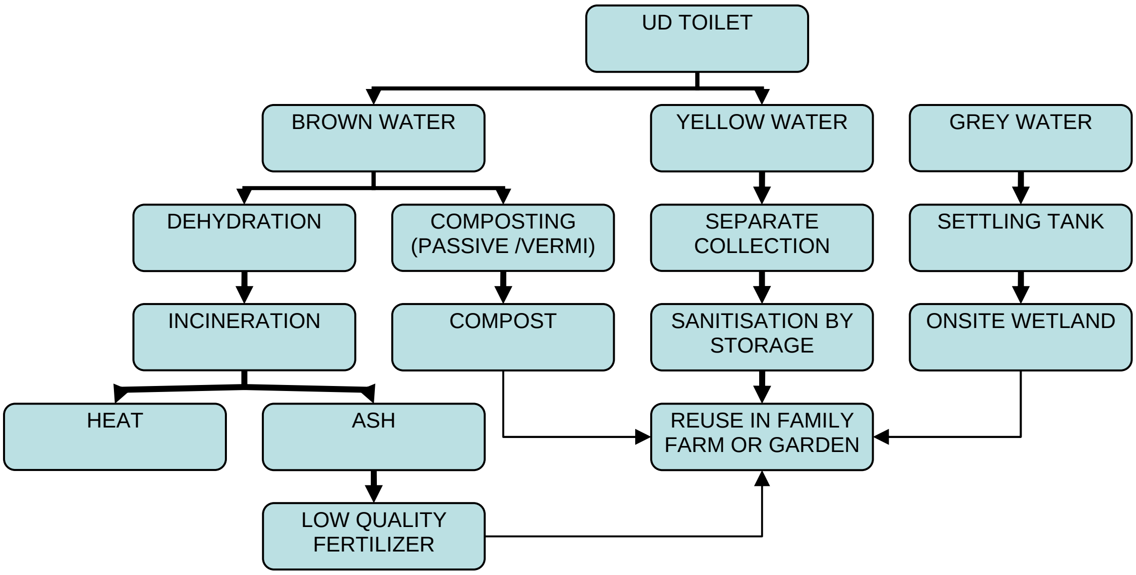


Figure 6. 6: Onsite dry sanitation scenario with urine diversion

If secondary step is to be incineration, placing a solar panel (blackened sheet) over the vault aids the dehydration process, which is the primary treatment step. Incineration produces ash which may be used as low quality fertiliser; the compost from the composting process may be used as a soil conditioner.

Installation, Operational and Management Requirements: the system has a low water requirement and allows for nutrients recycle. Adequate space is the primary requirement of this system; therefore it may not be suitable for densely populated areas. Another essential requirement is the opportunity for reuse of the products of the system in agriculture. User involvement in O&M activities is high. The system must be well designed and managed to avoid risks to human health particularly of those handling operation activities, as such training on operation must be provided to the households with a monitoring or support system also in place. Typical maintenance requirements include:

UD Toilet

- Regular inspection of household unit to check for blockage of the urine pipes, and flushing to remove accumulated deposits.
- Keep water out of the vault (washers are to use the wash facility provided).
- Keep the toilet (squat pan/seat and surrounding) clean but being careful to keep the cleaning water away from the vault or ensure only minimal amounts enter the vault.
- Removal of material from vault as planned.
- Ensure that no fresh excreta deposit is allowed in a vault in the resting phase.

Onsite Wetland Bed System: the requirements specified for the constructed wetlands discussed previously are applicable for this system as well.

Advantages of this Scenario

Some of the advantages of this scenario are:

- Low water requirement as such suitable for settlements that have hand carried water supply sources such as wells or stand pipes.
- Protection of soil and onsite water sources particularly water wells and ground water as vaults are above ground.
- Separation of the water and nutrient cycle.
- Reuse of waste products from the sanitation systems as input into agriculture.
- Suitable in locations with high water table as vault is above ground.
- Aesthetic value of wastewater garden to the home environment.

Disadvantages of this Scenario

Potential disadvantages include:

- System requires separate provision for greywater treatment.
- Significant risk of failure from improper operation of the unit e.g. introducing large amounts of water into the vault especially in the case of dehydration vaults.
- Risk of pathogen spread if fresh faeces are added to inactive vaults shortly before being emptied.
- Improper handling or inadequate treatment of the excreta prior to reuse could pose a risk to human health.

Proper O&M is essential in order to ensure proper functioning and derive maximum benefits from this system; it is preferable where reuse of the system's products is feasible.

Technical Details and Implementation

The following key assumptions are considered: adequate space for onsite wetland installation; user willingness to carry out required O&M operations; availability of water; availability of local materials for construction; and availability of skilled manpower and materials for installation, possibilities for treated wastewater reuse.

The system is designed for a household size of six persons. Based on the estimated annual per capita faecal sludge accumulation rate of 100 l per caput (includes cleaning/ added material, a vault volume of ~0.9 m^3 is required for a filling period of one year assuming an effective volume of 75%. The brown water can be composted along with solid organic waste, or simply dehydrated and incinerated to generate compost or ash for reuse. For urine collection, 1.5 l/day per capita generation with 65% capture rate is assumed based on the conditions that children produce less urine than adults and users are not at home all through the day – collected volume per month is thus 176 l. 30 l jerry cans are proposed for onsite urine collection and six will be required per month. The Ecosanres 'Guidelines for the Safe Use of Urine and Faeces in Ecological Sanitation Systems' recommends a storage time of one to six months for urine sanitisation at temperatures of 4 – 20°C, but states that no storage required for a single household reusing its own urine. However for safety a one month storage period is proposed as average temperature in the area is about 30°C.

For the grey water treatment system, for a daily flow taken to be 0.5 m^3, an area of ~7 m^2 and a retention time of 2.5 days are required to reduce influent BOD from 150 mg/l to 20 mg/l. A mixture of plants is proposed particularly ornamental plants to give the wetland aesthetic value.

Scenario Feasibility

Technical: the technology components of this scenario have low operation and maintenance requirements and have been successfully applied in various places e.g. Vietnam (Vietnamese DV toilets), Mexico, etc. Additional passive composting by storage is recommended in this case for ease of operation, according to the guideline on excreta reuse (Schönning and Stenström 2004), in areas with temperatures up to 20°C, storage for 1.5 to 2 years is sufficient to produce safe compost, based on this a 1 year storage period will provide adequate treatment as ambient temperatures in these regions reach up to 36°C. However composting is a complex process as such adequate training and support must be provided to the users for successful O&M. Further, research results from Shalabi (2006) suggest that vermicomposting can be applied for the conversion of faecal solids to soil like compost material that can be applied in agriculture in as little as three months.

Incineration can also be a viable treatment option as high temperatures aid dehydration and the incineration product, ash, is likely to be even more acceptable as an input into agriculture although the nutrient content is lower, therefore the incineration option and its implication should at least be presented to the user and the choice of secondary treatment left to them.

The yellow water collection and treatment requires only diversion piping and collection canisters, which are locally available at affordable prices, about 100 - 200 naira (0.6 – 1.5 Euro). Each family uses its own yellow water as such storage time can be as little as one month. The onsite wetland system utilises ornamental plants for aesthetics, a desirable feature in this scenario. They are low maintenance systems and have been successfully applied in many places e.g. Hotel Kandy in Sri Lanka (Corea 2001). They are simple to construct, operate and maintain with unskilled, but supervised, labour and O&M tasks are as described for constructed wetlands. Overall, as the whole system can be operated and managed by the user with little external or energy input; this scenario also has low requirements indicating that this scenario is potentially technically feasible in the study area.

Institutional: the likely stakeholders in managing this system are the user and possibly a service provider. The municipal authorities or service providers are required to provide assistance with construction and installation of the system or training and supervision of local artisans that users can pay to install the systems. They can also provide removal of the excreta from the homes in which case the secondary treatment will be communal incineration or composting. If users choose to have sole O&M responsibilities they may either do this at the household level in which case there will be no service charges accruable to them, or form cooperatives that may engage the services of a caretaker or service agency to carry out required activities at an agreed charge for which they are responsible. The importance of the user input into the selection and implementation of the system is invaluable as this will reinforce a sense of ownership and consequently influence their willingness to manage the system or pay for such service. If users are willing to operate and manage the system, training on operation and maintenance requirements may be necessary and must be provided where needed by the municipal authorities.

Socio-economic: this scenario is particularly suitable for users who have a need for reuse of the products in agriculture especially if they are able to carry out the operation and management of such systems themselves i.e. collect the faeces for composting. The scenario offers excellent reuse opportunities of yellow and brown water and the onsite wetland offers aesthetic value, which is important to a lot of home owners in many parts of Nigeria. The canisters for yellow water collection are easily available and affordable –

they are manufactured locally and already used for water collection and storage throughout Nigeria.

In spite of the obvious benefits of this scenario, based on user preference data, acceptance levels are not likely to be very high, particularly for the more upscale residents. Field study data indicate a high preference for flush toilets among these groups; they are not likely to agree to the behavioural adjustments necessary to have this system in place. The system is suitable and proposed for application for individual homes preferably in the rural or farming communities of this area i.e. the settlements that belong to the indigenous people of the study area as described in the field study results. As the handling and reuse of treated products is by the user, the problem of cultural objections to other people having access to their excreta does not arise in this scenario.

6.2.2.2 Wet System with Separation

Description: this scenario is based on combined collection of household wastewater. Black water from low or pour flush toilets is collected along with greywater in pre-composting tanks (Rottebehaelter, see Chapter 2 for description), which separates the wastewater into liquid and solid fractions. The solids from the Rottebehaelter are collected and further treated by composting with garden/ kitchen waste. The resulting compost is reused in agriculture. The liquid fraction is treated in an onsite wetland system as for the system in section 6.2.2.1.

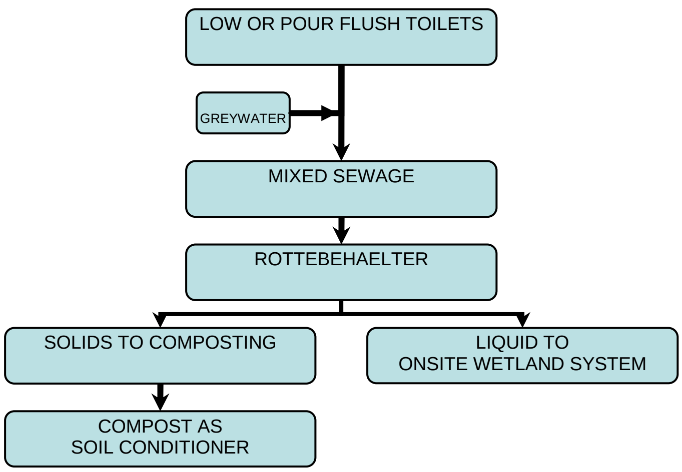


Figure 6. 7: shows the onsite sanitation scenario with low flush toilet and onsite treatment

Installation, Operational and Management Requirements: the requirements of this scenario are similar to those discussed for the system in section 6.2.1.2; thus the requirements in general are similar except that sewers are not included in this system and a Rottebehalter replaces the interceptor tank. In addition adequate space for the onsite wetland system and the opportunity for reuse of the products in agriculture are required. If onsite reuse of the compost material is not possible, then communal collection of the solids for treatment at a composting facility may be a more appropriate alternative, which may then allow the sale of the resulting compost to local farmers for use as soil conditioners.

Advantages of this Scenario

Some of the advantages of this scenario include:

- Users' familiarity with in-house sanitation units, which offer convenience and often have a high social acceptance; these units also allow water conservation.
- Maintenance requirements of various components are manageable to both users and municipal authorities as users can be trained to carry out simple onsite maintenance.
- The construction of onsite wetland system may be carried out using unskilled labour but with skilled supervision.
- Land area requirement for onsite wetland system is low and it adds aesthetic value to the home environment.
- This scenario presents an opportunity for the reuse of the treated wastewater streams.

Disadvantages of the Scenario: a potential disadvantage of this scenario is the mixing of the wastewater i.e. black and grey streams together is similar to that which occurs in the conventional wastewater management

Technical Details and Implementation

The following key assumptions are considered: assumptions are similar to those stated for that described in section 6.2.1.2, in addition to this sufficient gradient for wastewater flow into the Rottebehaelter and effluent to wetland system are necessary.

The wetland system is designed with the assumption of a wastewater flow of 0.8 m^3 and an influent BOD of 333 mg/l; thus the area required for BOD reduction to 20 mg/l is ~15 m^2 with a retention time of 3.4 days. Ornamental plants are used for aesthetics. A Rottebehaelter (1 m^3) is used for solids collection; these solids are then either composted onsite or collected by a service agency for composting at a communal facility. The system is suitable for application as an onsite system for single households preferably in rural or farming communities in the study area. Management of the system may be carried out solely by the user, however training may be required. There should also be some level of support from either the municipal authority or a service provider for potential issues the user may encounter.

Scenario Feasibility

Technical: as discussed previously onsite wetlands is relatively simple to construct, operate and maintain requiring only supervised unskilled labour for the most part; the materials needed are locally available. Filter bags made of jute can be used in the rottebehalter, reducing costs; spent bags may be composted along with the collected solid fraction. If composting is communal a collection and transport system must be put in place, at present the resources exist for solid waste collection, and these may be expanded to cover this situation as well. Where the user is willing to carry out O&M activities, then training and subsequent support should be provided. This scenario is potentially technically feasible in the study area.

Institutional: composting in this scenario may be onsite where users are willing to manage the systems on their own; otherwise this may be done communally by user cooperatives employing workers for O&M or by service providers who carry out O&M activities at an agreed charge. There is an existing composting facility in the area as such no extra costs are necessary in setting one up, the facility is however in disuse as such the investment would be in reviving the facility and setting up the operational and administrative structures.

Socio-economic: as discussed earlier, this scenario is suitable where a demand for alternative fertiliser sources exist as the scenario offers excellent reuse opportunities for composted solids in agriculture. The wetland system offers aesthetic value desirable to a lot of home owners in many parts of Nigeria. The main issue against this scenario is the cultural challenge of accepting the handling of wastes by service providers among those who have the belief that 'a person can be harmed if a malicious person has access to his or her excrement'; but this should not be a problem where users are willing to do O&M themselves. For others education may be necessary to debunk these beliefs; setting up pilot facilities in public places may be the best way to gradually introduce this concept as when people can see for the benefits themselves as opposed to simply being told about them, they are often more open to new ideas. Design details and cost estimates for each of the scenarios presented in this section are given in appendix B.

6.3 Cost Estimation and Analysis

6.3.1 Cost Estimation

Cost estimation can be cumbersome especially for developing countries where most things are not standardised; prices can vary widely. One way to estimate costs is to draw on examples from completed projects, the drawback to doing this is that many projects and prices are site specific, and may not give estimates applicable to the situation under consideration. Another possibility is to obtain estimates from local construction firms, preferably with cost estimates given as a bill of quantities based on design specifications rather than as a lump sum. Capital costs may be estimated fairly easily; estimating O&M costs on the other hand is more difficult. Discourse in the literature and various examples of project costs reveal a wide range of estimates given as O&M costs for various systems. Sasse (1998) in discussing the intricacies of estimating O&M costs states that 'an estimate of realistic running costs would need an in-depth study of the technical requirements of the system as well as the prevailing social environment. Further, it would need a fairly precise reading into future management structures. Overheads in form of salaries for the management, expenditure for the logistic requirements of operation and maintenance are extremely difficult to foresee, especially in the case of co-operatives'. This view is also supported by Lechner and Langergraber (2003).

For the scenarios presented in this work, construction costs (materials and labour) are based on cost estimates provided by several local construction firms based on the design specifications (see appendix B). Total investment cost includes allowances for contingencies and overheads estimated at 10% and 15% of capital costs respectively. 10% of the total investment cost is assumed as a rough estimate of annual O&M cost for respective scenarios; a summary of costs for each scenario is presented in tables 6.1 to 6.6. These estimates do not include the costs of in-house units, as it is assumed that these will be borne by the households. The designs and costs are for a settlement of 97 households with an average of six persons per household making a total of 582 inhabitants.

Cost estimates for the scenario presented in Section 6.2.1.1 are as follows in table 6.1, for details please refer to appendix B.

Table 6. 1: Costs for entire design area and population (scenario presented in 6.2.1.1)

Component	Amount (NGN)*
Wastewater collection (Simplified Sewer)	2,001,580
Treatment (Pond System: Ana, Fac, Mat)	1,600,510
Sludge Treatment (Drying beds)	158,200
Subtotal	**3,760,290**
Allowances for additional work	376,029
Overheads	546,043
Total Capital Investment	**4,700,362**
Annual Operation & Maintenance (10% of INV)	**470,036**

* 160 NGN = 1 Euro

Cost estimates for the scenario presented in Section 6.2.1.2 are as follows in table 6.2.

Table 6. 2: Costs for entire design area and population (scenario presented in 6.2.1.2)

Component	Amount (NGN)*
Wastewater collection (Settled Sewer)	1,814,580
Treatment (Communal Wetlands)	5,196,800
Interceptor Tanks	2,389,110
Subtotal	**9,400,490**
Allowances for additional work	940,049
Overheads	1,410,073
Total Capital Investment	**11,750,612**
Annual Operation & Maintenance (10% of INV)	**1,175,061**
Interceptor tank desludging every two years	**10000**

* 160 NGN = 1 Euro

For this scenario in addition to average capital and annual O&M costs, 10000 NGN per household is also estimated (based on local prices for emptying of septic tanks) for desludging the interceptor tanks every two years, for details please refer to appendix B.

Cost estimates for the scenario presented in Section 6.2.1.3 are as follows in table 6.3.

Table 6. 3: Costs per household with onsite management for scenario presented in 6.2.1.3

Component	Amount (NGN)*
Treatment (Onsite Wetlands)	144,413
Rottebehalter	29,450
Settling Tank	22,950
Subtotal	**196,813**
Allowances for additional work	19,681
Overheads	29,521
Total Capital Investment	**246,016**
Annual Operation & Maintenance (10% of INV)	**24,601**

* 160 NGN = 1 Euro

Costs for the scenario in section 6.2.1.3 are shown in tables 6.3 (onsite management of all wastewater streams) and 6.4 (centralised management of the yellow and brown water streams, greywater is treated in onsite wetlands).

The capital and annual O&M costs as shown in table 6.3 are borne by each household assuming all components of the system are managed onsite by the user. If users choose to have service providers handle O&M then costs will increase. Solid waste management service is provided by private agencies on contract with the AEPB, see appendix D for applicable charges. If one assumes that the same or a similar agency will provide collection and treatment service in this scenario, then a reasonable annual service charge (lump sum) based on the solid waste figures is estimated at about 25000 – 50000 NGN for the collection of the solid and liquid fractions of the wastewater, bringing the annual O&M to a sum of ca. 75000 NGN. In addition to this an expected increase in capital costs to include the cost of urine storage tanks (24 units of 4 m³ tanks are needed) estimated at 45,000 NGN will result in total costs as shown in table 6.4.

Table 6. 4: Costs per household with centralised management for scenario presented in 6.2.1.3

Component	**Amount (NGN)***
Treatment (Onsite Wetlands)	144,413
Rottebehalter	29,450
Settling Tank	22,950
Urine Storage Tanks	11,134
Subtotal	**207,947**
Allowances for additional work	20,794
Overheads	31,192
Total Capital Investment	**259,933**
Annual Operation & Maintenance (10% of INV) + provider charges ca. 50000 NGN	**75,993**

* 160 NGN = 1 Euro

Cost estimates for the scenario presented in Section 6.2.2.1 are as follows in table 6.5.

Table 6. 5: Costs per household for scenario presented in 6.2.2.1

Component	**Amount (NGN)***
Double Vault Toilet	75,500
Treatment (Onsite Wetlands)	93,675
Settling Tank	30,950
Urine Collection	1,200
Subtotal	**201,325**
Allowance for additional works	20,132
Overheads	30,198
Total Investment	**251,656**
Annual Operation & Maintenance	**25,165**
Settling tank desludging every two years	**8000**

* 160 NGN = 1 Euro

The management of this scenario is entirely onsite and by the user, therefore entire capital and annual O&M costs as shown in table 6.5 are borne by each household. A sum of 8000 NGN is assumed for tank desludging every two years.

Table 6.6 shows the capital and annual O&M costs for the scenario presented in section 6.2.2.2. All costs are borne by each household as all components of the system are onsite. Management by service providers is expected to attract increased O&M costs.

Table 6. 6: Costs per household with onsite management for scenario presented in 6.2.2.2

Component	Amount NGN
Treatment (Onsite Wetlands)	144,413
Rottebehalter	29,450
Subtotal	**173,863**
Allowances for additional work	17,386
Overheads	26,079
Total Investment	**217,328**
Operation & Maintenance (per household*year)	**21,732**
O&M with Service Providers @ 50000/yr	**71,372**

* 160 NGN = 1 Euro

Based on current local prices for solid waste management service provided by private AEPB contractors (see appendix D), a service (for collection of rottebehaelter solids) charge based on current solid waste figures would be about 50000 NGN bringing the annual O&M cost as shown in table 6.6.

All the costs presented in section 6.3 represent only rough estimates of the likely costs of each scenario locally. Land costs are not included; land in the FCT is generally under governmental control and is allocated to applicants as necessary by the Lands and Planning Authority; applicants typically only pay administrative charges for the plots allocated to them. It is thus assumed that for centralised systems scenario 1 & 2, the land needed will be contributed by the municipal authority governing the design area; for the onsite systems land required is assumed to be a part of the user's property.

6.3.2 Cost Analysis and Comparison

For ease of reference in this analysis the proposed scenarios are designated as given in table 6.7.

Table 6. 7: scenarios and their respective references

	Described in Section	Short description
Scenario 1	6.2.1.1	*Combined sewage collection with offsite treatment in ponds*
Scenario 2	6.2.1.2	*Wet sanitation with solids separation with offsite treatment in constructed wetlands*
Scenario 3	6.2.1.3	*Separation at source and onsite/centralised management*
Scenario 4	6.2.2.1	*Dry System with Urine Diversion*
Scenario 5	6.2.2.2	*Wet system with solids separation and onsite/centralised management*

A time period of 30 years is assumed for each of the scenarios, and the lifetime of each component of respective scenarios estimated from LAWA recommendations (LAWA, 2005), e.g. simplified or settled sewerage – 30 years; pond system – 15 years, etc. Based on this time period of 30 years, a discount rate of 10 % (World Bank, 1996), and assuming no variations occur in annual costs, the net present value (NPV) of the five scenarios were derived by determining for each scenario the NPV of capital costs (initial investments, replacement) and NPV of O&M (annual operating costs), the sum of these gave the NPV for each scenario.

From a purely economic perspective and the assumption that all scenarios have equal benefits, it can be inferred from table 6.8 that Scenarios 1, 3, 4 and 5 are the most attractive of all five scenarios. Ranking the scenarios on a least economic per capita cost basis will yield an order of preference shown in the ranking column.

Table 6. 8: NPV for the proposed scenarios

Scenario	NPV of COSTS (10%, 30 years)			NPV/cap	Ranking*
	Capital	O&M	Total		
Scenario 1	5,133,189	34,247,505	39,380,693	67,664	6
Scenario 2	14,425,727	48,087,423	62,513,150	107,410	7
Scenario 3 *Centralised Management*	365,488	1,679,412	2,044,900	3,514	5
Onsite Management	365,488	697,892	1,063,380	1,827	2
Scenario 4	340,980	763,901	1,104,881	1,898	3
Scenario 5 *Centralised Management*	322,869	1,623,097	1,945,966	3,344	4
Onsite Management	322,869	641,577	964,447	1,657	1

** this is an economic ranking showing least cost and does not reflect any other factor*
shaded cells show costs for entire design area, un-shaded cells show costs per household

The implication here is that Scenario 5 is the least cost alternative when management of system is carried out by the user onsite (see section 6.2.2.2), followed by scenarios 3 and 4 with onsite management. However an increase in costs is observed when management of the same system becomes communal as indicated by scenarios 3 and 5, which indicates that onsite systems with user management may be economically more cost effective than communal management of the same systems. The increase in cost for Scenario 3 with communal management arises from the cost of collection and storage of the yellow water. If this is collected and managed by the users the associated cost can be eliminated making the scenario more economically attractive. For scenarios 1 and 2, semi-central /offsite, scenario 1 is the least cost alternative, with the difference in costs arising mainly from the cost of constructing the treatment systems – ponds for scenarios 1 and communal wetland for scenario 2 (see tables 6.1 and 6.2). According to local prices ponds can be constructed at about 30% of the cost of a communal wetland.

Economic comparison yields a limited least cost analysis where all benefits are assumed to be equal; it does not incorporate qualitative criteria such as user preferences, and thus can not be taken as a sole basis for making a choice as many other factors influence the selection of a sanitation system.

Recommending a particular scenario as the most suitable is not the objective of this pre-feasibility assessment, rather it is to answer the question what is feasible in the study area, how much the feasible alternatives are likely to cost and how do these alternatives perform against selected criteria based on the objectives defined in Chapter 4 (section 4.4) namely: *human and environmental health protection; appropriate technology: low tech; low maintenance; affordability: low capital and recurrent cost; reuse possibilities where applicable.*

The comparison that follows is qualitative and simply gives an indication of the implications of selecting one scenario over the other, so that stakeholder decision is informed; the final choice lies with the user. Although various criteria can be found in the literature for qualitatively assessing sanitation systems (Kvarnström et al., 2004), the criteria for this assessment are based on the scenario development objectives which in turn are based on input from field study findings and recommendations from the literature. They are as follows: costs, ease of management, social acceptance, resource consumption, and reuse potential; scores of high (H), moderate (M), low (L) or ambivalent (A) are assigned to each scenario against the criteria considered, the results are presented in table 6.9.

Table 6. 9: Qualitative comparison of the proposed scenarios

Criteria	**Scenario**						
	1	**2**	**3a**	**3b**	**4**	**5a**	**5b**
Ease of Management	H	H	L	M	H	M	M
Resource Consumption							
Water	M	M	M	M	L	M	M
Land	H	H	H	M	L	L	L
Energy	L	L	H	L	L	M	L
Social Acceptance	H	H	M	M	A*	M	M
Reuse Potential	L	M	H	H	H	M	M

**A = largely dependent on the user*

3a and b refer to centralised and onsite management of scenario 3 respectively

5a and b refer to centralised and onsite management of scenario 5 respectively

Simplicity of management: this refers to the ease with which the O&M activities are carried out; for this criterion, scenarios 1 (simplified sewerage, pond system) and 2 (settled sewerage, wetland system) rank higher than all others especially from the user's perspective as user input is minimal and the O&M responsibility for the system is largely municipal authority's. Comparatively, the other scenarios require moderate to high user input in O&M activities.

Resource consumption: all the scenarios require relatively limited amounts of water 60 – 120l/c/d. For Land scenarios 1 and 2 require the highest amount of space and but the least amount of energy, it is largely a trade off between energy costs and space. Communal management of scenario 3a has the highest energy consumption due to the costs of centralised management of the systems (collection and transportation of urine and faecal solids to the storage/ treatment centres), and subsequent distribution of the treated material; scenario 5a requires moderate energy inputs also mainly for transportation. Scenario 4 ranks highest for both space requirements and low energy input.

Social acceptance: this is a very subjective criterion as opinions, perception, preferences differ from one user/community to another. Findings of the field study show that over 50% of those surveyed use WCs with septic tank systems. It is unlikely that this group of people will opt for any system that does not offer the convenience they currently enjoy, it can thus be inferred that for this group scenarios 1, 2, 3 and 5 would have the highest levels of acceptance. However in terms of user involvement in management scenarios 3 and 5 would rank lower than 1 and 2. For respondents in the indigenous people group, scenario 4, which is ranked 'A' is likely to have the highest level of acceptance as the use of excreta in farming is accepted by this group as indicated by their responses to that question in the field study; preferences expressed by respondents outside this people group suggest that this scenario is unlikely to be widely accepted. Vermicomposting may be included in scenario 5, however, this technology is new to Nigeria, and as such the acceptance of this practice cannot be ascertained at this time.

Reuse potential: all of the scenarios allow for some level of reuse of either the total wastewater stream for irrigation as in scenarios 1 and 2, or reuse of particular streams as in scenarios 3, 4, and 5. Aquaculture is not a feasible reuse option in the scenario 1 as extra space for a second maturation pond would be required to treat the wastewater to the WHO standard required for aquaculture; the benefits of this do not justify the costs to be incurred. The reduction in expenditure on chemical fertilizers is an attractive advantage of scenarios 3, 4, and 5 as utilising the fertiliser value of the treated wastewater will offset some of the O&M costs.

Ability and willingness to pay are also very important factors to consider; only the user is able to make a firm and final judgement on whether and how much he or she is willing to pay for any of the scenarios being considered. Once all the benefits have been weighed, it then becomes a question of how valuable those benefits are to the user. Sometimes a system that costs more but offers greater convenience may be chosen over a significantly cheaper alternative. It is important to explore possibilities for reducing costs wherever possible. An option for cost reduction for scenario 4 is to utilise prefabricated polyethylene vaults (with superstructures made from locally available materials), which can be easily mass produced at significantly lower costs than concrete vaults. PE technology is widely used in Nigeria for the production of water storage tanks and may be easily adapted for the production of the faeces vaults.

Summarily, the pros and cons of the scenarios proposed have been discussed in section 6.2 and highlighted in above. The decision on the choice of scenario is better taken by stakeholders using a participatory approach. The existing approaches of selecting sanitation systems '*engineer knows best*', which adopts a top-down approach in which the decision taken is forced on the user regardless of whether it is wanted or affordable; the '*user knows best*', in which the user is left to do what he wants regardless of the impact of his or her choice on the environment as well as other users, this often leads to an as 'one sees fit' situation; or the '*market*' approach that views sanitation as a commodity to be sold, have all be proven faulty (Tayler et al., 2003). A decision approach that unifies professional knowledge, user preferences, ability and willingness to pay, institutional capabilities and local resource base, in order words, a participatory approach that incorporates all of the models described above, will be far more beneficial in achieving human and environmental health protection as well as long term sustainability of the chosen systems.

Chapter 7: Conclusions and Recommendations

Wastewater management in Abuja and indeed Nigeria as a whole is fraught with problems; the many reasons for this have been discussed in this thesis; the most significant of these are: the non regulation of wastewater management, the use of conventional systems which have proven to be unsustainable in Nigeria, and lack of access to sanitation facilities by some sections of the population.

Different problems were observed in the different communities in the study areas. The use of unsustainable sanitation technologies was more of a problem for the FCC than a lack of access, even though sanitation coverage was not total, e.g. non availability of mechanical components for maintaining the wastewater treatment facilities. For the peri-urban settlements whose residents represent the primary subject of this study, pollution resulting from non regulation of private onsite sanitation facilities was the most common problem as people simply install what they wish without due regard for the impact such systems may pose to human health or the environment. For example gaps deliberately left in the walls of septic tanks to aid infiltration of effluent into the surrounding areas, as a means of limiting or totally eliminating the need for emptying the tanks. Among the indigenous population on the other hand, access to sanitation facilities was the major problem.

In terms of economic sustainability, the fee recovery system for the centralised sewerage and wastewater treatment system in the FCC is very poor; according to an official of the Sewage Management Department, users are not required to pay any charge for connections to the sewer system. In addition the fee charged for liquid waste management is often not paid by users. Considering the cost implications of this system as discussed in this work and the need for expansion of the system to serve growing population of the FCT; how is it possible to sustain such a system?

The observed problems are however merely manifestations of a more fundamental problem, that of the right focus and direction regarding managing wastewater and indeed environmental issues in Nigeria. Simply put our attempts at solving sanitation problems require a rethink; we cannot continue to replicate the current systems that are failing as this study reveals, in view of the impacts that would result from failures of such systems; considering the growing population, a continuation of the status quo will indeed be a recipe for an environmental disaster in the not so distant future.

Perhaps the greatest challenge the sanitation sector currently faces is that problems are yet to be acknowledged as problems; until this happens, solutions aimed at helping will remain largely exercises in futility.

The problem afflicting sanitation in Nigeria is multi-faceted and the place to begin to address them is to raise awareness and consequently the profile of sanitation in Nigeria;

there is consensus on the fact that water and health care are vital but the same importance is not attached to sanitation, which has the potential to negatively impact both water and health. We need to start honestly asking, what we are doing wrong now, what the impacts are likely to be in future, what should be done to forestall the problems.

The National Water Supply and Sanitation Policy (NWSSP) adopted in January 2000, basically stated as its aim, the provision of sufficient water and adequate sanitation to all Nigerians in an affordable and sustainable way through participatory investment by the three tiers of government, the private sector and the beneficiary (Monday, 2004).

Although having a defined policy is good, the further step of translating the policy into concrete action is needed and in this case this appears to be lacking. Policies without implementation have very little impact no matter how good they are. This policy therefore needs to be translated into strategies that allow concrete steps to be taken towards implementation.

There must be a vision of what is needed and goals set to achieve this especially regarding resource consumption and pollution as they affect the environment in general and sanitation in particular. This will require enlightenment and the political will to carry the vision through, and legislation that allows enforcement to locally appropriate standards. These standards should not merely replicate western examples but may use these as a guide while being based on the needs and peculiarities of the Nigerian situation without compromising on human and environmental protection. Further a system of enforcement and monitoring will give significance to the legislation and aid the implementation of such policies.

What can be done? There are no quick fixes and none is proposed in this study; rather developing a correct and firm foundation on which subsequent actions that yield the desired results are based must be the focus of efforts.

In terms of technology, the innate preference for unsustainable technologies must be set aside and technologies more suited to the situation on ground must be the focus of local technical interventions. To this end, a fundamental shift in the way we have done things so far as well as openness on the part of engineers and sanitation practitioners to new approaches, and knowledge of innovative technologies are necessities.

Technologies exist that are cost effective, non-polluting, and provide the benefits of a good sanitation system; however, knowledge about these is limited in the study area among both users and the decision makers – this situation must change in order to address the identified problems. Resources must thus be invested in seeking out alternatives technologies, testing the performance of these through pilot trials for suitability in the local context, especially considering that sanitation infrastructure represents one of the most capital intensive investments any community makes.

Affordability and sustainability are main focal points of the current national water and sanitation policy; this study revealed that existing systems are not meeting these conditions. The scenarios developed in this study represent an example of what is feasible in the study area, and utilised low cost components such as simplified sewerage for reticulation, and natural treatment systems, deliberately avoiding technologies that require external inputs such as electrical energy, mechanical or imported parts, etc., as these are some of the main reasons for failures and non-sustainability of existing systems.

Each of the five scenarios in addressing the problems identified considers factors such as available resources (human, material), expressed user preferences, etc. For example, one of the scenarios developed is basically a low cost version of the centralised system – reticulated transport with simplified sewerage and subsequent wastewater treatment using ponds. Compared to its conventional counterpart, it has the advantage of being low cost; additionally the pond system component does not require energy input or mechanical parts, and the system can be managed with the existing management infrastructure. Further it allows the possibility of treated wastewater reuse in irrigation or aquaculture. The scenario was found to be the most cost effective with the highest level of simplicity of management considering existing local resources (knowledge, personnel) out of the proposed centralised or semi-central concepts. It is a suitable alternative for users with a preference for centralised flush sanitation systems, who are willing and able afford the option.

Amongst the onsite systems, the rottebehaelter combined with onsite sullage treatment in wetlands and solids composting or vermicomposting appears promising offering the convenience of flush systems while still presenting the opportunity of reuse through solids separation and treatment. This scenario is more likely suited to the more upscale residents of the study peri-urban areas based on their expressed preferences especially as it is possible to have the system managed centrally.

For the indigenous population, the urine diverting dry vault system could be a suitable option as reuse of nutrient contained in treated excreta is possible with these systems, which is likely to be a benefit among this people group. Further as the need of this group is access to sanitation facilities, the simplicity means easy replication and use is feasible; the low cost implication of this scenario will be an advantage as regards affordability; finally the low water requirement means the system is suitable even where piped water supply is not available as is often the case with these settlements.

Existing systems are either already failing or will fail at some point in the not too distant future. It is not reasonable to continue to replicate existing systems considering that they are not fulfilling the requirements (affordability and sustainability) of the current sanitation policy stance.

While it may no longer be possible to have alternatives such as those this study proposes in the established parts of the FCC, most of the satellite towns currently exist only on paper; there is thus good opportunity to influence development of sanitation infrastructure in the satellite towns, encouraging the adoption of environmentally sound sanitation technologies that are low cost and efficient. However major changes made in the way sanitation infrastructure is developed are necessary for any such measures to be successful.

The scenarios presented in this work represent a small insight into what is possible in Nigeria using the case of Kuje as an example. These findings represent a call to action on environmental degradation issues in Nigeria and the imminent danger of the status quo. It is hoped that the outcome of this work will generate some interest and discussion among respective stakeholders in Nigeria, if this is the case then it would have been well worth the numerous problems that were encountered in this course of the study. Allowing a situation where a segment of the population still lack access to sanitation when something can be done to correct the problem is not an option, there is indeed "no truer sign of civilisation and culture than good sanitation" (Stobart, 1935).

References

AEPB (2005). Waste Management Rates/Charges Regulations 2005 (internal document)

Aina, T. A. (1990). Housing and health in Olaleye-Iponri, a low income settlement in Lagos, Nigeria. In Cairncross, S., Hardoy, J. E., Satterwaithe, D. (eds). The Poor Die Young: Housing and Health in Third World Cities. Earthscan Publications, London, UK.

Almedom, A.M., Blumenthal, U., and Manderson, L., (1997). Hygiene Evaluation Procedures: Approaches and methods for assessing water and sanitation related hygiene practices, Stylus Publishing, London.

Annan, K. (World Health Organization) Water, Sanitation and Hygiene Links to Health Facts and Figures, November 2004.

Annual Abstract of Statistics (2001).Federal Office of Statistics, Abuja, Nigeria.

Appelhof, M. (1997). Worms eat my garbage. 2nd edition. Flower Press, USA.

Bakalian, A., Wright, A., Otis, R., and Netto, J. (1994) Simplified sewerage design guidelines. UNDP, World Bank.

Belmont, M. A. and Metcalfe, C.D., (2002). Feasibility of using ornamental plants in subsurface flow wetlands for domestic wastewater treatment. In Holland, M. M.; Warren, M. L.; Stanturf, J. A., (eds.). Proceedings of a conference on sustainability of wetlands and water resources: how well can riverine wetlands continue to support society into the 21st century?

Blaise, C., Gagné, F., Salazar, M., Salazar, S., Trottier, S., Hansen, P.-D. (2003). Long term exposure of freshwater mussels to a municipal effluent plume leads to feminisation. Fresenius Environmental Bulletin.

Brikké, F., Bredero, M., (2003). Linking technology choice with operation and maintenance in the context of community water supply and sanitation: A reference document for planners and project staff. WHO.

Bunting, S. W. (2004). Wastewater aquaculture: perpetuating vulnerability or opportunity to enhance poor livelihoods? Aquatic Resources, Culture and Development 1(1), 51–75.

Carr, R. (2001) Excreta-related infections and the role of sanitation in the control of transmission. In Fewtrell, L. and Bartramn J. (eds). Water Quality Guidelines, Standards and Health: Assessment of risk and risk management for water-related infectious disease. World Health Organization, Geneva, Switzerland.

Chadwick E. (1842) Report...from the Poor Law Commissioners on an Inquiry into the Sanitary Conditions of the Labouring Population of Great Britain. London, 1842, pp. 369-372. (http://www.victorianweb.org/history/chadwick2.html)

Coker, A. O., Sridhar, M. K. C., and Martins, E. A. (2003). Management of septic sludge in southwest Nigeria. Towards the Millennium Development Goals. 29th WEDC International Conference Abuja, Nigeria,

Collier, C. A. and Ledbetter, W.B. (1988). Engineering Economic and Cost Analysis. 2nd ed. Harper and Row, USA.

Cone, M. (1998). River pollution study finds hormonal defects in fish. Los Angeles Times, September 22.

Cooper, P. F. (2001). Historical aspects of wastewater treatment. In Decentralised Sanitation and Reuse: Concepts, Systems and Implementation. P. Lens, G. Zeeman and G. Lettinga (eds). IWA Publishing.

Corea, E. (2001). Appropriate Disposal of Sewage in Urban and Suburban Sri Lanka. Doctoral thesis, University of Leeds, UK

Corrigan, W. J. (1932). Sanitation under the ancient Minoan civilization. Men and Books, P 77 – 78.
Cotton, A., and Franceys, R. (1991). Services for Shelter. Liverpool University Press, UK.
Degeener, S. (2004). Double Vault Toilet Design.
Del Porto D and Steinfeld C. (1997). The composting toilet system book. CEPP, USA.
DFID (2005) Factsheet on Child Mortality. Department for International Development, UK. (http://www.dfid.gov.uk/pubs/files/mdg-factsheets/childmortalityfactsheet.pdf)
Ecosanres (2005). Guidelines for the Safe Use of Urine and Faeces in Ecological Sanitation Systems. (Based on Schönning, C. and Stenström, T.A. 2004, Guidelines for the Safe Use of Urine and Faeces in Ecological Sanitation Systems).
Edwards, C. A. (1995). Commercial and Environmental Potential of Vermicomposting: A Historical Overview. BioCycle, June 1995, 62 – 63.
EHP (1997). Towards Better Programming: A Sanitation Handbook (Water, Environment and Sanitation Technical Guidelines Series - No. 3) EHP Applied Study No. 5. Joint publication of UNICEF's Water, Environment and Sanitation Section, Programme Division and USAID's Environmental Health Project. 1997.
Esrey, S.A. (2000). Rethinking Sanitation: Panacea or Pandora's Box. In Chorus, I., Ringelband U., Schlag G. and Schmoll O. (eds), Water, Sanitation and Health. International Water Association, London, UK.
Esrey, S.A., Gough, J., Rapaport, D., Sawyer, R., Simpson-Hébert, M., Vargas, J. and Winblad U. (eds). (1998). Ecological Sanitation. Stockholm: SIDA.
FCDA (2004). Environmental impact assessment of Wupa basin sewage treatment plant and interceptor sewer trunk mains projects.
FCT (1978). The Abuja Master Plan, International Planning Associates.
Feachem, R., Bradley, D., Garelick, H. and Mara, D. D., (1983). Sanitation and Disease: Health aspects of excreta and wastewater management, John Wiley & Sons, UK.
Fink, A. (1995). How to ask survey questions. Thousand Oaks, CA: SAGE Publications
Foster , V. (2001). Water and Sewerage Systems: Costs of implementation of the model. water and sanitation program. The World Bank.
Franceys, R., Pickford, J., Reed, R., (1992). A guide to the development of onsite sanitation. WHO.
Gajurel, D. R. (2003). Evaluation of decentral physico-biological systems for pre-treatment of household wastewater and their potential for ecological sanitation. Doctoral thesis, Hamburg University of Technology, Germany.
Grant, W., Steele, G. and Isiorho, S.A. (1996). Spontaneous abortions possibly related to ingestion of nitrate-contaminated well water - LaGrange County, Indiana, 1991-1994. Morbidity and Mortality Weekly Report 45, 569-571.
Guissé H. (2002) Economic, Social and Cultural Rights: Relationship between the enjoyment of economic, social and cultural rights and the promotion of the realization of the right to drinking water supply and sanitation. Preliminary report submitted in pursuance of decision 2002/105 of the Commission on Human Rights and resolution 2001/2 of the Sub-Commission on the Promotion and Protection of Human Rights. UN Economic and Social Council.
Gustafson, D. M., Anderson, J. L., Christopherson, S. H., and Axler, R. (2002). Innovative onsite sewage systems: constructed wetlands. http://www.extension.umn.edu/distribution/naturalresources/DD7671.html
Hardoy, J.E., Mitlin, D. and Satterthwaite, D. (2001). Environmental problems in an urbanizing world. Finding solutions for cities in Africam Asia and Latin America. Earthscan Publications, London UK, pg 265 – 282.

Hawkins, J. and Roberts, C.(1994). The growth of coastal tourism in the Red Sea: present and future effects on coral reefs. Ambio. 23, 503-508.
Hinrichsen, D., Robey, B. and Upadhyay, U. D. (1998). Solutions for a water short world. Population Reports, Johns Hopkins University, School of Public Health, Baltimore.
Ike A.C., (2004). The challenges of development a new capital for Nigeria. Abuja Development Bulletin, FCDA, Nigeria.
International Monetary Fund (2006). World Economic Outlook Database, April 2006.
Iwugo, K. O., D'Arcy, B., Andoh, R. (2003). Aspects of land-based pollution of an african coastal megacity. Diffuse Pollution Conference, Dublin 2003, Poster Paper.
Jibril, I. U., (2006). Resettlement issues, squatter settlements and the problems of land administration in abuja, nigeria's federal capital. Promoting Land Administration and Good Governance. 5th FIG Regional Conference, Accra, Ghana.
Jibril, I.U., (2000). Policy changes on resettlement and land administration in Abuja, Nigeria's Federal Capital Territory (FCT). In Afolabi J.F. et. al. (ed.), Issues in Land Administration and Development in Northern Nigeria – Proceedings of the National Workshop on Land Administration and Development in Northern Nigeria.
John Phillips surveyor of the Westminster Court of Sewers, report to Royal Commission 1847. http://www.victorianlondon.org/health/sewers.htm
Johnson, B., Christensen, L., (2003). Educational Research: Quantitative, Qualitative and Mixed Method Approaches. Ally and Bacon, USA.
Jönsson, H.(1997). Ecological Alternatives in Sanitation: Proceedings from Workshop (Drangert, J.-O., Bew, J., and Winblad, U., Eds.) SIDA.
Kalbermatten J.M., Julius D.S., Gunnerson, C., and Mara D.D. (1982). Appropriate Sanitation Alternatives: A Planning and Design Manual. John Hopkins University Press, USA.
Kosek, M., Bern, C., Guerrant, R.L. (2003). The global burden of diarrhoeal disease, as estimated from studies published between 1992 and 2000. Bull. WHO 81(3): 197-204.
Krohs, A. (2004). Review of water supply systems of abuja – results and chances (unpublished term paper).
Kvarnström, E., Bracken, P., Ysunza, A., Kärrman, E., Finnson A., Saywell, D. (2004) Sustainability Criteria in Sanitation Planning. People-Centred Approaches to Water and Environmental Sanitation. 30th WEDC International Conference, Vientiane, Lao PDR, 2004
Länderarbeitsgemeinschaft Wasser (LAWA): Leitlinien Zur Durchfürung Dynamischer Kostenvergleichsrechnungen, 2005
Leal, L., (2004). Design and evaluation of reuse oriented wastewater concepts for a village in Nile Delta of Egypt. (Unpublished project work).
LEE, J., (World Health Organization) Water, Sanitation and Hygiene Links to Health Facts and Figures, November 2004.
Mara, D. and Curtis, T. (2006). Waste satbilization ponds. In Henze, M. and Ujang, Z. (eds). Municipal Wastewater Management in Developing Countries: Principles and Engineering, IWA Publishing.
Mara, D. D., Sleigh, A., Tayler, K. (2001). PC-based simplified sewer design. University of Leeds, Leeds, UK.
Mara, D.D. (1996). Low cost sewerage. John Wiley & Sons, UK.
Mara, D.D. (1996). Low cost urban sanitation. John Wiley & Sons, UK.
Mara, D.D., (1997). Design manual for waste stabilization ponds in India. Lagoon Technology International Ltd., UK

Mara, D.D., (2003). Domestic Wastewater Treatment in Developing Countries. Earthscan, UK.

Microsoft Encarta Online Encyclopedia (2006). "Nigeria". http://encarta.msn.com 1997-2006 Microsoft Corporation.

Monday, J. O. (2004). Environmental and Social Management Framework: National Urban Water Sector Reform Project (NUWSRP) Report. Nigeria.

Morgan, P. The "ArborLoo" Leave the contents – move the loo: a method for recycling human waste. (available at http://aquamor.tripod.com/ArborLoo1.HTM)

Morgan, P., (2000). The "ArborLoo" Leave the contents – move the loo. A method for recycling human waste. (available at http://aquamor.tripod.com/ArborLoo2.HTM)

Myint, T., and Aye, U., (1988). Evalution of the health impact of tube well water supply in dry zone rural communities in burma. Unpublished document. Department of Medical Research, Ministry of Health, Rangoon.

Ola C.S. (1977). Town and Country Planning Law in Nigeria, Oxford University Press, Ibadan, Nigeria.

Olaleye, O. A. and Ameh, C. E., (1999). Forest Resource Situation Assessment of Nigeria. FAO.

Otis, R. J. and Mara, D. D., (1985). The design of small bore sewers systems. TAG Technical Note No. 14. The World Bank, Washington, DC.

Otterpohl, R and Meinzinger F. (2005). Economic aspects of wastewater management. Lecture material, Hamburg University of Technology.

Otterpohl, R. (2001). Black, brown, yellow, grey – the new colours of sanitation. Water 21, October 2001, pg 37 – 41.

Parry-Jones, S. and Kolsky, P. (2005). Some global statistics for water and sanitation related disease. WELL publication UK

Pickford J., and Shaw, R. (1999). Latrine Slabs and Seats. WEDC/IT Publications, UK.

Pickford, J., (1995). Low cost sanitation. ITDG Publishing UK.

Prüss, A., Kay, D., Fewtrell, L., Bartram, J. (2002). Estimating the Burden of Disease from Water, Sanitation, and Hygiene at a Global Level. Environmental Health Perspective Vol. 110:537–542 (http://ehpnet1.niehs.nih.gov/docs/2002/110p537-542prüss/abstract.html)

Raloff, J. (1998). Drugged waters: does it matter that pharmaceuticals are turning up in water supplies? Science News 153:187-189.

Reed, S. C., Crites, R. W., Middlebrooks, E. J. (1995). Natural systems for waste management and treatment. Mc Graw Hill, Inc., USA.

Rockström, J., Axberg, G., Falkenmark, M., Lannerstad, M., Rosemarin, A., Caldwell, I., Arvidson, A. and Nordström, M. (2005). Sustainable Pathways to Attain the Millennium Development Goals: Assessing the Key Role of Water, Energy and Sanitation, with contributions from the Stockholm International Water Institute (SIWI). Stockholm Environment Institute, Sweden.

Sarmento V., (2001). Low-cost Sanitation Improvements in Poor Communities: Conditions for Physical Sustainability. PhD Thesis, University of Leeds, UK.

Sasse, L. (1998). Decentralised wastewater treatment in developing countries, BORDA, Bremen, Germany

Scott, R., Cotton A., and Govindan, B. (2003). Sanitation and the Poor. WELL, WEDC, UK

Segerfeldt, F., (2005). Water for Sale: How Business and the Market Can Resolve the World's Water Crisis. Cato Institute, Washington, USA.

Shalabi, M. (2006). Vermicomposting of Faecal Matter as a Component of Source Control Sanitation. Doctoral thesis, Hamburg University of Technology, Germany.

Simpson-Herbert, M. (1984). Water and Sanitation: Cultural Considerations. Water and Sanitation – Economic and Soiciological Perspectives. Peter Bourne (ed.) Academic Press, USA.

Sinnatamby, G. (1990). Low Cost Sanitation. In The Poor Die Young: Housing and Health in Third World Cities. Cairncross, S., Hardoy, J. E., Satterwaithe, D. (eds). Earthscan Publications, London, UK.

Stobart, J.C. (1935). The glory that was Greece. Revised by F. N. Pryce. Appleton Century Co. New York, USA.

Tayler, K., Parkinson, J., Colin, J. (2003). Urban Sanitation: A Guide to Strategic Planning. ITDG Publishing, UK.

Tchobanologous, G. and Burton, F. L. (2003). Wastewater Engineering: Treatment, Disposal, and Reuse. Metcalf and Eddy, USA.

The Holy Bible, Deuteronomy 23: 12 – 13. New International Version.

Umeh, L. C. (1993). 'The building of a new capital city: the Abuja experience'. In Urban Development in Nigeria – Planning, Housing, and Land Policy. Robert Taylor (ed). Avebury, UK. Pg 215-228.

UN (1987). Development and International Economic Co-operation: Environment. Report of the Brundtland Commission (available at http://www.are.admin.ch/imperia/md/content/are/nachhaltigeentwicklung/brundtland_bericht.pdf?PHPSESSID=032c31fd198c82e167f876e3a9ee41dc)

UN (2004). World Population Prospects: The 2004 Revision. Department of Economic and Social Affairs, Population Division, United Nations, New York.

UNEP (2002). Africa Environment Outlook: Past, present and future perspectives. Available at http://www.unep.org/dewa/Africa/publications/AEO%2D1

UN-Habitat (2003). The challenge of slums: global report on human settlements

UNICEF (2004). Database of child mortality figures. (available at….

USACE (1999). Small Wastewater Systems: Design, Construction, and Operation. Engineer Manual 1110-2-501, U.S. Army Corps of Engineers, Washington, DC USA, available at (http://www.usace.army.mil/publications/eng-manuals/em1110-2-501/entire.pdf)

USEPA (1988). Constructed wetlands and aquatic plants systems for municipal wastewater treatment.

USEPA (1993). Subsurface flow constructed wetlands for wastewater treatment: a technology assessment.

Van der Ryn, S. (1995). The toilet papers: recycling waste and conserving water. Ecological Design Press, Sausalito.

Wagner E.G. and Lanoix, J.N., (1958). Excreta disposal for rural areas and small communities. WHO, Geneva.

Walonick David S., (1997). Survival Statistics. StatPac, Inc., USA.

Water Scarcity: Seasons of Unending Health Crises by Yakubu Ozohu-Suleiman, Newspaper Article July 31, 2003, Daily Trust Abuja

WHO (1954). Expert committee on environmental sanitation: third report. Geneva, World Health Organization (WHO Technical Report Series, No. 77)

WHO (1998). The World Health Report 1998: Life in the 21st century. A vision for all. World Health Organisation.

WHO (2004). Sanitation and hygiene links to health: facts and figures. November 2004

WHO and UNICEF (2000). Global water supply and sanitation assessment 2000 Report. Geneva.

WHO/UNICEF (2004). Joint Monitoring Programme for Water Supply and Sanitation; Meeting the MDG drinking water and sanitation target: a mid-term assessment of progress.

World Health Organization (WHO) (1992). Our planet, our health—Report of the WHO Commission on Health and Environment. Geneva. pg. 106-144

World Population Prospects: The 2004 Revision (2005) United Nations, New York, USA.

World Resources Institute (1998). A Guide to the Global Environment: Environmental Change and Human Health, Oxford University Press, New York.

Wyn-Jones, P. (2000). Water, water, everywhere – But is it safe to drink? Microbiology Today Vol. 27, May 2000.

Bibliography

Adelegan, J. A. (2004) The history of environmental policy and pollution of water sources in Nigeria (1960-2004): The way forward.

Adelegan, J., and Ojo, S. I.A. (1999). Low Cost Urban Sanitation in Nigeria. Integrated Development for Water Supply and Sanitation. 25th WEDC Conference, Addis Ababa, Ethiopia.

Agberemi, Z.O. (2003). Managing water supply and sanitation projects in Nigeria. Towards The Millennium Development Goals. 29th WEDC International Conference Abuja, Nigeria, 2003

Bijleveld, M. (2003). The possibilities for ecological sanitation in the Netherlands. Master Thesis, University of Twente.

Bolorunduro, P.I., Adesehinwa, A.O.K., and Bolorunduro, O. M. (2005). Policy options in managing the crisis of environmental degradation and the prevalence of poverty in urban Nigeria. Journal of Food, Agriculture & Environment Vol.3 (1), 216-219.

Cairncross, S., O'Neill, D., Mccoy, A., And Sethi, D. (2003). Health, Environment and The Burden of Disease: A Guidance Note. DFID, UK.

Daramola, S. A., And Aina, O. P Lanning Policies And Affordable Housing In Nigeria – An Analysis of Abuja Master-Plan Scheme and the Re-Validation of Certificate of Occupancy. (Unpublished Paper).

Habila, O. N. (2002). Rural Water Supply and Sanitation Development in Nigeria. Proceedings of the 28th WEDC Conference, Kolkata, India.

Harper, P. and Halestrop, L. (1999). Lifting the Lid: an Ecological Approach to Toilet Systems. Centre for Alternative Technology, UK.

Hassan, A. (2003). Effect of sanitation system on groundwater. TOWARDS THE MILLENNIUM DEVELOPMENT GOALS. 29th WEDC International Conference Abuja, Nigeria, 2003.

Henze, M. (1997). Waste design for households with respect to water, organics and nutrients. Water Science and Techonlogy, Vol. 35, No.9 pp. 113 – 120, 1997.

Henze, M. and Ujang, Z. (2006). Sustainable Sanitation for Developing Countries. In Henze, M. and Ujang, Z. (eds). Municipal Wastewater Management in Developing Countries: Principles and Engineering, IWA Publishing.

Hogrewe, W., Joyce, S.D., Perez, E. A. (1993) The Unique Challenges Of Improving Peri-Urban Sanitation. Water and Sanitation for Health. Project Office of Health, Bureau for Research and Development USAID, Washington, DC, USA.

Hughes, R., Ho, G., and Mathew, K. (2006). Conventional Small and Decentralized Wastewater Systems. In Henze, M. and Ujang, Z. (eds). Municipal Wastewater Management in Developing Countries: Principles and Engineering, IWA Publishing.

Japan International Cooperation Agency (1999). Country Profile on Environment Nigeria.
Mohammed, B. (2006). Design and Performance Evaluation of a Wastewater Treatment Unit Department of Agricultural Engineering, Federal University of Technology Minna, Niger State, Nigeria AU J.T. 9(3): 193-198 (Jan. 2006).
Montangero, A., and Strauss, M. (2002) Faecal Sludge Treatment. IHE Delft.
Niemczynowicz J. (2001) The urban sanitation dilemma. In Decentralised Sanitation and Reuse: Concepts, Systems and Implementation. Lens, P., Zeeman, G., and Lettinga, G. (eds). IWA Publishing, pg. 117 – 129.
Nimpuno, K. (1984). Viable Low-Cost Sanitation Options. Water and Sanitation – Economic and Soiciological Perspectives. Peter Bourne (ed.) Academic Press.
Ofong, I. (2002). Community Management of Sanitation Centres in Nigeria. Sustainable Environmental Sanitation and Water Services. Proceedings of the 28th WEDC Conference, Kolkata, India.
Olaleye, O. A. and Ameh, C. E., Forest Resource Situation Assessment of Nigeria, April 1999, FAO.
Otterpohl, R. (2000). Design of highly efficient Source Control Sanitation and practical Experience EURO-Summer School DESAR, Wageningen, The Netherlands.
Otterpohl, R., Braun, U., and Oldenburg, M. (2002). Innovative technologies for decentralised wastewater management in urban and peri-urban areas - keynote presentation, IWA 2002, Istanbul, Turkey.
Otterpohl, R., Grottker, M. and Lange J. (1997) Sustainable water and waste management in urban areas. Water Science and Technology. Vol. 35 No 9 pp 121–133.
Prüss, A., and Havelaar , A. (2001). The Global Burden of Disease study and applications in water, sanitation and hygiene. Water Quality Guidelines, Standards and Health: Assessment of risk and risk management for water-related infectious disease. Fewtrell, L. and Bartramn J. (eds). World Health Organization, Geneva, Switzerland
Roark, P., Hodgkin, J., and Wyatt, A. (1993). Models of management systems for the operation and maintenance of rural water supply and sanitation facilities. Environmental Health Project, USAID, Washington USA.
Sanitation and Hygiene Promotion Programming Guidance Water Supply and Sanitation Collaborative Council and World Health Organization, 2005
Simpson-Herbert, M. (1984). Water and Sanitation: Cultural Considerations. Water and Sanitation – Economic and Soiciological Perspectives. Peter Bourne (ed.) Academic Press, USA.
Sustainable wastewater management: a handbook for smaller communities, available at www.mfe.govt.nz
UNICEF (2000). Sanitation for All - promoting dignity and human rights.
WASTE (2005). Fact sheet on Sanitation Classification of sanitation systems. Mirjam Geurts, ed.
Werner, C. and Schlick, J. (2001). Ecosan – Introduction of closed-loop approaches in wastewater management and sanitation – a new supra-regional GTZ – project, presented at the International Conference on Freshwater, Bonn.
Wilderer, P.A. and Schreff, D. (2000). Decentralized and centralized wastewater management: a challenge for technology developers. Water Science and Technology. Vol 41 No 1 pp 1–8, IWA Publishing.
Yu, H., Tay, J., Wilson, F. (1997). A sustainable wastewater treatment process for tropical and subtropical regions in developing countries. Water Science and Techonlogy, Vol. 35, No.9 pp. 113 – 120, 1997.

Internet Sources

- City Sewage in the EU. Retrieved July 2006. (http://ec.europa.eu/environment/nsf/city_sevage.htm).
- Tools for Sanitation Choice (2000) (available at http://www.tcd.ie/Civil_engineering/Staff/Laurence.Gill/SS%20Hydraulics/c3%20Tools%20for%20sanitation%20choice.pdf#search=%22tools%20for%20sanitation%20choice%22)
- http://news.bbc.co.uk/2/hi/africa/4837582.stm
- http://www.lagosstate.gov.ng
- http://www.sewerhistory.org/
- Roman Sewers. http://www.schoolhistory.co.uk/year7links/romans/sewers.pdf
- Sanitation. (8 June 2006). http://www.bookrags.com/other/health/sanitation-woh.html
- www.gec.jp
- www.septicinspection.com
- www.toiletsforall.org

APPENDIX A: SURVEY TOOL AND DESCRIPTION OF STUDY METHODS

Survey Tool for the Study on Water and Sanitation in the Peri Urban Areas

Introduction: *We are carrying out a study for the water and sanitation situation in Abuja and would like your opinion on the issue. All information you provide will be kept strictly confidential and your name will not be printed or used in any document.*

DK = Don't Know **DTA = Declined to Answer**

Date of Interview Time
Name of Interviewer
Interview Number ____________

1. Name___________________________ (optional) Age:__________(optional)

2. Where do you live? *(circle as appropriate)*

   Idu Karmo Chika Gwagwa Kuchigoro Mpape Other _______

3. Where do you live? *(circle as appropriate)*

   In your own house rented with family squatting homeless DTA

4. Head of household *(circle as appropriate)*: Yes No DTA

5. Household size: Adults_________ Children________

Water Supply

6. What is your source of water? *Tick as appropriate*

Source Use	D	C	B	W	F	O
Piped into personal house						
Piped into yard or Compound						
Public tap						
Borehole with pump						
Well						
Protected spring						
Rainwater collection						
Bottled water						
Pond, river or stream						
Tanker-truck vendor						
Other (Specify)						
No answer or DK						

D = Drinking; C = Cooking; B = Bathing; W = Washing; F = Flushing; O = Others

7. Generally do you think your water is good? *(circle as appropriate)*

   Yes No DK DTA

8. How often do you have water? *(circle as appropriate)*

   Always Once a day Once or twice a week DK DTA

9. About how much water do you use per day? Jerry Cans________

10. How much do you pay per jerry can for water? _______________________

Sanitation

11. Are you satisfied with your current water situation? *(circle as appropriate)*

    Yes No DK DTA

12. Do you have a toilet where you live? *(circle as appropriate)*.

    Yes No DK DTA

13. What type of toilet do you have? *(circle as appropriate)*

    WC-Septic tank with Soak away PF Pit Open DK DTA

14. Who uses this toilet? *(circle as appropriate)*

    Men only Women only Men, Women & children everyone

15. What type of cleaning material do you use? *(circle as appropriate)*

    Water Dry Material *(T. paper, Paper, leaves)* Both Other

Preferences

14. When using the toilet do you prefer to Sit or Squat ? *(circle as appropriate)*

15. Level of privacy preferred *(circle as appropriate)*

    1 2 3 4 5

    increasing privacy

16. Are you satisfied with your toilet? Yes No DK DTA

    Why?____

    If NO what would you like or prefer __________________________

    ____

17. Where would you want your toilet to be located? *(circle as appropriate)*

    Inside the house outside the house DK DTA

Excreta Reuse

18.

Questions about reuse of excreta	**Yes**	**No**	**DK**	**DTA**
Have you ever heard about using **manure t***o grow food?*				
Have you ever heard about using **animal** *manure to grow food?*				
Have you ever heard about using **human excreta** *to grow food?*				

19. What do you think of using human excreta to grow food?

    OK Not OK DK DTA

20. Can you buy and eat food if you know it was grown using human excreta?

    Yes No DK DTA

21. What part of Nigeria are you from? __________________________

22. What are the local beliefs about touching, handling or using, human waste for farming; in your area? *(circle as appropriate)*

    No problem Not allowed Taboo Harmful DK DTA

    Comments____

    ____

Hygiene Knowledge

23. Do you think it is necessary to wash your hands after using the toilets?

Yes No DK DTA

Why?____

24. Who removes refuse from your house?

Service Provider	Yes	No	DTA	How much do you pay?
Self				
Govt Service				
Private Removers				

25. Are you satisfied with the service? *(circle as appropriate)*

Yes No DK DTA

26. Should it be improved? *(circle as appropriate)* Yes No DK DTA

27. Would you be willing to pay for better services if: *(circle as appropriate)*

Yes No DK DTA

Under what condition	Yes	No	DTA
If it were your own house			
If services were improved			
Doesn't matter as long as I have good services			

How much?

Water	Sanitation	Refuse

28. Who would you prefer to provide these services? *(circle as appropriate)*

Self Private Government DK DTA

Any Comments?

____

____

____

Thank you for your time and help.

Social Methods in Sanitation Research

Ideally research in sanitation planning should be participatory; an abundance of literature exists on the subject of participatory methods; the methods described in this section are those that were employed in the field study phase of this research.

Secondary and Primary Data Collection

In contrast to primary data, which is data collected as input into a new research project by the researcher, secondary data refers to data originally collected by other researchers possibly for purposes different from the current research. These include existing official documents (written or recorded for public or private organizations); other documents such as project reports, newspapers, journal articles, etc.

Interviews

Generally an interview involves the interviewer (researcher) asking questions and an interviewee (research subject) providing answers; this may be in person or over the telephone. According to Johnson et al. (2003), interviews may be quantitative or qualitative. The main difference between both types of interviews is the format of the questions used in the data collection process. For quantitative interviews questions are close ended (questions requiring a yes or no, true or false type answers) and standardized (i.e., all interviewees receive the same questions). The schedule used here is often similar to a questionnaire.

Qualitative interviews on the other hand employ open ended question format that allows the interviewee to not only answer the specific question asked but also to share their opinions on the subject of the question asked. Johnson et al. (2003), list three main types of qualitative interviews:

- *Informal conversational interview*: this uses no interview schedule and is spontaneous.
- *Interview guide approach*: employs an interview schedule, which is essentially a list of open-ended questions, which may be asked in any order by the interviewer. Although this format is more structured than the informal conversational interview, the interviewer may change the wording of the listed questions appropriately if necessary.
- *Standardized open-ended interview*: involves the use of open-ended questions asked in the exact order as it is listed on the interview schedule and does not allow any change to the wording of the questions.

Interviews are particularly useful in obtaining empirical data and also for the purpose of gaining valuable information in social research. This research work entailed conducting interviews with several key informants. The term key-informant may be used for anyone who can provide detailed information, on the basis of his or her expertise or knowledge of a particular issue (Almedom et al., 1997).

Observation / Familiarisation Walks

Observation method as the name implies involves observing research subjects and recording information obtained. Observations can be done in a structured way, using a set of pre-selected things to observe, or in an unstructured manner by noting down everything observed and then classifying the information according to relevant themes (Almedom et al, 1997). The observation process may occur in either laboratory or real world settings. The technique serves well as both a complementary method and as the main method for collecting research data in a social survey and is an important source of observational and behavioural data. For factual (on-ground) data, direct observation may yield the desired information, in which case careful records of the situations observed must be kept. According to Johnson et al (2003), there are two important forms of observation: quantitative observation and qualitative observation.

Quantitative observation involves producing quantitative data using standard procedures, which may involve defining who or what is to be observed; when, where and how the observations should be carried out and using a standard tool to generate the data required as the observation takes place. This type of observation also involves the use of specific sampling procedures such as:

- time-interval sampling (i.e. observing subjects during defined time intervals)
- event sampling (i.e. observing subjects in relation to the occurrence of a defined event, e.g. a patient's physical reaction to a particular drug).

Qualitative observation is both exploratory and open ended. It describes a situation in which the researcher observes the subject and takes notes. Qualitative observation involves role play where the qualitative observer may be a:

- *Complete Participant*: where he assumes the role of a full member of the observed group without informing the subjects.
- *Participant-as-Observer*: where the researcher observes the subject from within the group with the subjects aware of the study and participates in group activities.
- *Observer-as-Participant*: the researcher here observes the subject from within the group with the subjects aware of the study but does not participate in the group's activities.
- *Complete Observer*: here the researcher simply observes the subjects from outside without informing the subject that they are being studied.

The 'complete observer' technique was used in this research work to collect factual/ visual data on the existing situation in the study settlements as a complementary method with informal interviews during the systematic walks around the study settlements.

Questionnaires

A structured questionnaire is a powerful instrument for collecting data especially in a social survey. The reliability of the results of a questionnaire based data collection is often a function of factors such as defined objectives, feasible research plan, good questionnaire design, sampling, correct administration and response of subjects among others. Data collection by questionnaires must be carefully planned in order to avoid bias, decrease errors and enable the survey provide reliable answers to research questions. Recommendations on planning data collection using questionnaires are available in the literature.

Sampling

Sampling simply refers to the process of drawing a subset (sample) from a population with the goal of producing a subset that is representative of the whole population. The sampling method used in any research is as important to the data gathering as it is to the analysis and interpretation of findings. It may well be the backbone of the data collection process in a research.

Sampling technique represents perhaps the most significant distinguishing factor between quantitative and qualitative research. The main difference in the sampling techniques employed in either type of research is that, quantitative research tends to require large sample numbers, which are studied to ascertain statistical significance of findings while qualitative research employ smaller sample sizes for in depth study.

In quantitative surveys, standardized scales are used so that individuals and groups can be described as showing more or less a defined characteristic. The research subjects are rated on a limited set of predetermined dimensions. Statistical analyses of these dimensions emphasize central tendencies - averages and deviations from those averages. By comparison, qualitative investigations pay particular attention to uniqueness, be it of the individual, the household, or any other unit of analysis. For this reason, the scales used are not standardized. Instead, they are adapted to take individual variations into account, while being sensitive to similarities among people and generalizations about them (Almedom et al, 1997).

Sampling in Qualitative Research

Sampling techniques can in general be classified into probability and non-probability methods. Those employed in qualitative research are mainly non-probability techniques, which define samples based on the judgement of the researcher and/or on the needs of the research. According to Fink (1995), non-probability techniques are usually adequate for surveys of "hard-to-identify" groups, or in pilot studies. Non-probability sampling in these cases, are particularly appropriate especially in situations where difficulties in obtaining cooperation (or response ability) among the research subjects are encountered.

Some of the more common non probability sampling methods include:

- *Convenience sampling*: as the name suggests involves using participants who are the most available, willing and conveniently selected as subjects of the study. This method as described by Walonick (1997) is often used in exploratory (qualitative) research where the researcher intends to obtain an inexpensive overview or approximation of the truth. It is particularly useful in preliminary research.
- *Judgment sampling*: is another common non-probability method, which is more or less an extension of the convenience sampling method. The researcher selects the samples based on his or her judgment e.g. a researcher deciding to draw all required the samples from one "representative" city, even though the population includes all cities. This method requires the researcher to be confident that the chosen sample is truly representative of the entire population.

- *Quota sampling*: is the non-probability equivalent of stratified sampling (Walonick, 1997). It entails the initial identification of the different stratums and their proportions in the population being studied. Defining a quota to be filled for each stratum after which convenience or judgment sampling is used to select the required number of subjects from each stratum. This differs from stratified sampling, where the stratums are filled by random sampling.
- *Snowball sampling*: is a special non-probability method used when the desired sample characteristic is rare, (Walonick, 1997). Since it may be extremely difficult or cost prohibitive to locate appropriate participants in these situations, snowball sampling relies on asking initial subjects to indicate other potential participants for the same survey thereby generating additional subjects. This process continues until the required samples size is reached. While this technique can dramatically lower research costs, it comes at the expense of introducing bias because the technique itself reduces the likelihood that the sample will represent a good cross section from the population.

Sampling in qualitative research is usually purposive and below is a list of some specific purposive sampling techniques that are used in qualitative research (Johnson et al, 2003):

- *Maximum variation sampling*: wide range of cases selected e.g. best case, worst-case.
- *Homogeneous sampling*: small homogeneous case or set of cases for intensive study.
- *Extreme case sampling*: selecting cases that represent the extremes on some dimension.
- *Typical-case sampling*: selecting typical or average cases.
- *Critical-case sampling*: selecting cases that are known to be very important.
- *Negative-case sampling*: purposive selection of cases that disconfirm previous generalizations, to ensure the researcher does not just selectively find cases to support a personal theory.
- *Opportunistic sampling*: selecting useful cases as the opportunity arises.
- *Mixed purposeful sampling*: refers to the mixing of more than one sampling strategy.

Although different sampling techniques serve different purposes, combined or mixed sampling strategies may be employed within the same study, these are often not pre-specified at the beginning of the study and can evolve during the study.

APPENDIX B: SCENARIO DESIGN AND COST ESTIMATES

1. Combined Sewerage with Offsite Treatment *(see section 6.2.1.1 for description)*

Components: *simplified sewerage, waste stabilisation ponds, sludge drying beds.*

a) Simplified Sewerage Design using Tactive Tension Method

Input Parameters (wastewater only)

Average Inhabitants per Household	6	based on data obtained from Master Plan
Number of Households	97	
Water Consumption (l/c/d)	120	
Return Factor (%)	85	
Peak Factor	1.8	
Infiltration	0	

Minimum Tractive Tension (N/m², Pa) = 1
G-Manning's n (-) = 0.013
Minimum Sewer Cover (m) = 0.4

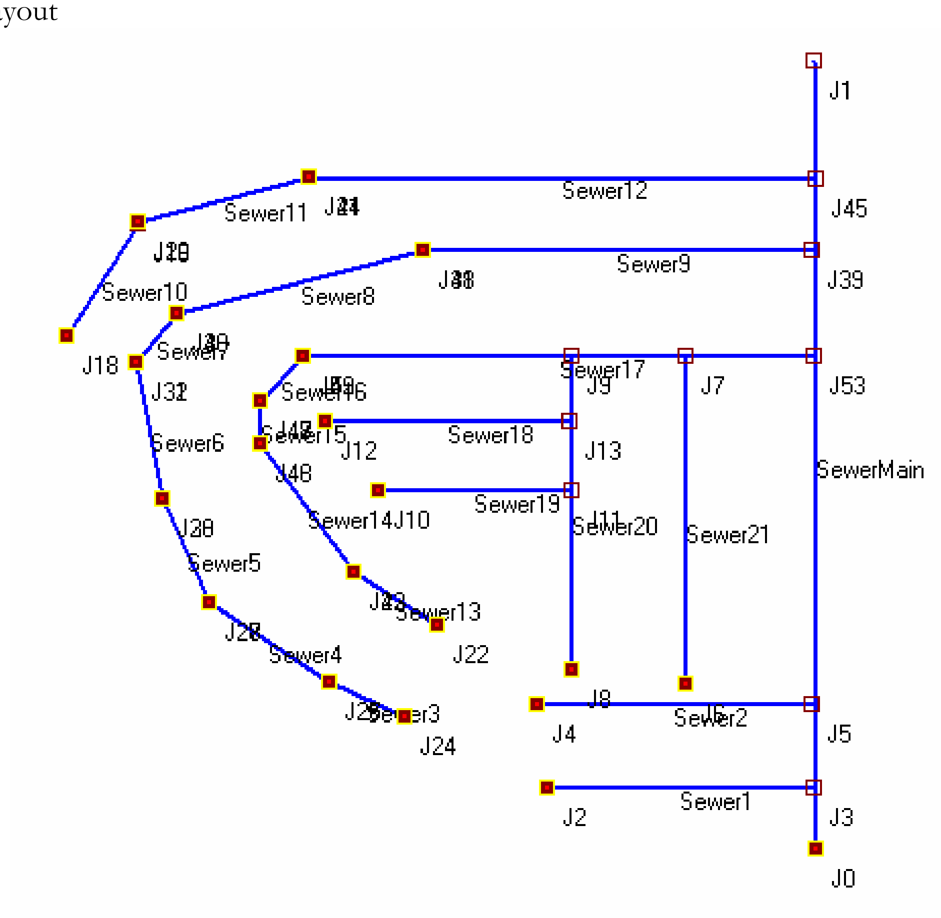
Design Limits
Minimum flow q_i (l/s) = 1.5
Minimum pipe diameter (m) = 0.1
Ground Slope

Results (see results table for details)
Required pipe diameter (m) = 0.1
Sewer depth upstream (m) = 0.5 (average)
Total sewer length (m) = 2991

Appurtenances
Junction boxes = 97 *(one at the point of connection to the sewer)*
Access Chambers = 55 *(placed at intervals of 50 m in the condominial sections and 100 m intervals in the main collector section of the network respectively)*

Map of the design area

Sewer Layout



Simplified sewerage design results table.

Sewer	*Length (m)*	*Total flow (l/s) Initial & final*	*u/s Junct name*	*d/s Junct name*	*Ground level u/s (m)*	*Ground level d/s (m)*	*Ground slope*	*Invert level u/s (m)*	*Invert level d/s (m)*	*Gradient*	*Diam. (m)*	*Chosen Pipe Diam. (m)*	*d/D Initial flow*	*d/D Final flow*	*Velocity of initial flow (m/s)*	*Velocity of final flow (m/s)*	*Depth u/s (m)*	*Depth d/s (m)*
Sewer Main	425	1.5	J0	J1	295.5	290	0.013	295.1	289.6	0.013	0.1	0.1	0.35	0.35	0.612	0.612	0.5	0.482
Sewer1	185	1.5	J2	J3	297.5	295	0.014	297.1	294.6	0.013	0.1	0.1	0.35	0.35	0.612	0.612	0.5	0.497
Sewer2	182	1.5	J4	J5	296.5	294.5	0.011	296.1	294.1	0.011	0.1	0.1	0.36	0.36	0.589	0.589	0.5	0.502
Sewer21	176	1.5	J6	J7	295.2	291.2	0.023	294.8	290.8	0.023	0.1	0.1	0.3	0.3	0.757	0.757	0.5	0.495
Sewer20	170	1.5	J8	J9	296.2	293.2	0.018	295.8	292.8	0.018	0.1	0.1	0.32	0.32	0.692	0.692	0.5	0.492
Sewer19	99	1.5	J10	J11	296.1	294.8	0.013	295.7	294.4	0.013	0.1	0.1	0.35	0.35	0.612	0.612	0.5	0.497
Sewer18	150	1.5	J12	J13	296.2	294	0.015	295.8	293.6	0.015	0.1	0.1	0.34	0.34	0.637	0.637	0.5	0.505
Sewer10	62	1.5	J18	J19	296	294.9	0.018	295.6	294.5	0.018	0.1	0.1	0.32	0.32	0.692	0.692	0.5	0.497
Sewer11	136	1.5	J20	J21	295	292.5	0.018	294.6	292.1	0.018	0.1	0.1	0.32	0.32	0.692	0.692	0.5	0.502
Sewer3	83	1.5	J24	J25	297.5	297.3	0.002	297.1	296.7	0.005	0.1	0.1	0.46	0.46	0.425	0.425	0.5	0.688
Sewer4	97	1.5	J26	J27	297.8	297.6	0.002	297.4	296.0	0.005	0.1	0.1	0.46	0.46	0.425	0.425	0.5	0.754
Sewer5	50	1.5	J28	J29	297.2	296.8	0.008	296.8	296.4	0.008	0.1	0.1	0.4	0.4	0.511	0.511	0.5	0.5
Sewer6	36	1.5	J30	J31	296.8	296	0.022	296.4	295.6	0.022	0.1	0.1	0.3	0.3	0.757	0.757	0.5	0.499
Sewer7	40	1.5	J32	J33	296	291	0.125	295.6	290.6	0.125	0.1	0.1	0.2	0.2	1.341	1.341	0.5	0.5
Sewer9	222	1.5	J38	J39	293.8	291	0.013	293.4	290.6	0.013	0.1	0.1	0.35	0.35	0.612	0.612	0.5	0.497
Sewer8	117	1.5	J40	J41	296.3	293.8	0.021	295.9	293.4	0.021	0.1	0.1	0.31	0.31	0.723	0.723	0.5	0.504
Sewer12	216	1.5	J44	J45	292.5	290	0.012	292.1	289.6	0.012	0.1	0.1	0.36	0.36	0.589	0.589	0.5	0.506
Sewer13	77	1.5	J22	J23	296.9	296.5	0.005	296.5	296.1	0.005	0.1	0.1	0.45	0.45	0.438	0.438	0.5	0.5
Sewer14	80	1.5	J42	J43	297	296.6	0.005	296.6	296.2	0.005	0.1	0.1	0.45	0.45	0.438	0.438	0.5	0.5
Sewer15	35	1.5	J46	J47	296.8	296.2	0.017	296.4	295.8	0.017	0.1	0.1	0.33	0.33	0.664	0.664	0.5	0.498
Sewer16	29	1.5	J48	J49	296.2	295.8	0.014	295.8	295.4	0.014	0.1	0.1	0.34	0.34	0.637	0.637	0.5	0.5
Sewer17	324	1.5	J52	J53	295.8	290	0.018	295.4	289.6	0.018	0.1	0.1	0.32	0.32	0.692	0.692	0.5	0.5

b) Design of Pond System

Input Parameters

Average Inhabitants per Household	6	based on data obtained from Master Plan
Number of Households	97	
Water Consumption (l/c/d)	120	
Return Factor (%)	85	
Wastewater flow q (m^3/d)	59.36	Taken as 70 m^3 for safety
Temperature	> 25°C	
BOD Contribution B (g/c/d)	40	Based on Mara (2003)
	Influent	**Effluent**
BOD Li (mg/l)	333.3 (calc)	30 (FMEnv Limits, Nigeria)
Suspended Solids (mg/l)		20

Results

Pond	Residence Time (days)	Pond Area (m^2)
Anaerobic	0.95 (taken as 1)	31.04
Facultative	3.43	158.57
Maturation	3	140
Total	**7.43**	**329.61**

c) Pond Process Design

Anaerobic Pond

Parameters

Influent BOD L_i (mg/l)	333.3	
Volumetric Load λ_v (g/m^3)	350	value at >25°C, (Mara, 2003) Table 4.1
Flow Q (m^3d^{-1})	70	
Pond Depth D (m)	3	
Sludge Accumulation Rate (m^3/yr)	0.04	Mara (1997)
BOD Removal (%)	70	(Mara, 2003) Table 4.1

Design Estimates

	Formula	Result
Residence Time θ_a (days)	Li/λ_v	0.95 *(subject to min. value = 1, Mara, 2003)*
Pond Volume V_a (m^3)	Q/θ_a	70
Pond Area A_a (m^2)	V_a/D	23.28
BOD Removal (mg/l)	Influent BOD * Removal Factor	99.99
Sludge Volume V_s (m^3)	Rate * Population	23.28
Total Pond Volume V_t (m^3)	$V_a + V_s$	93.12
Total Area (m^2)	$A_a = V_t/D$	31.04

Facultative Pond

Parameters

Influent BOD L_i (mg/l)	99.99	
Volumetric Load λ_s (kg/ha d)	440	(value allowed >30°C ref: Table 4.4, Mara, 2003)
Flow Q (m^3d^{-1})	70	
Pond Depth D (m)	1.5	
Sludge Accumulation Rate (m^3/yr)	0.04	(Mara, 1997)
BOD Removal (%)	90	cumulative for Anaerobic and Facultative ponds (Mara, 2003)
Evaporation e (mm/day)	5	assumed value

Design Estimates

	Formula	Result
Residence Time θ_f (days)	$(2*A_f*D)/(2Qi - 0.001 * A_f * e)$	3.43
Pond Area Af (m^2)	$(10*L_i*Q)/\lambda_s$	158.57
BOD Removal (mg/l)	Influent BOD * Removal Factor	33.33
Area Required without Anaerobic Pond (m^2)	$A_f=(10*L_i*Q)/\lambda_s$	952.36
Area Required with Anaerobic Pond (m^2)	$A_a + A_f$	189.61
Land Saving with Anaerobic Pond (%)		20

Maturation Pond (for Restricted Irrigation or Surface Discharge)

Parameters

Influent BOD Li (mg/l)	33.3	
Influent intestinal nematode eggs (egg/l)	400	*(assumed value, community mixed, high hygiene awareness, field study results)*
Flow Q (m^3d^{-1})	70	
Pond Depth D (m)	1.5	
Sludge Accumulation Rate (m^3/yr)	0.04	*(Mara, 1997)*
BOD Removal (%)	90	*cumulative for anaerobic and facultative ponds (Mara, 2003)*
Evaporation e (mm/day)	5	*assumed value*

Design Estimates

		% Egg Removal	Eggs in Effluent	
Anaerobic Pond Residence Time θ_a (days)	1	74.67	101	ref Mara - Table 4.7
Facultative Pond Residence Time θ_f (days)	3.43	91.45	9	

Maturation Pond is required to achieve desired nematode egg levels (<1egg/l).

	Formula	Result
Required Removal (%)	100[(eggs in fac pond effluent - 1)/(eggs in fac pond effluent)	88
Residence Time θ_m (days)	from Design values for egg removal table (Mara, 1997)	3
Maturation Pond Area A_m (m^2)	$2Qi*\theta_m/2D+0.0001*e*\theta_m$	140
Eggs in Maturation Pond effluent (eggs/l)	$E_e = E_i$ (1-0.9) *3 day residence time gives 90% egg removal (Mara, 2003)*	0.9
BOD Removal (mg/l)	Influent BOD * Removal Factor	25

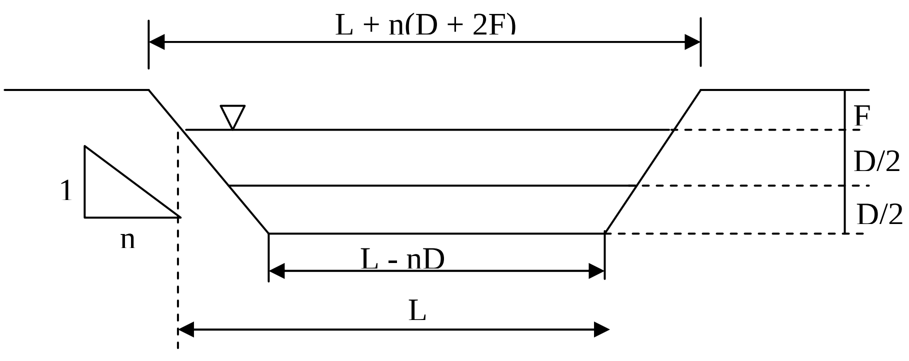
One maturation pond with an area of 140 m² and a residence time of 3 days is required to achieve a nematode egg concentration of 0.9 eggs/l and a BOD of 25 mg/l.

d) Physical Design of Pond System

Input Parameters

Pond	Pond Area (m^2)	Depth (m)	L:W	L	W
Anaerobic	31.04	3	2:1	7.9	3.9
Facultative	158.57	1.5	3:1	21.8	7.3
Maturation	140	1.5	6:1	28.9	4.8

The above are mid depth values and dimensions; for pond construction, dimensions should be corrected for embankment slope as given in the figure below.



Where

F = Freeboard (m) = 0.5 for small ponds < 1 ha (Mara, 1997, 2003)

L = calculated pond length (m)

D = pond depth (m)

Dimension	Anaerobic	Facultative	Maturation
L (m)	7.9	21.8	28.9
F (m)	0.5	0.5	0.5
D/2 (m)	1.5	0.75	0.75
n	1	1.5	1.5
L + n(D + 2F) (m) – *(top of pond)*	**11.9**	**26.8**	**33.9**
L – nD (m) – *(bottom of pond)*	**4.9**	**18.8**	**25.9**
Pond Liner (m²)	**850**		

e) Drying Bed Design

Parameters

Contributing Population (PE)	**582**
Sludge accumulation rate R (m³/yr)	**0.04**
Depths (m): Sludge D_{SL}, Sand D_S, Gravel D_G, Air D_A	**0.2** *assumed value*
L:W	**2:1**

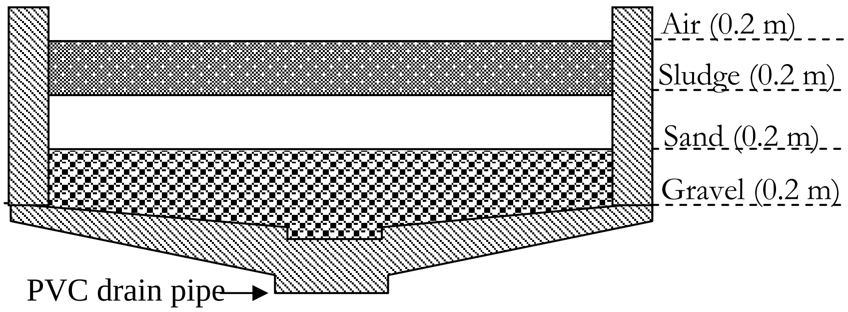


Figure shows cross section of the drying bed (adapted from Leal, 2004)

Results

Volume (V) of sludge to be treated per month (m³)	(R x PE)/12	**2** *(2.5 for safety)*
Area of drying bed (m²)	V/D_{SL}	**12.5**
Bed Length (m)	$(A/2)^{1/2}$	**5**
Bed Width	A= L x W	**2.5**

f) Cost Estimates

Investment Costs for total design area				160 NGN = 1 €
Item	**Quantity**	**Unit**	**Unit price NGN**	**Investment NGN**
Wastewater collection (Simplified Sewerage)				
Excavation of Trenches (av. depth 0.5 m)	1093	m^3	250	273,250
Pipes 100mm	3500	m	250	875,000
Junction Boxes	97	No.	1890	183,330
Inspection chambers	55	No.	6000	330,000
Labour (Pipes and Backfilling)				340,000
				2,001,580
Treatment (Pond System: Ana, Fac, Mat)				
Excavation + Earthwork	320	m^3	820	262,400
Pond Liner	850	m^2	1050	892,500
Concrete work	10	m^3	10000	100,000
Interconnecting pipes	100	m	280	28,000
Inlet Box	3	No.	10870	32,610
Other Fittings	3	No.	5000	15,000
Gravel	10	m^3	4500	45,000
Labour				225,000
				1,600,510
Sludge Treatment (Drying beds)				
Excavation + Earthwork	10	m^3	820	8,200
Concrete	5	m^3	10000	50,000
Sand	8	m^3	2500	20,000
Coarse Gravel	8	m^3	4500	36,000
Labour				44,000
				158,200
Subtotal				**3,760,290**
Allowances for additional work (10%)				376,029
Overheads (15%)				564,044
TOTAL Investment				**4,700,362**
Operation and Maintenance				NGN
O&M (10% of Investment Cost)				470,036
TOTAL O&M cost				**470,036**

Construction costs are from local construction contractors, although some assumptions were also made.

2. Wet Sanitation with Separation of Solids *(see section 6.2.1.2 for description)*

Components: *settled sewerage, interceptor tanks, communal wetlands, solids transport, composting.*

a) Settled Sewerage Design

Input Parameters (no solids)

Average Inhabitants per Household	6	based on data obtained from Master Plan
Number of Households	97	
Water Consumption (l/c/d)	120	
Return Factor (%)	85	
Infiltration	0	

Results

Results from the simplified sewerage design are adapted for the settled sewerage as the design is for the same settlement as such no design is made for the settled sewerage.

Required pipe diameter (m) = 75 – 100 mm
Sewer length (m) = 2991 *(based on length for the simplified sewer)*
Sewer depth upstream (m) = 0.5 *(average)*

Appurtenances

Interceptor Tanks = 97 *(one at the point of connection to the sewer)*
Access Chambers = 53 *(placed at all upstream end, major intersections, at intervals of 150 m in the flat sections of the network)*

Map of the design area is as for the Simplified Sewer

b) Communal Wetland Design for Grey water and Interceptor Tank Effluent

Design Parameters

Wastewater			**Media**	
Influent BOD (mg/l)	300		Type	fine gravel
COD (mg/l)	600		Size (mm)	12.5 - 25
TSS (mg/l)	200		Depth (m)	0.6
Temperature (°C)	25		K_s ($m^3/m^2/d$)	1500
Water consumption (l/c/d)	100		Porosity n	0.38
Population size	582		Water depth (m)	0.5
k_{20} (d^{-1})	1.104		Effluent BOD (mg/l)	20
k_{20} (d^{-1}) (take 75% of value for safety USEPA 1993)	0.828		Plant type	Mixed
FMEnv. Effluent Standards			**Size of the tanks**	
BOD (mg/l)	25		Before Inlet (m^3)	1
TSS (mg/l)	30		Outlet (m^3)	0.5
FC	99%			

FMEnv = Federal Ministry of Environment; influent BOD estimated from 40g BOD per capita contribution (Mara, 2003).

Wetland Results

		Single Unit	Multiple Units
Design Flow Q (m^3/d)	Q = (Water Consumption * PE)/ 1000	**58.2**	**58.2**
Rate Constant k_T (d^{-1})	$k_T = k_{20} * (1.06)^{T-20}$	**0.828**	**0.828**
Retention Time t (days)	$t = \ln [C_e/C_o]/k_T$	**3.27**	**3.27**
Surface Area As (m^2)	$As = Q[\ln(C_o/C_e)]/ k_T*d*n$	**1033**	**206.6**
Wetland Dimensions (L:W = 2:1)	Bed Width= $\{A/2\}^{1/2}$	**22.72**	**10.2**
	Bed Length = A/W	**45.45**	**20.3**
TSS Removal	Estimate HLR = Q/A_s (cm/d)	**5.81**	**29.05**
	$C_e=C_o*(0.1058+0.0011*(HLR))$	**22.44**	**27.55**

For the design Q is assumed to be 60 m³ (to include a safety factor). A temperature of 25°C has been used although the actual temperature in the design area is higher, this will give added operational safety.

c) Cost Estimates

Investment Costs for total design area			**160 NGN = 1 €**	
Item	**Quantity**	**Unit**	**Unit price NGN**	**Investment NGN**
Wastewater collection				
Excavation of Trenches (av. depth 0.5 m)	1093	m³	250	273,250
Pipes 75 mm	3500	m	200	700,000
Junction Boxes	97	No.	1890	183,330
Inspection chambers	53	No.	6000	318,000
Labour				340,000
				1,814,580
Treatment (Communal Wetlands)				
Excavation + Earthwork	630	m³	812	516,600
Pond Liner	1650	m²	1050	1,732,500
Interconnecting pipes	250	m	280	70,000
Inlet/ Outlet Boxes	10	No.	10870	108,700
Other Fittings	5	No.	5000	25,000
Coarse Gravel	50	m³	4500	225,000
Fine Gravel	515	m³	3500	1,802,500
Plants	1033	m²	500	516,500
Labour				200,000
				5,196,800
Interceptor Tanks				
Excavation + Earthwork	1.5	m³	820	1,230
Concrete work	1	m³	10000	10,000
Piping	5	m	280	1,400
Labour	LS		12000	12,000
				2,389,110
Subtotal				**9,400,490**
Allowances for additional work (10%)				940,049
Overheads (15%)				1,410,073
TOTAL investment				**11,750,612**
Operation and Maintenance				NGN
TOTAL O&M cost				1,175,061

Construction costs are from local construction contractors; some assumptions were also made.

d) Interceptor Tank for 1 Household (6 PE)

Parameters

Design Population P (PE)	6
Water Consumption (l)	120
Return Factor (%)	85%
Wastewater Volume (l)	102
Desludging Time n (years)	2

Results

Sedimentation Time t_h (days)	$t_h = 1.5 - 0.3 \log (P*q)$	**0.66**
Sedimentation Volume V_h (m³)	$V_h = (P * q * t_h)/1000$	**0.41**
Sludge Digestion Time t_d (days)	$t_d = 30 * (1.035)^{35-T}$	**35.63**
Sludge Digestion Volume V_d (m³)	$V_d = 0.5 * 10^{-3} * P * t_d$	**0.11**
Digested Sludge Storage V_{SL} (m³)	$V_{SL} = r * P * n$	**0.72**
Scum Storage Volume V_{SC} (m³)	$V_{SC} = 0.4 * V_{SL}$	**0.29**
Overall Tank Volume V_{TOT} (m³)	$V_{TOT} = V_h + V_d + V_{SL}$	**1.23**

Calculated Volume = 1.23 m³ (but assumed to be 1.5 m³ to include safety factor)

Description	**Quantity**	**Unit**	**Unit Price**	**Amount**
Excavation and Earthwork	1.5	m³	850	1275
Concrete	1	m³	10000	10000
100m PVC pipe for water movement	5	m	280	1400
Labour			12000	12000
Total Investment Costs				**24675**
O&M (desludging every 2yrs)			10000	10000
Grand Total				**34675**

Construction costs are from local construction contractors; some assumptions were also made.

Costs not included in the Estimates:
Interceptor: the cost for the interceptor tank should be borne by the home owner as some homeowners already use septic tanks in the area.

Composting Plant: there is an existing composting facility in the area as such this cost is not included in the estimate; the facility is located at a maximum distance of about 25 km (AEPB official, personal communication). Tanker trucks are also available from the AEPB; these trucks are currently employed in emptying septic tanks at an average cost of about 10000 NGN.

3. **Separation at Source with Onsite or Offsite Treatment** *(see section 6.2.1.3 for description)*

Components: *onsite wetland, yellow water collection system, solids collection and communal composting.*

a) **Design of Onsite Wetland for Grey water and Rottebehaelter Effluent**

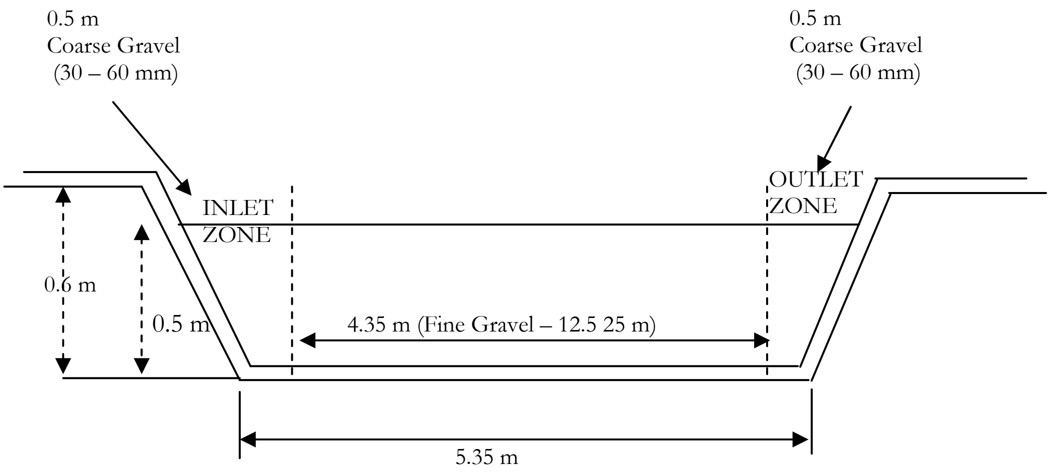
Parameters

Wastewater		**Media**	
Influent BOD (mg/l)	333	Type	fine gravel
COD (mg/l)	600	Size (mm)	12.5 - 25
TSS (mg/l)	200	Depth (m)	0.6
Temperature °C	25	K_s ($m^3/m^2/d$)	1500
Water consumption (l/c/d)	100	Porosity n	0.38
Population size	6	Water depth (m)	0.5
k_{20} (d^{-1})	1.104	Effluent BOD (mg/l)	20
k_{20} (d^{-1}) (75% of value taken for safety USEPA, 1993)	0.828	Plant type	Mixed/ Ornamental
FMEnv Effluent Standards		**Size of the tanks**	
BOD (mg/l)	25	Before Inlet (m^3)	1
TSS (mg/l)	30	Outlet (m^3)	0.5
FC	99%		

Results

Design Flow Q (m^3/d)	Q = (Water Consumption * PE) / 1000	**0.6**
Rate Constant k_T (d^{-1})	$k_T = k_{20} * (1.06)^{T-20}$	**0.828**
Retention Time t (days)	$t = \ln [C_e/C_o]/k_T$	**3.40**
Surface Area As (m^2)	$As = Q[\ln(C_o/C_e)]/ k_T*d*n$	**14.3**
Wetland Dimensions (m)	Bed Width= $\{A/2\}^{1/2}$	**2.67**
(L:W = 2:1)	Bed Length = A/W	**5.35**
	Estimate HLR = Q/A_s (cm/d)	**5.60**
TSS Removal	$C_e=C_o*(0.1058+0.0011*(HLR))$	**22.39**

For safety Q is assumed to be 0.8 m^3



b) Settling Tank Design

Parameters

Wastewater flow Q (m^3/d)	0.8
Retention time t (h)	12
Desludging time td (yrs)	1

Results

- Settling Tank Size: Q*(t/24) = 0.4 m^3 *(value taken as* ***0.5 m^3*** *to include safety factor)*
- Tank Dimensions
    - Volume = 0.5 m^3
    - Assumed
        - Depth (D) = 1 m
        - width (W) = 0.5 m
    - Estimated Length: V/D*W = 1 m

c) Rottebehaelter Design and Composting of retained Solids
Parameters

Contributing Population P (PE)	6
Dimensions of filter sacks	
Length (m)	0.5
Width (m)	0.5
Depth (m)	0.9
Volume (m^3)	0.225
Dimensions of Rottebehaelter	
Length (m)	1.20
Width (m)	0.70
Depth (m)	1.10
Volume (m^3)	0.92

The estimates are based on the specifications from Lambertsmuehle project (Leal, 2004). The Rottebehaelter contains the two filter sacks of the volume and dimensions specified above. A space of 5 cm is allowed around each side of the filter sack, and a distance of 10 cm from the sack to the bottom of the container.

Composting Plant: a composting facility located at a maximum distance of about 25 km (AEPB official, personal communication) is available in the area as such estimates for this are not included. Communal composting or vermicomposting will be done at a charge to the user. Costs for transporting the solids to the composting facility is estimated at 50000 NGN per year based on solid waste services tariffs from the AEPB (see appendix D).

d) Yellow Water System
Design assumptions/considerations include:
Capture rate: contribution from children is lower than that of adults and not all the time is spent at home.

Treatment time: Ecosanres recommends storage times between 1 and 6 months at 4-20°C. When single households use their own yellow water as a fertilizer, there is no need for storage prior to application (Ecosanres' "Guidelines on the Use of Urine and Faeces in Crop Production and Guidelines for the Safe Use of Urine and Faeces in Ecological Sanitation Systems" recommendations based on Schonning and Stenstrom, 2004). However this design allows a treatment period of six months for communal collection and sanitisation with the treated stream used locally at nearby farm settlements; or one month for use at household level.

Parameters

Design Population (PE)	6
Design Volume (l/c/d)	1.5
Assumed capture rate (%)	65%
Collection time (days)	30

Results: household collection

Daily Volume per household (l)	5.9
Volume per month (l)	176
Storage Time (months)	1
Capcity of available vessels (l)	30
Number required per household	6

1 m³ PE tanks could be installed in the household in place of the canisters and emptied once a month by the collection agency; the collected urine is then stored at the communal facility for sanitisation. Due to management and energy costs, it is recommended that the urine is collected and utilised at household level.

e) Cost Estimate for Scenario 3 with Onsite Management

Investment Costs per household			**160 NGN = 1 €**	
Item	**Quantity**	**Unit**	**Unit price NGN**	**Investment NGN**
Treatment (Onsite Wetlands)				
Excavation + Earthwork	9	m³	957	8,613
Pond Liner	80	m²	1050	84,000
Gravel (fine)	6	m³	3500	21,000
Gravel (coarse)	1	m³	4500	4,500
Plants	15	m²	500	7,500
Other Materials / Items for Complete unit	1	No.	5000	5,000
Labour (Skilled)	6	Days	1500	9,000
Labour (Skilled + Unskilled)	6	Days	800	4,800
				144,413
Rottebehalter				
PE Tank (1m³)	1	No	16000	16,000
Filter Sacks	2	No	2500	4,000
Labour (Skilled)	2.5	Days	2000	6,250
Labour (Skilled + Unskilled)	4	Days	800	3,200
				29,450
Settling Tank				
Materials for Settling Tank	1	m³	16000	16,000
Labour (Skilled)	1	Days	1500	3,750
Labour (Skilled + Unskilled)	4	Days	800	3,200
				22,950
Subtotal				**196,813**
Allowances for additional work (10%)				19,681
Overheads (15%)				29,522
TOTAL Investment				**246,016**
O&M (10% of Investment Cost)				24,601
TOTAL O&M cost				**24,601**

Construction costs are from local construction contractors; some assumptions were also made.

f) Cost Estimate for Scenario 3 with Centralised Management

Investment Costs per household			160 NGN = 1 €	
Item	Quantity	Unit	Unit price NGN	Investment NGN
Treatment (Onsite Wetlands)				
Excavation + Earthwork	9	m^3	957	8,613
Pond Liner	80	m^2	1050	84,000
Gravel (fine)	6	m^3	3500	21,000
Gravel (coarse)	1	m^3	4500	4,500
Plants	15	m^2	500	7,500
Other Materials / Items for Complete unit	1	No.	5000	5,000
Labour (Skilled)	6	Days	1500	9,000
Labour (Skilled + Unskilled)	6	Days	800	4,800
				144,413
Rottebehalter				
PE Tank ($1m^3$)	1	No	16000	16,000
Filter Sacks	2	No	2500	4,000
Labour (Skilled)	2.5	Days	2000	6,250
Labour (Skilled + Unskilled)	4	Days	800	3,200
				29,450
Settling Tank				
Materials for Settling Tank	1	m^3	16000	16,000
Labour (Skilled)	1	Days	1500	3,750
Labour (Skilled + Unskilled)	4	Days	800	3,200
				22,950
Urine Storage Tanks				
4 m^3 Tanks @ 45000 NGN	1	LS	11134.0206	11,134
				11,134
Subtotal				**207,947**
Allowances for additional work (10%)				20,795
Overheads (15%)				31,192
TOTAL Investment				**259,933**
Operation and Maintenance				**NGN**
O&M (10% of Investment Cost)				25,993
Composting Facility (Solids – Transport + Composting Service)	1	/hh*year	50000	50,000
TOTAL O&M cost				**75,993**

Construction costs are from local construction contractors; some assumptions were also made.

4. Dry System with Urine Diversion *(see section 6.2.2.1 for description)*

Components: *double vault toilet, settling tank, onsite wetland for grey water, yellow water collection.*

a) Double Vault Toilet Design

Parameters

Contributing Population P (PE) = 6
Sludge Accumulation Rate R (l/c/d) = 100
Effective Vault Volume (%) = 75

Results

Vault Volume (m^3):

(4/3) * R * P = 0.8

4/3 = *factor for effective volume; value taken as 0.9 m³ for safety*

Vault Dimensions: Depth (m) = 0.8; Length (m) = 0.8; Width (m) = 1.4

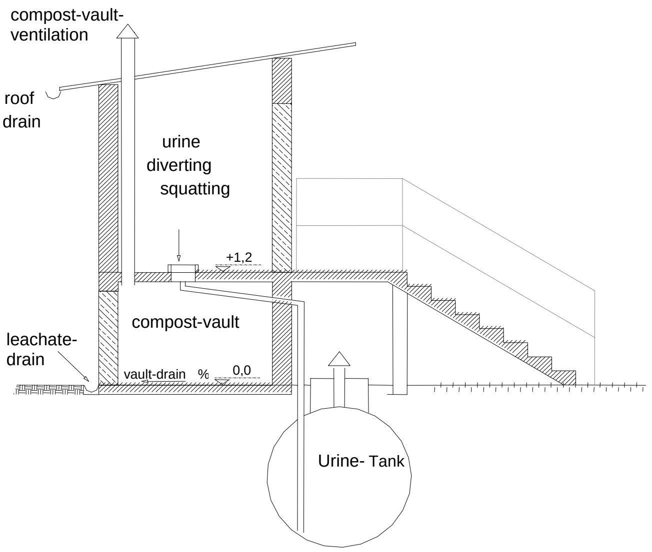


Figure shows section of the double vault toilet (source: Deegener, 2004)

Materials list and costing template are adapted from the EcoSan Toilet unit from Gramalaya Toilets For All (www.toiletsforall.org) ; costs are as provided by local construction contractors.

b) Design of Onsite Wetland for Grey Water

Parameters

Wastewater		**Media**	
Influent BOD (mg/l)	150	Type	fine gravel
COD (mg/l)	300	Size (mm)	12.5 - 25
TSS (mg/l)	200	Depth (m)	0.6
Temperature °C	25	K_s ($m^3/m^2/d$)	1500
Water consumption (l/c/d)	100	Porosity n	0.38
Population size	6	Water depth (m)	0.5
k_{20} (d^{-1})	1.104	Effluent BOD (mg/l)	20
k_{20} (d^{-1}) (take 75% of value for safety USEPA 1993)	0.828	Plant type	Mixed
FMEnv Effluent Standards		**Size of the tanks**	
BOD (mg/l)	25	Before Inlet (m^3)	1
TSS (mg/l)	30	Outlet (m^3)	0.5
FC	99%		

Results

Design Flow Q (m^3/d)	Q = (Water Consumption * PE) / 1000	**0.6**
Rate Constant k_T (d^{-1})	$k_T = k_{20} * (1.06)^{T-20}$	**1.108**
Retention Time t (days)	$t = \ln [C_e/C_o]/k_T$	**2.43**
Surface Area A_s (m^2)	$A_s = Q[\ln(C_o/C_e)]/ k_T*d*n$	**10.25**
Wetland Dimensions (L:W = 2:1)	Bed Width= $\{A/2\}^{1/2}$	**2.26**
	Bed Length = A/W	**4.53**
TSS Removal	Estimate HLR = Q/A_s (cm/d)	**7.81**
	$C_e=C_o*(0.1058+0.0011*(HLR))$	**22.9**

For safety Q is assumed to be 0.8 m^3/d

c) Settling Tank Design

Parameters

Wastewater flow Q (m^3/d)	0.8
Retention time t (h)	12
Desludging time td (yrs)	1

Result

- Settling Tank Size: Q*(t/24) = 0.4 m^3 *(value taken as **0.5 m^3** to include safety factor)*
- Tank Dimensions
  - Volume = 0.5 m^3
  - Assumed
    - Depth (D) = 1 m
    - width (W) = 0.5 m
  - Estimated Length: V/D*W = 1 m

d) Yellow Water System

Parameters

Design Population (PE)	6
Design Volume (l/c/d)	1.5
Assumed capture rate (%)	65%
Collection time (days)	30

Results

Daily Volume per household (l)	5.9
Volume per month (l)	176
Storage Time (months)	1
Capcity of available vessels (l)	30
Number required	5.9

Design assumptions/considerations include:
Capture Rate: contribution from children is lower than that of adults and not all the time is spent at home.

Treatment time: Ecosanres recommends storage times between 1 and 6 months at 4-20°C. When single households use their own yellow water as a fertilizer, there is no need for storage prior to application (Ecosanres' "Guidelines on the Use of Urine and Faeces in Crop Production and Guidelines for the Safe Use of Urine and Faeces in Ecological Sanitation Systems" recommendations based on Schonning and Stenstrom, 2004). However this design allows a treatment period of one month and assumes the treated stream will be used by the generating household.

e) **Cost Estimate (per household)**

Investment Costs			**160 NGN = 1 €**	
Item	**Quantity**	**Unit**	**Unit price NGN**	**Investment NGN**
Double Vault Toilet				
Materials for Complete unit (Vault, Urinal, Superstructure)	1	No.	63200	63,200
Labour (Skilled)	5	Days	1500	7,500
Labour (Skilled + Unskilled)	6	Days	800	4,800
				75,500
Treatment (Onsite Wetlands)				
Excavation + Earthwork	6.5	m^3	957	6,220
Pond Liner	30	m^2	1050	31,500
Gravel (fine)	6	m^3	3500	21,000
Gravel (coarse)	1.5	m^3	4500	6,750
Plants	10	m^2	500	5,000
Other Materials / Items for Complete unit	1	No.	9400	9,400
Labour (Skilled)	6	Days	1500	9,000
Labour (Skilled + Unskilled)	6	Days	800	4,800
				93,675
Settling Tank				
Materials for Settling Tank (1x Inlet ($1m^3$); 1x Outlet ($0.5m^3$)	1.5	m^3	16000	24,000
Labour (Skilled)	2.5	Days	1500	3,750
Labour (Skilled + Unskilled)	4	Days	800	3,200
				30,950
Urine Collection				
PE Cans (30l)	6	No.	200	1,200
				1,200
Subtotal				**201,325**
Allowances for additional work 10%				20,132
Overheads & Admin 15%				30,198
TOTAL investment				**251,656**
Operation and Maintenance				**NGN**
O&M (10% of Investment Cost)				25,165
TOTAL O&M cost				**25,165**

All construction costs are as given by local construction contractors

5. Wet Sanitation with Separation of Solids *(see section 6.2.2.2 for description)*

Components: *Rottebehaelter, onsite wetlands, solids transport, composting.*

a) Design of Onsite Wetland for Rottebehaelter Effluent

Parameters

Wastewater		**Media**	
Influent BOD (mg/l)	333	Type	fine gravel
COD (mg/l)	600	Size (mm)	12.5 - 25
TSS (mg/l)	200	Depth (m)	0.6
Temperature °C	25	K_s ($m^3/m^2/d$)	1500
Water consumption (l/c/d)	100	Porosity n	0.38
Population size	6	Water depth (m)	0.5
k_{20} (d^{-1})	1.104	Effluent BOD (mg/l)	20
k_{20} (d^{-1}) (take 75% of value for safety USEPA 1993)	0.828	Plant type	Mixed/ Ornamental
FMEnv Effluent Standards		**Size of the tanks**	
BOD (mg/l)	25	Before Inlet (m^3)	1
TSS (mg/l)	30	Outlet (m^3)	0.5
FC	99%		

Results

Design Flow Q (m^3/d)	Q = (Water Consumption * PE) / 1000	**0.6**
Rate Constant k_T (d^{-1})	$k_T = k_{20} * (1.06)^{T-20}$	**0.828**
Retention Time t (days)	$t = \ln [C_e/C_o]/k_T$	**3.40**
Surface Area As (m^2)	$As = Q[\ln(C_o/C_e)]/ k_T*d*n$	**14.3**
Wetland Dimensions (m) (L:W = 2:1)	Bed Width= $\{A/2\}^{1/2}$	**2.67**
	Bed Length = A/W	**5.35**
TSS Removal	Estimate HLR = Q/A_s (cm/d)	**5.60**
	$C_e=C_o*(0.1058+0.0011*(HLR))$	**22.39**

For safety Q is assumed to be 0.8 m^3

b) Rottebehaelter Design and Composting of retained Solids

Parameters

Contributing Population P (PE)	6
Dimensions of filter sacks	
Length (m)	0.5
Width (m)	0.5
Depth (m)	0.9
Volume (m^3)	0.225
Dimensions of Rottebehaelter	
Length (m)	1.20
Width (m)	0.70
Depth (m)	1.10
Volume (m^3)	0.92

The estimates are based on the specifications from Lambertsmuehle project (Leal, 2004). The Rottebehaelter contains the two filter sacks of the volume and dimensions specified above. A space of 5 cm is allowed around each side of the filter sack, and a distance of 10 cm from the sack to the bottom of the container.

Composting Plant: there is an existing composting facility in the area as such estimates for this are not included; the facility is located at a maximum distance of about 25 km (AEPB official, personal communication). Communal composting or vermicomposting may be done at a charge to the user otherwise the user may carry out composting onsite and also reuse the compost.

c) Cost Estimate (per household)

Investment Costs			**160 NGN = 1 €**	
Item	**Quantity**	**Unit**	**Unit price NGN**	**Investment NGN**
Treatment (Onsite Wetlands)				
Excavation + Earthwork	9	m^3	957	8,613
Pond Liner	80	m^2	1050	84,000
Gravel (fine)	6	m^3	3500	21,000
Gravel (coarse)	1	m^3	4500	4,500
Plants	15	m^2	500	7,500
Other Materials / Items for Complete unit	1	No.	5000	5,000
Labour (Skilled)	6	Days	1500	9,000
Labour (Skilled + Unskilled)	6	Days	800	4,800
				144,413
Rottebehalter				
PE Tank ($1m^3$)	1	No	16000	16,000
Filter Sacks	2	No	2500	4,000
Labour (Skilled)	2.5	Days	2000	6,250
Labour (Skilled + Unskilled)	4	Days	800	3,200
				29,450
Subtotal				**173,863**
Allowances for additional work (10%)				17,386
Overheads (15%)				26,080
TOTAL Investment				**217,329**
Operation and Maintenance				**NGN**
O&M (10% of Investment Cost) Self Service				21,733
TOTAL O&M cost				**21,733**
O&M (10% of Investment Cost) Agency Service	1	LS		50,000
TOTAL O&M cost				**71,733**

All construction costs are as given by local construction contractors

APPENDIX C: NET PRESENT VALUES

Scenario 1: *Combined Sewerage with Offsite Treatment (see section 6.2.1.1 for description)*

		Discount Rate		10%		
Yr.	**Investment Cost**	**NPV Factor**	**NPV OF INVESTMENT**	**O & M**	**NPV Factor**	**NPV OF O&M**
0	4700363	1	47003623	0	0	0
1	0	0.9091	0	1744616	0.0909	158,602
2	0	0.8264	0	1744616	0.1736	302,785
3	0	0.7513	0	1744616	0.2487	433,860
4	0	0.6830	0	1744616	0.3170	553,020
5	0	0.6209	0	1744616	0.3791	661,347
6	0	0.5645	0	1744616	0.4355	759,826
7	0	0.5132	0	1744616	0.4868	849,352
8	0	0.4665	0	1744616	0.5335	930,740
9	0	0.4241	0	1744616	0.5759	1,004,729
10	0	0.3855	0	1744616	0.6145	1,071,991
11	174020	0.3505	60993	1744616	0.6495	1,133,139
12	0	0.3186	0	1744616	0.6814	1,188,728
13	0	0.2897	0	1744616	0.7103	1,239,263
14	0	0.2633	0	1744616	0.7367	1,285,204
15	0	0.2394	0	1744616	0.7606	1,326,969
16	1600510	0.2176	348318	1744616	0.7824	1,364,937
17	0	0.1978	0	1744616	0.8022	1,399,453
18	0	0.1799	0	1744616	0.8201	1,430,832
19	0	0.1635	0	1744616	0.8365	1,459,358
20	0	0.1486	0	1744616	0.8514	1,485,290
21	174020	0.1351	23515	1744616	0.8649	1,508,865
22	0	0.1228	0	1744616	0.8772	1,530,297
23	0	0.1117	0	1744616	0.8883	1,549,781
24	0	0.1015	0	1744616	0.8985	1,567,493
25	0	0.0923	0	1744616	0.9077	1,583,595
26	0	0.0839	0	1744616	0.9161	1,598,233
27	0	0.0763	0	1744616	0.9237	1,611,541
28	0	0.0693	0	1744616	0.9307	1,623,639
29	0	0.0630	0	1744616	0.9370	1,634,637
30	0	0.0573	0	0	0.9427	0
NPV			5133189			34,247,505
				TOTAL NPV		**39,380,693**

Scenario 2: **Wet Sanitation with Separation of Solids** *(see section 6.2.1.2 for description)*

Discount Rate 10%						
Yr.	**Investment Cost**	**NPV Factor**	**NPV OF INVESTMENT**	**O & M**	**NPV Factor**	**NPV OF O&M**
0	11750613	1	11750613	0	0	0
1	0	0.9091	0	2449641	0.0909	222,694
2	0	0.8264	0	2449641	0.1736	425,144
3	0	0.7513	0	2449641	0.2487	609,189
4	0	0.6830	0	2449641	0.3170	776,503
5	0	0.6209	0	2449641	0.3791	928,606
6	0	0.5645	0	2449641	0.4355	1,066,882
7	0	0.5132	0	2449641	0.4868	1,192,588
8	0	0.4665	0	2449641	0.5335	1,306,865
9	0	0.4241	0	2449641	0.5759	1,410,754
10	0	0.3855	0	2449641	0.6145	1,505,198
11	5508608	0.3505	1930734	2449641	0.6495	1,591,056
12	0	0.3186	0	2449641	0.6814	1,669,110
13	0	0.2897	0	2449641	0.7103	1,740,067
14	0	0.2633	0	2449641	0.7367	1,804,574
15	0	0.2394	0	2449641	0.7606	1,863,217
16	0	0.2176	0	2449641	0.7824	1,916,528
17	0	0.1978	0	2449641	0.8022	1,964,993
18	0	0.1799	0	2449641	0.8201	2,009,052
19	0	0.1635	0	2449641	0.8365	2,049,105
20	0	0.1486	0	2449641	0.8514	2,085,518
21	5508608	0.1351	744381	2449641	0.8649	2,118,620
22	0	0.1228	0	2449641	0.8772	2,148,713
23	0	0.1117	0	2449641	0.8883	2,176,070
24	0	0.1015	0	2449641	0.8985	2,200,940
25	0	0.0923	0	2449641	0.9077	2,223,549
26	0	0.0839	0	2449641	0.9161	2,244,103
27	0	0.0763	0	2449641	0.9237	2,262,788
28	0	0.0693	0	2449641	0.9307	2,279,775
29	0	0.0630	0	2449641	0.9370	2,295,217
30	0	0.0573	0	0	0.9427	0
NPV			14425727			48,087,423
				TOTAL NPV		**62,513,151**

3. Separation at Source with Onsite or Offsite Treatment *(see section 6.2.1.3 for description)*

Discount Rate				10%				
				O & M (Centralised Management)			O & M (Onsite Management)	
Yr.	**Investment Cost**	**NPV Factor**	**NPV OF INVESTMENT**	**Annual O&M**	**NPV - Cen. Mgt.**	**NPV Factor**	**Annual O&M**	**NPV - Onsite**
0	246016	1	246016	0	0	0	0	0
1	0	0.9091	0	85552	7,777	0.0909	35552	3,232
2	0	0.8264	0	85552	14,849	0.1736	35552	6,170
3	0	0.7513	0	85552	21,275	0.2487	35552	8,841
4	0	0.6830	0	85552	27,119	0.3170	35552	11,269
5	0	0.6209	0	85552	32,431	0.3791	35552	13,477
6	0	0.5645	0	85552	37,260	0.4355	35552	15,484
7	0	0.5132	0	85552	41,650	0.4868	35552	17,308
8	0	0.4665	0	85552	45,641	0.5335	35552	18,967
9	0	0.4241	0	85552	49,269	0.5759	35552	20,474
10	0	0.3855	0	85552	52,568	0.6145	35552	21,845
11	246016	0.3505	86227	85552	55,566	0.6495	35552	23,091
12	0	0.3186	0	85552	58,292	0.6814	35552	24,224
13	0	0.2897	0	85552	60,770	0.7103	35552	25,254
14	0	0.2633	0	85552	63,023	0.7367	35552	26,190
15	0	0.2394	0	85552	65,071	0.7606	35552	27,041
16	0	0.2176	0	85552	66,933	0.7824	35552	27,815
17	0	0.1978	0	85552	68,626	0.8022	35552	28,5180
18	0	0.1799	0	85552	70,164	0.8201	35552	29,157
19	0	0.1635	0	85552	71,563	0.8365	35552	29,739
20	0	0.1486	0	85552	72,835	0.8514	35552	30,267
21	246016	0.1351	33244	85552	73,991	0.8649	35552	30,748
22	0	0.1228	0	85552	75,042	0.8772	35552	31,184
23	0	0.1117	0	85552	75,997	0.8883	35552	31,581
24	0	0.1015	0	85552	76,866	0.8985	35552	31,942
25	0	0.0923	0	85552	77,656	0.9077	35552	32,270
26	0	0.0839	0	85552	78,373	0.9161	35552	32,569
27	0	0.0763	0	85552	79,026	0.9237	35552	32,840
28	0	0.0693	0	85552	79,619	0.9307	35552	33,086
29	0	0.0630	0	85552	80,159	0.9370	35552	33,311
30	0	0.0573	0	0	0	0.9427	0	0
NPV			365,488		1679412			697,892
			TOTAL NPV	Centralised	**2,044,899**		Onsite	**1,063,380**

4. Dry System with Urine Diversion *(see section 6.2.2.1 for description)*

Discount Rate					10%		
Yr.	**Investment Cost**	**NPV Factor**	**NPV OF INVESTMENT**		**Annual O & M**	**NPV Factor**	**NPV**
0	251656	1	251,656		0	0	0
1	0	0.9091	0		36116	0.0909	3,283
2	1200	0.8264	992		44116	0.1736	7,656
3	0	0.7513	0		36116	0.2487	8,981
4	1200	0.6830	820		36116	0.3170	11,448
5	0	0.6209	0		44116	0.3791	16,723
6	1200	0.5645	677		36116	0.4355	15,729
7	0	0.5132	0		36116	0.4868	17,583
8	1200	0.4665	560		44116	0.5335	23,535
9	0	0.4241	0		36116	0.5759	20,799
10	1200	0.3855	463		36116	0.6145	22,192
11	137088	0.3505	48,048		44116	0.6495	28,653
12	1200	0.3186	382		36116	0.6814	24,608
13	0	0.2897	0		36116	0.7103	25,654
14	1200	0.2633	316		44116	0.7367	32,499
15	0	0.2394	0		36116	0.7606	27,470
16	81302	0.2176	17,694		36116	0.7824	28,256
17	0	0.1978	0		44116	0.8022	35,388
18	1200	0.1799	216		36116	0.8201	29,620
19	0	0.1635	0		36116	0.8365	30,210
20	1200	0.1486	178		44116	0.8514	37,558
21	137088	0.1351	18,525		36116	0.8649	31,235
22	1200	0.1228	147		36116	0.8772	31,679
23	0	0.1117	0		44116	0.8883	39,189
24	1200	0.1015	122		36116	0.8985	32,449
25	0	0.0923	0		36116	0.9077	32,782
26	1200	0.0839	101		44116	0.9161	40,414
27	0	0.0763	0		36116	0.9237	33,361
28	1200	0.0693	83		36116	0.9307	33,611
29	0	0.0630	0		44116	0.9370	41,335
30	0	0.0573	0		0.0	0.9427	0.0
NPV			340,980				763902
			TOTAL NPV		**1,104,881**		

5. Wet Sanitation with Separation of Solids *(see section 6.2.2.2 for description)*

Discount Rate				10%				
				O & M (Centralised Management)			O & M (Onsite Management)	
Yr.	Investment Cost	NPV Factor	NPV OF INVESTMENT	Annual O&M	NPV - Cen. Mgt.	NPV Factor	Annual O&M	NPV - Onsite
0	217329	1	217329	0	0	0	0	0
1	0	0.9091	0	82683	7,517	0.0909	32683	2,971
2	0	0.8264	0	82683	14,350	0.1736	32683	5,672
3	0	0.7513	0	82683	20,562	0.2487	32683	8,128
4	0	0.6830	0	82683	26,209	0.3170	32683	10,360
5	0	0.6209	0	82683	31,343	0.3791	32683	12,389
6	0	0.5645	0	82683	36,011	0.4355	32683	14,234
7	0	0.5132	0	82683	40,254	0.4868	32683	15,911
8	0	0.4665	0	82683	44,111	0.5335	32683	17,436
9	0	0.4241	0	82683	47,617	0.5759	32683	18,822
10	0	0.3855	0	82683	50,805	0.6145	32683	20,082
11	217329	0.3505	76172	82683	53,703	0.6495	32683	21,228
12	0	0.3186	0	82683	56,338	0.6814	32683	22,269
13	0	0.2897	0	82683	58,733	0.7103	32683	23,216
14	0	0.2633	0	82683	60,910	0.7367	32683	24,077
15	0	0.2394	0	82683	62,889	0.7606	32683	24,859
16	0	0.2176	0	82683	64,689	0.7824	32683	25,570
17	0	0.1978	0	82683	66,325	0.8022	32683	26,217
18	0	0.1799	0	82683	67,812	0.8201	32683	26,805
19	0	0.1635	0	82683	69,164	0.8365	32683	27,339
20	0	0.1486	0	82683	70,393	0.8514	32683	27,825
21	217329	0.1351	29368	82683	71,510	0.8649	32683	28,266
22	0	0.1228	0	82683	72,526	0.8772	32683	28,668
23	0	0.1117	0	82683	73,449	0.8883	32683	29,033
24	0	0.1015	0	82683	74,288	0.8985	32683	29,365
25	0	0.0923	0	82683	75,052	0.9077	32683	29,666
26	0	0.0839	0	82683	75,745	0.9161	32683	29,941
27	0	0.0763	0	82683	76,376	0.9237	32683	30,190
28	0	0.0693	0	82683	76,949	0.9307	32683	30,417
29	0	0.0630	0	82683	77,471	0.9370	32683	30,623
30	0	0.0573	0	0.0	0.0	0.9427	0.0	0.0
NPV			322,869		1,623,097			641,578
			TOTAL NPV	**Centralised**	**1,945,966**		**Onsite**	**964,447**

Sensitivity Analysis of Total NPV based on Discount Rates

	12%	**10%**	8%
Scenario 1	41,626,472	**39,380,693**	36,403,475
Scenario 2	65,233,129	**62,513,151**	58,912,981
Scenario 3			
Centralised Management	2,134,229	**2,044,899**	1,926,778
Onsite Management	1,085,320	**1,063,380**	1,034,698
Scenario 4	1,137,592	**1,104,881**	1,061,839
Scenario 5			
Centralised Management	2,034,459	**1,945,966**	1,828,905
Onsite Management	985,549	**964,447**	936,825

APPENDIX D: SOLID WASTE TARIFFS FOR THE FCC

Schedule of Monthly City Sanitation Fees for Residential Property

	Group I		Group II		Group III	
	L/W	**S/W**	**L/W**	**S/W**	**L/W**	**S/W**
Large Detached Duplex	3,000	2,500	3,000	3,125	3,000	3,750
Small Detached Duplex	2,500	2,000	2,500	2,500	2,500	3,000
Semi Detached Duplex	2,250	2,000	2,250	2,500	2,250	3,000
Detached Bungalow	1,500	1,500	1,500	1,875	1,500	2,250
Detached Back House	1,000	1,000	1,000	1,250	1,000	1,500
3-4 Bedroom Flat	500	750	500	938	500	1,125
1-2 Bedroom Flat	300	500	300	625	300	750
Mud House	200	100	200	125	200	150

Source: Waste Management Rates/Charges Regulations (AEPB, 2005)
L/W: Liquid Waste;   S/W: Solid Waste

* Group I: covers all satellite towns of Kubwa, Nyanya, Karu, Bwari, Gwagwalada, Kuje, Abaji, etc and such other areas as the Board may specify from time to time.

* Group II: covers Garki I & II, Wuse I, Jabi, Utako, Wuye, Durumi, Gwarimpa, Kado and such other areas as the Board may specify from time to time.

* Group III: covers Asokoro, Maitama, Wuse II, Life camp, Mabushi etc and such other areas as the Board may specify from time to time. Central Area.