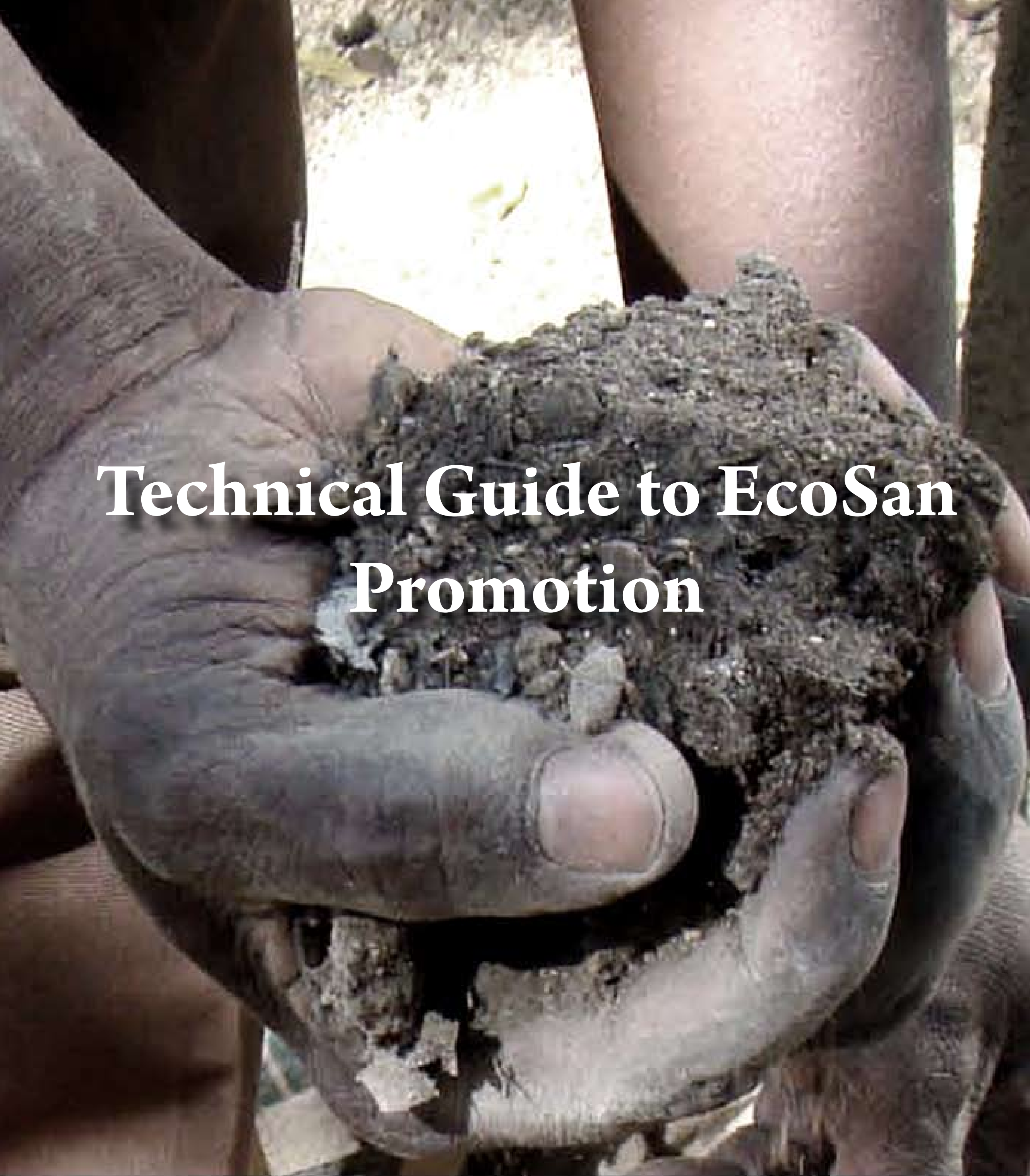

Technical Guide to EcoSan Promotion

EU-GTZ/SIDA EcoSan Promotion Project
Ministry of Water & Irrigation
P.O.Box 19512-00202 Nairobi, Kenya
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November 2009

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Patrick Onyango and Orodi Odhiambo
With
Alex R. Oduor

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Preface

The EcoSan Promotion Project (EPP) is a project component of the Water Sector Reform Programme in Kenya co-funded by the European Union, SIDA and GTZ and implemented between November 2006 and June 2010. It was started towards the end of 2006. The project's aim is to develop, test and promote the Ecological Sanitation concept including development of technical designs for large and small-scale sanitation projects in Kenya. The focus is on: individual households; public places such as markets and bus parks; public institutions such as primary schools, secondary schools and prisons; and informal settlements. Consequently, the potential of sanitizing, recycling or re-using human waste for production of biogas and bio-fertilizers, through closing of the water and nutrient loops is realized while their use gets promoted for economic and social development.

In the past decades, many public places such as markets, bus parks, recreational parks, town centre's et cetera, did not have sanitation facilities. The few that were in use under the management of the local authorities were totally run down to the extent of being unsuitable for human use. They got filthy and overflowed with human waste.

No management systems of these facilities, mainly toilet blocks for ladies and gentlemen, were put in place for daily operation. As a result, Kenyans had inadequate access to sanitation in public places. The unmanaged public toilets became dens for gangs ready to pounce and mug people during the day as well as nighttime. The public thus dreaded such sanitation facilities. The problem of unsafe and inadequate sanitation is also being experienced in both primary and secondary schools. Other public institutions in Kenya are experiencing the same sanitation problems. The urban poor in the growing informal settlements have some of the worst sanitation facilities in the country leading to frequent water born disease outbreaks. The centralized sewer system is not providing a sustainable solution for increasing the sanitation coverage in urban areas. The systems are expensive to construct with about 20% of the urban population covered by the sewer lines.

The EU-GTZ–SIDA EcoSan Promotion Project started implementing pilot projects in rural households, public places, primary schools, secondary schools and in prisons.

This has been done with the involvement of all the major stakeholders that include: The Water Services Trust Fund (WSTF); Municipal Councils; Water Services Boards (WSBs); and Water Service Providers (WSP). WSPs manage public sanitation facilities through their respective WSBs who own the facilities.

The rural households, schools and prisons operate and manage their respective sanitation facilities. The following technological options have been piloted successfully in Kenya by the project:

- Primary schools;
- Secondary schools and prisons; and
- Public places (Markets and bus parks)

Biogas is exploited from all systems using digesters for use as a source of renewable energy. The organic fertilizer from the sanitation facilities is thereafter used for agricultural production especially in schools and rural households.

Acronyms

ABR	Anaerobic Baffle Reactor
BC	Before Christ
BDBR	Biogas Digester & Baffle Reactor
BOD	Biological Oxygen Demand
COD	Chemical Oxygen Demand
DTS	Decentralized Treatment System
EcoSan	Ecological Sanitation
EPP	EcoSan Promotion Project
EU	European Union
GK	Government of Kenya
GPS	Geographic Positioning System
GTZ	German Technical Cooperation
HRT	Hydraulic Retention Time
LPG	Liquid Petroleum Gas
Ksh	Kenya Shillings
MDG	Millennium Development Goals
MoE	Ministry of Education
MoI	Ministry of Information
MLD	Ministry of Livestock Developemnt
MoWI	Ministry of Water & Irrigation
NAWASCO	Naivasha Water & Sewerage Company
NEMA	National Environment Management Authority
NWSS	National Water & Sanitation Strategy
pH	Degree of Acidity or Alkalinity
SWAP	Sector Wide Approach Programming
UDDT	Urine Diverting Dehydrating Toilet
UNEP	United Nations Environmental Programme
US$	United States Dollars
UV	Ultra Violet
WASH	Water and Sanitation Hygiene
WHO	World Health Organization
WSTF	Water Services Trust Fund
VIP	Ventilated Improved Pit (Latrine)

Contents

List of figures

List of tables

Chapter 1:

Introduction and Purpose: General Overview on Sanitation in Public Schools and Households

1.1 Global historical perspective to ecological sanitation

According to Wikipedia free encyclopedia, EcoSan is an acronym for ecological sanitation and represents the modern alternative to conventional sanitation practices. EcoSan aims at offering economically and ecologically sustainable and culturally acceptable systems capable of closing the natural nutrient and water loops. A distinctive difference between EcoSan and other sanitation methods is that it processes human waste to recover nutrients that would otherwise be discarded and pollute water bodies.

History has shown that the recovery and use of urine and faeces has been practiced over millennia by many cultures. For instance, due to its disinfecting attributes, the Romans used urine to wash cloths.

From time immemorial, earlier than 500 B.C, the Chinese used human excreta to produce crops in order to sustain a higher density of people. In Yemen, the separation of urine and excreta even in multi-storey buildings has been a common practice for evaporation and fuel respectively. While in Mexico and Peru, human excreta were collected for agricultural use.

In continental Europe, and especially in the Schengen countries of Sweden, the Netherlands, Norway and Germany, an increasing number of research and demonstration projects for excreta reuse was carried out between 1980s to the early 21st century. These closed-loop sanitation systems placed emphasis on hygenisation of the contaminated flow streams, thus becoming popular under the name "ecosan", "dewats" or "desar" (Esrey et al. 2003). The diversity of some of the EcoSan projects are highlighted below:

- *Large-scale UDDT projects in Guanxi province, China*

  Guanxi is one of the poorest provinces in China. Its dissemination programme on ecological dry toilets started in 1997 with support from UNICEF, SIDA and the Red Cross. The programme has been expanded until the year 2003 to 17 provinces. By 2009, the scale of the project had increased to approximately 685,000 toilet units – with more than a million double vault UDDTs being installed in rural areas of China.

- *Vacuum toilets and greywater treatment in Frankfurt, Germany*

  The sanitation concept of the modern office building "Ostarkarde" of the KfW Bankengruppe in Frankfurt is based on the separation of excreta and greywater.

- and greywater. As urine and faeces are collected via vacuum toilets, with sewerage using very little water for flushing, the greywater from hand washing and kitchen is collected and treated separately in a compact-activated-sludge-reactor combined with membrane filtration.

1.2 The Bellagio Principles: Household-Centred Environmental Sanitation Approach (HCES)

The natural supply of freshwater in the world is subject to increasing environmental and economic pressures. These pressures are attributed to increases in population and per capita water demand, which eventually culminates in the contamination and depletion of the already over-exploited water sources (Schertenleib and Morel, 2003). In addition, 1.2 billion people do not have access to safe drinking water. Three billion people do not have access to proper sanitation while 50% of all solid waste are uncollected. No one knows how many people are flooded out each year and three billion people have to survive on less than US$ 2/day.

To address these issues, a new approach known as *Household Centred Environmental Sanitation* (HCES) was developed. This approach aims at overcoming the serious lack of sanitation services, which often culminates in illnesses and slow-down, especially in the developing countries. HCES draws its foundation on the Bellagio principles, which are in turn inspired by the failure of conventional approaches to meet sanitation needs. The Bellagio principles are enumerated herebelow as follows;

- Human dignity, quality of life and environmental security at household level should be at the centre of the new approach. This should be responsive and accountable to needs and demands in the local and national setting.

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

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

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

1.3 The MDG sanitation targets

According to the MDG Water and Sanitation report (2006), more than 60% of the rural dwellers, constituting two billion people by 2004 did not have access to basic sanitation facilities, whilst 40% defecated in the open unsanitary conditions. This is in contrast to the urban situation, which had double the rural sanitation coverage. If this trend persists, it is projected that the World will miss the sanitation target by more than 500 million people, with 1.7 billion, mostly from the rural areas unable to access improved sanitation by 2015.

Clean water is important for basic sanitation. Although the world appeared to be on track to achieve the MDG drinking water target by 2004, the trend seems to be deteriorating. A lot of rural people are migrating to benefit from the high water coverage in the urban areas. This poses a major challenge for city planners who have to meet the demand of slum and peri-urban inhabitants to avoid disease outbreaks. Already, 1.6 million children are dying every year because of unsafe water coupled with lack of basic sanitation.

1.4 Keeping the spotlight on sanitation

In a meeting at the United Nations headquarters in New York in September 2000, delegates outlined a series of targets to be achieved by 2015. The objective was poverty eradication and sustainable development for all by rapidly increasing access to basic requirements such as clean water, energy, health care, food security and the protection of biodiversity. These are known as the Millennium Development Goals (MDGs).

Very little attention was paid to sanitation that it was not even included in this shopping list for a better and healthier lifestyle. Then at the 2002 UN Summit on Sustainable Development in Johannesburg, South Africa, delegates reassessed the goal pertaining to water supply and extended it to the provision of sanitation.

Now one of the targets for MDG 7 – Ensuring Environmental Sustainability – is to halve the proportion of people without access to safe drinking water and adequate sanitation. While the water aspect is on course, sanitation trails far behind. Kenya and other African countries will not meet the sanitation target unless approaches to sanitation changes. To attain its MDG, the sanitary provision rates of the '90s will have to be increased fourfold. Adequate sanitation as defined by MDG 7 means that there are improved sanitation facilities that are not publicly shared.

The year 2008 was made the International Year of Sanitation to keep the spotlight on sanitation issues. The Water Supply and Sanitation Collaborative Council has launched a Global Sanitation Fund to help meet the MDG sanitation target. Nevertheless, governments and other stakeholders in Kenya and elsewhere around the world, must put sanitation high on the list of development priorities so that half of the world's population that never uses a toilet can do so.

Achieving the sanitation MDG in Kenya means extending coverage to an additional. Two million people every year – roughly half in the rural areas and half in urban settlements. At the current rate of progress, Kenya will not meet its sanitation MDG until the second half of this century. Areas of focus for progress in achieving the MDG sanitation target include:

- Generation and sustenance of political support at all levels;
- Ensuring there is the national capacity and institutional support; and
- Improving the quality of services in a way that is sustainable

1.5 Sanitation – The antidote to a silent killer

Human excreta is a weapon of mass destruction. This has been known for centuries. Unsanitary conditions and overcrowding were widespread throughout Europe and Asia during the middle ages. This triggered periodic pandemics of cataclysmic proportion. Tens of millions of people died in the Plague of Justinian (541-42) and the Black Death (1347-1351).

Just as a lack of sanitation has life-threatening consequences and spells disease and death so does improved sanitation prevent as many as 1.6 million deaths annually. This is equivalent to five times the death toll during the tsunami that swept through the Indian Ocean in 2004. Good sanitation prolongs life too. Toilets can double a user's lifespan.

One gram of human excreta contains as many as ten million viruses. It is easy to pass on a communicable disease such as cholera or typhoid from one person to the next. The most common carriers of faecal matter are fingers, food, flies, soil and contaminated water. For instance, when a child walks barefoot where someone has defecated or plays in the soil and then dips his fingers into the communal pot of food as it is being served to the family, he is spreading disease.

Diarrhoeal diseases are often described as being waterborne. In fact they are excreta-related because the pathogens that cause them originated in faecal matter. When the Brazilian city of Salvador expanded its sanitation coverage, the prevalence of diarrhoea among infant children was almost halved.

There are some 50 diseases, including worms, which can be passed on in this manner. However, by far the most dangerous of all is a commonplace one that is easily preventable – diarrhoea. Diarrhoeal disease is the second biggest killer of small children under five. (Pneumonia, which has also been linked to poor sanitation, is the biggest killer of small children.) Diarrhoeal disease makes children malnourished. It is one of the sanitation-related reasons for low school attendance. It lays up workers and robs the economy of productive man hours. Evidence-based analysis shows that deaths caused by diarrhoeal diseases can be reduced by more than 30% simply by using a toilet. Several studies have shown that people who live without sanitation are 1.6 times more likely to suffer diahrroea.

A 1996 World Health Organization study carried out in Asia showed that sanitation and hygiene are the overriding deciding factors in reducing the incidence of diarrhoeal diseases. Improved sanitation systems were clearly responsible for 77% of the instances of reduced disease burden. By comparison, 48% was linked to improvements in the water supply. A different, multi-country study confirmed that incidences of diarrhoea were reduced by more than a third where improved sanitation was introduced to communities where none existed before.

The prevalence of diarrhoea among children in the slums of Kenya's cities, is much higher than among children living in the countryside or in neighbourhoods that are economically better off. So is the mortality rate. This is not because these children have not been immunised against measles and other childhood diseases. It is because they are exposed to faecal matter and contaminated water on a daily basis. Studies trace a direct linkage between child mortality rates and the rate of inaccesibility to proper toilets.

Overcrowded urban settlements are not the only target areas for disease in the absence of proper sanitation. There is a direct correlation between low-lying areas prone to seasonal flooding and cholera outbreaks. Consistently badly hit are Coast Province and Nyanza Province where high water tables lie close to the surface. When water levels rise after heavy rains, the inevitable seepage from traditional pit latrines contaminates shallow well water. To illustrate these phenomena, water samples from Kisumu and Nyando, two of the most affected districts in Nyanza Province, showed that 75% of water sources were contaminated, including seepage from pit latrines. Mr. Shanaaz Sharif, Kenya's Ministry of Health Senior Deputy Director of Medical Services amptly put in that "*Poor sanitation is one of the major causes of cholera epidemics. Sanitation is health. If you have poor sanitation, you become prone to ill health*".

1.6 Kenyan context of eco-sanitation

Kenya is one of the signatories of the Bonn Ministerial Declaration assigning high priority to water and sanitation as essential keys to sustainable development. She also signed the Rio declaration that makes water, sanitation and hygiene a top priority for action on the continent that is badly affected by inadequate water and sanitation services. At less than 637 m^3 per capita per year, Kenya is ranked amongst Africa's water scarce countries facing the twin challenges of availing and accessing water for domestic use, as well as providing adequate sanitation.

More than half of Kenya's population do not have access to improved sanitation. However, in the late nineties, NGOs introduced ecological sanitation in Kenya. The Ecosan-type technologies introduced included the urine-diversion dehydration toilets (UDDTs), Arboloos and Fossa Alternas.

According to Otieno el.al. (2010), The EcoSan concept has to date not been widely tested in Kenya as a viable alternative to conventional sewerage systems. This is despite its considerable potential advantages and cost savings. This is attributed to inadequate awareness creation and cultural barricades on the handling of human waste that have hindered large-scale adoption of this technology. The few cases tried have been on pilot scale and are confined to small areas within some towns.

The EU-GTZ EcoSan Promotion Project has been developing, testing, and promoting ecological sanitation in pilot areas of seven provinces in Kenya since November 2006. Implementing sanitation in Kenya is still a challenge just like in other developing countries. This is due to the stigma among many communities that prevents easy and public discussion of the importance of sanitation.

There is also the issue of low access to affordable sanitation technologies to the low-income population. Furthermore, strategies for highlighting poverty reduction and benefits that flow from better hygiene are still not well developed. In addition to these challenges, MWI (2009) also identified other key sanitation challenges in Kenya as:

- Insufficiency of sanitation activities to meet the rapid population growth
- Lack of affordable technological options for reuse of wastes
- Poor development of promotion packages and subsidy schemes
- Insufficient and non-harmonized database and information

It is in regard to the above issues that EcoSan Promotion Project (EPP) started the promotion of ecological sanitation as a concept for improving the health standards and environmental friendly approaches for managing wastes. One of the EPP objectives for achieving this goal was to promote affordable and appropriate ecological sanitation technologies in pilot areas of Kenya. Since the onset of the project in 2006, a number of activities such as training and construction of alternative sanitation facilities have been initiated.

The EU-Sida-GTZ Ecosan Promotion Project was concerned about the numerous school days missed by many children in Africa either due to preventable diarrheal diseases or lack of private and hygienic toilet facilities at their schools – thus jeopardizing the chances to the MDG Goal Number 2 on universal primary education. The latter case particularly affected adolescent girls during their menstruation days.

In the the EU-Sida-GTZ Ecosan Promotion Project, Odhiambo et al.(2008) utilised the existing experience in "dry excreta management" and engaged respective NGOs to kick-start activities in their areas. At first NGOs and CBOs carried out the selection of beneficiaries, awareness campaigns, training sessions and construction supervision with technical support by the GTZ-Kenya team. The selection criteria for the benefiting schools included availability of farmland for fertiliser use and inappropriateness of existing sanitation facilities such as pit latrines in areas with collapsing soils, flooding, water pollution etcetera. In some cases, schools had "grave yards" of old, filled pit latrines that took up the entire compound.

The participatory design, planning and implementation process was used by the school administration and board, local government authorities such as area education officers, public health officers and other stakeholders. Furthermore, the schools cost-shared the toilet construction by means of providing locally available materials and unskilled labour in creating ownership and thus sustainability of the toilets.

1.6.1 Sanitation in public institutions of Kenya

In Kenya, many public institutions such as prisons, boarding schools or colleges face a myriad of problems with regard to the provision of safe and adequate sanitation services. Only 18% of the total population is covered by a sewer system necessitating most public institutions to develop their own onsite sanitation facilities.

The most commonly used technologies are ablution blocks with septic tanks or various types of pit latrines. However, the population in these public institutions is often 50% higher than the design capacity, culminating in the filling up of pits within two to three years. Consequently, septic tanks have to be emptied 2-3 times a year. The exhauster services are however not adequately available country wide to facilitate this. Given the above scenario, more and more public institutions are opting to use a large number of pit latrines which are abandoned as soon as they fill up. This creates large spaces occupied by graveyards of pit latrines.

Institutions that have initiated EcoSan activities include the East African Communities Organisation for the management of Lake Victoria and its resources (ECOVIC), in collaboration with CARE Kenya . ECOVIC erected EcoSan toilets in Homa Bay with scaling up plans for districts along the Lake Victoria region namely Busia, Bondo, Siaya, Nyando, Migori, Rachuonyo and Suba.

1.6.2 Rural sanitation at household level and primary schools

Western, Nyanza and North Eastern provinces of Kenya are characterised by sanitation hot spots. These are areas where annual cholera epidemics occur during the long rains (April-July). There are also cases of cholera being reported in some of these areas during the dry periods (December- March). The disease outbreaks can be linked directly to the inadequate sanitation, poor hygienic conditions and high poverty index. Most of the existing pit toilets have very poor structures that are easily flooded during the rains thus contaminating the water resources with human faecal waste.

Water in the wells is often polluted by seepage from the toilet pits if safe distances are not observed during the positioning and construction. In addition, flies, maggots, pathogens and cockroaches breed in these toilet pits. Spread of diseases is thus common from these types of pit toilets. The odours from the pits are often offensive due to the wet mixtures of urine and faeces in the pits. The pits are filled within a period of 3-5 years thus making the owners to reinvest in the construction of new toilets. The digging of pits is expensive in rocky areas and dangerous in loose sandy soil areas where lining of the pit cannot be avoided.

Ministry of Water and Irrigation
& Ministry of Education
GACHOIRE GIRLS' HIGH School
Ecological Sanitation (Ecosan) pilot project
Implementation Period: May to December 2007
Funded by:
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European union in co-operation with sida and gtz
Implementation by:
Gtz-German Techn. Co-operation· EcoSan
Promotion Project
Sida
ECOLOGICAL
SANITATION

The EU-GTZ–SIDA EcoSan Promotion project is implementing pilot rural sanitation projects in the affected areas of Nyanza, Western and North Eastern provinces with the aim of addressing the above named challenges. Measures being undertaken in the project includes a combination of the following:

- Use of the existing community based groups as entry points into the rural areas;
- Conducting hygiene education;
- Promotion of hand washing after toilet use.

Piloting of Urine Diverting Dry Toilets (UDDT) with rainwater harvesting for hand washing which serves five households (each having an average of eight individuals) in order to produce adequate organic manure for the household farms. These toilets are odourless since they operate totally under dry condition (no mixing of urine and faeces). No water is required for flushing. This condition (pH, temperature and level of moisture) does not allow flies, cockroaches, pathogens and maggots to survive thus making the toilet clean, hygienic and comfortable to use. The per capita cost of US$ 13.3 (KSh 1,000) is within the acceptable range. The cost of digging and lining a pit are not incurred as in the case of pit toilets. Economic use of organic manure from the UDDT for agricultural and agroforestry production is for income generation. land is saved for other beneficial activities instead of digging pits for latrines.

The UDDT already has a high acceptability in rural households and at primary schools. This can be attributed not only to its sanitation benefits, but majorly to its economic benefits. By 2009, about 250 UDDTs were already in use in these areas of Kenya.

At household level, grey water from the kitchen and bathrooms are often discharged into the environment, creating wet dirty grassy areas where mosquitoes, cockroaches and flies breed.

Organic waste from the kitchen are disposed of inappropriately thus causing stench and filth. Due to the high cost of energy, cheap wood fuel is used in large amounts for cooking in the kitchens. This causes stress on the already dilapidated forest cover of Kenya. In an article that appeared in the Standard Newspaper of 2nd March 2009, The United Nations Environmental Programme, UNEP, reiterated that Kenya is tottering towards environmental disaster due to the destruction of forests.

1.6.3 Meeting the demand for sanitation in Kenyan schools and markets

Sanitation standards require one public facility per urban population of 25,000. Kenya has 277 urban centres needing more than 1,000 facilities. If half already exist in working order, then the demand would be for 500 units. EcoSan meets the set standard of safe effluent disposal with the additional advantages of recycling waste into biogas and fertiliser and also providing water for public showers and for sale at kiosks. It would need an investment of US$ 13.3 Million (KSh 1 billion) over 10 years to meet this target. Similarly, there is a demand for about 7,900 facilities in schools and public institutions. It would need an investment of US$ 9.6 Billion (Sh 720 billion) to achieve this.

This century is seeing a new phenomenon as the locus of poverty moves from the countryside to the cities and towns. The growth rate of African cities, at 4.58%, is the most aggressive in the world. In Kenya, 60% of urbanites live in slums. Given this surge of population growth among urban squatters on government land, it is clear that the MDG 7 will never be attained as long as there is no major investment in water and sanitation for the urban poor. Meanwhile, poverty, exclusion and inequality in Kenya's cities and towns are on the rise.

Sanitation is not just about infrastructure. It is also about rights and dignity. There have been debates about privacy since Aristotle first posited the concept in 350 BC. Those of us who are financially better off take our privacy for granted, unlike the urban poor. The appalling hygiene conditions in slums are an affront to human dignity. In Kenya, the majority of slums offer residents the use of dirty and dilapidated pit latrines at a ratio of several hundred per latrine. Most people prefer to defecate in the open or in a plastic bag that is commonly thrown into an open drain or onto the neighbour's roof.

Slums have been largely ignored in country and agency reports on the progress of MDGs. This is due in part to the absence of intra-city data disaggregated across slum and non-slum areas. As a result, most reports underestimate the level of urban poverty.

By analysing data specifically relating to the urban poor, it is possible to see that living in an unsanitary slum is more life threatening than living in a poor rural village. In Nairobi, for instance, a study showed that the prevalence of diarrhoea among slum children was 27% compared with 19% in rural areas.

Vision 2030 focuses on correcting Kenya's economic inequity. Thus bringing adequate sanitation to those residing in urban slums is one of the important tasks that lies ahead for city councils and planners. Conventional sewerage is neither feasible nor affordable given population densities, spatial configurations and the absence of land adjudication. In addition, net-bound sewer systems are expensive to construct, costly to maintain and use large amounts of water to operate.

Sanitation coverage in slums and low-income settlements is a major investment that only becomes cost effective when using EcoSan. EcoSan is an innovative, reliable and sustainable alternative to out-dated conventional sanitation systems.

Pilot projects were initiated in Nairobi's Kibera slum. One of these is the Katwekera Tosha Bio-Centre where a dozen clean, quality toilets as well as showers are available to residents at a cost of US Cents 2.67 (KSh 2.00) a visit. The biogas produced as a result of about 500 daily visitors is used to fuel the stoves for the centre's rooftop restaurant.

Chapter 2:

The Philosophy and Benefits of Ecologocal-Sanitation

2.1 The Philosophy of Ecological-sanitation

The underlying philosophy of ecological sanitation hereafter referred to as EcoSan, is that if treated properly, human waste is a valuable resource. EcoSan operates on the basic principle of separating urine and faeces so that each can be safely disposed of, then processed individually.

Eco-san can be viewed as a three pronged process that entails the following: containment of pathogens so as not to cause diseases; sanitization of waste so as not to pollute the environment and finally; reclamation, recycling and reuse of energy, water and nutrients through a modular circular system. This implies a complete recovery of nutrients in human waste and household wastewater so that they can be recycled as high-nutrient fertilizer for agriculture.

Pathogens are contained through their destruction using temperature, time and pH factors. The destruction is achieved via: dehydration or drying to reduce moisture; composting as a heating process; and anaerobic digestion to reduce faecal coliforms, BOD and COD. Thermophylic composting uses a ratio of 69% raw faecal matter, 20% vegetative matter, 10% soil and 1% of ash to reduce the existence or proliferation of ascaris by inactivating its eggs.

With regard to time as a critical factor, it is important to note that it takes a shorter time in the tropics as compared to temperate zones for pathogens to be destroyed (See Figure 1 below).

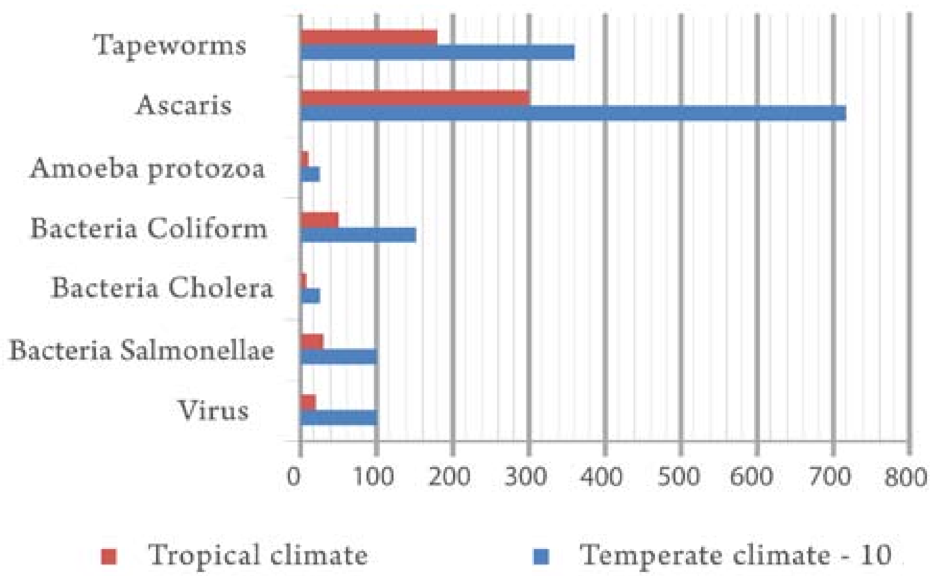


Figure 1 : Average survival time in days of pathogens in wet sludge

2.2 Fertilizer equivalent of human excreta

One of the major benefits of human excreta is its fertilizer potential. Each day, humans excrete approximately 30g of carbon (equivalent to 90g of organic matter), 10-12g of nitrogen, 2g of phosphorus and 3g of potassium. Most of the organic matter is contained in the faeces, while 70-80% of the nitrogen and potassium are contained in urine. Phosphorus is equally distributed between urine and faeces (See Figure 2 below).

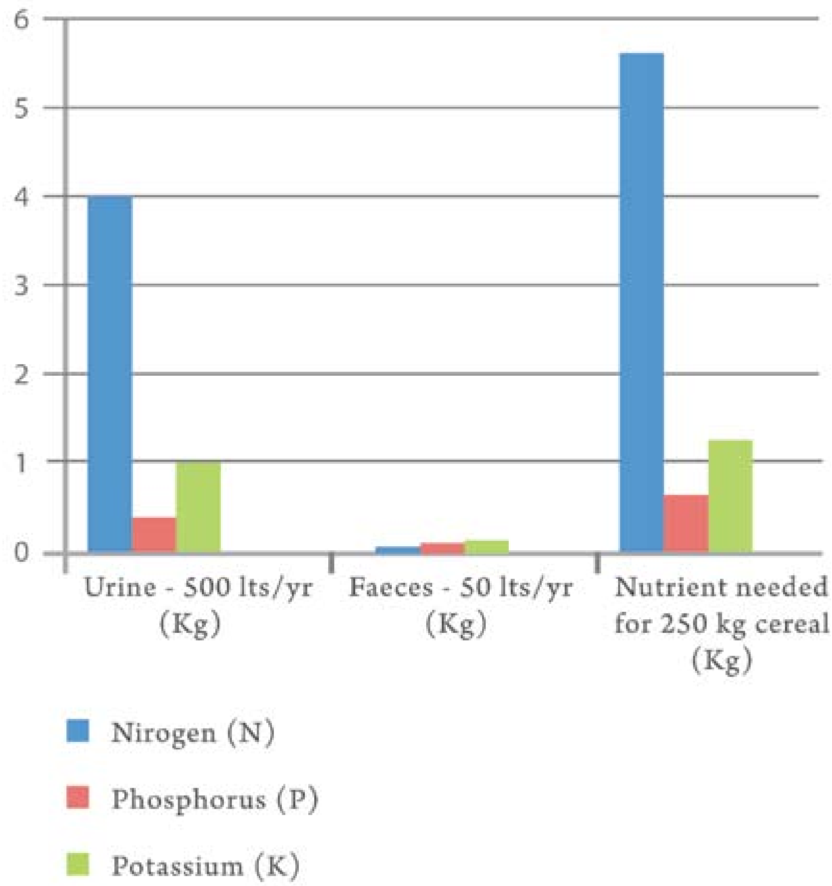


Figure 2 : Fertilizer equivalent of human excreta generation

The benefits of humanure is maximized by combining the use of urea fertilizer with compost. Urea's peak release of nitrogen is attained after about 2.5 to 3 months. This tapers off and gets depleted after four months. By this time, the compost release of nitrogen will be approaching its peak, which is attained after six months. Sanitized human waste acts as a good soil conditioner. It also modifies the soil moisture regime by enhancing its availability for critical growth periods to counter intra-seasonal dry spells.

2.3 Enhancing Ecosan water and nutrient cycle capacity

Rain is partitioned into both green and blue water fluxes that are useful in the agricultural and domestic sectors respectively. At a global average, the greenwater in particular constitutes over 80% of precipitation, part of which is used for agricultural and thus food production (Oduor A.R. and Malesu M.M, 2005). On the other hand, conventional domestic water consumption is about 3.3%, most of which goes to cooking, drinking and washing.

The ingestion of food and water is essential as ingredients for the by-production of faecal matter and urine, both referred to as - the brown and liquid gold respectively. These are major resources that can be used in the exploitation of bio-energy for cooking, lighting and as plant nutrients. Grey water that emanates from sanitation and kitchen activities are conveyed to wetlands and later recycled (See figure 3 below). The rest of the water is evapotranspired back to the atmosphere to restock the clouds for future precipitation.

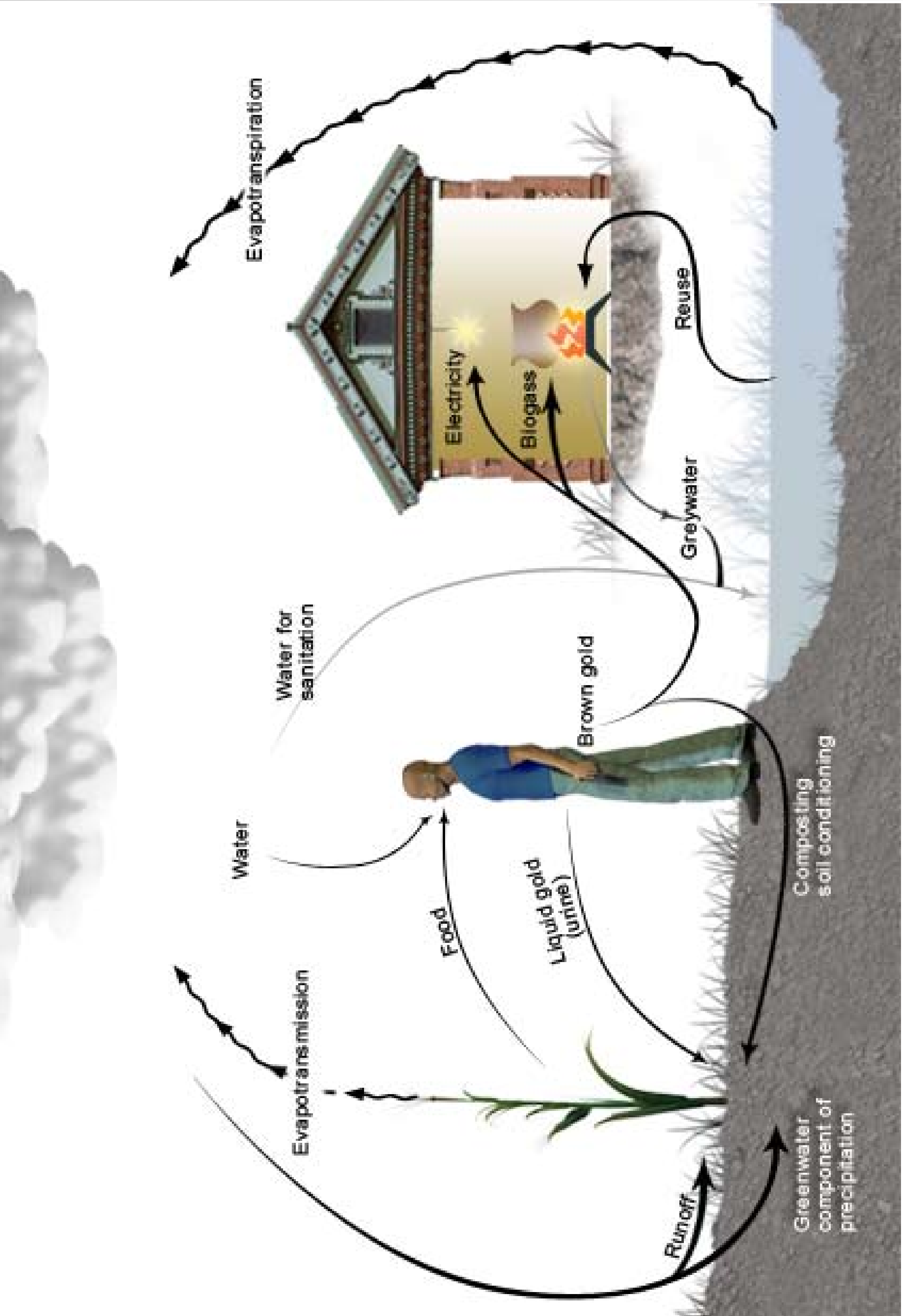


Figure 3 : Ecosan water and nutrient cycles

2.4 Reaping maximum benefits from Ecosan

An EcoSan toilet is a permanent on-site system ideal for places of high volume use, or even households where there is no sewerage system. It is particularly applicable to low-income urban settlements where there is no municipal infrastructure. It is also applicable in markets, bus stations and institutions such as schools, universities, prisons and health facilities.

The EcoSan process restores soil fertility and safeguards long-term food security. It minimises water use, protects water sources against pollution and by contrast to conventional sanitation technology, proves to be economically and ecologically sustainable.

EcoSan is a concept that was borne out of concern for the shrinking resources available to the world's expanding population. It is designed to maintain and improve our standard of living while at the same time preserving our planet for future generations. EcoSan achieves this by converting human waste into a valuable resource.

EcoSan helps solve some of society's most pressing problems - environmental degradation, water scarcity and the food and energy crises. It also helps to restore soil fertility, conserve fresh water and protect marine environments. Ecosan lowers the incidence of diseases and provides a valid alternative source of fuel. The traditional system of piped sewerage treats human excreta and grey water (dirty household water) as waste that must be disposed of efficiently. The EcoSan concept provides an efficient and sustainable option for improved sanitation by sanitizing and re-using human waste rather than releasing it into the environment. Its process is based on the separation of urine and faeces at source for sanitization and recycling. The waste matter is converted into fertilizer, reusable grey water and biogas.

Ecosan offers a flexible framework. Centralised elements can be combined with decentralised ones, waterborne with dry sanitation and high-tech with low-tech. By considering a much larger range of options, optimal and economic solutions can be developed for each particular situation. This is known as closing the loop. This process preserves soil fertility and safeguards long term food security while at the same time reducing the incidence of waterborne diseases and minimising the pollution of water, ground and air and conserving the water tables through lowering of its consumption. This is further supported by the National policy which clearly states that sewage disposal must not contaminate water sources with effluent. The policy advocates for the recycling of human waste in the form of biogas and fertilizer.

EcoSan anaerobically treats faecal matter to convert it to dry compost and to extract methane – commonly known as biogas – for use as an energy source. The biogas as a fuel, is used for cooking, lighting and general power generation. Some of the advantages of ecological sanitation systems includes:

- Safeguarding good health by preventing faecal pathogens from entering water systems
- Recovering macro and micro nutrients and trace elements from waster matter to recycle for agricultural use
- Restoring soil fertility
- Conserving water consumption and preventing water pollution
- Contributing to food security by boosting crop yields
- Cost-efficiency and adaptability to local circumstances

EcoSan may sound like an alchemist's tale of turning dust into gold, but it is the product of years of scientific research. Its benefits are proven and indisputable. Owing to lack of awareness on its availability and advantages for individuals and the nation, EcoSan systems are not yet widely used in Kenya. This situation will change following its vigorous marketing in Kenya. For those intent in adopting Ecosan, the following criteria have to be taken into account:

- Cost and long-term sustainability
- Pro-poor advantages
- Health safeguards in place
- Benefits to the environment
- Convenience and privacy of toilets
- Hygiene, safety and pro-conservation method of final disposal

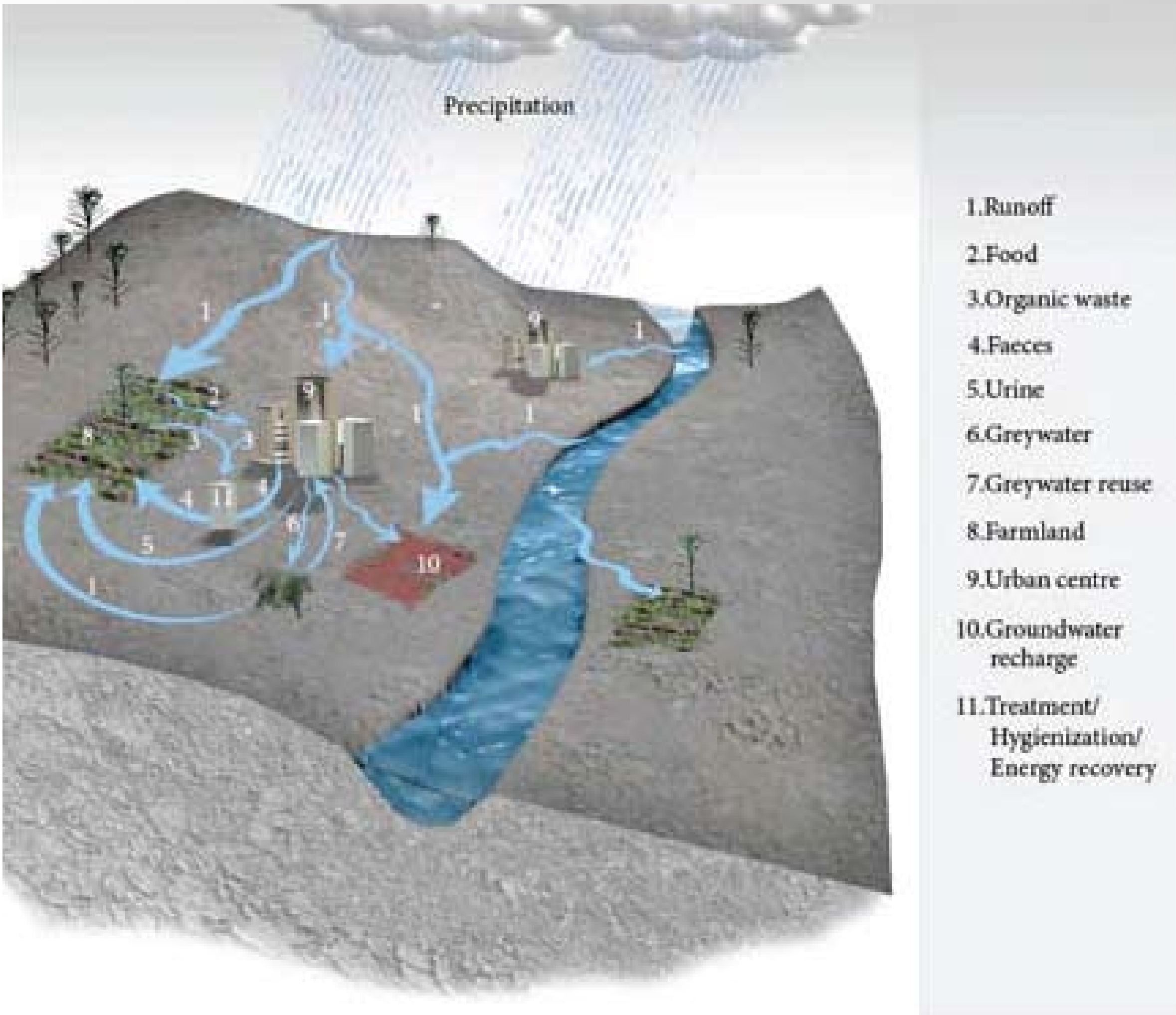


Figure 4 : Ecosan water and nutrient cycles

2.5 Why sanitation and water go hand-in-hand

Water and sanitation are so inextricably linked that they are usually referred to in one breath as 'watsan'. Yet there is no doubt that water issues overshadow those of sanitation in our minds. Water has always received the lion's share of finances. A look at national budgets underscores this imbalance.

According to the 2006 United Nations Human Development Report, most of sub-Saharan Africa allocated only 12-15% of the watsan budget line to sanitation. As most of these countries spend less than 0.5% of GDP on watsan, it can be seen that sanitation is habitually underfunded.

From now on, sanitation and water programs must be planned and implemented in tandem. Environmentalists predict that if global warming increases at its current rate, by 2020, more than 25% of the continent's population will suffer chronic and damaging water shortages. This problem will be exacerbated by daily pollution of the blue water resources owing to poor sanitation practices as well as the conventional use of the flush toilet that draws upto seven litres of precious water every time a user flushes away the toilet. This practice not only makes the water-shortage crisis even more acute, but is unhygienic and extremely damaging to the environment. If we continue to promote conventional sewerage technologies, the overall result will be devastating. Water systems will become irreversibly polluted and safe water will be even harder to source.

Absence of sewerage pollutes towns. To illustrate this, Kenya has 104 urban centres with populations exceeding 19,000. Yet only 29 of these towns have sewerage systems. Even where sewerage exists, relatively large numbers of households and business premises are not connected. Instead they dispose of their sewage in cesspools, septic tanks and streams. All these serve to contaminate the shallow groundwater aquifers from which the informal providers and private and community consumers draw their drinking water.

2.6 The smart answer to escalating fertilizer prices

Soaring prices are rendering fertiliser unreachable to millions of Kenyan farmers. At the same time, the country often faces unprecedented food crisis owing to frequent droughts. Kenya, alongside other African countries, is coming to grips with a looming, chronic food deficits. Some proven facts: The world's farmers require 135 million tons of mineral fertiliser for their crops every year. Ironically, conventional sanitation through the use of piped sewerage systems, dumps 50 million tons of mineral-rich waste into the oceans, seas, rivers and lakes. This untreated fertiliser - has a market value of around $50 billion. As an illustration, in 2005, Norway estimated that the value of nutrients disappearing annually down their sewers has a market value of $30 million. On the contrary, the annual fertilizer value of human waste for 900 million Chinese is a whooping $2.5 Billion.

Figure 5 : Imparting knowledge of sustainable sanitation to the future generation

Nitrogen, phosphorous and potassium are the three vital minerals that plants need to grow and flourish. Chemical fertilisers contain these minerals as does human waste. Nitrogen fertilizers are derived from fossil fuels such as natural gas. Potassium and phosphorus come from mines whose reserves are finite. For instance, phosphorous supplies will be exhausted after another one to two centuries.The world's phosphorous reserves could well be mined out over one to two centuries at the current rate of fertilizer consumption.

Human waste is an excellent alternative to these fossil sources. As long as humans exist, this source of supply will never be exhausted. The EcoSan system closes the loop between humans and agriculture by safely recovering all the minerals produced in food and plowing it back into the soil. In fact, humans can produce sufficient waste matter to fertilise all they need to eat once it has been properly treated. Put another way, there are enough nutrients in human toilet waste and domestic organic waste matter to grow sufficient food for feeding the world as depicted in the Table 1 below.

Table 1: Annual average mineral content in grey water, urine and faeces

Major plant nutrient	Grey water	Urine	Faces
Nitrogen	3%	87%	10%
Phosphorous	10%	50%	40%
Potassium	34%	54%	12%
COD	41%	12%	47%

2.7 EcoSan - ideal for office blocks

Ecosan has been in use in European cities and countryside since the 1990s. The sanitation concept of the modern office building of the KfW Bankengruppe in Frankfurt, Germany, is based on the separate collection of excreta and greywater. While urine and faeces are collected via vacuum toilets and a vacuum sewerage using much less water for flushing, the greywater from hand washing and the kitchen is collected and treated separately in a compact activated sludge reactor combined with membrane filtration. The treated greywater is then reused for toilet flushing and cleaning water. The amount of greywater can be reduced by 76% by this cost-efficient system which could be one of the prior choices for sanitation systems of newly constructed office buildings.

2.8 Policy And Advocacy Issues On Sanitation In Kenya

Kenya's water and sanitation sector is undergoing ambitious reforms rooted in the guidelines of international conventions. Elsewhere in africa, reforms target either the management sector or the provision of services.

In Kenya, both the institutional and legal frameworks are being revised. These reforms outline good governance, transparency and accountability for the consumer.

The goal of the 2007-2015 National Water Services Strategy (NWSS) is to increase access to improved, safe sanitation to 77.5% for urban residents and 72.5% for the rural population. The NWSS realises that this cannot be achieved by conventional sewerage systems, particularly as the recycling of effluent is critical. Thus the NWSS promotes EcoSan wherever this concept is acceptable to communities.

To date, improvements in water supply have been substantial, but parallel progress in the sanitation sector has been unsatisfactory. We must take advantage of the momentum created by the water reform process and use that potential to create expanded access to quality sanitation. While this applies to all Kenyans, there must be special focus on providing access for the poor and on correcting gender imbalances.

A key principle of the reforms is the recognition that they must be implemented with a sector-wide approach to planning (SWAP) to fast-track the expansion of sanitation coverage. Kenya has had the foresight to give the Ministry of Public Health and Sanitation the task of coordinating all sanitation issues with a view to bridging the following shortfalls in sanitation planning: that 90% of wastewater is poorly treated or not treated at all at the point of discharge; 75% of wastewater treatment plants malfunction; 80% of all disease is caused by polluted water and that 25% of the mortality rate is attributed to polluted water. The Water Act 2002 provides for the following reforms:

- Devolution of centralized administration so that responsibility clearly lies with those at the regional and local levels;
- Separation of policy and regulatory functions as well as the ownership of assets, sanitation and water services;
- Making the distinction between sanitation and water supply services;
- Privatization of sanitation and water supply services as an incentive for good service

Other very involved ministries are the Ministry of Water and Irrigation (MWI), the Ministry of Education (MoE), the Ministry of Local Government (MLG) and the Ministry for Nairobi Metropolitan.

The National Environmental Management Authority (NEMA) is also involved. MWI is responsible for infrastructure. MoE has created a separate budget line for basic sanitation and water in schools. The MLG is revising legislation to ensure that new construction, particularly in low-income settlements, contains adequate sanitation facilities.

The second step, which is underway, is to formulate a national sanitation policy. This will provide the missing link of supportive policies to provide the basis for planning and implementing sanitation programmes on a large scale. Kenya must also institute other reforms such as introducing a countrywide sanitation plan that addresses conditions in the slums and a separate sanitation budget line. Perhaps because it is hidden from the public eye, sanitation has always been perceived as tomorrow's project rather than today's priority.

In the past, it has consistently been relegated to the back of the queue in the national development and recurrent budgets. Even though water and sanitation are always lumped together, the relationship between the two is usually ignored when allocating resources. For every US$. 1.33 (KSh 100) invested in water supply, only US$. 0.27 (KSh 20) went toward sanitation.

In February 2008 32 African ministers committed to establishing national sanitation and hygiene budgets of at least 0.5% of GDP when they signed the Thekwini Declaration. National policy calls on private sector and civil society to get involved and contribute too. Government sanitation investment has been in urban sewerage and solid waste collection and disposal management. Public toilets and household sanitation was left to NGOs and CBOs. Conventional public finance in sanitation was interpreted to mean a subsidy for the private interventions.

In 2004, the Water Services Trust Fund (WSTF) was created as part of the water and sanitation reform package to scale up the supply of sanitation to the poor. EcoSan systems are very applicable to this goal.

There is already a pilot project for an EcoSan facility at the Naivasha bus station. It is run by Naivasha Water and Sanitation Company (NAWASCO) and funded by WSTF. Donors such as Danida, GTZ, Sida, Unicef and the World Bank are attracted to WSTF as it is transparent and accountable in its operations.

National policy advocates the annual construction of 30 public EcoSan facilities that will recycle effluent as biogas and fertiliser. There will also be 10 demonstration facilities built at public institutions every year.

The MWI and WSTF provides technical expertise to interested institutions on demand. Similarly, 500-1,000 demonstration toilets for households were set for construction every year.

Less than 20% of the urban population is connected to sewerage networks. It makes longterm investment sense to install EcoSan systems for future use rather than sewerage networks. Sewerage networks need a large volume of water to function to the required public health standards and become a health hazard if they are not properly maintained. Further, they can only be constructed in a planned, urban environment.

2.9 Investing in EcoSan to realize high returns

It has been estimated that improved sanitation such as EcoSan yields a return seven to nine times the sum invested. That is an outstanding performance by any standards. This figure denotes benefits to the environment and savings on curative health services and economic productivity.

Sanitation coupled with hygienic hand washing after visits to the toilet is one of the most cost-effective health interventions that exists. For instance, treating preventable infectious diarrhoea eats up as much as 10% of the national health budget. If the MDG target for sanitation is met, it is estimated this would add more than three billion working days a year worldwide. Numerous work days are lost as a result of illness either when a worker is sick or has to stay home to tend to a sick child. Where workplaces have substandard toilets or none at all, women lose workdays during their menstrual cycle. Improved sanitation such as EcoSan contributes to social development. Part of this is simply by bestowing dignity on those who are able to access it. No one likes searching for somewhere to defecate in the open or to queue for using a toilet that is often smelly and in disrepair.

Privacy and hygiene are particularly crucial at schools. Schools should have separate toilet facilities for teachers and students. If the schools are mixed, they should also have separate facilities for girls and boys. It is well known that girls are reluctant to attend schools if the toilet facilities are not private. This holds particularly true once they reach puberty.

More than 500,000 Kenyan girls stay at home during their menstrual cycle. Or put another way, girls attending school where the sanitation is poor miss out on 90 school days a year. Thus good sanitation increases female school enrolment. By the same token, improved sanitation slashes absenteeism and contributes to a better academic performance.

EcoSan protects the environment too. It sanitises and composts on site at no additional cost to the user. This means that neither sewage nor effluent can pollute the environment. By contrast, human waste contaminates water sources and soil not only where sanitation does not exist, but where it does exist if that sanitation is not EcoSan. In many countries around the world, an astonishing 90% of sewage is discharged untreated into rivers. Effluent from pit latrines, including VIP latrines, frequently seeps into the surrounding land.

2.10 The benefits of sanitation

Sanitation encompasses the removal, disposal and management of human waste. Improved sanitation means having consistent access to safe, hygienic and convenient toilet facilities. The basic requirements for improved sanitation systems are privacy, safety, hygiene and convenience. Some 2.5 billion people, nearly half the population of the developing world, are deprived of sanitation.

Of these, 470 million live in Africa which lags behind other continents in sanitation coverage. In Kenya, 56% of those who live in urban areas and 43% of those in rural areas have access to sanitation. Nearly 10% of all Kenyan households are connected to a sewerage system while some 50% use pit latrines. At 10%, national sanitation coverage is slightly less than half the population. This means that some 18 million people (51.4%) do not have access to a toilet.

Sanitation has been a part of our lives for thousands of years. The world's first known urban sanitation systems were constructed in the cities of the ancient Indus Valley civilization that flourished between 2600 and 1900 BCE in Pakistan's Sindh province. Homes had a room that appears to have been set aside for bathing. The waste water was flushed into covered drains that lined the major streets.

The benefits of sanitation have been substantiated by research and are clear to comprehend. Every year, hundreds of thousands of people still die needlessly because of the unhealthy living conditions caused by a lack of sanitation. In fact, so important is sanitation to our good health and longevity that British Medical Journal readers voted it as having greater value as a health intervention than penicillin or anaesthesia.

There are other advantages to sanitation. It significantly boosts school attendance and grants dignity to those who use it, particularly women and girls. Every shilling spent on sanitation saves seven shillings on curative health services and lost productivity. Currently, 200 million tonnes of human waste goes uncollected and untreated around the world. So where sanitation exists, it saves the environment from being polluted with toxic waste.

Sanitation is also a secret weapon for preserving the planet. This falls under the category of ecological sanitation. Sanitation is there to cope with the results of bodily functions that every person on this planet experiences every single day of his or her life.

Yet despite its longstanding existence and the critical part it plays in our wellbeing, no one is willing to talk about it. In today's global community of communication and openness, sanitation is one of the last great cultural taboos for the great majority of societies.This may be why the budget for sanitation trails far behind spending on either health or water even though the benefits of improved sanitation are tangible and proven. As long as sanitation is perceived to be an unspeakable topic, the politicians, policymakers, bureaucrats, development partners, community leaders, humanitarians and business executives who could make a difference to the coverage and quality of sanitation services shy away from contributing to its development

Chapter 3:

Technical Construction, Management, Operation And Maintenance Guide On Urine Diverting Dehydrating Toilets (UDDTs)

3.1 Introduction

A Urine Diverting Dehydrating Toilet (UDDT) is a toilet that operates without water and has a divider that enables the user to divert the urine away from the faeces with little effort (Tilley Elizabeth et al, 2008). The origin of UDDT is the conclusion of efforts by environmentalists,NGOs and donors to produce a toilet that not only meets personal sanitation needs, but also overcomes the challenges of local conditions without negative environmental impacts. The UDDT was invented in Africa in the 1990s.

Some users find difficulty in immediately comprehending what a UDDT entails. In their first encounter with this gadget, such users may hesitate to use it. This is exacerbated when mistakes such as dropping of faeces in the urine bowl may deter them from accepting this type of toilet. This therefore justifies the need for education and demonstration projects essential to boost user acceptance.

Fertiliser produced by a UDDT is sufficient to recover the cost of building it. This has been a greater incentive for buying into the idea than hygiene or convenience. In western Kenya, the driving force for converting to Ecosan is the benefits it brings to agriculture. The cost of building a UDDT starts from US$ 307(Ksh.23,000), with the cheapest model derived from the use of iron sheets instead of cement blocks or earth bricks.

The UDDTs are appropriate for almost every climate (Tilley, 2008). Hygienisation in the faeces chamber is realized through heating of up to 50 degrees Celsius and high pH value from the addition of alkaline material. This way, the moisture content is reduced to about 25%. UDDTs are particularly suitable for areas with the following characteristics: Low sanitation access and coverage; Unstable, shifting soils; A high incidence of waterborne disease, especially routine cholera outbreaks; High water tables and seasonal flooding; and Low agricultural yields caused by depleted soils.

3.2 Systems Description of a UDDT

3.2.1 Definition and how a UDDT works

A Urine Diversion Dehydrating Toilet is basically a collection system where human urine is separated at the source before it mixes with faeces using specially designed toilets and urinals, piping systems and storage containers. The UDDT is built such that urine is collected and drained from the front area of the toilet, while faeces fall through a large chute in the back(for details see annex 1). Depending on the collection and storage/treatment technology that follows, drying material such as lime, ash or earth should be added into the same hole after defecation.

Figure 6 : Artists impression of a UDDT

It is important that the two sections of the toilet are well separated to ensure that faeces do not fall into, and clog the urine collection area in the front section. The faecal matter is collected in a drying chamber where it is sanitized in a dry state for a minimum of six months to ensure pathogen destruction. To prevent flies, minimize odours and encourage drying, a small amount of ash, soil, or lime should be used in covering faeces after each use. This allows for thorough dehydration. The faeces also become odourless and hygienic because it decomposes anaerobically.

There are also 3-hole separating toilets that allow anal cleansing water to be separated from the urine and the faeces into a third, dedicated hole. It is important that the faeces remain separate and dry. When the toilet is cleaned with water, care should be taken to ensure that the faeces are not mixed with water. Both a pedestal and a squat slab can be used to separate urine from faeces depending on user preference.

The diverted urine that is loaded with essential plant nutrients is collected in a container and then applied hygienically as fertilizer and pesticide into the soil media of field crops. Care should be taken to ensure that no water or urine gets into the drying chamber. If this happens, extra soil, ash, lime, or sawdust should be added to help absorb the liquid. Where water is used for cleansing, an appropriate User Interface should be installed to divert and collect it separately.

To empty the chambers, a shovel, gloves and possibly a face mask (cloth) should be used to limit contact with the dried faeces. Sanitized human excreta are a good soil conditioner.

UDDTs and toilets connected to a biogas are recommended by WHO as hygienically safe recycling sanitation systems which are regarded as sustainable to basic sanitation. The concrete or porcelain toilet slab has more than one hole so that urine and faeces are separated at source.

This allows waste matter to be disposed of separately and hygienically treated in storage chambers beneath the toilet floor. There are two holes for faecal matter - one on each side of the centre hole - which can be interchanged to allow a container of faeces to decompose once it is full. The intake cover is marked USE and DON'T USE. Only the chamber in use has a handle.If the urine is not collected into a container but piped away instead, the room can be used as a bathing space. However, the outlet cover must be kept firmly closed.

A plastic pipe flushes the urine into a storage canister such as a plastic debe (Kenyan colloquial for tin). This becomes liquid fertiliser high in nutrients after being diluted with water on a 1:5 ratio. It must remain in a darkened container for a minimum of two weeks. The end product is excellent for planting tree seedlings and for horticulture because of its exceptionally high nitrogen, phosphorous and potassium content.

UDDT owners have a choice of collection methods. A container such as a plastic-lined basket needs to be emptied about every two weeks. The alternative is to use the drying chamber in its entirety. This has the advantage that collection from the chamber need be done only about twice a year. This process yields organic compost that has no faecal pathogens. It has the same look, smell and consistency of any other manure.

3.2.2 Types of a UDDT

UDDTs come in many different designs of urinals and toilets connected to a collection container via drain pipe or channels. These include; seated pedestal, squatting plate and urine diversion toilet insert. There are also standing urinals and squatting urinals to offer comfort to men and women or girls respectively. The designs are available as water flushing or waterless systems. Waterless systems collect undiluted urine thus requiring smaller piping and storage capacity, treatment and transport components.

During defecation, the faeces are dropped directly to a container placed in a separate vault/chamber (See figure 7 – top left).

Figure 7 : Different types of UDDTs

Flush systems come in different designs. There are the fully wet systems which flush both the faeces and urine (figure 8 – top right), the dry-wet systems where urine is flushed whilst faeces is not flushed (figure below – bottom left), or the dry-wet system where the faeces is flushed whilst the urine is not (figure 8 – bottom right). There is a wide range of materials to choose from for the construction of toilets and urinals. These include ceramic, concrete, fibreglass or plastic. Drainpipes and tubing's are often made of durable polyethylene plastic, while storage containers use plastic or concrete. By allmeans, metallic components ought to be avoided as they are easily corroded by urine.

3.2.3 Advantage of UDDT over VIP Latrines

A urine diverting dehydrating toilet has a permanent slab and composting capability that never needs replacement. It does not contaminate ground or well water as the urine is conveyed to a container in a chamber away from another container that the faeces is directed to in a vault at the rear of the toilet. This way, both the faeces and the urine are blocked from percolating to the ground water bodies.

UDDT continuously supplies top-grade fertiliser from urine and faeces. The use of urine and faeces as fertilizers is a long-term investment not possible in pit latrines. There is cost recovery when agricultural produce are sold to recoup money used in establishing the uddts. Consequent profit can then be used to support other livelihood needs. Owing to minimal or no use of water, especially for flushing, uddt does not deplete water supplies. It reduces wastage by 10-30% of original volume. In addition, UDDTs are hygienic and free from odours and flies.

On the contrary, vip latrines which cost upto US$ 10. 467 Per unit, and often-about 6m deep, easily cave in and collapse from heavy rains and unstable soils. This reduces their life to only two year for an average family or school. They also create avoidable health hazards when waste matter seeps into groundwater and shallow wells.

While a single vault UDDT requires a small space for construction, the double vault uddt has the disadvantage of requiring an increased surface area for construction of toilet. In addition, it is prone to smell if too much liquid (urine, anal cleansing water, etc.) Enters the processing compartment. However, double vault uddt is suitable for hard rock soil areas, high ground water levels and areas prone to flooding. The use of a double vault UDDT does not culminate in contamination of groundwater sources due to contained processing of human faeces.

3.3. Design of a UDDT in Kenya

3.3.1 Introduction

The UDDT is simple to design and build using such materials as concrete and wire mesh or plastic. The UDDT design can be altered to suit the needs of specific populations (i.e. smaller for children, people who prefer to squat, etc.) They are appropriate for almost every climate.

The UDDT is simple technology that can be designed and altered to suit the needs of specific populations. For instance, it can be made smaller for children, or designed to suit the defecation posture. Some people prefer to squat while others are comfortable in sitting positions.

The Urine Diverting Dehydrating Toilet can be designed as a single of double vault system. In a Single Vault UDDT, faeces are collected in one vault beneath the toilet seat or squatting pan where they are dried. Whilst in a Double Vault UDDT, faeces are collected in two vaults beneath the toilet seat or squatting pan ready for drying. The urine is diverted by a funnel or specially designed squatting pan/toilet seat into a urine container beneath the toilet. In a double vault UDDT system, vaults are used alternately with only one vault in use at any time until it almost full. When it is full the defecation hole is closed and the pan transferred to the second vault. Depending on the Collection and Storage/Treatment technology that follows, drying material such as lime, ash or earth should be added into the same hole after defecation.

3.3.2 Current design and costs of UDDs in Kenya

The Foundation

The foundation is dug depending on the soil type foundation in order to get a stable ground.Basic aim is to remove the loose underlying soil type foundation in order to get a stable ground.Basic aim is to remove the loose underlying soil. The area to be excavated for providing a slab foundation has to exceed the projected outer dimension of the superstructure of the toilet by 10 cm on all sides. Excavation has to be done to a depth of approximately 15 cm. Compaction follows after excavation by use of heavy compaction block. The depth of foundation is to be determined on site based on the type ranging from 300 mm - 450 mm. get a stable ground.Basic aim is to remove the loose underlying soil.

The area to be excavated for providing a slab foundation has to exceed the projected outer dimension of the superstructure of toilet by 10 cm on all sides. Excavation has to be done to a depth of approximately 15 cm. Compaction follows after excavation by use of heavy compaction block. The depth of foundation is to be determined on site based on the type ranging from 300 mm-450 mm.

The excavated area is filled with ballast, stones and on top plain cement concrete slab is cast in-situ. The size of the slab must exceed the projected outer dimension of the superstructure of the toilet by at least 5 cm on all sides. The height of the PCC slab is set with 10 cm over surrounding ground and thus prevents stagnant water to flows into the chambers. Material costs are US$ 60 (Ksh 4,525). Added by US$ 10 (Ksh 750) for labour this sums up to US$ 70 (Ksh 5,275).

Toilet slab

The slab is made of cement, ballast, sand and twisted iron bars. Shuttering timber is fixed in the walls during time of construction. Shuttering timber can be used for last four times. Thus costs are depreciated over four UDDTs. The mortar is then filled on top of the shuttering timber.

The slab is fixed atop the walls and is about 80 mm thick. A hole for the ventilation pipe is made by an old pipe with the some diameter as the pipe later used. Costs are dominated by the squatting pan, cement and urinal. Material costs sum up to US$ 117.2 (Ksh 8,789) and including labour it is US$ 127.2 (Ksh 9,539).

Sub-structure slab construction

Reinforcement during the casting of slab is not so necessary except in areas with flooding in black cotton soils and at sites with possible landslides or mudslides. The structural concrete should be of Class 20/20 with a ratio of 1:2:4 (cement: sand: ballast) and maximum thickness of 100 mm. Hardcore can be used in case the foundation is deep. Ballast size should be from sizes ¼ to ¾ inches. Minimum concrete cover is 50 mm for the foundation. The stairs to the toilet should conform with the standard specifications of at least 150 mm height from step to step and at the recommended gradient of 3:4. Steel rails are constructed to assist the old and weak family members to climb the stairs to the facility where necessary. Back-filling of the stair ramp with soil can be done at household level to reduce the cost and also in areas with no hardcore.

Sub-structure

Every toilet has two chambers for storage of wastes. They are interchanged for use at intervals and are both connected to a vent pipe to expel odour.

Locally available materials such as bricks of 225 mm x 150 mm x 100 mm can be used to build the wall of the sub structure using a mortar ratio of 1:6 (cement: sand). Plastering within the chambers has to be done extremely well to make them water tight. In order to allow easy removal of the compost, a minimum chamber height of 750 mm is used. Every chamber floor should have a minor slope towards the back panel of 1-5%. Sub-structure walling should be 150 mm with a maximum thickness of 20mm for the inner plaster. Only keying and not plastering of the outside walls should be done to reduce on costs. The concrete cover should have a minimum of 20 mm for the slab.

Super-structure construction

The structural concrete slab should be of class 20/20. It is mandatory that reinforcements with proper force balancing where shorter steel is laid on longer ones, should be done using Y8 steel . The slab is casted in-situ with the squatting pan right at the centre of the slab. Shuttering is done with 6”x1” wood.

Slab thickness of 80 mm is used to support the super structure. Wall thickness of 170mm, including a 20 mm plaster layer, is build with mortar of 1:6 mixing ratio. Finally, plastering is done on the inside while keying is done on the outside to attain a good finish.

It is advisable to use locally available materials for making ventilations that allow sufficient light and air in line with the design considerations. A wooden door with frame of size 1,800 mm x 800 mm is fixed. All super-structure walling is thereafter reinforced with hoop iron at every three courses of bricks.

Faeces chambers

Faeces chambers are made of burned bricks and have a volume of approximately 0,56 m^3. The length, width and height are 750 x 1100 x 750 mm. Chambers are plastered, some even from the inside. Plain black painted iron sheets are fixed on a wooden frame. The back doors are painted black and are fixed in a certain angle to the ground in order to enhance solar radiation. Back doors should be secured against theft. Material costs are US$ 85(Ksh 6,350) and labour is US$10(Ksh 750). In total this is US$ 95(Ksh 7,100)

Water tank slab

For the construction of the water tank slab, cement, building sand, twisted Iron bars and ballast and shuttering timber is needed. Construction details is highlighted in The total cost is UD$ 33 (Ksh 2,500), containing US$ 23 (Ksh 1,750) for materials and US$ 10 (Ksh 750) for labour.

Water tank slab

Same design as for faeces chambers. Total cost is US$ 51 (Ksh 3,830) including US$ 41 (Ksh 3,080) for material and US$ 10 (Ksh 750) for labour. This cost does not include costs for jerry cans.

Steps

Steps are direct in front of the door. The ratio of height to step-depth should be 200 mm x 300 mm. With a height of approximately. 800 mm, this results in four steps. This makes it easy to climb the toilet, even for children. Steps are masonry and plastered with cement from the outside. Ballast is used to reduce cement costs. For disabled people this is not appropriate and alternatives should be designed. Cost, including US$ 10 (Ksh 750) for labour, sums up to US$ 29 (Ksh 2,175) in total.

Walls (Including plastering)

Steps are direct in front of the door. The ratio of height to step-depth should be 200 mm x 300 mm. The superstructure, which is 2200 to 2100 mm in height, is made from 9” x 6” x 8” burned bricks. The walls are plastered from the inside and outside. The inside is consequently painted. Various small open gabs in the back wall and a bigger gab over the door provide light and ventilation inside the cubicle. Cost for material is us$ 95.6 (Ksh 7,174) and a quite a bit of labour (5 days skilled and unskilled) sums up to us$ 145.6 (Ksh 10,924).

Roofing

Sub-structure for roofing is made out of roofing timber (4” x 2”). Corrugated iron sheets are then nailed on the sub-structure. The roof is surrounded by a facia board (6” x1”). Slope of the roof is approximately. 10%. Cost for material is US$ 51.6 (Ksh 3,868) and with additional US$ 10 (Ksh 750) for labour this sums up to US$61.6 (Ksh 4.618) in total.

Water harvesting devices

Water harvesting devices contain one steel gutter of 1500 mm which is fixed beneath the corrugated iron sheets on the back site. From there, water is diverted through three down pipes into a 100 litre water tank. The tank has a tap and should be fixed to the walls for security because it gets stolen easily. Material cost is US$ 20.9 (Ksh 1,570) and with US$ 6.7 (Ksh 500) for labour this sums to US$ 27.6 (Ksh 2,070) in total.

General fittings

The general fittings contain wooden door/frame, wire nails, tower bolts, binding wire, turpentine and door hinges.

A 2 inch (50 mm) PVC class B waste pipes is used for urine drainage which is connected to the 20 litre storage containers. Heavy gauge flexible PVC can also be used. Material cost is US$ 33.4 (Ksh 2.505) plus US$ 6.7 (Ksh 500) this sums to US$ 40.1 (Ksh 3,005).

Roofing

The roofing is done in such away as to allow for partial heating from the sun to the panel behind the toilet. This facilitates drying of the compost in the chamber.

Storage Chamber closing panels

This must be painted black to absorb radiant heat from the sun for drying the compost. They must also fit well on the chambers to avoid spillage of the waste to the environment.

Summarized cost data of a Double Vault UDDT

Current total costs of a one door double vault UDDT is US$ 680 (Ksh 51,000) per unit. The ratio of material to labour cost is 80% to 20%. US$ 54.7 (Ksh 41,000 compared to US$ 133.3 (Ksh 10,000).

European Union contribution about 80% whereas owner contribution of about 20% results mostly from building sand US$ 70.3 (Ksh 5,270), labour US$ 40 (Ksh 3,000), hardcore US$ 22.7 (Ksh 1,700) and poles for shuttering and scaffolding US$ 1,92(Ksh 144 each). Highest material costs are born by cement {US$ 128 (Ksh 9,600)– 23 %} of material cost), building sand {US$ 70.3 (Ksh 5,270)– 13 %}, burned bricks {US$ 54.4 (Ksh 4,080)– 10%} and the squatting pan {US$ 46.7 (Ksh 3,500)– 9%}. Highest labour costs are born by the walls with five days skilled US$ 33.3 (Ksh 2,500) and unskilled labour US$ 16.7 (Ksh 1,250).

Cost of toilet slab is dominated by costs for the squatting pan US$ 46.7 (Ksh 3500) produced by the Kentainer. Alternatively, the squatting pan could also be modulated from mortar and included in the slab as pictures shown in figure 8:

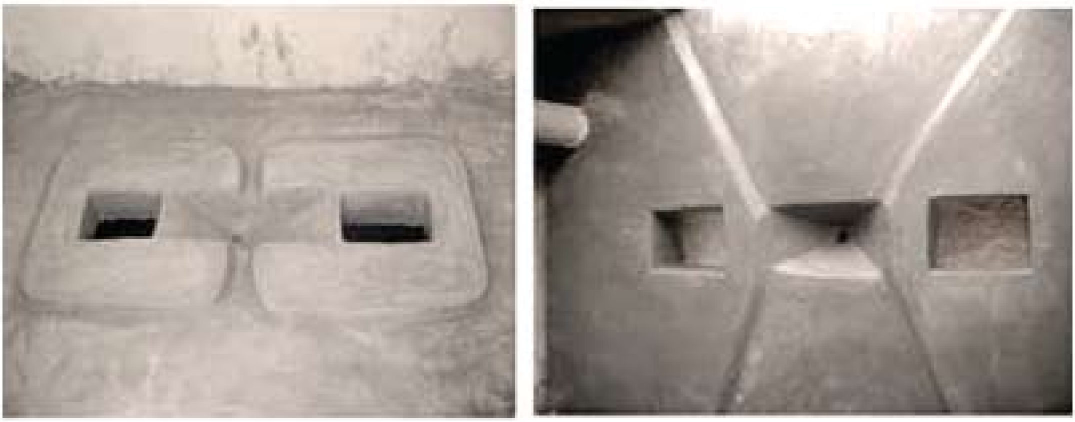


Figure 8: Modulated squatting pan in Mumias (Left picture) Modulated squatting pan in Kericho Unilever estate (Right picture)

Figure 9: Squating pan manufactured by Kentainers

A simpler way of installing this solid hand washing device might be the so called tippy tap. This is a simple device that allows people to wash hands with very little water. It also allows the user to rub his or her hands together while water runs over them. It is made of materials that are available at no cost in most places and can be put wherever people need to wash their hands: like near the cooking stove, at the toilet, or in rural food stores. As there is no water slab tank, water harvesting and urine chamber is constructed, this saves about US$ 89.3 (Ksh 6,700). Cost could be reduce up to US$ 333.6 (Ksh 25,023).

Although this is the cheapest option, it is doubtful that EU financed toilets should look like this. Hence, it is questionable how durable this superstructure is. But however this option is much more affordable and therefore worth while to consider.

3.4 Operation & Maintenance

A UDDT is slightly more difficult to keep clean compared to other toilets because of both the lack of water and the need to separate the solid faeces and liquid urine. For cleaning, a damp cloth may be used to wipe down the seat and the inner bowls. Some toilets are easily removable and can be cleaned more thoroughly. No design will work for everyone and therefore, some users may have difficulty separating both streams perfectly which may result in extra cleaning and maintenance.

3.5 Use of UDDTs for agricultural production at household level.

3.5.1 Using urine as a fertilizer

Urine is rich in nitrogen and thus has similar fertilizing effect as that of a nitrogenous fertilizer (Vinnerås et.al, 2003). If collected and stored in a correct manner, it can be used in fertilizing crops and vegetables that have high demand for nitrogen. The amount of urine to be applied should be based on the amount of nitrogen demanded or required by a particular crop. This is often already documented especially in respect to chemical fertilizers. If this is not known, then a rule of thumb can be used.

Figure 10: Container for storing urine

Generally, one litre of urine has a concentration of 3 – 7 grams of nitrogen for non-flushed UDDTs. However, if flushed UDDTs are used, then the concentration reduces to a range of 1.5 – 3.5 grams per litre of urine. Alternatively, urine collected from one person every day can be applied on a square metre of land. The maximum dosage is five times this amount before toxic levels take effect. Urine should be applied only once during the cultivation period.

In order to reap maximum benefit from urine as a fertilizer, it should be applied just prior to sowing to between two-thirds and three-quarters of the period between sowing and harvest time. Plant roots, especially those of seedlings, are sensitive to the toxic effects of urine and therefore should not be soaked in urine.

3.5.2 Using faeces as a fertilizer

Unlike urine with high nutrient content, faeces has considerably lower levels of nutrients, especially nitrogen. Instead, it contains organic matter that improves soil fertility through release of phosphorus and potassium. In addition, faeces enhance the buffering capacity of the soil, especially when mixed with ash. These effects are more pronounced in soils with low pH.

Faeces should be applied and mixed in the soil prior to cultivation. The faeces should not be applied too deep, away from the reach of roots of the crops. Rather, the application should be close to the roots to capitalize on uptake of nutrients from faeces. Use current recommendations of phosphorus application to determine the amount of faeces to be applied. Although faeces do not have toxic effects as compared to urine, care should be taken not to mix too much ash. In order to safeguard on hygiene, faeces should be sanitized before application. The faeces should also be covered after application.

3.6 VIP Latrine

Despite their simplicity, well-designed single vips can be completely smell free, and be more pleasant to use than some other water-based technologies. Flies that hatch in the pit are attracted to the light at the top of the ventilation pipe. When they fly towards the light and try to escape, they are trapped by the fly-screen and die. The ventilation also allows odours to escape and minimizes the attraction for flies.

Treatment processes in the single vip (aerobic, anaerobic, dehydration, composting or otherwise) are limited, and therefore, pathogen reduction and organic degradation is not significant. However, since the excreta are contained, pathogen transmission to the user is limited as long as the pits are not linked to any water aquifers and spoil local wells. This technology is a significant improvement over single pits or open defecation.

In urban or dense areas it is often difficult to empty and/or have insufficient space for infiltration. This technology is only appropriate for areas where groundwater table is low and should be located in an area with a good breeze. They are not suited for rocky or compacted soils (that are difficult to dig) or for areas that flood frequently. Emptying costs or costs for new pits might be significant compared to capital costs.

Assumption made are that volume of the pit {sludge accumulation about 0.05 m^3 + 0.01 m^3 (paper) + 0.02 m^3 (additional material) 0.08 m^3/person/yr, 80% pit filling rate)} results in filling time of 4.5 Years when 20 people use the toilet. Costs for digging the pit are assumed at US$ 4 (KSh 300) per feet. The first meter of the pit is lined with burned bricks.

Chapter 4:

Technical Construction, Management, Operation And Maintenance Guide On Bio Digester-Baffle Reactor Systems. (BDBR)

4.1 Introduction

An Anaerobic Baffle reactor is an improved septic tank with a series of baffles under which the wastewater is forced to flow. This increases the contact time with the active sludge resulting in improved treatment with BOD reduction of up to 90%, which is far superior to that of a conventional septic tank. Accumulated sludge is desludged every 2 to 3 years. Critical design parameters include a hydraulic retention time (HRT) of 48 to 72 hours, upflow velocity of the wastewater less than 0.6 m/h and the number of up-flow chambers.

On the other hand, an Anaerobic Biogas Digester and Baffled Reactor (ABR) hybrid system is an improved system being piloted in Kenya for partial wastewater treatment. These hybrid systems produce: digested slurry for soil amendment; water for non-potable uses (flushing toilets and irrigation); and biogas for energy. The biogas is a mixture of methane, carbon dioxide and other trace gasses that are easily converted to electricity, light and heat.

4.2 Basic Principles of Anaerobic Fermentation

The bio-digesters are used under anaerobic conditions to degrade organic matter that includes carbohydrates, proteins and fats into Methane (CH_4 65%), Carbon dioxide (CO_2 35%) and Water (H_20). The process of anaerobic digestion is done by micro-organisms represented by hydrolytic, fermentative, acetogenic and methanogic bacteria. This process sequentially starts with hydrolysis, acid production, acetate production and ends with the methane stage. The organic material is converted into sludge, biogas while pathogenic germs are simultaneously eliminated. In the hydrolysis stage, polysaccharides, proteins and fats are digested to saccharin and amino acids. During the acid production stage, saccharin and amino acids are digested to alcohols, fatty acids, carbon dioxide (CO_2) and hydrogen (H_2). In the acetate stage on the other hand, alcohols, fatty acids, CO_2, H_2 are converted to acetic acid, CH_3COOH). Finally at the methane stage, acetate acid is converted to biogas that constitutes methane (CH_4) and CO_2 . The individual steps of digestion have different demands for their optimum conditions as shown in table 2 :

Table 2: demand for bio digester optimum conditions

Parameter	Hydrolysis	Methanism
Time for regenerating speed of growth	20-90 hours	5-15 days
	25-35^{o}C	Psychrophilic: 20-30^{o}C
		Mesophilic: 32-42^{o}C
		Thermophilic: 50-58^{o}C
PH	5.2-6.3	6.7-7.5
C:N ratio	Oct-45	20-30

$$RT(d) = \frac{Effective\ digestor\ volume.(m^3)\ in\ days}{Daily\ substrate.\inf lows.(m3\ /d)}$$

$$= \frac{Mass\ of\ solids\ in\ the\ system.(Kg)}{Solids\ accumulation.(Kg/d)}$$

The necessary retention time depends on the temperature of the process and the type of substrate. The following retention times are distinguished for various temperatures: Psychrophilic digestion 10-25 ^{o}C, retention time 30 to 60 days Mesophilic digestion 25-40 ^{o}C, retention time around 20 days. Thermophilic digestion 40-60 ^{o}C, retention time 8 days or less.

For sewage water, the retention time should be 1 to 2 days since the faecal matter is digested within this short time. The degree of digestion increases with the retention time for animal dungs and other stuff rich in cellulose. The longer the retention time, the higher the digestion rate of the material fed into the plant with a lot of cellulose fibre. The human waste is however digested within 2 days. Simple biogas plants in tropical regions operate within an ambient temperature range of between 15 ^{o}C to 25 ^{o}C and a retention time between 30 to 60 days for animal dung or plant parts. For sewage water retention time, 1 to 2 days is sufficient.

$$CR = \frac{Organic.dry.matter.(Kg).(Kg.ODM/m3)}{Effective.digestor.volume.(m3)}$$

Table 3: The recommended maximum digester charge ratio

Temperature of digestion(^oC)	Change ratio CR (Kg ODM/m^3)
25	3-Feb
35	4-Mar
45	5-Apr
55	6-May

Biogas is a mixture of methane and carbon dioxide as described above. It has a density of 1.2 kg/ m^3 and a caloric value of 6 KWh/m^3 .The amount of biogas and its percentage of methane is basically depended on the type and composition of the fed substrate, the digester volume and the temperature.

4.3 Design Procedure of fixed dome biogas digesters

The inflow is forced through the sludge which settles at the base of the tanks to come into contact with the biologically active bacteria. Baffled reactors have at least six chambers. The treatment capacity increases with the number of chambers. This system requires no electricity. The wastewater constituents are broken down anaerobically. The treatment capacity lies between 70 to 90% BOD decomposition. The space required for a baffled reactor for 8 persons is less than 5 m^2. Calculating the size of the reactor is based on the maximum up-flow velocity of approximately 1.4 m/hr and retention time of the waste in the reactor of 40 hours.

Step 1

Conduct baseline survey of the project area (public place, institution or informal settlement)

- GPS mapping and levelling (location, topography & hydrogeology of the location, climate, rainfall, farming systems, soils)
- Data collection (Populations, water use & availability, peak and average black, grey and brown water flows, daily solid faecal and other animal dung production, waste water quality, existing sanitation system, level of awareness on proper sanitation and hygiene, energy requirements

and existing sources of energy.
- Site selection (close to gas use points, low ground water table, far from big trees and other buildings, etc).
- Establishment of site layout plan with existing and proposed sanitation systems.

Step 2

Conducting the necessary trainings for the beneficiaries
- Basics of biogas technology
- Use of biogas and slurry
- Safety measures
- Operation and maintenance
- Monitoring and data collection during the operation

Step 3

Choosing the design parameters for the anaerobic digestion process and doing the design work (See Annex 1)
- Start by identifying the source(s) of wastewater constituents which includes grey water from the kitchen and bathrooms, urine and faeces
- In parameters for design, determine the following: total population served by sanitation infrastructure; amount of urine produced; amount of water used in the kitchen, water used in hand and toilet washing, toilet flushing and finally amount of water used in laundering and showering.

Determine daily sludge flow by computing the BOD reductions in urine, faecal matter, toilet flushing and showering. Biochemical oxygen demand (BOD) is the main evaluation parameter for the organic contamination of wastewater. BOD5(20) describes the oxygen required over 5 days at a temperature of 20^{o}C to oxidise the organic constituents of sewage.
- Calculate the chemical oxygen demand (COD) fluxes; i.e. COD coming in and out of the system, and COD reduction. Chemical Oxygen demand (COD) is the amount of oxygen required to oxidise all of the oxidisable constituents including those which are not biologically degradable. Volatile Solids (VS) are presumed to be organic matter (proteins, carbohydrates and fats).
- Calculate the volume of fixed dome digester by computing the volumes of liquid, gas, sludge and scum as shown in the formula and table 4 below:

$$Effective.digestor.volume.(m^3) = \frac{Total.Organic.Dry.Matter(ODMkg)}{Digester.Discharge.Ratio(kgODM/m3))}$$

Table 4: The charge ratio for various temperatures.

Temperature of digestion(^{o}C)	Change ratio CR (Kg ODM/m^3)
25	2-3
35	3-4
45	4-5
55	5-6

- For the fixed dome digester calculation; compute the height and radius of the sphere sector, height and radius of the cylinder and finally, volume of the cone.
- Work out the chamber expansion by computing: the estimated head losses in the gas pipe; total gas pressure required; height and radius of the sector and radius of the cylinder.
- Compute the level of the P-line, or lowest slurry level.
- In the energy cost calculation, determine the following: Calorific value of Biogas; Total gas production; Equivalent diesel and LPG use; Cost saving on Diesel & LPG; Annual saving on Diesel & LPG.
- Calculation for anaerobic baffled reactor entails the following: Maximum up-flow.
- Determine the folloeing: velocity; Minimum chambers required; Length of each chamber; Depth of each chamber at the outlet; Hourly distribution of peak flow; Maximum peak flow; Required chamber area; Calculated chamber width; Chosen chamber Width; Actual up-flow velocity; BOD reduction; BOD in from digester; BOD out from anaerobic baffled reactor; Biogas Production
- Consult with the National Environmental Management Authority on the following: BOD allowed to be discharged to open waters surfaces; BOD allowed for irrigation and BOD allowed to be discharged to municipal sewer.
- Establish the mean temperature of the area in ^{o}C for the operation of the digester.
- Chose the expected solid retention (hydraulic retention time-RT) based on the temperature, 1 kg organic dry matter and required gas production from a standard monogram. For sewage water chose retention time between 1 to 2 days.
- Consult with the National Environmental Management Authority on the following: BOD allowed to be discharged to open waters surfaces; BOD allowed for irrigation and BOD allowed to be discharged to municipal sewer.
- Establish the mean temperature of the area in ^{o}C for the operation of the digester.

- Chose the expected solid retention (hydraulic retention time-RT) based on the temperature, 1 kg organic dry matter and required gas production from a standard monogram. For sewage water chose retention time between 1 to 2 days.

Step 4

Site setting and excavation of digester hole based on the design:

- Locate the position of outlet tank, chambers and centre of the digester
- Establish the reference line with a peg at the centre of the digester. This guides themason and the supervisor throughout the whole construction
- Excavation as per design drawings for the digester hole and the base cone

Step 5

Construction of the digester:

- The slab with the shape of cone
- The vertical cylindrical wall
- Reinforcements where necessary
- Backfilling during the construction
- Inlet pipes
- Expansion chamber steps/pipe
- The dome
- The expansion chamber manholes
- Feeding chamber
- Lid casting
- Outside plastering
- Inside plastering
- Soil levelling

Materials to be used:

- High quality Portland cement (fresh, stored in a dry place and protected from dampness)
- Sand (clean river sand, course and granular for concreting and fine sand for plastering work)
- Ballast is a course aggregate for concrete. Must be clean and none oily.
- Water-must be clean
- Fire bricks or cement , sand, ballast chipping brick (ratio C:S:G is 1:3:3)
- Clean stones

Proportion of building materials:

- First class concrete for heavy duty floors, tanks, basins, etc
- The slab: 1 cement, 3 sand, 3-6 ballast
- The top coat: 1 cement, 3 parts medium and fine sand
- Second class concrete for any coursing, cistern, steps, reinforced floors, etc
- Slab: 1 cement, 3 parts medium and fine sand
- Weakest class concrete for walls, light duty floors (dwellings)
- The slab: 1 cement, 4 parts medium and fine sand

Foundation

The ring foundation carries the building and the respective earth loads (wet and dry). The conical shape bottom slab carries the sludge. Is more stable than a flat bottom and provides more volume. Casting of the foundation should be done early in the day so as to allow sufficient time to place the first layer of brickwork later on the fresh concrete on the same day.

The centre GI pipe is fixed in the centre of the excavation before casting of the slab. This GI pipe should be exactly vertical. The concrete should be mixed in the ratio 1:3:4 (cement: sand: ballast). Concrete has to be mixed using concrete mixing machines. All earth bases and forms should be wetted just enough to prevent the absorption of the water from the concrete and not so much that there be excess water content of the mixture. The concrete must be cured for at least 10 days and upto 21 days depending on the prevailing weather.

The cylindrical Masonry Wall

The digester wall is constructed of either blocks or stone masonry depending on the local availability of these materials. The wall thickness is 15 cm. Masonry mortar mixture used is 1:11/2:5 (cement: lime: sand.) The construction of the vertical wall starts at the concrete slab. To construct the cylindrical wall, a guide square fixed at the centre GI pipe is used which keeps the radius constant. After 3 to 4 layers of blocks, backfilling and compacting should be done so that the completed part is properly reinforced by the soil.

On sites with high groundwater level the cylindrical wall must be plastered properly also from the outside before backfilling. After that the space for the outlet steps is dug out and the construction of the vertical walls proceeds incorporating the outlet steps. Completion of the vertical wall construction should include installing of the inlet pipe (at a slope of $45^{o}C$) taking into consideration the location of the inlet mixing chamber.

Backfilling should be done until the level of the ring beam. The interior part of the digester wall has to be plastered with water proof cement. Mixture 1:5(cement: sand). Before application, the surface of the wall should be cleaned and moistened and the plaster is applied in one coat of about 2 cm. The plaster is applied to ensure that the structure is firm and water tight.

The Brickwork of spherical Wall

A square is fixed on the central GI pipe according the design to create an absolute half bowl shape. The radius square is controlled during the dome construction, fastening and correct distance from the guide pipe. Good quality bricks are to be used. The bricks are soaked in water before being laid into 1 cm mortar bed. The masonry mortar should be 1 part cement, ½ lime and 5 parts sand.

The mortar should have the lime to make it more workable and more water tight. Use gauge boxes or buckets to measure the volumes for mixing the mortar. The outside of the dome should be plastered before covering with the earth. The mortar used should be 1:4 (cement: sand). The plaster has to be left overnight to dry before backfilling is done. The inside plastering of the dome is done in seven courses to ensure the gas tightness of the dome:

- layer cement-water brushing
- layer of 1cm cement plaster, ratio 1:4
- layer cement-water brushing
- layer 1 cm cement plaster with water proof compound (1cement+4 sand+WP)
- layer cement-water brushing with water proof compound
- layer cement plaster with water proof compound (1 cement+3 sand +WP)
- Layer cement-water finish with water proof compound

The lids

The lid is sealed by clay, which is kept by a water bath above. The clay is dried and grained before being mixed with water into putty like paste. It is then applied by hand approximately in 3 cm thick layer. The lid is placed in the clay bending and rammed in.

4.4 Anaerobic Baffled Reactor in parallel with a dome digester

4.4.1 General

Anaerobic baffled reactor (ABR) consists of several chambers for settling and digestion. The inflow is forced through the sludge which settles at the base of the tanks to come into contact with the biologically active bacteria. Baffled reactors have at least six chambers. The treatment capacity increases with the number of chambers. This system requires no electricity. The wastewater constituents are broken down anaerobically. The treatment capacity lies between 70 to 90% BOD decomposition. The space required for a baffled reactor for 8 persons is less than 5 m^2. Clearing of the sludge

4.4.2 Design Steps

- Calculating the size of the reactor is based on the maximum up-flow velocity of approximately 1.4 m/h and retention time of the waste in the reactor of 40h
- Calculate the daily average waste water flow(m^3/d)
- Find out the time of most waste water flow in hours(hr), i.e. peak hours
- Calculate max peak flow per hour(m3/hr)
- Calculate BOD inflow (mg/l)
- Calculate COD inflow (mg/l). Can be estimated as 2 times the inflow BOD
- Find the lowest expected digester temperature
- Chose the de-sludging interval (normally 18 months)
- Chose HRT in settler(normally 1 to 2 days)
- COD and BOD removal in digester (35 %)
- BOD/COD removal in the anaerobic baffled reactor (90%)
- Chose max upflow velocity(1.0-1.4m/hr) for the baffled reactor
- Chose minimum of 6 chambers
- Chose depth at the outlet of 1.50 m for each chamber
- Chose the length of each chamber of 1m
- Calculate the area of single upflow chamber m^2(max peak flow/ max upflow velocity)
- Calculate the width of chambers in m (area of single chamber / length of single chamber). Round to a one significant figure which is easy to construct
- Calculate the actual upflow velocity m/h(max peak flow/length of single chamber/actual width of single chamber)
- 350 liters of methane is produced from each kg COD removed
- Calculate biogas produced m3/d (COD reduction x daily average flow x 0.35/1000/0.7 x 0.5. It is assumed that 70% is available CH_4 and 50% is dissolved.

Biogas and its formation

Biogas is a natural by-product formed when organic materials are degraded by bacteria in the absence of air. (Anaerobic degradation). Its major constituents includes: methane (CH_4) which occupies 40 -70% by volume; carbon dioxide (CO_2)

occupying 30 -60%; hydrogen (H_2): 0 -1%; hydrogen sulfide (H_2S): 0 -3%; and other gases occupying 1 -5%. Calorific value of biogas is about 6 kWh/m^3 where one KL of Biogas = 0.5 liters of Diesel or 0.4 kg of LPG. Biogas undergoes three processes i.e. hydrolysis and fermentation, acidification and methane formation.

Hydrolysis and fermentation

In the first step (hydrolisis), the organic matter is enzymolyzed externally by extracellular enzymes (cellulase, amylase, protease and lipase) of microorganisms. Bacteria decompose the long chains of the complex carbohydrates, proteins and lipids into shorter parts. For example, polysaccharides are converted into monosaccharides. Proteins are split into peptides and amino acids.

Acidification

Acid-producing bacteria, involved in the second step, convert the intermediates of fermenting bacteria into acetic acid (CH_3COOH), hydrogen (H_2) and carbon dioxide (CO_2). These bacteria are facultativelyanaerobic and can grow under acid

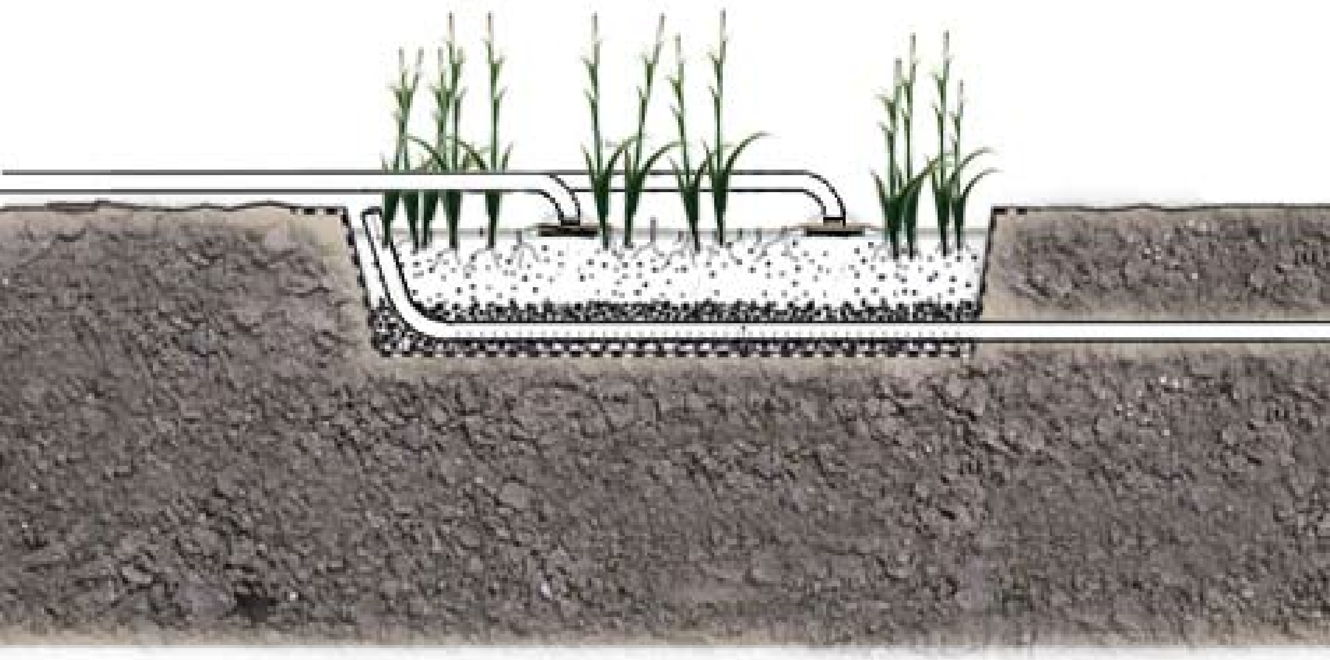
conditions. To produce acetic acid, they need oxygen and carbon. For this, they use the oxygen solved in the solution or bound oxygen. Hereby, the acid- producing bacteria create an anaerobic condition, which is essential for the methane producing microorganisms. Moreover, they reduce the compounds with a low molecular weight into alcohols, organic acids, amino acids, carbon dioxide, hydrogen sulphideand traces of methane.

Methane formation

Methane-producing bacteria, involved in the third step, decompose compounds with a low molecular weight. For example, they utilize hydrogen, carbon dioxide and acetic acid to form methane and carbon dioxide. Under natural conditions, methane producing microorganisms occur to the extent that anaerobic conditions are provided, e.g. under water (for exemple marine sediments), in ruminant stomachesand in marshes. They are obligatory anaerobic and very sensitive to environmental changes.

Chapter 5:

Other EcoSan Technologies



5.1 The Fossa Alterna

5.1.1 Introduction

The Fossa Alterna is an alternating, waterless (dry) double pit technology best suited for household use but also applicable at neighbourhood level. When compared to the Double VIP which is just designed to collect, store and partially treat excreta, the Fossa Alterna on the other hand is designed to produce EcoHumus.

It is dug to a maximum depth of 1.5 m and has to be constantly filled with soil after every use. Depending on the size of the pit and the number of people using it, a Fossa Alterna pit would fill within a period of one to two years. By the time the first pit is full, it will start degrading during the period of time, often one year, when the second pit is filling. The stuff degraded in this full pit is a dry, earth-like concoction that can easily be removed by hand.

The 1.5 m deep Fossa Alterna pits though shallow, provide more than enough space to annually cater for a family of six. To optimize the space, the material that builds up at the centre of the pit should periodically be pushed to the sides. This material can be reused. Caution should be taken not to put garbage into the pit as this will reduce the quality of the material recovered, or even make it unusable (see figure 11).

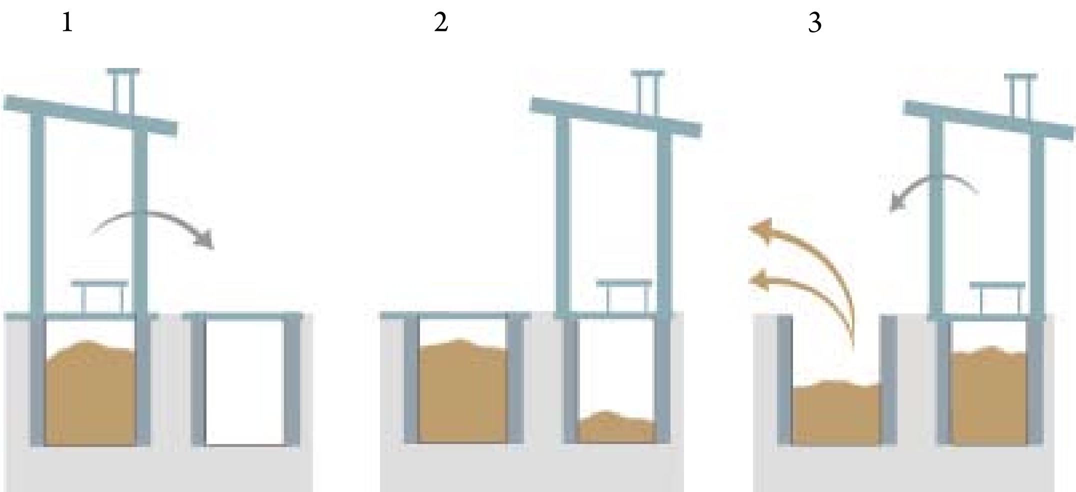


Figure 11: The Fossa Alterna showing its sequencial use

Since the Fossa Alterna pits are shallower whilst the addition of soil makes their material less compact, it is a lot easier to empty than emptying other pits. In addition, the material removed is not disgusting and presents a reduced risk of contamination.

5.1.2 Suitability of the technology

The Fossa Alterna which is best adapted to water scarce environments is most suitable for rural and peri-urban areas, especially areas with poor soils that could benefit from the composted humic material as a soil amendment. It is however not suited to rocky or compacted soils, or areas prone to flooding. However, it is not appropriate for greywater as the pit is shallow and the conditions must remain aerobic for degradation. A Urine Diversion Dehydration Toilet can be used with the Fossa Alterna, but only when the soil is unable to adequately absorb the urine or when urine is highly valued for application.

The Fossa Alterna technology works properly when the two pits are used sequentially rather than concurrently. Therefore, an adequate cover for the out of service pit is required.

5.1.3 Maintenance

After defecation and not urination, soil, ash, and/or leaves should be added to the pit. The soil and leaves contribute in the introduction of a variety of organisms such as worms, fungi and bacteria. These organisms help in the process of degradation. In addition, the pore space is increased, allowing for anaerobic conditions. On the other hand, the ash helps to control flies, reduce odours and make the mix somewhat more alkaline.

Although the Fossa Alterna could be used for urine, water should not be indiscriminately added, unless for small amounts of anal cleansing. Water has the disadvantage of facilitating the development of vectors and pathogens whilst also filling the pore-spaces and depriving aerobic bacteria of the crucial oxygen required for degradation. Bulking material used to constantly cover the excreta, helps in reducing the smells. This is further enhanced by the addition of a ventilation pipe.

In summary, the following maintanance practices should be followed;

- Put a layer of leaves into the bottom of the first pit.

- Add more leaves periodically to increase the porosity and oxygen availability.
- After every defecation, add a small amount of soil or ash.
- Do not add soil to the pit following urination to lengthen its filling time.
- Occasionally, push the heap of material beneath the toilet hole to the sides of the pit for an even distribution.
- Depending on the dimensions of the pits, empty materials every year.

Advantages

Locally available materials can be used for building and repairs

- Virtually unlimited life due to double pits used alternately
- Easier excavation of humus
- Stored faecal material can be used as a soil conditioner
- There is significant reduction flies, odours and pathogens
- Constant source of water is not required
- The technology is suitable for all types of users i.e. sitters, squatters, washers and wipers
- Low capital and operating costs if self-emptied, depending on materials
- Small land area required

Disadvantages

- The technology requires constant sourcing of soil, ash, leaves, etc. for covering
- Garbage may ruin reuse opportunities of compost/EcoHumus

5.2 Anaerobic Filter

An Anaerobic Filter is a fixed-bed biological reactor with a sedimentation or septic tank and one or more filter tanks. The filter material commonly used consists of gravel, crushed rocks, cinder, or specially formed plastic pieces with sizes ranging from 12 to 55mm in diameter. The material will provide between 90 to 300 m2 of surface area per 1 m^3 of reactor volume (Tilley et. al., 2005).

The filter material has biomass that traps particles and degrades organic matter as wastewater flows through it. A large surface area is provided for the bacterial mass, thus increasing the contact between the organic matter and the active biomass that effectively degrades it.

Although the Anaerobic Filter can be operated in either upflow or downflow mode, the upflow mode is preffered because of reduced risk of fixed biomass being washed out. Tilley et/ al. (2005) further reiterates that the water level should cover the filter media by at least 0.3 m to guarantee an even flow regime. A maximum surface-loading rate of 2.8m/day has proven to be suitable. Suspended solids and BOD removal can be as high as 85 % to 90 % but is typically between 50 % and 80 %. Nitrogen removal is limited and normally does not exceed 15 % in terms of total nitrogen (TN).

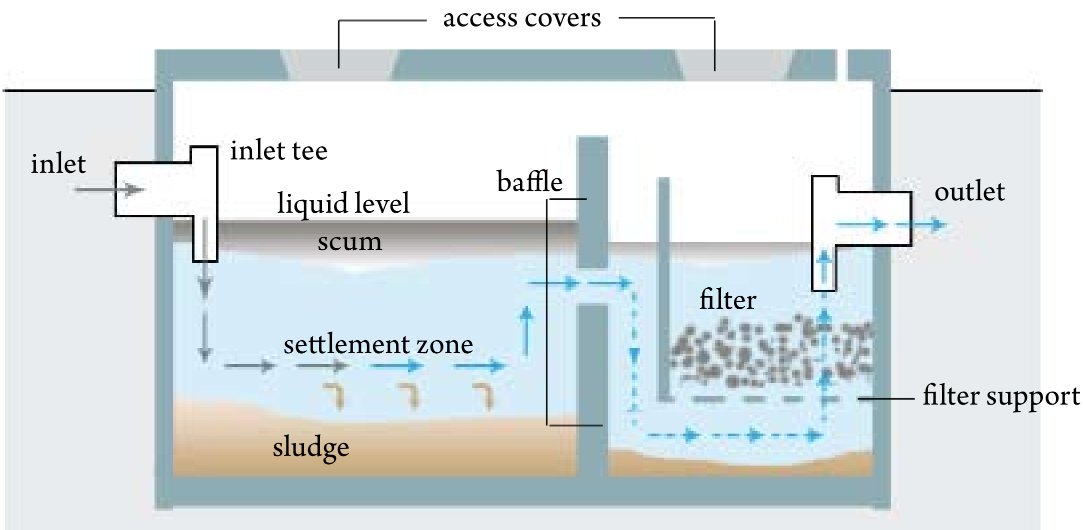


Figure 12: Anaerobic Filter - general design

Suitability

An Anaerobic Filter is easily adaptable and can be applied at the household level or a small neighbourhood. It can be designed for a single house or a group of houses that use a lot of water for washing of clothes, showering, and flushing of toilets. It is only appropriate if water use is high, ensuring that the supply of wastewater is constant. The Filter will not operate at full capacity for six to nine months after installation because of the long start up time required for the anaerobic biomass to stabilize. Therefore, the Anaerobic Filter technology should not be used when the need for a treatment technology is immediate.

Once working at full capacity it is a stable technology that requires little attention.

5.3 Constructed wetlands

5.3.1 Free-Water Surface Constructed Wetland

This is a series of flooded channels that aims at replicating the naturally occurring processes of a natural wetland, marsh or swamp. It is different from the Horizontal Subsurface Flow Constructed Wetland in that it allows water to flow above ground, thus being exposed to the atmosphere and direct sunlight (figure 13).

The channel of this Free-Water Surface Constructed Wetland is lined with an impermeable barrier such as clay or geo-textile covered with rocks, gravel and soil and planted with native vegetation like reeds. The wetland is flooded with wastewater to a depth of 10 to 45 cm above the ground. As the water slowly flows through the wetland, physical, chemical and biological processes simultaneously filter solids, degrade organics and remove nutrients from the wastewater. Particles settle, pathogens are destroyed, and organisms and plants utilize the nutrients (Tilley et. al., 2005).

Blackwater fresh from discharge should be pretreated to avoid excess accumulation of solids and garbage. Once in the pond, the heavier sediment particles settle out, thus removing nutrients that are attached to particles. Plants, and the communities of microorganisms around the stems and roots take up nutrients such as nitrogen and phosphorus. Pathogens are expelled from the water by natural decay, predation from higher organisms, sedimentation and UV irradiation.

The efficiency of this wetland depends on how well the water is distributed at the inlet. Wastewater can be input to the wetland using weirs or by drilling holes in a distribution pipe to allow it to enter in even spaced intervals.

Suitability

Depending on the volume of water, and therefore the size, the wetland can be appropriate for small sections of urban areas or more appropriate for peri-urban and rural communities. This is a good treatment technology for communities that have a primary treatment facility. Where land is cheap and available, it is a good option as long as the community is organized enough to thoroughly plan and maintain the wetland for the duration of its life.

This wetland can achieve high removals of suspended solids and moderate removal of pathogens, nutrients and other pollutants such as heavy metals. Free-Water Surface Constructed Wetlands are only appropriate when they follow some type of primary treatment to lower the BOD. The technology is best suited to warm climates but can be designed to tolerate some freezing and periods of low biological activity.

The open surface can act as a potential breeding ground for mosquitoes. However, good design and maintenance can prevent this. The Free-Water Surface Constructed Wetlands are generally aesthetically pleasing, especially when they are integrated into pre-existing natural areas. Care should be taken to prevent people from coming in contact with the effluent because of the potential for disease transmission and the risk of drowning in deeper waters.

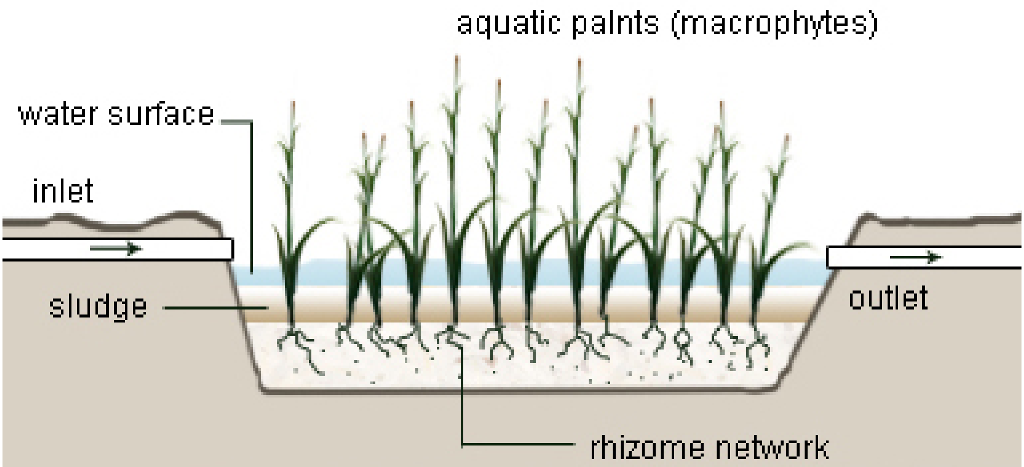


Figure 13: Free-Water Surface Constructed Wetland

Maintenance

Regular maintenance should be done to ensure that water is not short-circuiting, or backing up because of fallen branches, garbage, or beaver dams blocking the wetland outlet. Vegetation may have to be cut back or thinned out periodically.

Advantages

- Can be built and repaired with locally available materials
- Construction can provide short-term employment to local labourers

- No electrical energy required
- No real problems with flies or odours if used correctly

Disadvantages

- May facilitate mosquito breeding
- Long start up time to work at full capacity
- Requires large land area
- Requires expert design and super vision
- Moderate capital cost depending on land, liner, etc.; low operating costs

5.3.2 Horizontal Subsurface Flow Constructed Wetland

This is a large gravel and sand-filled channel planted with aquatic vegetation. As wastewater flows horizontally through a shallow and wide channel bed at a sub-surface depth of 5 and 15 cm below the ground level, the filter material filters out particles while the microorganisms degrade the organics (figure 14).

The bed is lined with an impermeable layer made of clay or geotextile to prevent leaching. Small, round, evenly sized gravel of 3–32 mm diameters, is commonly used to fill the bed to a depth of 0.5 to 1 m. This gravel should be cleaned to minimize clogging. Although sand can also be used, it is more prone to clogging. The removal efficiency of the wetland is a function of the surface area, while the cross-sectional area determines the maximum possible flow. The inlet should be well designed to allow for even distribution of wastewater thus preventing prevent short-circuiting. The outlet on the other hand should be variable so that the water surface can be adjusted to optimize treatment performance.

Plant roots play an important role in maintaining the permeability of the filter Plants with deep, wide roots can grow in the wet, nutrient-rich environment is appropriate. Phragmites australis (reed) is a good choice because it forms horizontal rhizomes that penetrate the entire filter depth. Pathogen removal is accomplished by natural decay, predation by higher organisms, and sedimentation.

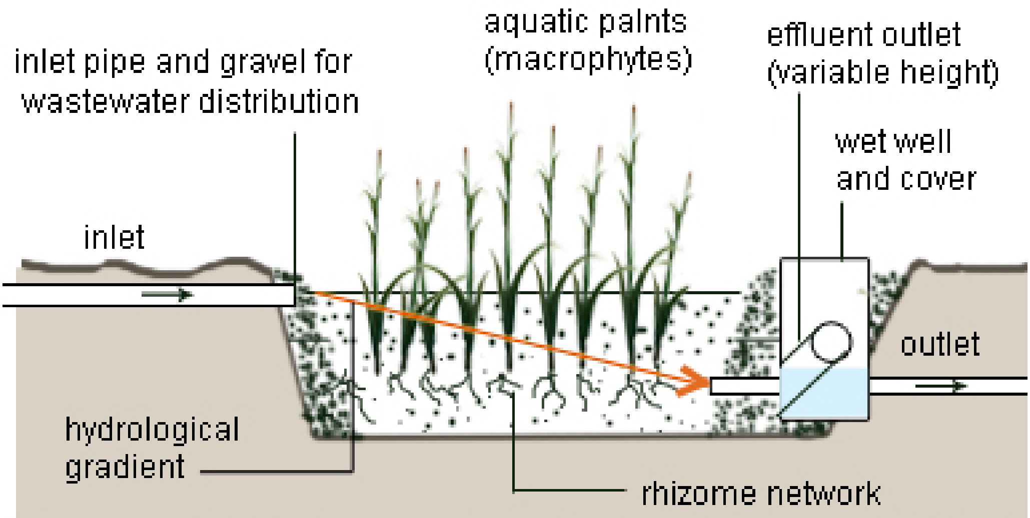


Figure 14: Horizontal sub-surface flow constructed wetland

Suitability

This technology is not appropriate for untreated domestic wastewater (i.e. blackwater). It provides good service for communities with primary treatment facilities such as Septic Tanks who opt to achieve a higher quality effluent. It is good where land is cheap and available.

Depending on the volume of water, and therefore the size, this type of wetland can be appropriate for small sections of urban areas, peri-urban and rural communities. They can also be designed for single households. The technology is best suited for warm climates but they can be designed to tolerate some freezing and periods of low biological activity. Since there is no standing water, the risk of mosquito breeding is reduced. The wetland is aesthetically pleasing and can be integrated into wild areas or parklands.

Maintenance

- The filter material should be replaced every 8 to 15 or more years.

- Ensure that primary treatment is effective at reducing the concentration of solids in the wastewater before it enters the wetland and also that trees do not grow in the area as the roots can harm the liner.

Advantages
- Can be built and repaired with locally available materials
- Construction can provide short-term employment to local labourers
- No electrical energy required

Disadvantages
- Requires expert design and super vision
- Moderate capital cost depending on land, liner, fill, etc.; low operating costs
- Pre-treatment is required to prevent clogging

5.3.3 Vertical Flow Constructed Wetland

This is a filter bed planted with aquatic plants. Wastewater is dosed onto the wetland surface from above using a mechanical system. The water flows vertically down through the filter matrix (figure 15).

When the wetland is dosed four to ten times a day, the filter goes through stages of saturation and unsaturation, with consequent phases of aerobic and anaerobic conditions. Wetland dosing frequency should be timed so that previous wastewater, percolates through the filter bed. This provides ample time for oxygen to diffuse through the media and fill the void spaces.

The wetland can be designed as shallow or an above ground infrastructure. Each filter should have an impermeable liner and an effluent collection system. They are commonly designed to treat wastewater that has undergone primary treatment. Structurally, there is a layer of gravel for drainage (a minimum of 20 cm), followed by layers of either sand and gravel (for settled effluent) or sand and fine gravel (for raw wastewater).

Depending on the climate, reeds can be used. The vegetation transfers a small amount of oxygen to the root zone so that aerobic bacteria can colonize the area and degrade organics. The vegetation is therefore a good habitat for micro-organisms.

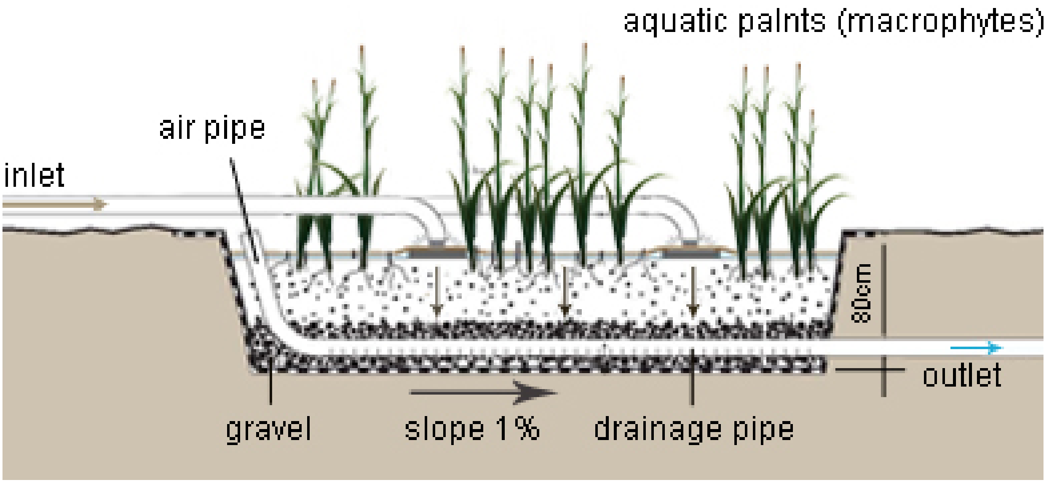


Figure 15: Vertical flow constructed wetland

Suitability

It provides good service for communities with primary treatment facilities such as Septic Tanks who opt to achieve a higher quality effluent. It is good where land is cheap and available. It is a good option where land is cheap and available, although the wetland will require maintenance for the duration of its life. It is also best suited for communities of warm climates with trained maintenance staff, constant power supply, and spare parts.

Since there is no standing water, the risk of mosquito breeding is reduced. The wetland is aesthetically pleasing and can be integrated into wild areas or parklands.

Maintenance

- The filter material should be replaced every 8 to 15 or more years.

- Ensure that primary treatment is effective at reducing the concentration of solids in the wastewater before it enters the wetland and also that trees do not grow in the area as the roots can harm the liner.

Advantages

- No mosquito problems
- Less clogging than in a Horizontal Flow Constructed Wetland
- Requires less space than the Free-Water Surface Constructed Wetland
- High reduction in BOD, suspended solids and pathogens
- Construction can provide short-term employment to local labourers

Disadvantages

- Constant source of electrical energy required
- Not all parts and materials may be available locally
- Requires expert design and supervision
- Moderate capital cost and low operating costs
- Pre-treatment is required to prevent clogging
- Dosing system requires more complex engineering

Chapter 6:

Ecological Sanitation with Case examples for Kenyan Schools

6.1 Introduction

Many public institutions in Kenya such as prisons, boarding schools, colleges - face numerous challenges with regard to the provision of safe and adequate sanitation services. Many areas have no sewer systems. Only 18% of the total population is covered by the sewer system. Most public institutions are therefore developing their own onsite sanitation facilities. The most commonly used technologies are ablution blocks with septic tanks or various types of pit latrines. However, due to the high population in these public institutions (often 50% higher than the design capacity), the pits are get filled up within short periods of 2-3 years. Septic tanks have to be emptied 2-3 times a year. The exhauster services are however not adequately available country wide to facilitate this. More and more public institutions are opting to use large number of pit latrines which are abandoned as soon as they fill. This creates large spaces occupied by grave yards of pit latrines.

Grey water from the kitchen and bathrooms are often discharged into the environment. This creates wet dirty grassy areas where mosquitoes, cockroaches and flies breed. Organic waste from the kitchen are disposed of inappropriately thus causing stench and filth. Due to the high cost of energy, cheap wood fuel is used in large amounts for cooking in the kitchens. This causes stress on the already dilapidated forest cover of Kenya. It has been reported by UNEP in an article which appeared in the Standard Newspaper of 2nd March 2009 that Kenya as a country is tottering towards environmental disaster due to the destruction of forests.

The EU-GTZ –SIDA EcoSan Promotion project has started implementing pilot projects in public institutions in an attempt to address the above named challenges. This is done with the involvement of all the relevant stakeholders e.g Ministry of Education, Prison department, Water Services Boards and Water Service Providers. The management of these facilities is done by the institutions through the Water Service Providers. The measures undertaken include: Conducting hygiene education and operation trainings; Promoting hand washing after the use of toilet; Construction of onsite sanitation facilities consisting of a biodigester (primary treatment) and anaerobic baffled reactor (secondary treatment). These systems can serve institutions with populations up to 2,000 people with a reasonable per capita cost of US$ 13.3 (KSh 1,000). It has a major added value in the amount of energy generated and environmental conservation (reducing climate change)

- Collection of black, grey and yellow water through short sewer lines to one central point (biodigester) for onsite treatment and fermentation to produce biogas. The biogas replaces wood fuel as a source of energy for cooking. A clean and healthy environment is thus created.

- Collection and fermentation of all the organic waste in the biodigester to increase the biogas yield. This reduces the problem of solid waste disposal. Economic use of organic sludge and effluent generated from the system in farming to produce sufficient food for these public institutions

- Ingle et.al. (2010) demonstrated that Urine Diversion Dehydration Toilets (UDDTs) and pour-flush toilets connected to biogas plants are suitable for school sanitation, given that the students can easily grasp their concepts and appreciate the consequent benefits especially of fertiliser and biogas. The Project thus promoted a sense of ownership and continuous capacity development. Further, the following reasons backed up these concerns:

- EcoSan technologies in the form of UDDTs are easy to build and understood by school children, and can be built and maintained together with children and teachers (Shangwa and Morgan, 2009), thus increasing ownership.

- EcoSan technologies in the form of pour-flush toilets connected to a biogas plant and further treatment components can supply biogas for cooking replacing either firewood (thus conserving the vegetation around the school) or reducing costs for having to purchase LPG (liquefied petroleum gas) cylinders.

- Ecosan systems can produce valuable liquid and solid products (e.g. urine, dried faeces, compost, digestate, irrigation water) which can be used as fertiliser in school gardens, where the students can learn how to increase the yield of vegetables by safely applying treated excreta as fertiliser and soil conditioner.

- UDDTs do not rely on soil infiltration, unlike pit latrines, and are more suitable than pit latrines in dense urban settlements, in areas with high groundwater table, hard rock, collapsing ground or seasonal flooding.

- If the school children can be convinced of the benefits of sanitation in general, and the special benefits of EcoSan systems in particular, they can create a ripple effect and promote the need for sanitation and the concept of EcoSan more widely. Schools therefore provide a strong entry point for sustainable sanitation systems in the community (SuSanA, 2009b).

6.2 Case examples of schools using EcoSan technology

6.2.1 Khaimba Primary School in Butere, Kenya

A successful pilot project within the Ecosan Promotion Program is Khaimba Primary School (1,000 pupils) in Butere, a town in the Western Province of Kenya in the Butere/Mumias District. One 40 m^3 rainwater harvesting tank for hand washing was constructed in conjunction with two units of UDDTs for teachers and two for students.

A health club was established in the school where students and teachers take up responsibility for the operation, cleanliness and maintenance of the toilets as well as the reuse of the fertiliser in the school farm. The health club is very active, hence the toilets are properly used, and the urine and the excreta-based compost are applied in the school farm for a school feeding program. Common crops on which the fertiliser is used are bananas, maize and spinach. The surplus of the farm products which are not consumed by the school are sold, primarily benefiting the health club members with books and other rewards. This encourages the members to fully engage in the utilisation and maintenance of the UDDTs.

Awareness, training sessions and follow-up monitoring and support are crucial for the success of ecosan in schools. The schools started to integrate ecosan and general WASH issues (http://www.schools.watsan.net/page/248) in the school's curriculum and school activities. These actions are highly recommended because UDDTs requires a full involvement of the users. They are easily prone to mismanagement as the UDDT user needs to apply ash after defecation (other covering materials are also possible) and keep the faeces chamber dry from urine and water.

The UDDT caretaker needs to regularly empty the urine storage tanks and excreta chamber and organise reuse of the fertiliser. Hence a strong emphasis is laid on user and caretaker education, operation and maintenance training for both students and school administration.

The main incentive for schools to decide for UDDTs remains the cost advantages compared to costs for regular digging and construction of new pit latrines with limited space at hand.

The use of fertiliser to support school feeding programs thereby reducing costs for food purchases becomes a very important incentive. For schools it is also appealing to raise their social status and image with improved sanitation facilities that are likely to attract more students and funds. The awareness on environmental benefits of ecosan is well understood by the local population, but it is lower-ranking as an incentive for schools.

6.2.2 Gachoire Girls High School in Nairobi, Kenya

The Gachoire Girls High School is in the outskirts of Nairobi. 30 low pour flush toilets (800 girl students) are connected to a fixed dome biogas digester with a wetland and 3 double chambered UDDTs are provided for the 40 teaching staff. The biogas is used in the school kitchen to substitute firewood which accounts for a great part of the schools operational costs.

The school administration has therefore shown great interest in the biogas in order to save costs. Kenyans have also recognized the potential of biogas to help conserve the increasingly endangered forests. The school has started to successfully use the biogas in the kitchen since its operation. Monitoring is still being carried out to document the lessons learnt.

The reuse of treated wastewater with a high content of nutrients for food production in the school farms or for growing trees and animal feed is also accepted but more complex to carry out. School farms usually rely on rainfed agriculture; hence irrigation plays a limited role and is rarely practiced. Since schools spend up to 50% of their operational costs on food, the outlook of improved food supply from school farms is creating demand. An extended training on irrigation and safety standards for reuse of treated wastewater is planned, especially for agricultural teachers and agricultural student clubs.

6.3 Challenges and way forward with ecosan systems in Kenyan Schools

Schools have the routine of rotation and replacement of students every year as well as occasionally of teachers and school management. Thus learnt knowledge and experience on operation and maintenance of UDDTs, anaerobic treatment facilities and proper use of biogas, water and nutrients might get lost for the school. Hence a continuous demand to replenish this knowledge to the arriving new students and teachers is essential in order to prevent mismanagement and abandonment of EcoSan installations. It is therefore recommended to include sustainable sanitation and EcoSan in as many activities of the school as possible to make them a part of their daily lives.

Only when these installations have proven successful to the schools, and advantages compared to the conventional systems like pit latrines in terms of odour, costs, hygiene and fertiliser productivity are clearly observed, EcoSan will be a feasible choice for school sanitation in the future. Ongoing monitoring and evaluation of EcoSan installations is necessary to determine their performance and practicality for schools for large-scale roll-out. Another very important component for EcoSan promotion in schools is the linkage to the policy level, the research and educational sector. The Ministry of Water and Irrigation in Kenya has already taken a promising step and included EcoSan in its Water Sector Sanitation Concept (WSSC) in 2008.

Other sector institutions like the Ministry of Public Health and Sanitation, the Ministry of Education and Ministry of Agriculture have shown interest in adopting EcoSan as one option of sanitation intervention. On the research and educational level the Kenya Water Institute (KEWI) and the Kenyatta University are introducing training and curriculum on EcoSan.

6.4 Conclusion

In the EcoSan school projects in Kenya, ecosan-type sanitation systems (UDDT or pour-flush toilets with biogas plants) have received acceptance due to their lack of odour, additional economic benefits and cost savings.

Capacity development on the concept of the ecosan-type sanitation systems and their use is a constant exercise for the success of such projects. Moreover there is a need to develop ownership among the users to ensure proper use and maintenance of the toilets. The students, through their experience at their schools, can play an important role in spreading knowledge of sanitation and hygiene in their communities. A potential strategy to boost ecosan for schools may be by incorporating it into the curriculum and by tying EcoSan-type sanitation systems to WASH initiatives, school gardening activities and school feeding programs. This and many more actions will improve publicity and governmental support for sustainable sanitation approaches in urban schools with ecosan as one of many components.

UDDTs are popular in Wajir, Butere, Mumias and Rachuonyo because they were introduced in the wake of awareness campaigns on Water, Sanitation and Hygiene (WASH). This was followed by training on the use and maintenance of UDDTs. Stakeholders included the District Health Officer, local government officials, members of the regional Water Services Board and community leaders. When the concept of UDDTs is absorbed into local cultural and social behaviour patterns, these toilets are fully accepted by communities.

6.5 Direct Impact of Pilot Activities

Improved Access to safe and dignified sanitation: No flies. No bad smell & good aeration Creates of employment to youth and local artisans and SMEs who run Water Kiosks cum Public toilets.

Biogas production and use in secondary schools and prisons provide up to nine hours of cooking gas per day. This overcomes the shortcomings of conventional, drop and store‘ Sanitation by VIPs by protecting water sources.

Improved crop production is noted when one drum of urine collected per week in school units and 20 litres per week in household units are used. Urine fertilized fields have better yields and are not infested with pests. One person generates enough fertilizer to produce 250 kg of cereals per yr.

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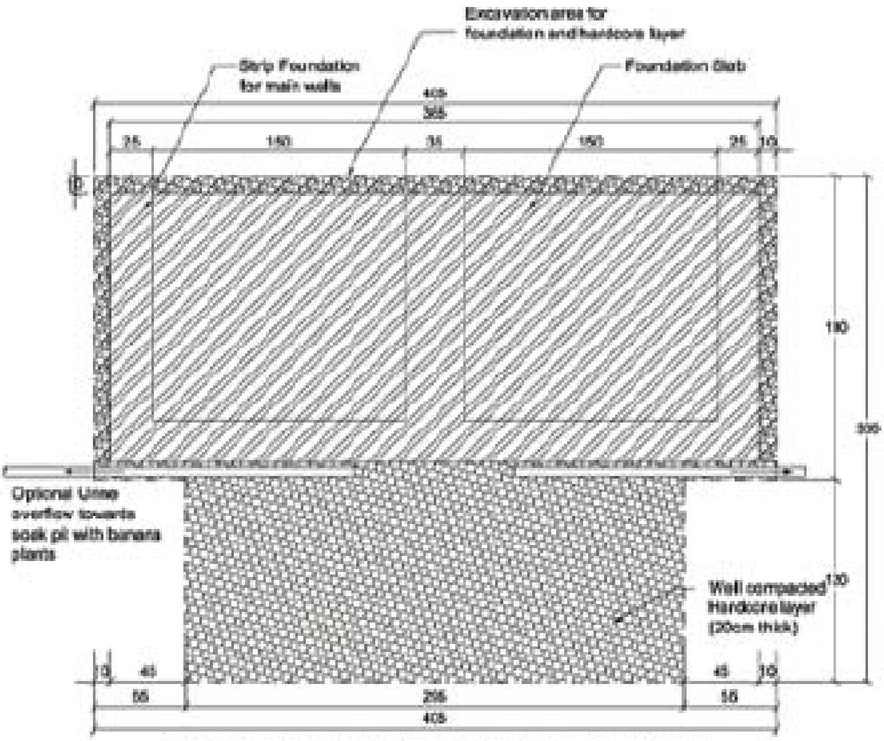
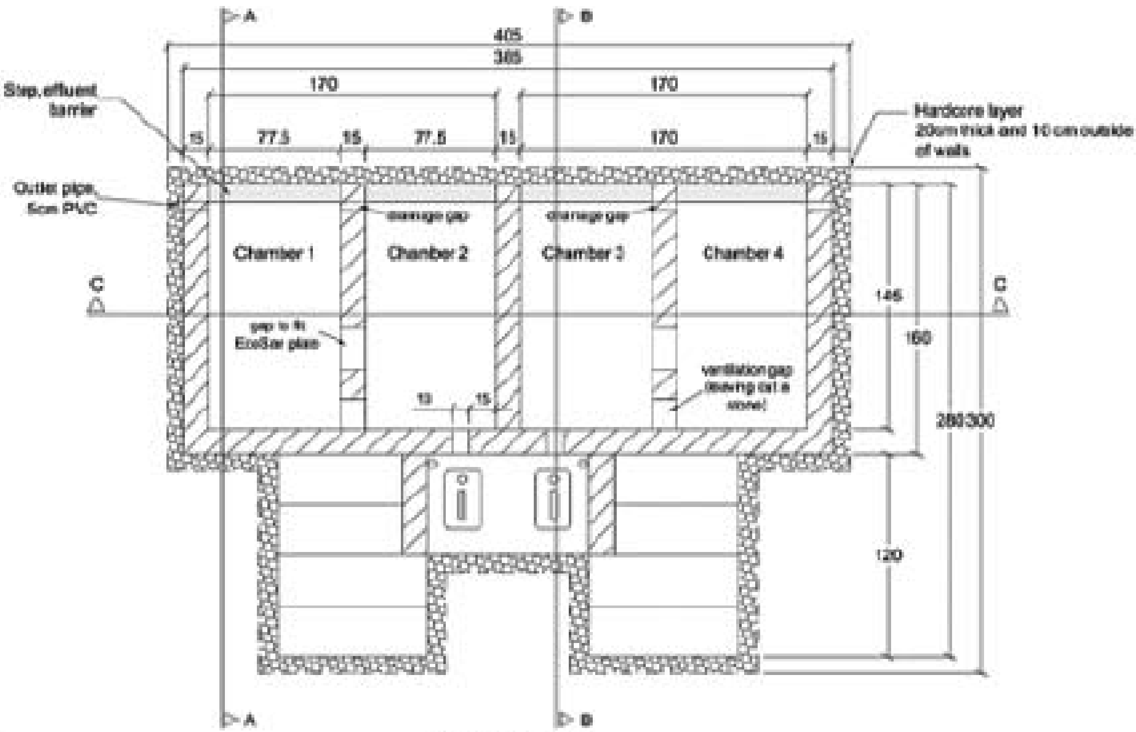
Annex 1

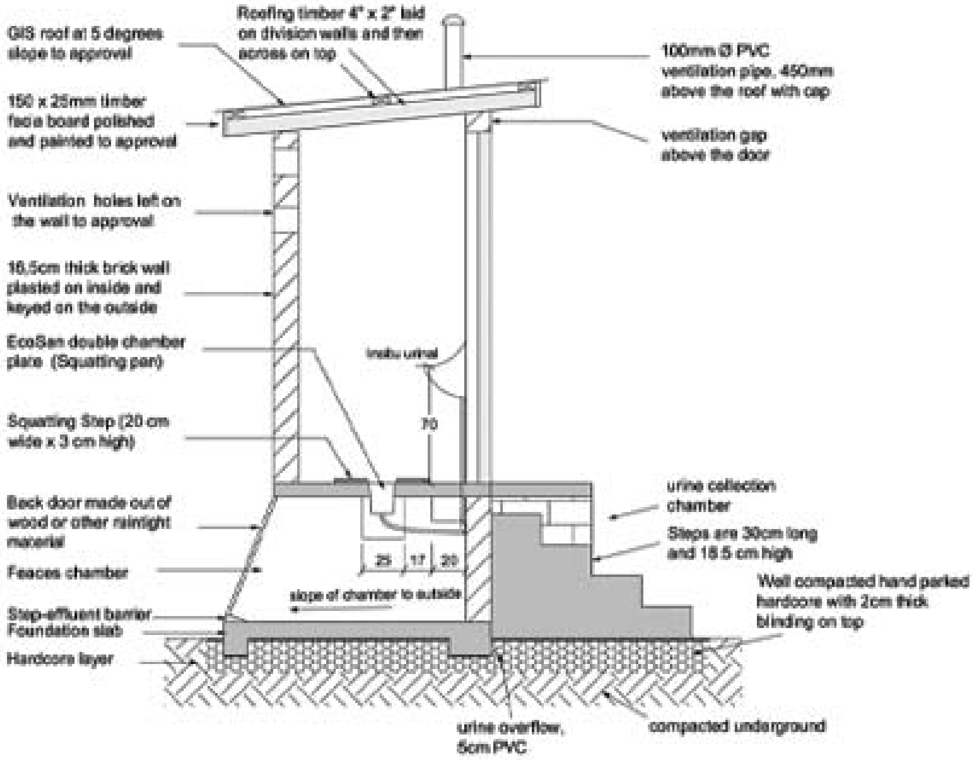
Drawings of UDDT



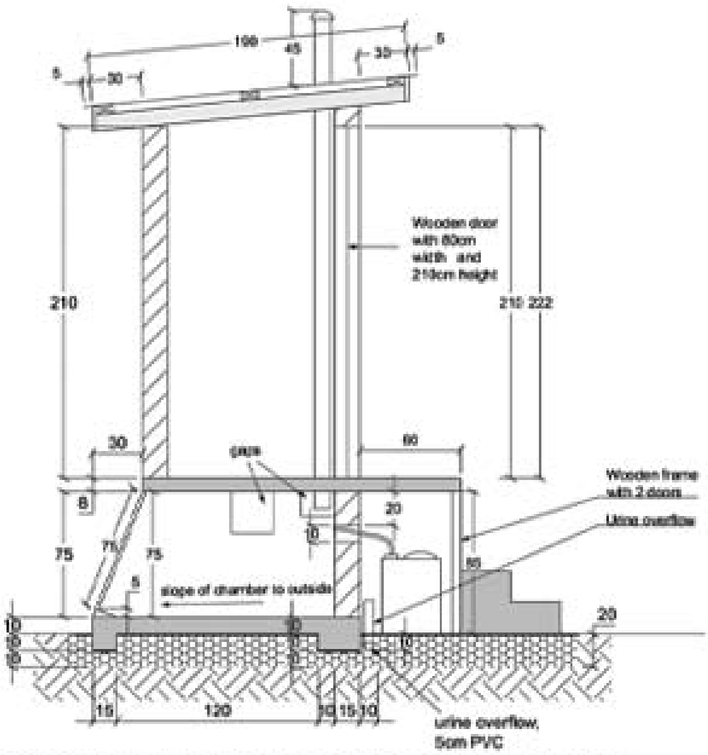
EXCAVATION AND FOUNDATION PLAN



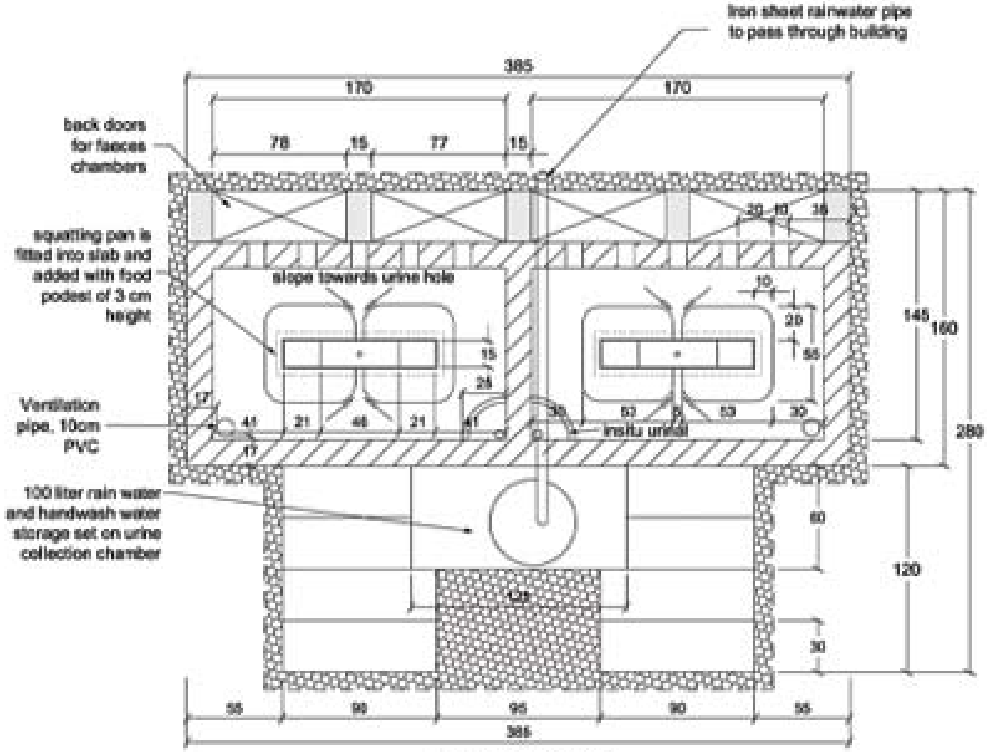
BASEMENT



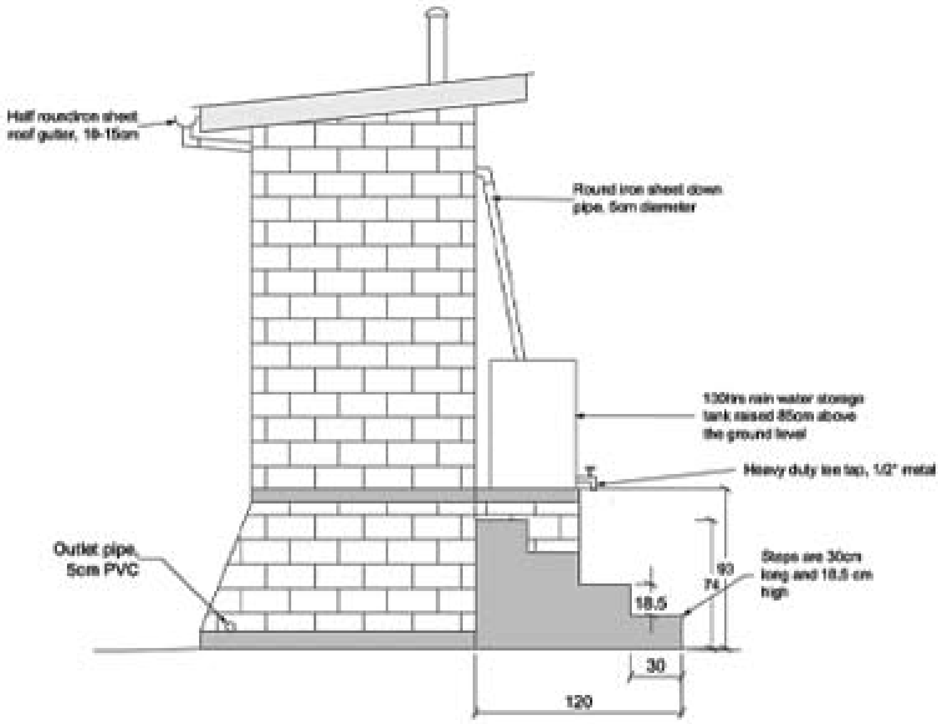
CROSS SECTION CHAMBER A-A



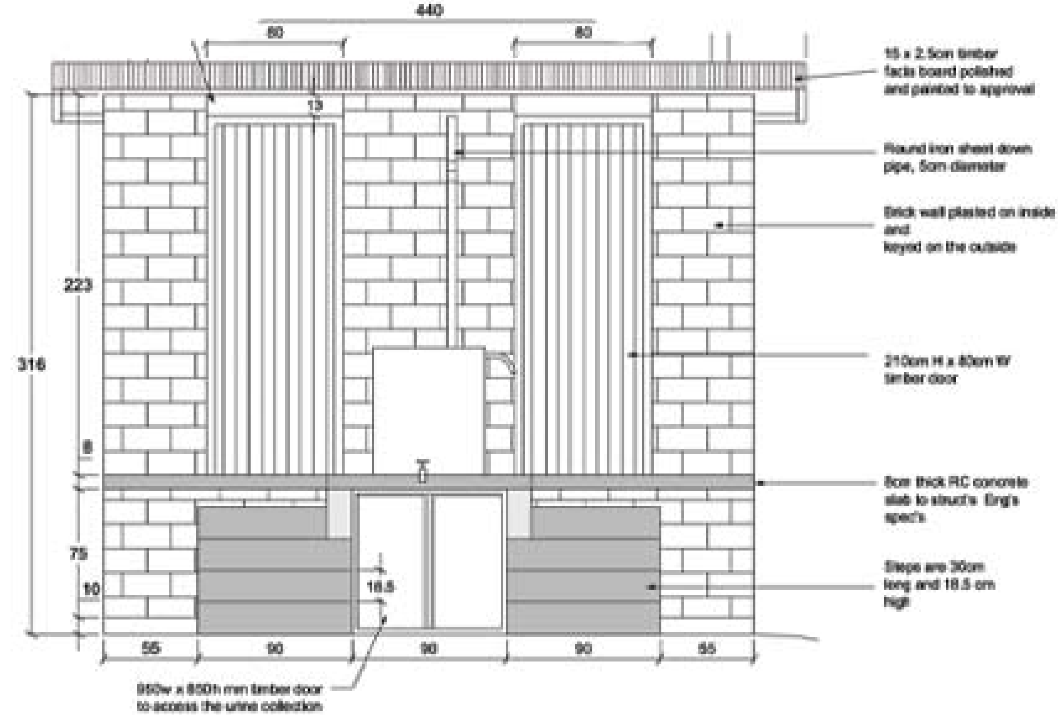
CROSS-SECTION URINE COLLECTION CHAMBER B-B



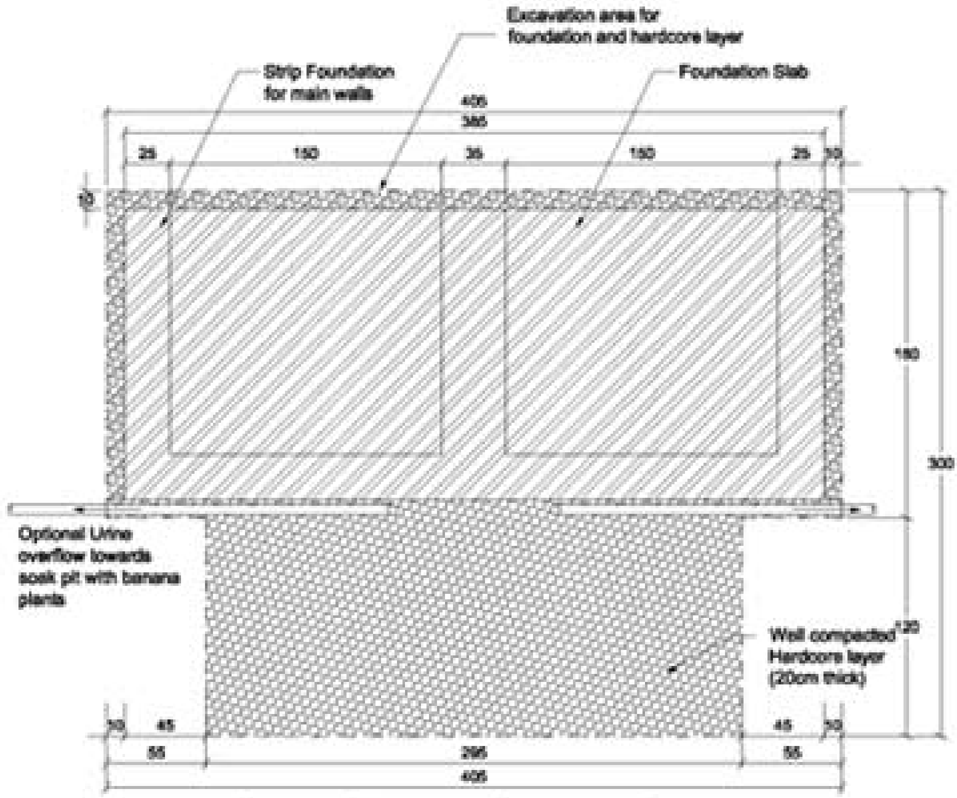
FLOOR PLAN



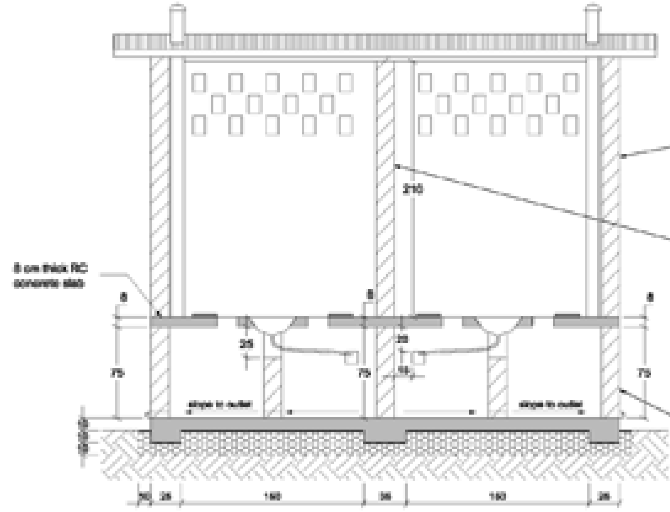
SIDE VIEW



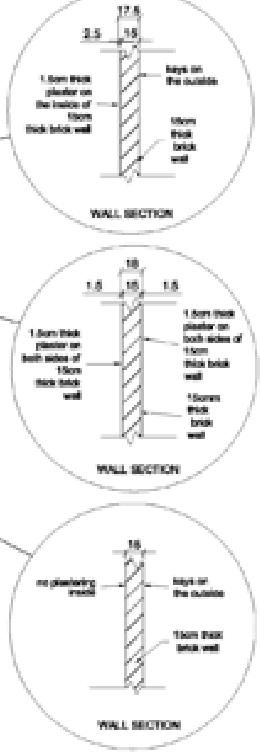
FRONT VIEW



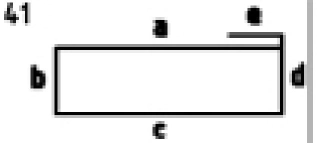
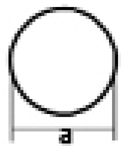
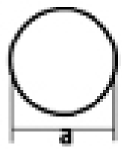
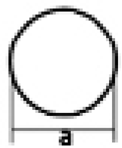
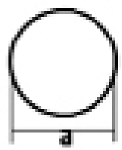
EXCAVATION AND FOUNDATION PLAN



CROSS SECTION SQUATTING PAN C-C

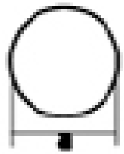
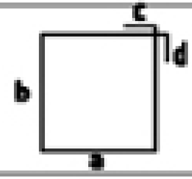
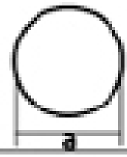
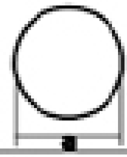
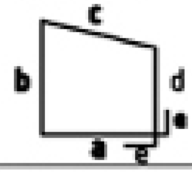


Annex 2
Drawings of Bio digester

					member				a	b	c	d	e
ting	01	Y10	1 275	1	93	93	118 575	41 	500	150	500	150	50
	02	Y10	23 075	1	2	2	46 150	77 	7 350				
	03	Y10	19 925	1	2	2	39 850	77 	6 350				
	04	Y10	21 525	1	1	1	21 525	77 	6 860				
ate	05	Y8	21 825	1	2	2	43 650	77 	6 950				

Ministry of Water and Irrigation U-Sida-GTZ Ecosan Promotion Project Sida gtz	Drawing title: 124CM BIODIGESTER BENDING SCHEDULE	Preparation date: May 2009 Prepared by: IBSA Approved by: Eng. Patrick Onyango	Drawing number:	Bar schedule No: **Sheet 1 of 4**	Revision d Revision:

dule has been prepared in accordance with the requirements of ISO 4066

			member					a	b	c	d	e/r
Y8	21 200	1	2	2	42 400	77		6 750				
R6	400	1	88	88	35 200	51		200	200	25	25	
Y8	21 825	1	2	2	43 650	77		6 950				
Y8	21 200	1	2	2	42 400	77		6 750				
R6	500	1	88	88	44 000	99		100	180	120	100	25

f Water and Irrigation
Ecosan Promotion Project

Sida

Drawing title:
124CM BIODIGESTER BENDING SCHEDULE

Preparation date:
May 2009

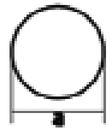
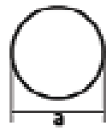
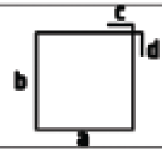
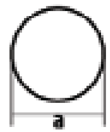
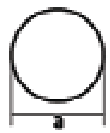
Prepared by:
IBSA

Drawing number:

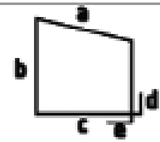
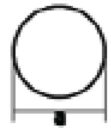
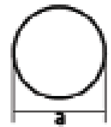
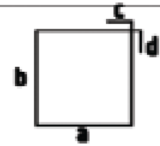
Bar schedule No:
Sheet 2 of 4

Revision dat

Revision:

Member	Bar Mark	Type and Size	Length of each bar (mm)	Number of members	Number of bars in each member	Total number	Total Length (mm)	Shape code/ Shape	Bending dimensions (mm)				
									a	b	c	d	e/R
Neck ring beam	11	Y8	2 350	01	2	2	4 700	77 	750				
	12	Y8	2 025	01	2	2	4 050	77 	650				
	13	R6	200	01	10	10	2 000	51 	50	50	25	25	
Expansion chamber ring beam	14	Y8	14 775	01	2	2	29 550	77 	4 710				
	15	Y8	14 475	01	2	2	28 950	77 	4 610				

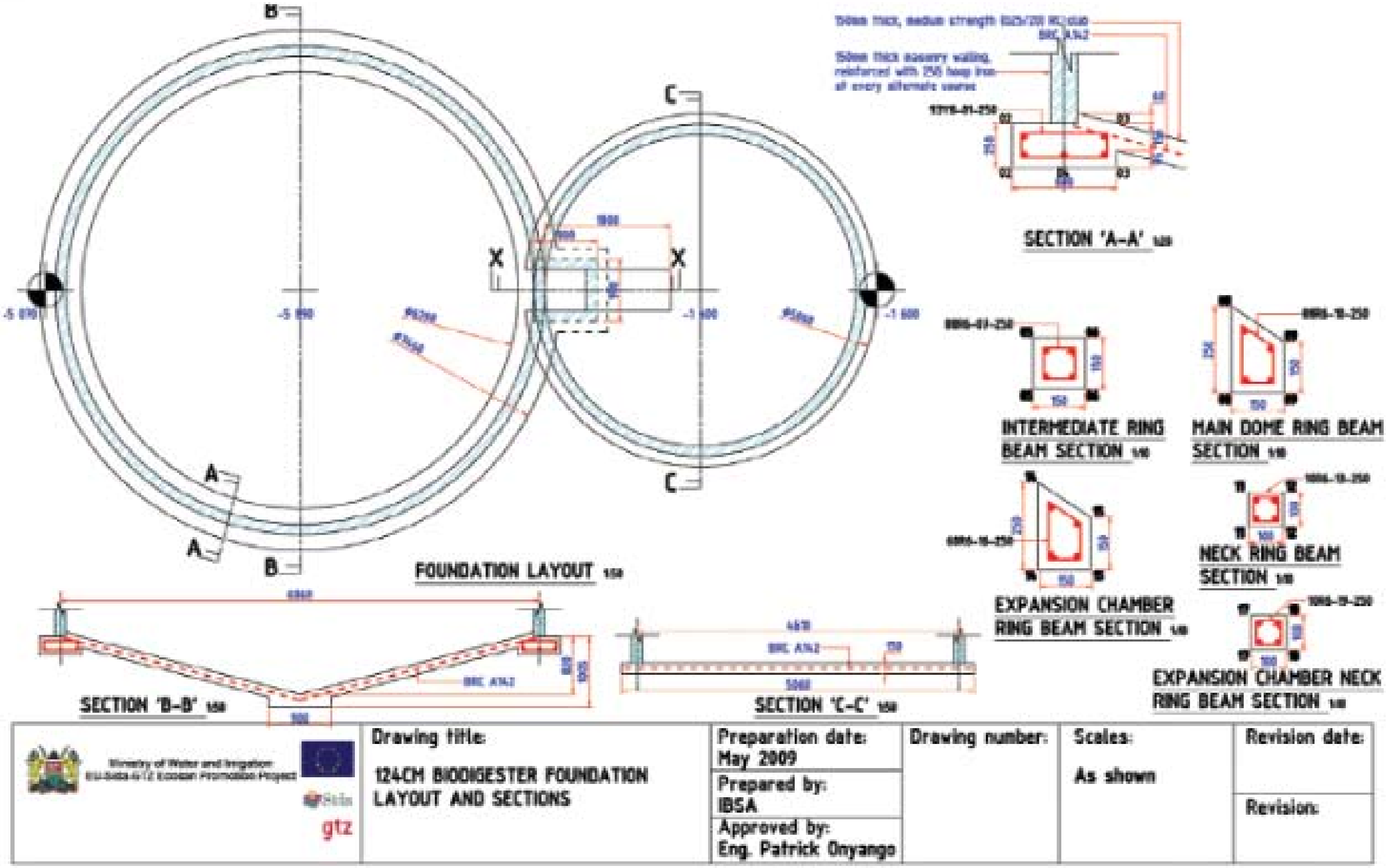
Ministry of Water and Irrigation EU-Sida-GTZ Ecosan Promotion Project Sida gtz	Drawing title: 124CM BIODIGESTER BENDING SCHEDULE	Preparation date: May 2009 Prepared by: IBSA Approved by: Eng. Patrick Onyango	Drawing number:	Bar schedule No: **Sheet 3 of 4**	Revision date: Revision:

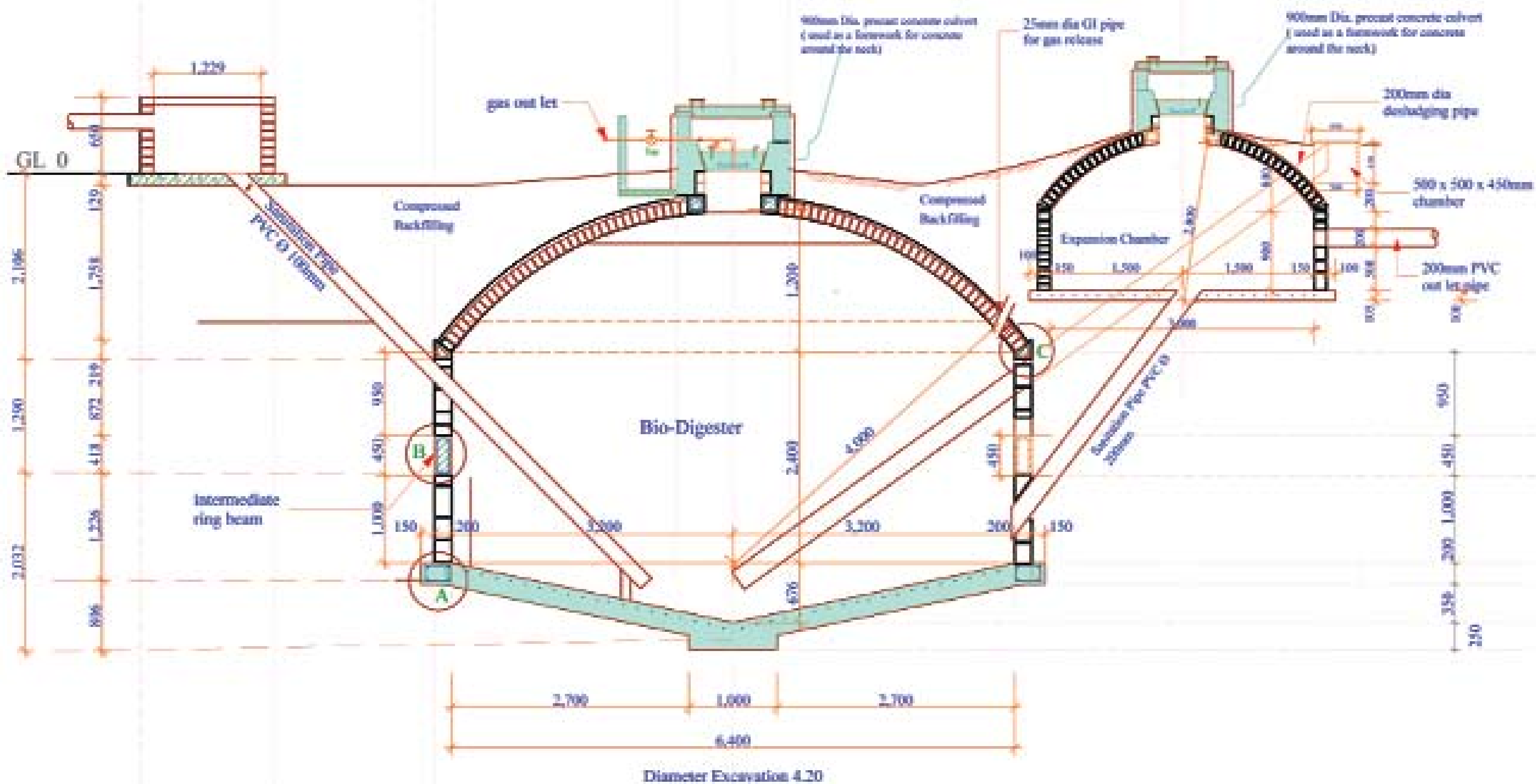
Member	Bar Mark	Type and Size	Length of each bar (mm)	Number of members	Number of bars in each member	Total number	Total Length (mm)	Shape code/ Shape	Bending dimensions (mm)				
									a	b	c	d	e/R
Expansion chamber ring beam	16	R6	600	01	60	60	36 000	99 	100	180	120	**100**	**25**
Expansion chamber neck ring beam	17	Y8	2 350	01	2	2	4 700	77 	750				
	18	Y8	2 025	01	2	2	4 050	77 	650		200		
	19	**R6**	**200**	**01**	**10**	**10**	**2 000**	51 	**50**	**50**	**25**	**25**	

Ministry of Water and Irrigation
EU-Sida-GTZ Ecosan Promotion Project

Sida
gtz

Drawing title:	Preparation date: May 2009	Drawing number:	Bar schedule No:	Revision date:
124CM BIODIGESTER BENDING SCHEDULE	Prepared by: IBSA		**Sheet 4 of 4**	Revision:
	Approved by: Eng. Patrick Onyango			


FOUNDATION LAYOUT 1:50
SECTION 'A-A' 1:20
INTERMEDIATE RING BEAM SECTION 1:10
MAIN DOME RING BEAM SECTION 1:10
EXPANSION CHAMBER RING BEAM SECTION 1:10
NECK RING BEAM SECTION 1:10
EXPANSION CHAMBER NECK RING BEAM SECTION 1:10
SECTION 'B-B' 1:50
SECTION 'C-C' 1:50
BRC A142
Ministry of Water and Irrigation
gtz
Drawing title:
124CM BIODIGESTER FOUNDATION LAYOUT AND SECTIONS
Preparation date:
May 2009
Prepared by:
IBSA
Approved by:
Eng. Patrick Onyango
Drawing number:
Scales:
As shown
Revision date:
Revision:

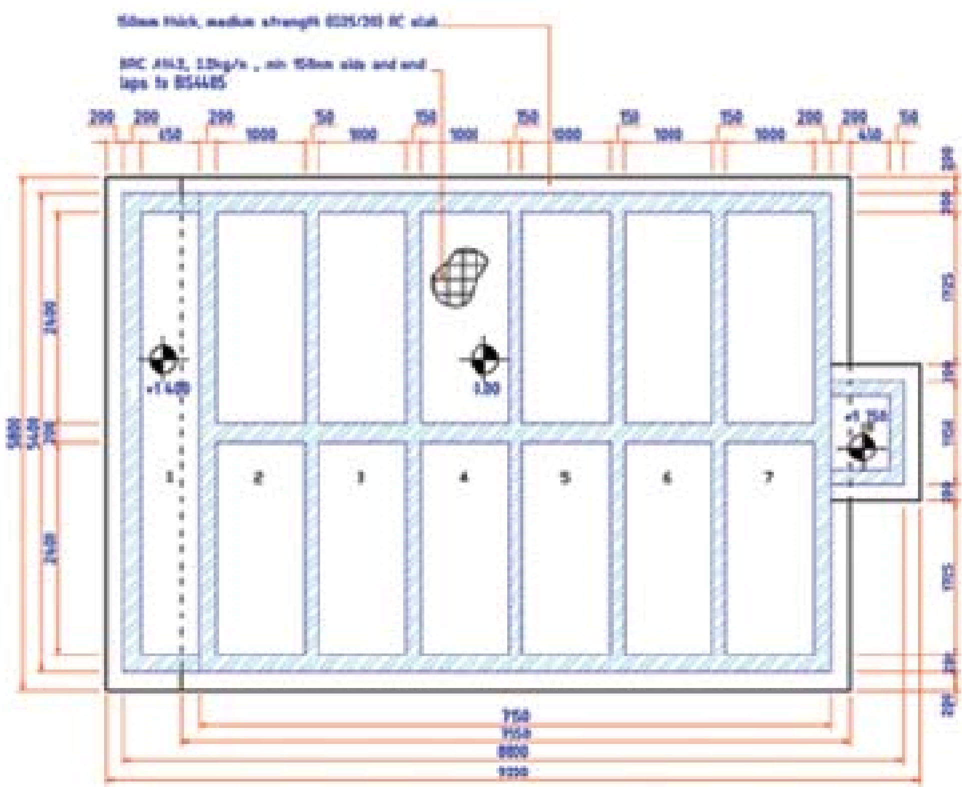


Fixed Dome Biogas Plant Volume 90 m³

Cross Section A-A

Annex 3

Drawings of 6m Anaerobic Baffled Reactor

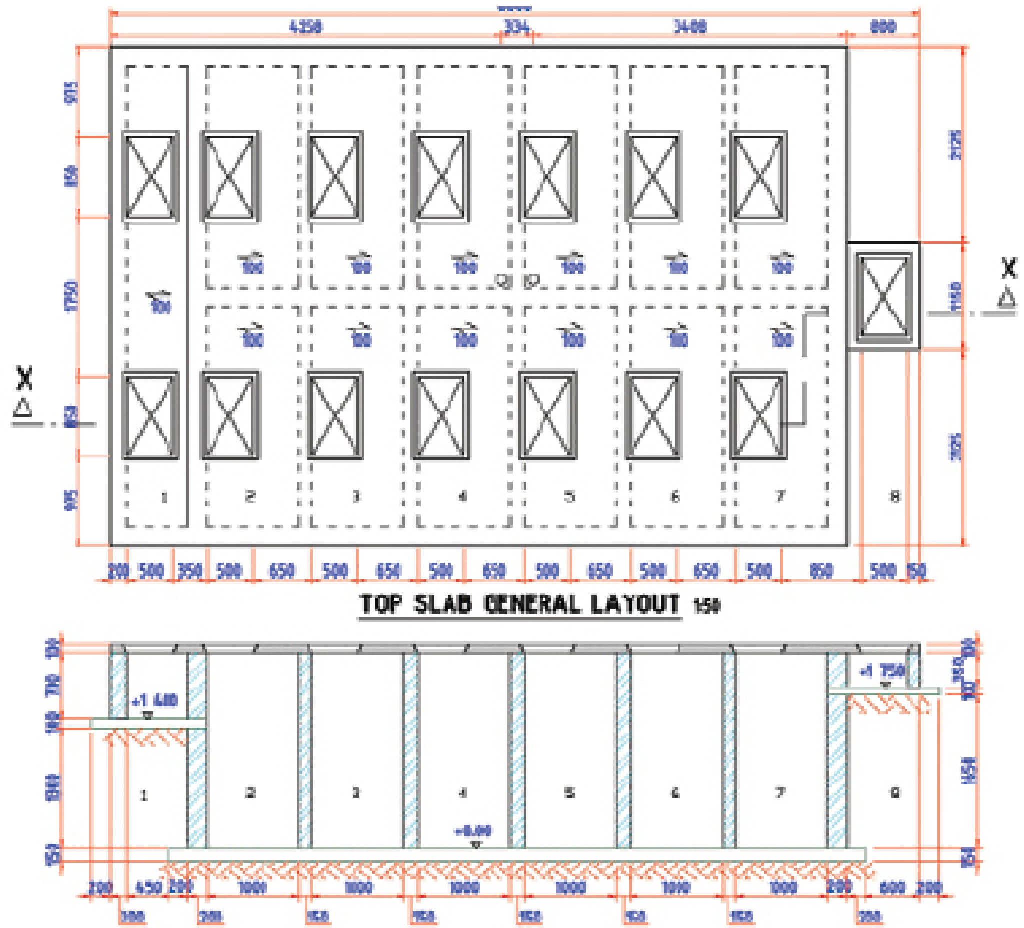


FOUNDATION LAYOUT 1:50

NOTES

1. All dimensions are in mm unless otherwise indicated.
2. These drawings should be read in conjuction with all other relevant drawings.
3. Structural concrete to be medium strength (C25/30). Min 350kg/m3 cement content to EAS 419-1 and 2. Cement to comply with the requirements of KS EAS 18-1
4. Aggregates to comply with requirements of KS 95
5. Minimum cover to reinforcement to be as below
   a) Foundations = 50mm
   b) Suspended Slab = 25mm
6. Masonry to BS 5628: Code of practice for use of masonry
7. Masonry should be set out relative to securely marked or pegged reference lines and datum levels using appropriate serviceable equipment. Squareness should be checked with diagonal measurements or a builder's square.
8. Datum and profile marks should be securely fixed. Leave datum level points in position so that a gauge rod can be used for coursing other heights such as openings and string courses.
9. No concrete blocks allowed to be used in the walling until atleast 28days after manufacture and samples have been approved by the Engineer.
10. Masonry wall to be reinforced with hoop iron after every alternate course.
11. ABR top slab design distributed imposed load= 5.0kN/m2.

Ministry of Water and Irrigation EU-Sida-GTZ Ecosan Promotion Project	Drawing title: 6M ANAEROBIC BAFFLED REACTOR FOUNDATION LAYOUT	Preparation date: September 2009	Drawing number: 6M ABR/Str/01	Scales: As shown	Revision date:
		Prepared by: IBSA			Revision:
		Approved by: Eng. Patrick Onyango			



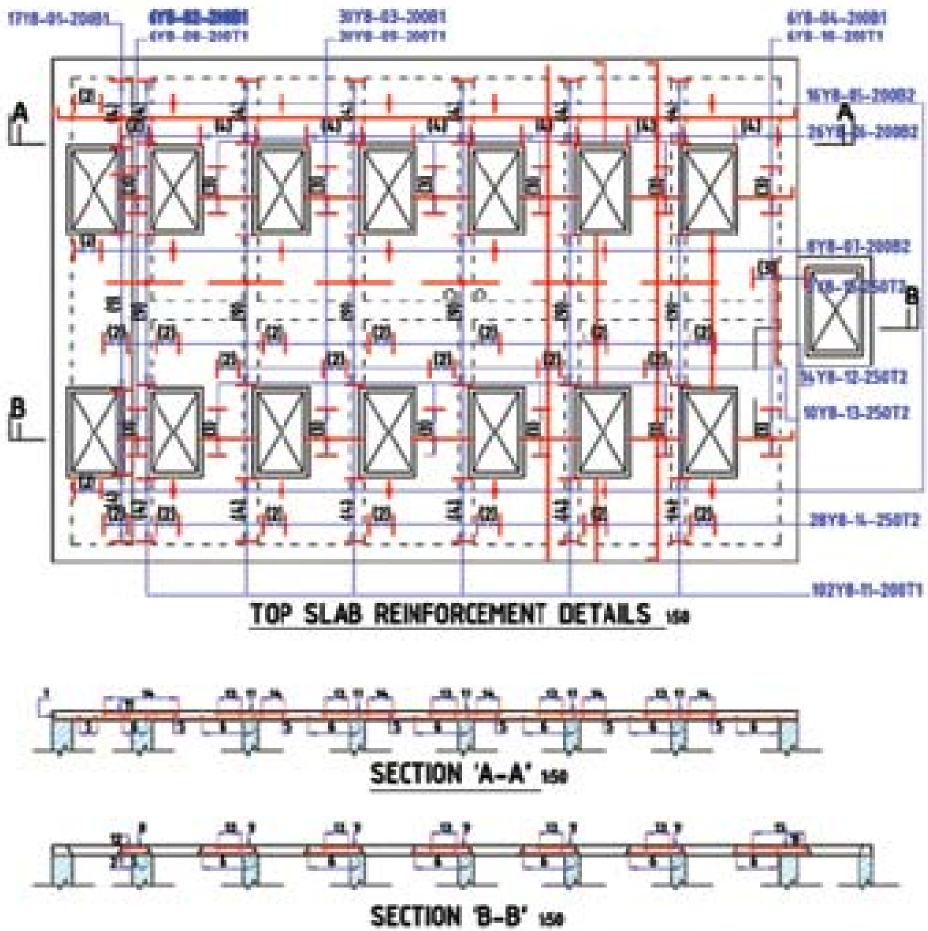
TOP SLAB GENERAL LAYOUT 1:50

SECTION 'X-X' 1:50

NOTES

Refer to Drwn No: 6M ABR/Str/01

Ministry of Water and Irrigation EU-Sida-GTZ Ecosan Promotion Project Sida gtz	Drawing title: 6M ANAEROBIC BAFFLED TOP SLAB GENERAL LAYOUT AND SECTION	Preparation date: September 2009 Prepared by: IBSA Approved by: Eng. Patrick Onyango	Drawing number: 6M ABR/Str/02	Scales: As shown	Revision date: Revision:



NOTES

Refer to Drwn No: 6M ABR/Str/01

Ministry of Water and Irrigation EU-Sida-GTZ Ecosan Promotion Project Sida gtz	Drawing title: 6M ANAEROBIC BAFFLED REACTOR TOP SLAB REINFORCEMENT DETAILS	Preparation date: September 2009	Drawing number: 6M ABR/Str/03	Scales: As shown	Revision date:
		Prepared by: IBSA			Revision:
		Approved by:			

ember	Bar Mark	Type and Size	Length of each bar (mm)	Number of members	Number of bars in each member	Total number	Total Length (mm)	Shape code/ Shape	Bending dimensions (mm)				
									a	b	c	d	e
p slab	01	Y8	8 025	1	17	17	136 425	21 a b c	50	7 950	50		
	02	Y8	300	1	6	6	1 800	00 a	300				
	03	Y8	600	1	30	30	18 000	00 a	600				
	04	Y8	650	1	6	6	3 900	11 a b	50	600			
	05	Y8	950	1	16	16	15 200	11 a b	50	900			

Ministry of Water and Irrigation EU-Sida-GTZ Ecosan Promotion Project	Drawing title: 6H ABR TOP RC SLAB BENDING SCHEDULE	Preparation date: September 2009 Prepared by: BSA	Drawing number:	Bar schedule No: Sheet 1 of 3	Revision d Revision:

Member	Bar Mark	Type and Size	Length of each bar (mm)	Number of members	Number of bars in each member	Total number	Total Length (mm)	Shape code/ Shape	Bending dimensions (mm)				
									a	b	c	d	e/R
C top slab	06	Y8	5 375	1	27	27	145 125	11 a|___b___|c	50	5 300	50		
	07	Y8	1 700	1	8	8	13 600	00 ___a___	1 700				
	08	Y8	300	1	6	6	1 800	00 ___a___	300				
	09	Y8	600	1	30	30	18 000	00 ___a___	600				
	10	Y8	600	1	6	6	3 600	00 ___a___	600				

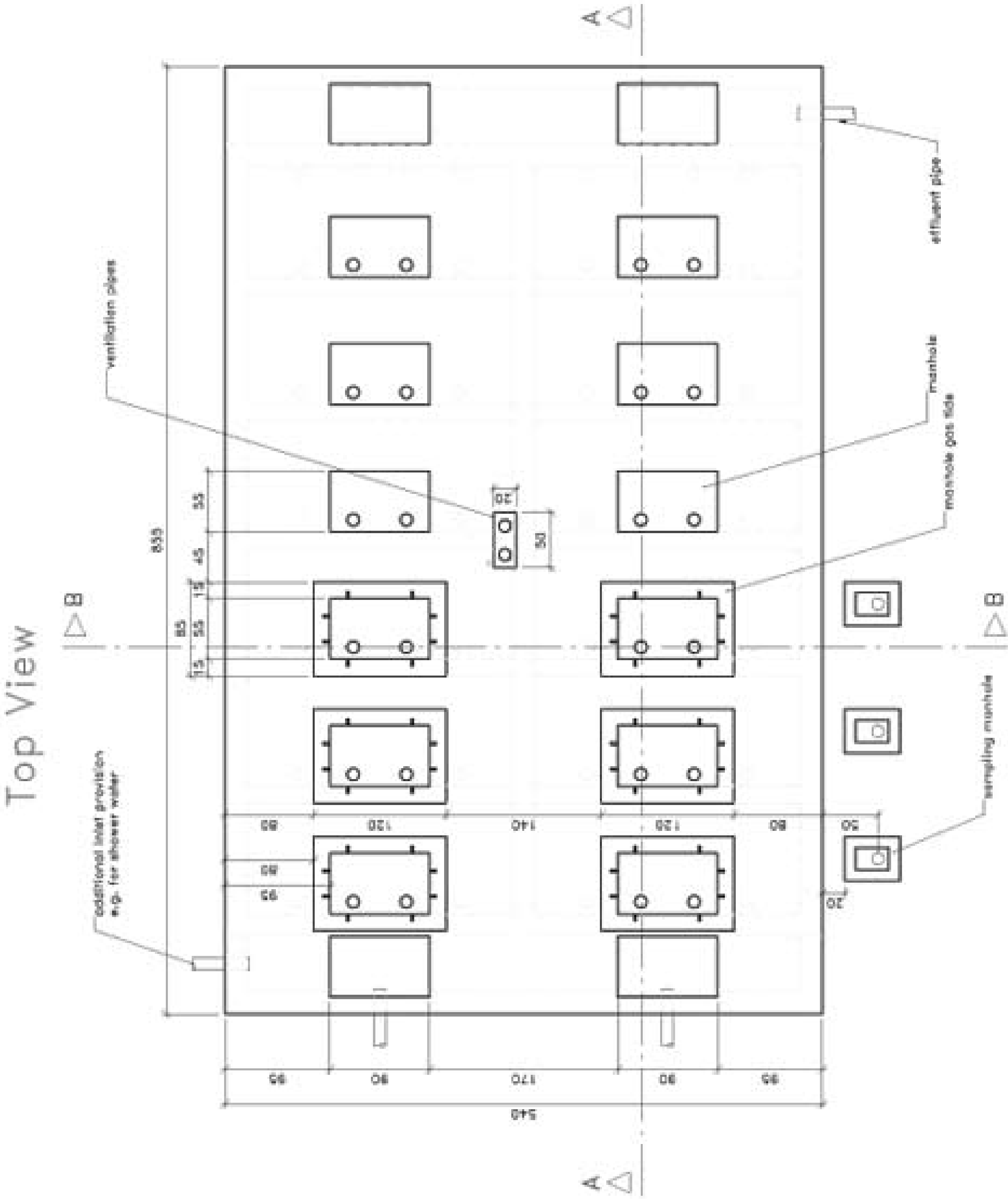
Ministry of Water and Irrigation EU-Sida-GTZ Ecosan Promotion Project; Sida; gtz	Drawing title: 6M ABR TOP RC SLAB BENDING SCHEDULE	Preparation date: September 2009 Prepared by: IBSA Approved by: Eng. Patrick Onyango	Drawing number:	Bar schedule No: Sheet 2 of 3	Revision date: Revision:

his schedule has been prepared in accordance with the requirements of ISO 4066

Member	Mark	and Size	each bar (mm)	of members	of bars in each member	number	(mm)	Shape	a	b	c	d	e/R
top slab	11	Y8	800	1	102	102	81 640	00 a	800				
	12	Y8	1 600	1	14	14	22 400	00 a	1 600				
	13	Y8	5 300	1	10	10	53 000	00 a	5 300				
	14	Y8	875	1	28	28	24 500	00 a	875				

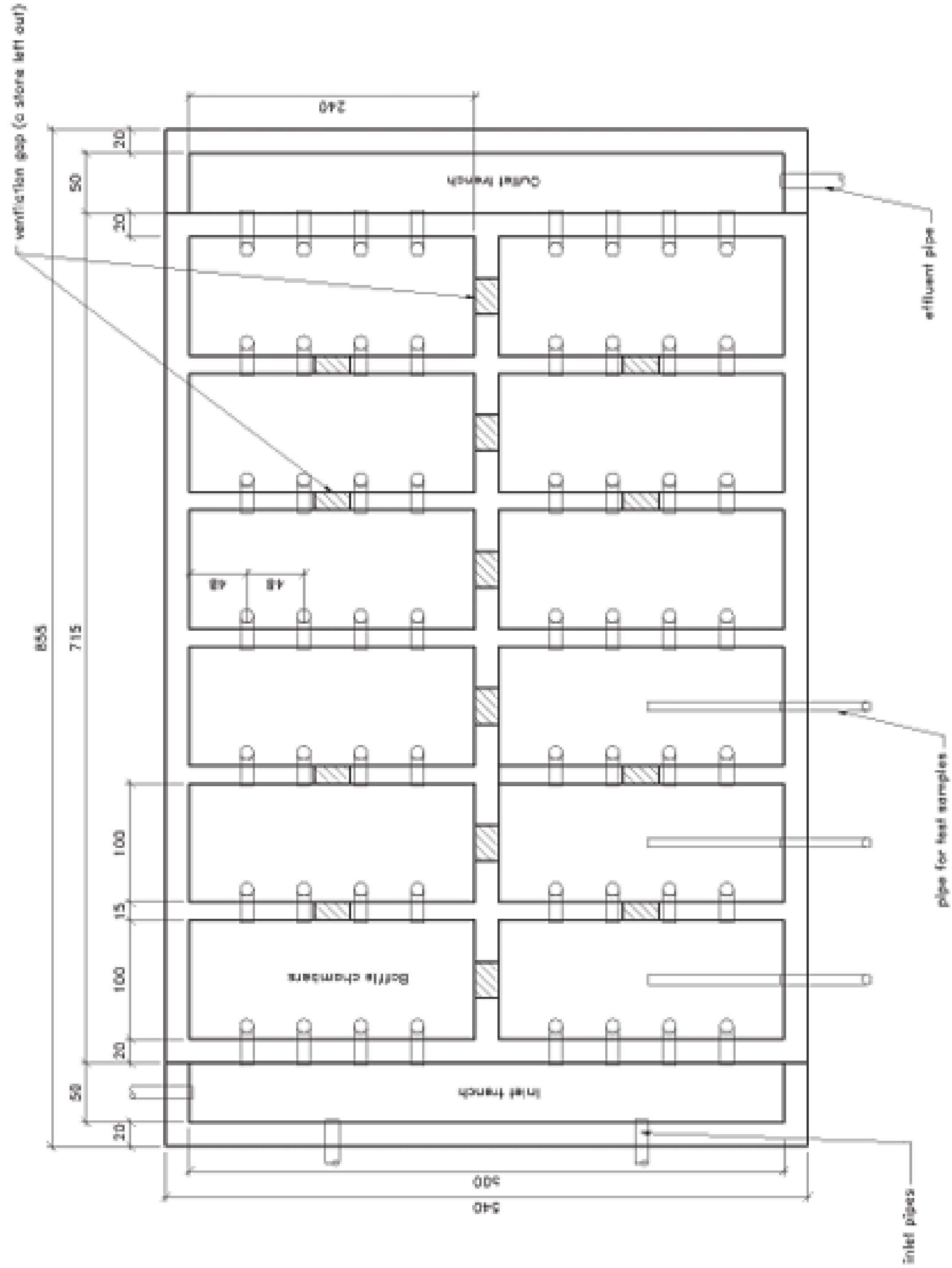
Ministry of Water and Irrigation EU-Sida-GTZ Ecosan Promotion Project Sida gtz	Drawing title: 6M ABR TOP RC SLAB BENDING SCHEDULE	Preparation date: September 2009 Prepared by: IBSA Approved by: Eng. Patrick Onyango	Drawing number:	Bar schedule No: Sheet 3 of 3	Revision date: Revision:

is schedule has been prepared in accordance with the requirements of ISO 4066

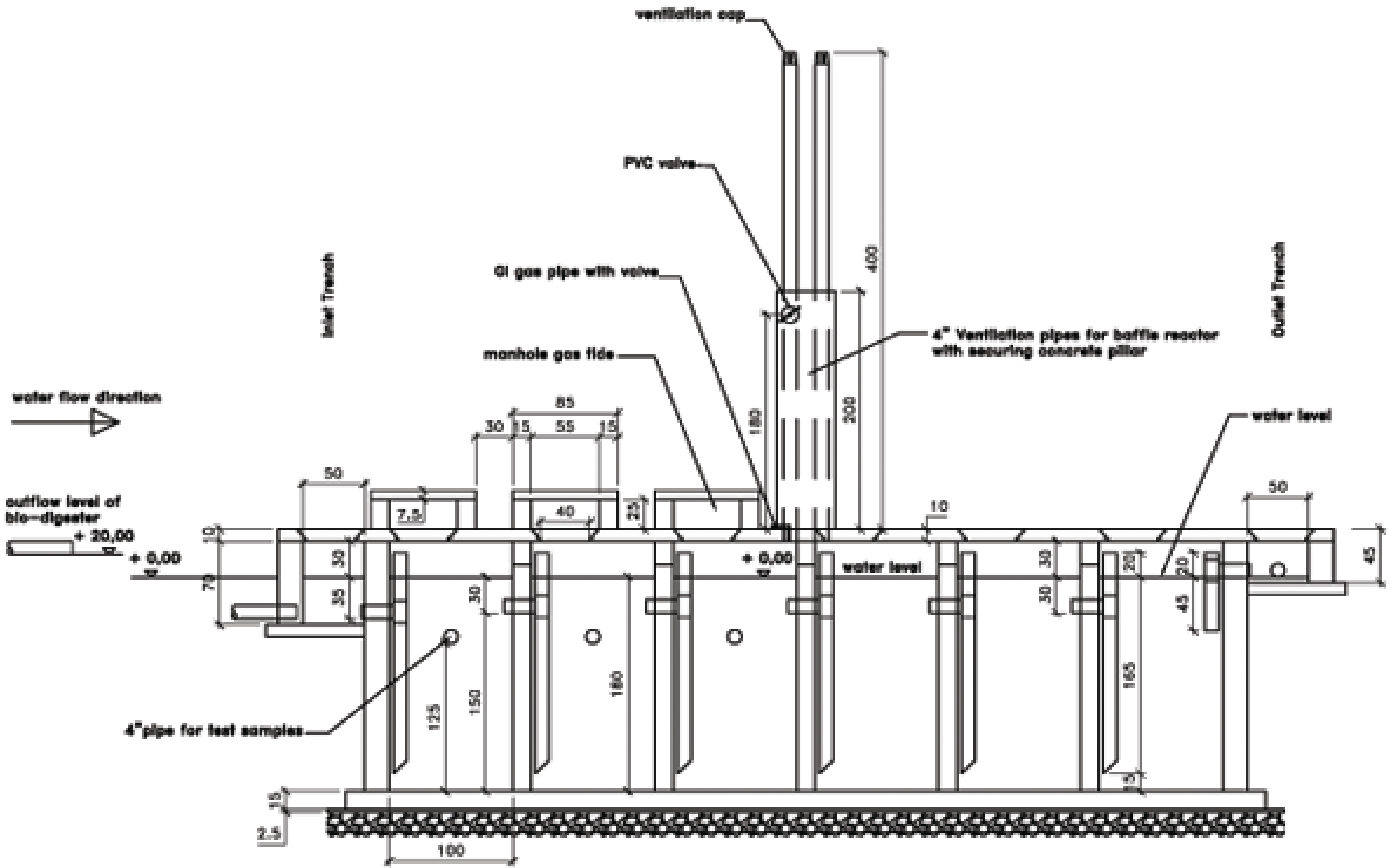


Top View
ventilation pipes
effluent pipe
manhole
manhole gas tide
sampling manhole
additional inlet provision
e.g. for shower water
A
A
B
B
835
540

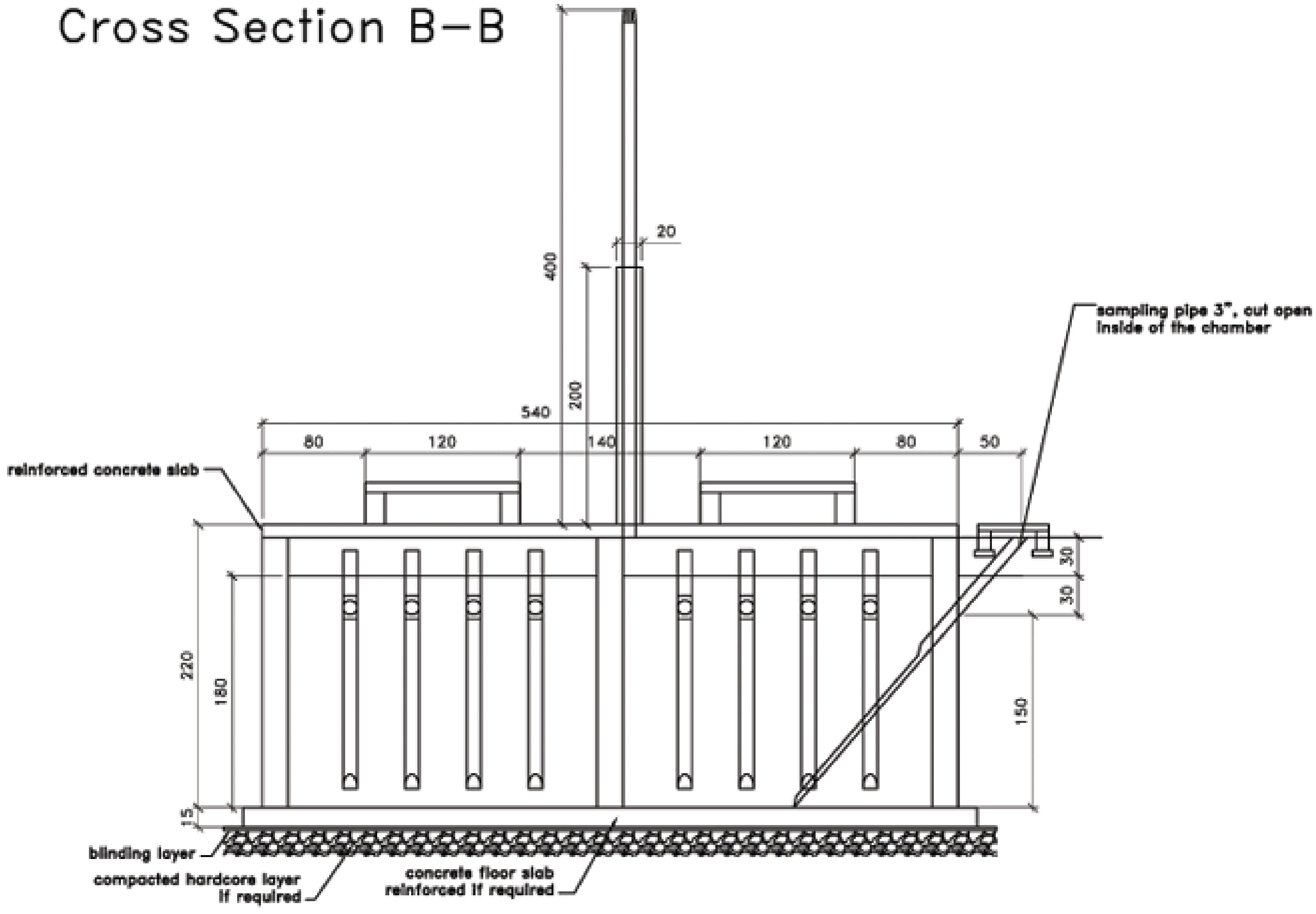
Cross Section Horizontal



Cross Section A–A

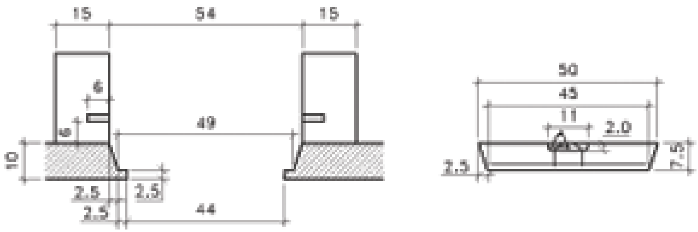


Cross Section B–B

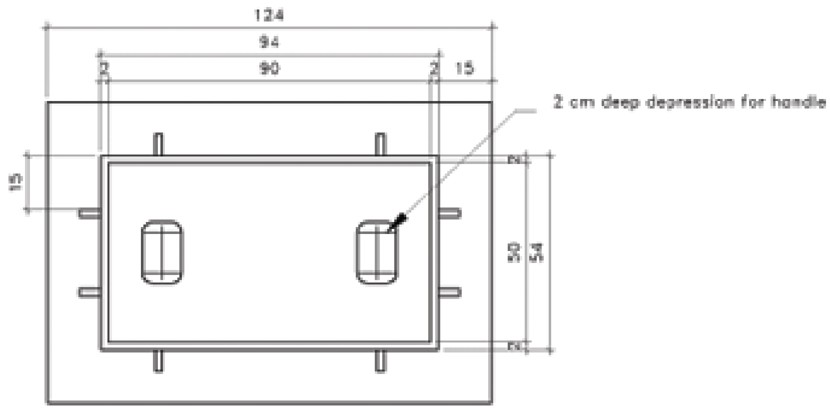


Manehole gas tide

Cross-Section Lid+Manhole

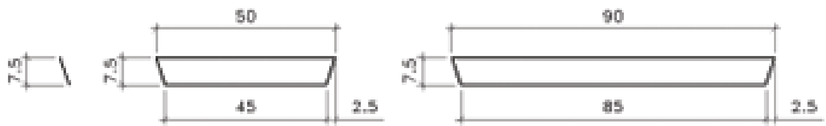


Top View Lid+Manhole



Cross-Sections Mould Lid

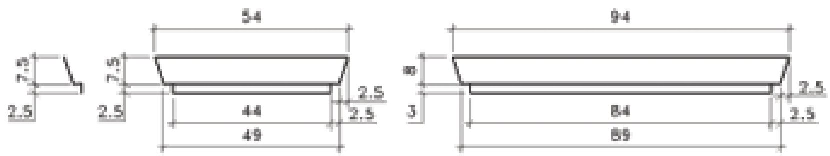
1. 2. 3.



Top View 4 Pieces of Mould with outside latches

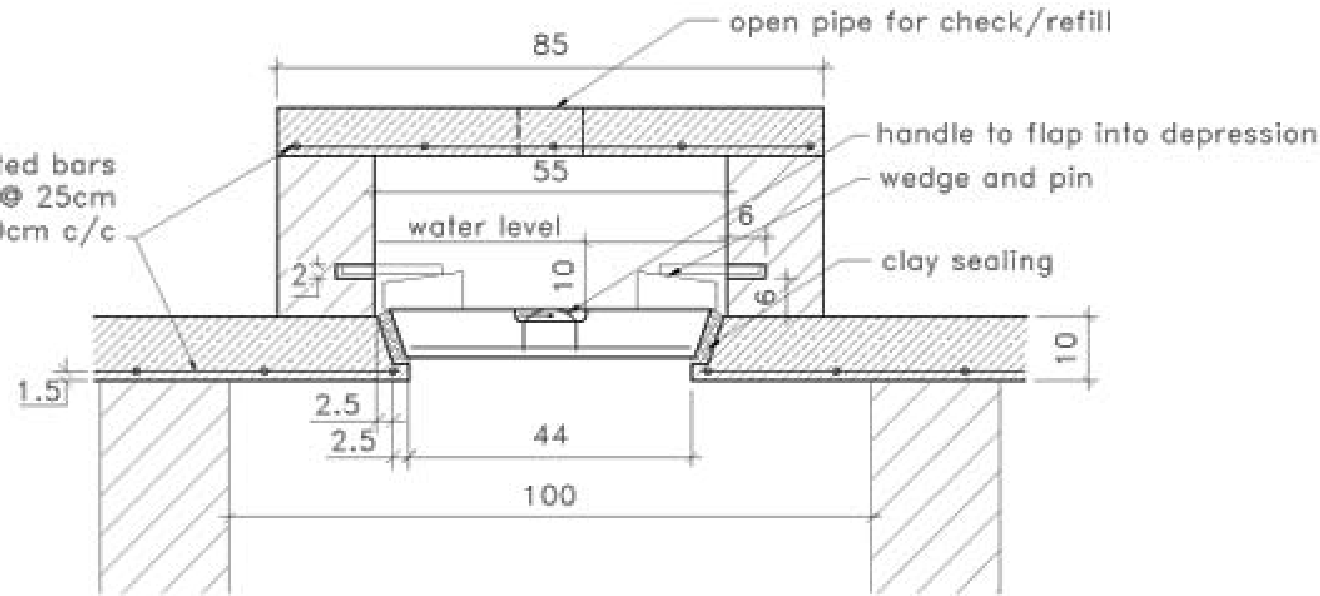
Cross-Sections Mould Lid-Frame

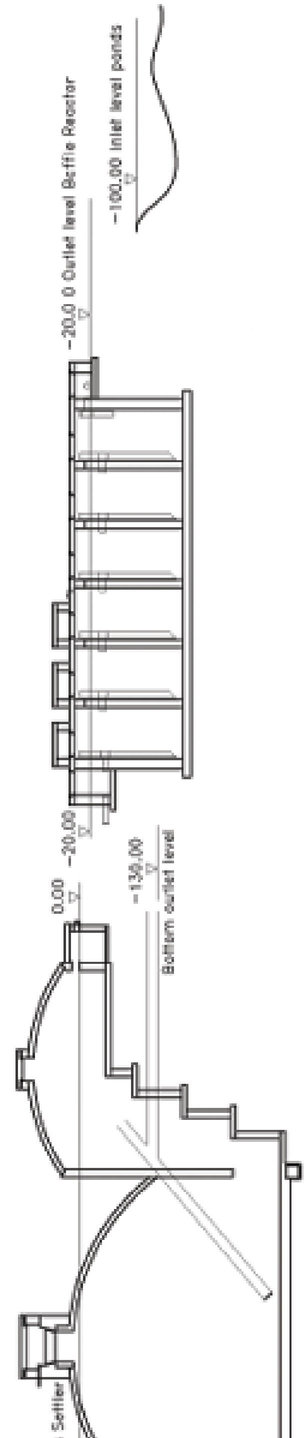
1. 2. 3.



Top View 4 Pieces of Mould with outside latches

Cross-Section Complete Manhole gas tide




0.00 Outlet level Biogas Settler
0.00
-20.00
-138.00
Bottom outlet level
-20.00 Outlet level Baffle Reactor
-100.00 Inlet level ponds

Annex 4

Sources of waste water constituents (None industrial)

Population			
Total Porpulation served	No.		
Standard Data			
Pi		3.14	
Urine production	1/c/d	1.5	
Hand cleaning	1/c/d	0.5	Grey Water
Toilet washing	1/c/d	1	Black Water
Toilet flushing	1/c/d	6	Black Water
Laundry water	1/c/d	15	Grey Water
Kitchen	1/c/d	15	Grey Water
Shower	1/c/d	15	Grey Water
Total Daily Flow	1/d		Is equal to total per capita flow X population
Hydraulic Retention time (HRT)	d	1-2	(Recommended 1 and 2 days)
Specific sludge generation	1/g BOD	0.0037	BOD removed
Specific gas generation	m^3/KgCOD	0.35	COD removed
Percentage BOD reduction	%	35	(For 1 d HRT)
BOD faecal matter	g/p/d	11	
BOD urine	g/p/d	10	
BOD shower water	g/p/d	5	
BOD laundry water	g/p/d	5	
BOD kitchen water	g/p/d	7	
Total BOD	g/p/d		
BOD Calculation			
BOD in	Kg/d		is equal to per capita BOD x population/1,000
BOD out	Kg/d		is equal to (1-0.35)xBOD in
BOD reduction	Kg/d		is equal to BOD in X0.35
COD Culculation			
COD in	Kg/d		2 *BOD in
COD out	Kg/d		(1-0.35)xCOD in
COD reduction	Kg/d		0.35X COD in

Parameter for Design	unit	Quantities	Remarks
Required Digester Volume			

Volume of liquid(VL)	m^3/d		Is equal to daily flow x retention time
Volume of sludge(VSL)	m^3/d		Specific sludge gen x BOD reduction
Volume of gas(VG)	m^3/d		Specific gas gen x COD reduction
Volume of scum(VSC)	m^3/d		Should be 20% of VL
Total Digester Volume	m^3/d		
Fixed Dome Digester Calculation			
Height of sphere sector	m		h
Radius of cylinder	m		r
Height of cylinder	m		H
Radius of sphere sector	m		R.Is calculated iteratively from Vs and Ve
Volume of sphere sector	m^3		Vs=pi*h^2*(R-h/3) R=radius of sphere, h=height of sphere sector
Volume of cylinder			Vc=pi*r^2*H
Volume of cone			V=pi*r^2*h/3 , r=R/4 or r=R/5
Expansion Chamber Calculation			
Estimated head losses in the gas pipe	m		Calculate based on pipe type and distance
Total Gas pressure required	m		0.45+total head losses
Radius of cylinder	m		Re
Height of the sector	m		hs is to be chosen iteratively with Rs to give the required Vg-gas volume space
Radius of sector sphere	m		Rs is calculated from Vg=pi*h^2*(R-h/3)
P-Line calculation			
Level of P-Line (Lowest slurry level)-hp	m		pi*hp^2*(Rs-hp/3)=pi*Rc^2*hp
Energy cost calculation			
Calorific value of Biogas	KWh/m3	6	1 m^3 of biogas=0.5 litres of diesel=0.4Kg LPG
Total gas production	m^3/d		
Equivalent diesel use	m^3/d		
Equivalent LPG use	m^3/d		
Cost saving on diesel	Ksh/d		
Cost saving on LPG	Ksh/d		
Annual savings on diesel	Ksh		
Annual savings on LPG	Ksh		
Calculation for anaerobic baffled reactor			
Max upflow velocity	m/h		Normal 1-1.4m/h
Min chambers required	No.	6	

Grey Water (bath/kitchen)	Urine	Faeces	
Volume (1/{capa})	25,000-100000	500	50
NItrogen	3%	87%	10%
Phosphorous	10%	50%	40%
Potassium	34%	54%	12%
COD	40%	10%	50%

Parameter for Design	unit	Quantities	Remarks
Population			
Total Porpulation served	No.		
Standard Data			
Pi		3.14	
Urine production	1/c/d	1.5	
Hand cleaning	1/c/d	0.5	Grey Water
Toilet washing	1/c/d	1	Black Water
Toilet flushing	1/c/d	6	Black Water
Laundry water	1/c/d	15	Grey Water
Kitchen	1/c/d	15	Grey Water
Shower	1/c/d	15	Grey Water
Total Daily Flow	1/d		Is equal to total per capita flow X population
Hydraulic Retention time (HRT)	d	1-2	(Recommended 1 and 2 days)
Specific sludge generation	1/g BOD	0.0037	BOD removed
Specific gas generation	m^3/KgCOD	0.35	COD removed
Percentage BOD reduction	%	35	(For 1 d HRT)
BOD faecal matter	g/p/d	11	
BOD urine	g/p/d	10	
BOD shower water	g/p/d	5	
BOD laundry water	g/p/d	5	
BOD kitchen water	g/p/d	7	
Total BOD	g/p/d		
BOD Calculation			
BOD in	Kg/d		is equal to per capita BOD x population/1,000
BOD out	Kg/d		is equal to (1-0.35)xBOD in
BOD reduction	Kg/d		is equal to BOD in X0.35
COD Culculation			
COD in	Kg/d		2 *BOD in
COD out	Kg/d		(1-0.55)xCOD in
COD reduction	Kg/d		0.35X COD in

Length of each chamber	m	1	
Depth of each chamber at the outlet	m	1.50	
Hourly distribution of peak flow	h		
Maximum peak flow	m3/d		
Hours flow	h		
Required chamber area	m2		Max peak flow/max upflow velocity
Calculated chamber width	m		Required chamber area/ chamber length
Chosen chamber width	m2		Rounded figure to allow easy constraction
Actual upflow velocity	m/h		Max peak flow/(chosen length*chosen width)
BOD reduction	%	90	
BOD in from digester	m g / 1 mg/1		
BOD out from anaerobic baffled reactor	mg/1		
Legal requirements of NEEMA			
BOD allowed to be discharged to open waters surfaces	mg/1	30	
BOD allowed for irrigation	mg/1	100	
BOD allowed to be discharged to municipal sewer	mg/1	350	

Authors' profiles

Mr. Patrick Onyango

Onyango has 20 years experience in Water Supply & Sanitation and holds a BSc. Degree in Civil & Hydraulic Engineering from Suderburg Engineering Institute based in Lower Saxony, Federal Republic of Germany. He is a member of the European Institute of Civil Engineers (ATV). Mr. Onyango's career commenced in 1990 when he worked with the German Technical Cooperation in Kenya for 14 years until 2004. He then left for Southern Sudan where he worked for the World Food Programme and GTZ-IS International Programme. From 2007 – 2008, Mr. Onyango joined Western Kenyan Water & Sewerage Services Company spanning five districts. Towards the end of 2008, he moved to Nairobi as one of the pioneers of GTZ/SIDA/EU EcoSan Promotion Project (EPP) hosted by the Kenyan Ministry of Water & Irrigation. He holds the position of GTZ Project Manager for the EPP.

Onyango's competence is more pronounced in the following technical areas: Rural Water Supply & Sanitation; Urban Water Supply & Sanitation; Ecological Sanitation with more emphasis on on-site sanitation systems; General Project Management; Project Design & Project Planning in multi-disciplinary integrated Programmes, and last but not least, moderation & facilitation domains. These competencies have been well demonstrated in the Southern Sudan Emergency Road & Dyke Rehabilitation Programme and also in Lamu & Tana Districts of Kenyan coastal province where 60,000 people were settled within the German Assisted Programme (GASP).

Mr. Onyango has also presided over production of over 40 internal publications targeting counterpart ministries and settlers within the GASP. In 2009, he attended the Water & Sanitation Conference in Boswana. In January 2010, he also participated in the International Conference in Japan whose theme dwelt on the follow up of year of Sanitation. Finally, Mr. Onyango has had long and short-term international engagements in S. Africa, Japan, Botswana, Germany, Tanzania, Sudan, Uganda and of course, his home country - Kenya.

Mr. Orodi Odhiambo

Orodi Odhiambo Johannes Dovens holds an Egerton College diploma in Agricultural Engineering (Power and Machinery option) and a BSc honours degree in Agricultural Engineering from Egerton University. He has submitted a thesis titled" Predicting Sugarcane biomass using remote sensing and GIS techniques" for an MSc degree examination with the Board of Post Graduate studies of the University of Nairobi and is currently developing a PhD proposal.

He is a versatile, experienced hands-on technocrat with a wide range of exposure in the training of diploma, undergraduate and post graduate students in diverse areas of Engineering that spans through Mechanical Engineering (Thermodynamics, Mechanics of Machines, Material Science), Surveying, Water Resources and Irrigation Engineering, Soil and Water Conservation, Environmental Engineering, Structures Engineering, Food and Process Engineering, Power and Machinery Systems Engineering and a host of short courses in rainwater harvesting, grain storage structures, coffee processing, micro-hydropower and integrated water resources management (IWRM) among others.

He is a seasoned extension worker providing outreach services to communities, consultancy services to NGOs, line Ministries and International agencies. He is a possibility believer thriving on challenges while seeking technological solutions to express the depth of Gods infinite endowment in mankind for the benefit of the world and the physical earth. An astute public speaker, writer and team leader, he is currently serving as a Chief Technologist at the University of Nairobi and a consultant on rainwater management technologies to Global Water Partnership- Associated Partnership based at World Agroforestry Centre.

Mr. Alex R. Oduor

Oduor has 25 years experience in agricultural engineering with a bias in soil & water conservation, and holds an MSc. Degree in Water and Environmental Resources Management from UNESCO-IHE (Infrastructural, Hydraulics & Environmental Engineering) Institute for Water Education in Delft, The Netherlands. He is a member of Southern and Eastern Africa Rainwater Network, Southern and Eastern Africa Society for Agricultural Engineers, the Kenya Society of Agricultural Engineers, Kenya Rainwater Association and Rainwater Partnership hosted at UNEP.

His career commenced during Sida's Soil & Water Conservation era of the 80's when he worked with Kenya's Ministry of Agriculture, the Swedish Agency for Research in Developing Countries (SAREC) on Soil & Water Management Post Graduate Programme at the University of Nairobi and lately, the Regional Land Management Unit (RELMA and the World Agroforestry Centre (ICRAF). His competence is more pronounced in the Research & design of Soil, Water & Environmental Engineering Infrastructure; Watershed Management, technological development for Rainwater Harvesting; Soil Erosion & Environmental Conservation. He has assessed and developed frameworks on the potential of rainwater harvesting for the African continent and 12 selected countries. Mr. Oduor has also evaluated sand dam potentials in sub-basins of rivers in Mwala and Yatta Districts (Kenya). He has been engaged in developing Rwanda's Irrigation Master Plan under the auspices of the Ministry of Agriculture & Mineral Resources.

Mr. Oduor has also presided over Documentation and some authorship of over 80 Land Management publications during his tenure with the Regional Land Management Unit and the Global Water Partnership Associated Programme. Co-authorship with his colleagues has earned several awards for their publications especially at the Stockholm World Water Week symposium. Finally, Mr. Oduor has had long and short-term international engagements in Belgium, Botswana, Burundi, Brazil, China, Ethiopia, France, India, Kenya, Malawi, Mozambique, The Netherlands, Norway, Rwanda, Somalia, Swaziland, Switzerland, Sweden, Tanzania, Uganda, Zambia, and Zimbabwe.

About this book

In Kenya, many public institutions face a myriad of problems with regard to the provision of safe and adequate sanitation services. Only 18% of the total population is covered by a sewer system necessitating most public institutions to develop their own sanitation facilities.

The handbook addresses the issues above in addition to matters on the promotion of human rights through the provision of adequate water supply and safe Sanitation in line with the *Bellagio Principles* and the *Millennium Development Goals*. EcoSan Philosophy and Scientific Principles of closing the nutrient and water cycle loops, drying & dehydrating, composting, anaerobic & aerobic digestion and heating are also highlighted. EcoSan is further recognized as a technological investment with high returns and an added benefit of reducing environmental degradation and rural poverty.

The handbook underscores a number of EcoSan technological options where issues such as their advantages and disadvantages over conventional sanitation; systems design, setting & construction; operation & maintenance; use especially in relation to agricultural production, including lighting and energy at household level - are tackled. Some of the EcoSan technological options covered in the handbook includes the *Urine Diversion Dehydration Toilets; Biodigester Baffle Reactors*; Composting Toilets such as *Fosa Alterna*; and *Decentralised Treatment Systems* such as Filters & Constricted Wetlands.

Finally, some case examples of EcoSan pilot activities are showcased for selected Kenyan institutions. The handbook is thus highly suited for use in institutions of higher learning, by technologists keen to understand the principles and philosophies of EcoSan and for policy or decision makers from government and external support agencies at district, regional or national levels.

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