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MIP

MASTERS COURSE IN
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NEW TOILETS FOR ORPHANAGE

ECOLOGICAL SANITATION: A FEASIBILITY STUDY OF SANITATION TECHNOLOGIES FOR AN ORPHANAGE IN RURAL ORISSA, INDIA.

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Erklärung des Autors

Hiermit erkläre ich, dass ich die vorliegende Arbeit selbständig verfasst und keine anderen als die angegebenen Hilfsmittel verwendet habe.

Author's Statement

I hereby certify that I have prepared this Master's Thesis independently, and that only those sources, aids and advisors that are duly noted herein have been used and / or consulted.

Date: 06.05.2008

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Signature: ____

Dedication

This master thesis is dedicated to the wonderful children and staff of the Bhorosna orphanage located in Sarangada, Orissa, India.

Acknowledgement

I wish to first appreciate the recommendable work being carried out by the Act! Orissa NGO for helping the poor orphan children of Sarangada. I wish to thank them for offering me this opportunity to write my master thesis on this feasibility study which is directly connected to the lives of the children. It has been a learning experience while working with the orphanage.

I wish to extend my gratitude to my professors and thesis supervisors Dr.-Ing. Dipl.-Chem. Klaus Fischer from the Institute of Sanitary engineering, water quality and solid waste management, University of Stuttgart and Prof. Dr. agr. Giselher Kaule, from the Institute of Landscape planning and Ecology, University Stuttgart, for their continuous support and valuable inputs in the master thesis.

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Abstract

The year 2008 has been proclaimed as the 'World Sanitation Year' by the World Health Organisation. Lack of sanitation has claimed the lives of millions of people in the past few decades. The growing scarcity of water is questioning the use of sanitation technologies that use fresh drinking water for flushing the toilets. The growing dependency on artificial fertilizers for improving the soil fertility is giving rise to harmful genetic disorders. There is therefore an urgent need to consider technologies which provide a common solution to all these problems.

Ecological sanitation technologies provide onsite solutions for improved sanitation, for reduction in the use of water and for improving soil fertility naturally. These technologies aim at closing the loop of different materials involved in sanitation by recycling them. However a sustainable sanitation technology is one which is technically suitable, economically viable, environmentally friendly, hygienic and socially acceptable. In this endeavor this master thesis aims at conducting a feasibility study on sanitation technologies which can be adopted for an orphanage in Sarangada, Orissa, India for a sustainable development. Based on this evaluation this master thesis intends to provide recommendation to the decision makers on the most feasible sustainable sanitation technology option for the Orphanage.

1. New toilets for orphanage!

1.1 Background of this Master thesis

Act!Orissa is a Berlin based NGO set up in 2005 to support an orphanage in rural Orissa, India. In the past 3 years the NGO has raised funds to provide food, clothing and education to the children of the orphanage. Ever since inception the NGO has also tried to improve the living conditions of the children. In this endeavour the NGO constructed a Kitchen and dining hall next to the orphanage in 2006. This year the NGO wishes to construct toilets for which the NGO intends to evaluate the possibility of incorporating the ecological sanitation technology based toilets and therefore intends to conduct a feasibility study based on the economic, environmental and social analysis.

Figure 1 : The orphanage

This master thesis thus aims at providing a recommendations to the NGO on the kind of toilets best suited for this specific situation based on technical, economic, environmental and social analysis.

1.2 Methodology of the thesis

This feasibility study is based on the following methodology. The chapter 2 provides background of the orphanage and its surrounding in terms of its location, topography climate, culture etc. The 3rd chapter provides a brief overview of the sanitation situation in the world and in India, and the ill effects of the conventional sanitation systems. The 4th chapter explains the concept of ecological sanitation and various technologies which can be adAlted for constructing on site toilets while the 5th chapter shortlists a few sanitation technologies and prepares a concept design of that technologies for the orphanage. In the 6th chapter case studies are evaluated of the projects similar to the selected alternative technologies and observations are made for adopting ecological sanitation technologies. In the 7th, 8th, 9th, 10, and the 11th chapters the 4 alternative technologies are analysed for technical, economic, environmental, health and social objectives. The results of the above mentioned chapters are compiled in the 12th chapter which uses multi-criteria evaluation to identify the best choice and discuss the possible spread effect of this technology with recommendations. The 13th and the final chapter concludes the entire feasibility study.

1.3 Limitations of the thesis

While preparing this feasibility study, it was observed that huge amount of information was available on Ecological sanitation technologies. Effort has been made to have the most updated information incorporated in the study. However due to time constraint it was possible to read only a limited amount of information and therefore request is being made to bring to notice of the author any contradictions to the latest development in the technologies.

Also a lot of important information was available on the internet without any reference dates which made it difficult to use the information for analysis. The observations made during the case studies, published information and personal empathy have contributed while evaluating the qualitative indicators.

Effort has been made to make this feasibility study as comprehensive as possible within the set time limits.

2. Introduction

2.1 Background : Sanitation failing in sustainability

The global sanitation coverage in the year 2002 was recorded to be 58%, which implied almost half the world population lacked basic sanitation! Only 49% of the population in the developing countries had access to improved sanitation. Approximately two third of the population of South Asia lived without access to improved sanitation. Almost 50 % of this population lived in China and India.[1] Lack of proper sanitation is responsible for the spread of various infections and diseases. Statistics have shown that sanitation and personal/domestic hygeine is responsible for the death of more than 2.6 million people in the world in the year 1990 and is the second largest killer in the developing countries. [2] There is therefore an urgent need to improve the condition of sanitation in the developing countries.

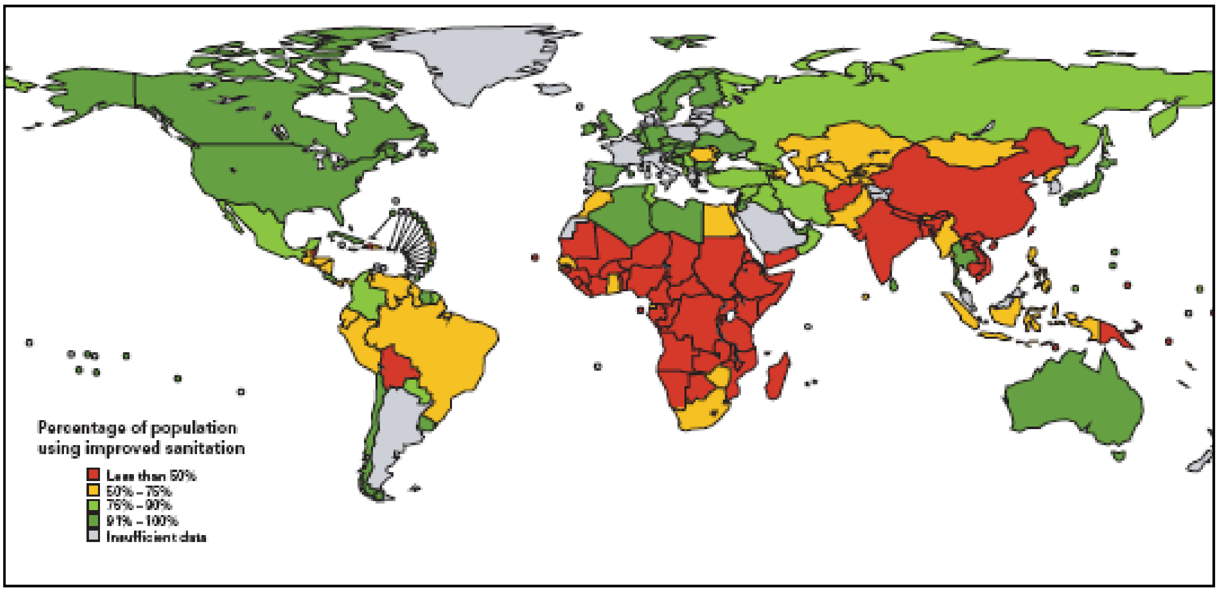


Figure 2 : Sanitation coverage in 2002. Source: [1]

Sanitation for most people implies a hygienic way of removal of feces and urine from households, and maintaining personal hygiene. This waste contains a lot of valuable nutrients. These nutrients need to be returned to the environment in a safe manner. Most international organisations and studies usually concentrate on the hygienic removal of the human waste and tend to neglect the effects of this accumulated waste to the environment.

The term 'improved sanitation' implies 'connection to a public sewer, connection to a septic tank, Pour-flush latrine, Simple pit latrine and Ventilated improved pit latrine'.[1] 'Improved Sanitation' does not necessarily mean that the sanitation is ecologically sustainable but merely that it is hygienically suitable. The aim to improve sanitation conditions by the WHO/UNICEF poses ecological danger to the environment and therefore needs to be redefined to incorporate ecological sustainability.

2.2 Sanitation in India - The Urban and Rural divide

Around 30% of the total population of the India lives in the urban areas. Due to lack of economic opportunities in the rural areas there is continuous migration to the cities. This migrant population usually cannot afford the expensive standard of living of the cities. Major cities like Mumbai have almost half of its population living in the slums and on the streets, and lack sanitation facilities. A majority of this population defecate in the open areas, in the storm water drains etc.

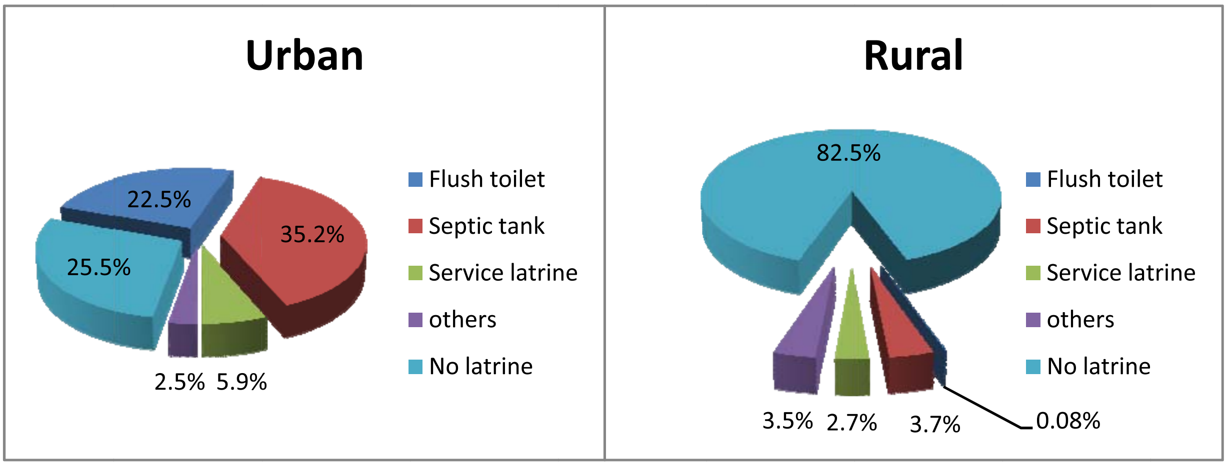


Figure 3 : The Urban-Rural divide. Source: [4]

Most cities have constructed centralised sanitation systems and every year huge amounts of money is spent on constructing sewers throughout the city. Even though only about 25% of the urban population depend on centralised sanitation system, it is a huge burden on the treatment plants due to high population density in the urban areas. Most of the treatment plants are overburdened and do not perform to the required standards thereby polluting water bodies due to continuous dumping of the treated residue. Septic tanks are constructed without any regards to the ground water table leading to contamination of the ground water. Also owing to high density and overuse of the toilets the soil quality is deteriorated and saturated. Rural areas lack basic sanitation facilities. People usually defecate in the open in farms, bushes etc. The continuous defecation in the open leads to health risks by the spread of infections and diseases.

The myth that centralised systems are the best solution for sanitation is leading to the growing shift from other forms of toilet to flush toilets as the economic condition of the people improves. Most of the rural areas do not have piped supply of drinking water and they depend on ground water for their needs of fresh water. As the population is increasing the ground water tables are steadily sinking more and more drought prone areas. There is also an immediate need for realisation that water is a scarce resource and needs to be preserved.

2.3 Conventional water-borne sanitation systems - a mindless approach

Conventional water borne systems use water as a medium for the removal of excreta from the households. These systems were developed in the late nineteenth century in Europe after the introduction of piped water supply in the cities. The solution to eradicate the problem of sanitation related diseases was to transport the human waste from the households and discharged into the water. But soon this solution proved futile due to the health hazards caused due to polluted water. Various technologies have been invented ever since then to treat this accumulated wastewater. Today most cities of the developed world depend on such water borne sewerage systems. Modern technologies have been able to treat this wastewater by step by step treatment (primary, secondary, tertiary) to a level where it can be harmlessly disposed off. [5] Conventional systems have helped drastically to reduce the deaths caused due to improper sanitation however the after effects of these systems are being felt now.

Even though modern technology solutions can provide safe treatment and disposal techniques, they have major drawbacks

1) Cost - The investment, operation and maintenance costs of theses centralised sewage systems are very high. Due to lack of financial resources these hi-tech solutions cannot be afforded and cheaper low tech solutions or poor quality treatment plants are installed. The effect of such decisions is that there is effective removal of wastewater from the urban areas but resultant pollution of the neighbouring water bodies.[5]

2) Health - Sanitation in India is a luxury of the rich and the middle class who have access to toilets. The poor have no access to toilets and they defecate in the open. From Figure 2 it is evident that more than 95% of the toilets used in India (i.e. sewer and septic) are water borne systems. These water borne systems involve very high investment and maintenance costs. These systems therefore tend to serve only a small affluent portion of the society. The treatment plants often do not meet the quality standards prescribed which affect the quality of treated wastewater. This treated wastewater is discharged in the neighbouring water bodies which affects the poor people who depend on these water bodies for their daily needs. Therefore the toilets of the rich affect the health of the poor.[3] A study shows 'Poor people without sanitation or hygiene education spent six times more on medical care than people with access to sanitation and who had a basic knowledge of household hygiene.'[4]

3) Ecology – Large scale contamination of the water bodies is rendering the water bodies dead affecting human and aquatic life. Most of the Indian rivers today are highly polluted. The continuous pressure of population on the sewage treatment plants, the chocked up drains and sewers leads to untreated sewage being dumped into the river. In Delhi, the treatment plants have been able to only treat about 50% of the waste water. While the remaining 50% is being dumped into the Yamuna. [3] Also onsite technologies pose major health hazards due to contamination of the ground water. Due to lack of

knowledge these toilets are constructed without determining the depth of the water table. Overuse of toilets due to increasing population density also affects the ground water quality.

4) Technical failures – Sewage treatment plants are susceptible to total breakdown due to various reasons. Heavy rains can dilute the waste water and create pressure on the treatment plant. In 2005, a treatment in Switzerland was completely destroyed due to heavy rains. For almost 2 months the untreated waste water of several thousand inhabitants had to be discharged into the rivers.[6]

5) Water – Water is a scarce resource. The increasing demand of water supply to meet the needs of the growing population of the cities has put a huge pressure on our existing water resources. Water cuts and limited supply of drinking water for a short period of time in a day is a common scenario. Precious drinking water is used to flush toilets and to carry sewage to the treatment plant which could have quenched the thirst of greater population of people. In many rural areas of the country water supply network is not available. Most of the people depend on ground water to meet their needs of drinking water. The constant use of ground water has led to lower ground water tables and the day is not far when we would hit the bottom.

6) Nutrient recovery – The most important drawback of this system is that it does not facilitate the reuse of the nutrients present in the waste. This invariably leads to a linear flow of nutrients from the soil via agriculture via humans to the water bodies. The treatment process either eliminates nutrients like Nitrogen and so very little is returned to soil when the treated excreta is used as manure in agriculture or the nutrients enter the water bodies causing eutrophication of lakes and rivers. [7,8,9]

7) High energy input – The treatment plants consume huge amounts of energy to treat the waste water. The costs of operating such high energy intensive treatment plants, is borne by the government which could have used the funds for the development of the community. Also only a part of the treated excreta can be used as fertilizers. A huge amount of energy is used to manufacture artificial fertilizers every year when in reality the human excreta has the potential to meet almost one third the fertilizer demand of the world. In a time when growing energy prices depending on such high energy systems is questionable.

2.4 Need of sustainable sanitation system

Sanitation is no longer a hygienic way of excretion but now also aims at providing human dignity, quality of life, environmental security, economic benefits etc. The conventional systems have a lot of major shortcomings and are not sustainable in the long run. A system which is cost effective, having economic benefits, water independent, localised, returns nutrients back to soil and which can provide improved sanitation to the poor is the need of the hour. Such a sanitation system can be sustainable in the long run.

The Bellagio principles established by a group of experts during the 5th Global forum of the Water Supply and Sanitation Collaborative Council (WSSCC) in November 2000 aims at achieveing Sustainable sanitation. These principles state that :

- ‘Human dignity, quality of life and environmental security at household level should be at the centre of the new approach, which 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 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. ‘ [5]

To call a sanitation scheme Sustainable, the scheme has to perform well in the following objectives:

1) Technical
2) Economic
3) Environmental
4) Health
5) Social

2.5 Are sustainable solutions feasible?

As is a case with most ‘ECO-Friendly’ goods which are more expensive than the regular commodities making them less popular with the community, sustainable solutions need to perform better than the conventional systems in terms of cost, benefits, environmental security and human comfort and only then they can be feasible solutions for the community.

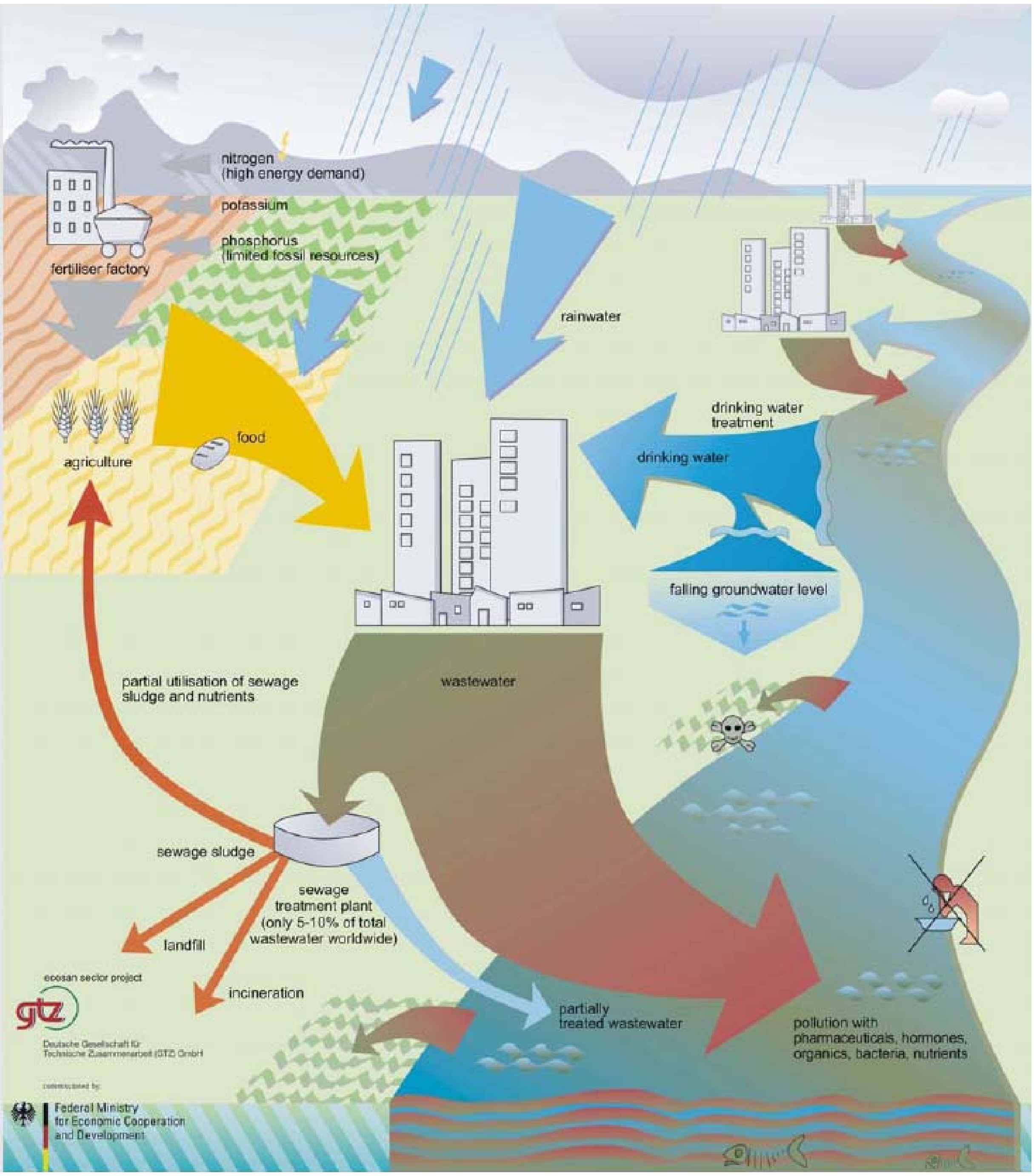


Figure 4 : Shortcomings of Conventional water borne systems [11]

3. Ecological sanitation

3.1 What is Ecological sanitation?

'Ecological sanitation is a new holistic paradigm in sanitation, which is based on an overall view of material flows as part of an ecologically and economically sustainable wastewater management system tailored to the needs of the users and to the respective local conditions. It does not favour a specific sanitation technology, but is rather a new philosophy in handling substances that have so far been seen simply as wastewater and water-carried waste for disposal. Ecological sanitation introduces the concept of sustainability and integrated, eco-system oriented water and natural

- providing affordable, safe and appropriate sanitary systems;
- reducing the health risks related to sanitation, contaminated water and waste;
- improving the quality of surface and groundwater;
- improving soil fertility; and
- optimizing the management of nutrients and water resources' [10]

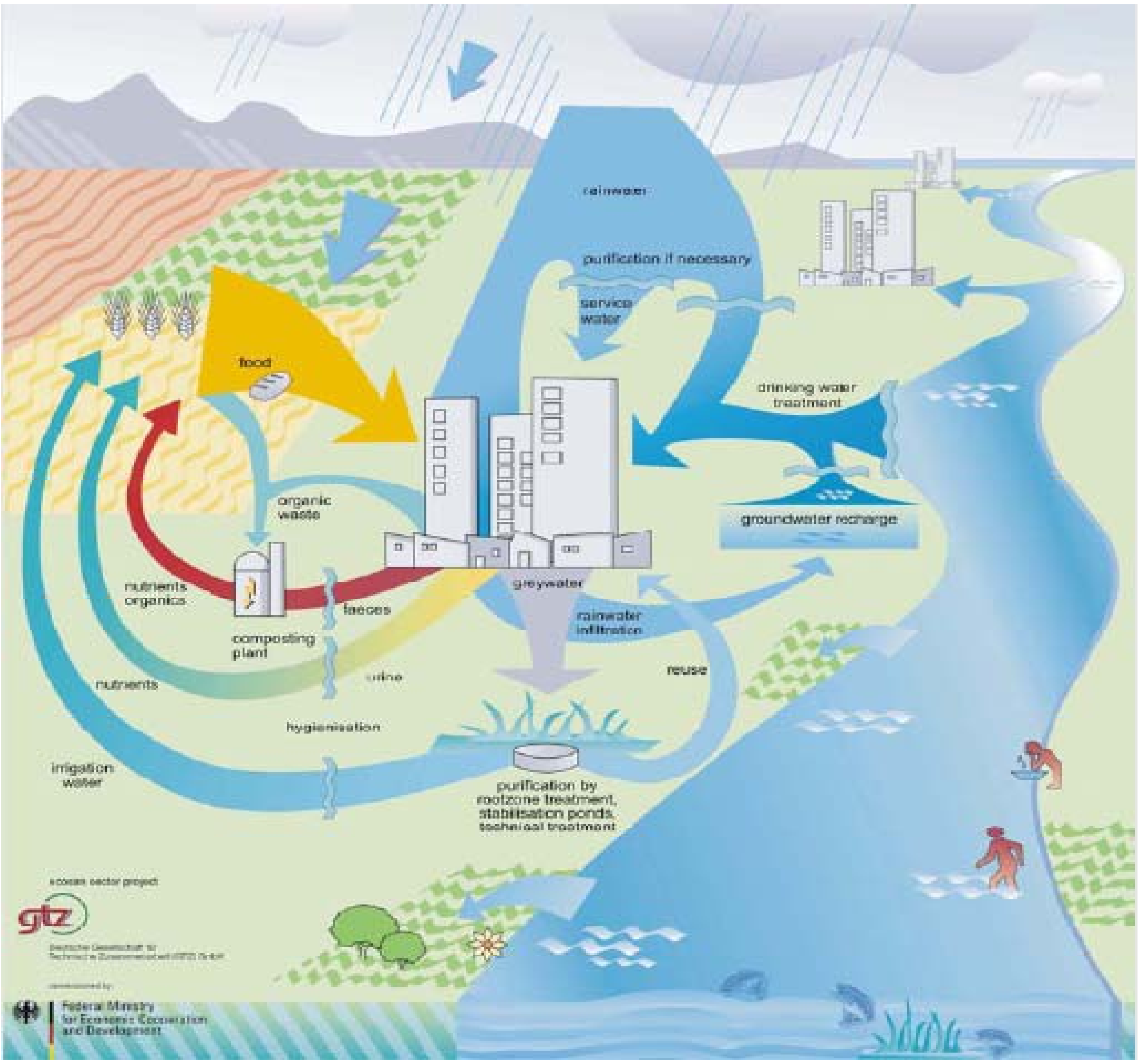


Figure 5 : Benefits of Ecological Sanitation [11]

3.2 Material cycle in Ecological sanitation

Sanitation forms a part of several cycles of the ecosystem. Some of the important cycles are the pathogen cycle, the water-nutrient and the energy cycle. The concept of ecological sanitation aims at closing these flow cycles. To promote public health ecological sanitation intercepts the life cycle of the pathogens; to promote nutrient recovery ecological sanitation treats the excreta, urine and household water as a resource which can be recycled to return the nutrients back to the soil thus improving the soil fertility and plant growth; to promote energy recovery the process of sanitization of the waste which involves the emission of various energy intensive gases is used to generate energy for everyday utilization. The conventional sanitation technologies ensure hygienic in-house conditions, however end up polluting the outer environments and thus only tend to export the problems. Ecological sanitation technologies on the other hand sanitizes the waste and return it back to the environment and thus close the loop of the flow cycles.[5].

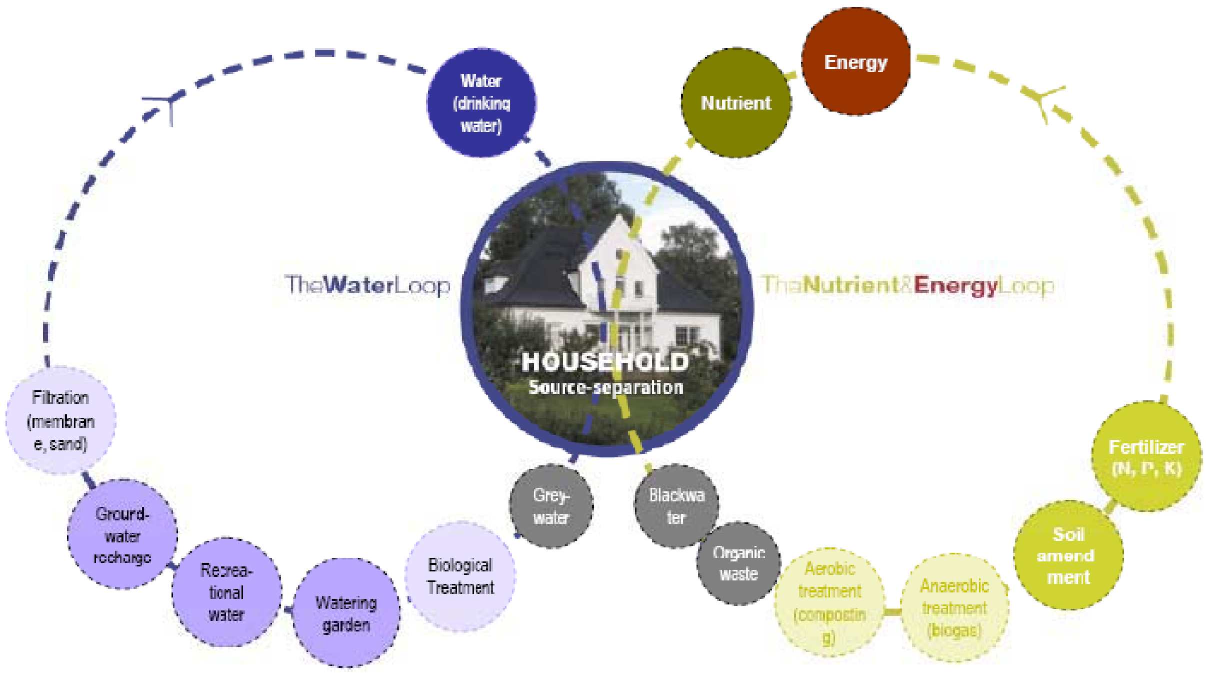


Figure 6 : Material cycles [12]

3.3 Health aspects of Nutrient reuse

Human excreta contains a lot of harmful pathogens. These pathogens can enter our human body through various routes such as hands due to improper personal hygiene, through flies, through water contamination etc. the principle aim of any sanitation technology is to prevent diseases due to these pathogens. Pathogens exist in the form of bacteria, viruses, parasitic protozoa, ova, Hook worms, flat worms etc. these pathogens can cause harm to the human body resulting into death.

Many of these pathogens die on exposure to external atmosphere while a few of them survive for weeks before they die. However some of the environmental factors play an important role in the die off rate of these pathogens such as high temperature, time, low moisture contents and Ph. Pathogens cannot survive beyond a certain temperature and time while low moisture contents halts the biological activity. Ph values greater than 9, restricts the growth of pathogens. [17] Control of pathogens can lead to hygienic utilization of feces in the agriculture.

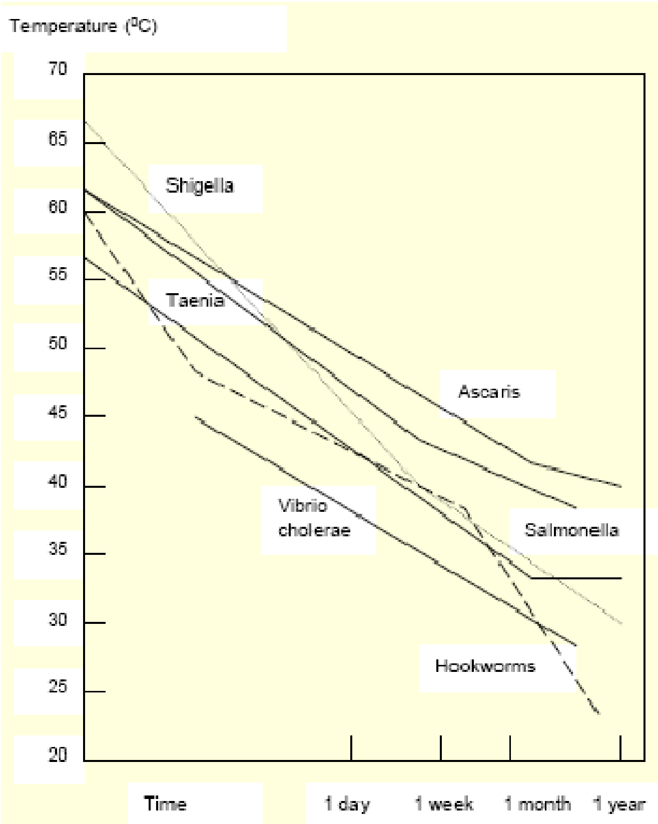


Figure 7 : Influence of time and temperature on the death of various pathogens present in the excreta: [18]

From the above graph it can be seen that higher the temperature, lower is the retention time of the excreta for killing the pathogens and vice versa.

3.4 Technologies in Ecosan

3.4.1 Pit Toilets

Pit toilets are of 3 types:

A. Simple pit toilets – A simple pit toilet consists slab placed over a deep pit with a hole for defecating. It does not need water for flushing. The pit is covered once full and the toilet is shifted to a new place. If the pit is close to the ground water table and the soil permeable then there is a possibility of ground water contamination and such toilets should be avoided. This kind of sanitation is low cost also provides benefits to the farmer. [19]

B. Ventilated Improved Pit toilets – a VIP toilet is an improved version of the pit toilet. The pit is provided with a vent pipe to provide circulation of the air to remove the foul smell. The vent pipe is provided with a fly mesh to prevent the fly nuisance. This system is low cost and eliminates the shortcomings of the simple pit toilet. [19]

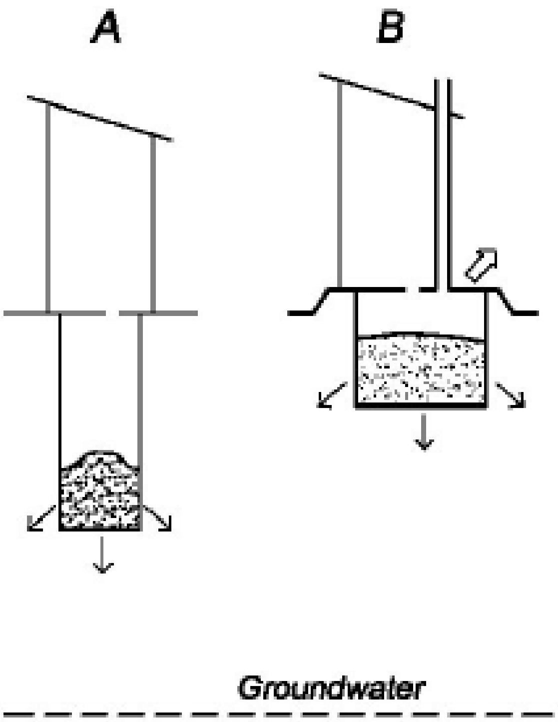


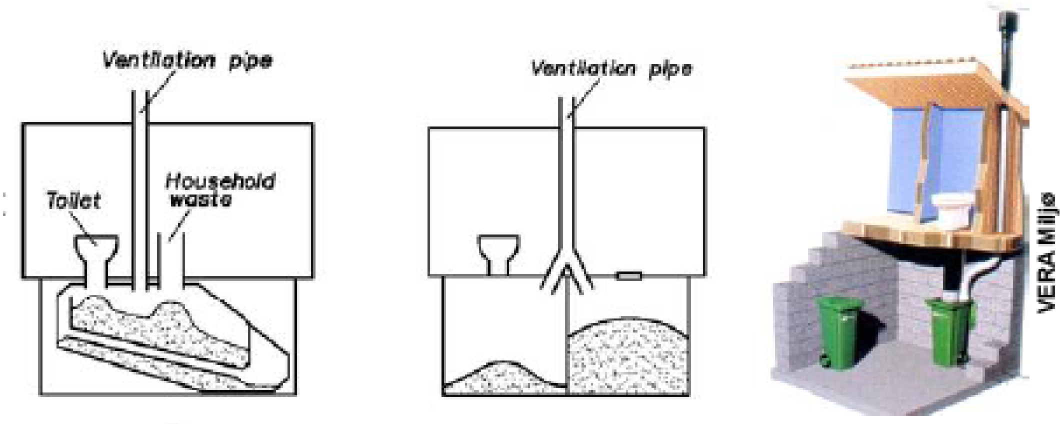
Figure 8 : Pit toilets [18]

C. Pour flush type toilet with a leach pit– A pour flush type toilet uses water to transport the feces. It is built like the conventional toilet and is connected to two leach pits. The capacity of each pit is generally designed to hold the contents for 2 years or more. When one pit is full the connection is shifted to the adjoining pit while the earlier pit is closed and left for 2 years. The pit is opened after 2 years and the content is ready to be used for agricultural purposes. Pour flush type toilets need low maintenance and give users the convenience of the water closet. It is odour free and free from the nuisance of flies. However it is water intensive and gets clogged if anal cleaning material is used. Also the toilets can be within the house or attached to the house. [19]

3.4.2 Composting and Dehydration

Composting Toilets: Composting is a Biological aerobic process that decomposes the excreta and converts it into soil conditioner. Excreta is stored in the composting chamber for a long period of time for the pathogens to die and then when safe it is use as fertilizers in the fields. The efficiency of composting depends mainly on the volume of the mass. Other environmental factors of importance which affect composting are the moisture content which should preferably be 50-60%, Carbon to Nitrogen ratio which should preferably be 25:35, aeration, temperature etc. The moisture content and carbon nitrogen ratio can be reduced by adding bulking material which absorbs moisture such as saw dust, toilet paper, ash etc. [18]

The compost toilet may be constructed as a continuous process or a batch operated process where the composting could take place onsite or offsite. This type of system produces valuable manure for the farms but it needs maintenance and bulking matter.



A: Single chamber B: Dual chamber C: Removable Compartments

Figure 9 : Compost toilets [20]

Dehydrating toilets: The dehydrating toilets are based on a similar principle as the compost toilet. However instead of using the existing conditions for reducing the moisture content, it is dried with external heat. The heat can preferably be from solar energy, natural ventilation and by adding bulking material. Dehydrating toilets can be combined with urine diversion to reduce the moisture content. This system has similar benefits like the compost toilet but needs less maintenance. Also when combined with Urine separation the toilets provides additional benefits in terms of farming activity.

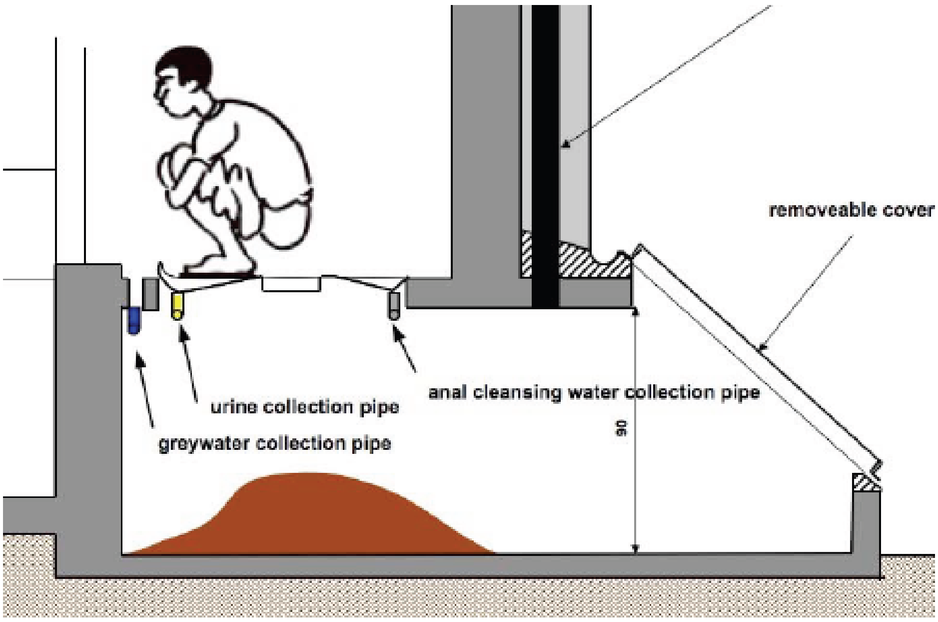


Figure 10 : Urine diversion dehydrating toilet [21]

1.1.1 Bio gas

Bio gas production is an anaerobic process and takes place in the absence of oxygen. The process is an endothermic process and the material is decomposed into water, biogas and slurry. Biogas consists of methane, carbon dioxide and traces of few other gases. The Biogas thus generated can be used for cooking, lighting etc. Also the slurry is rich in phosphorous and potassium and is a very good fertilizer for the plants. The input to the biogas plant is animal dung, organic wastes and human excreta. The bio gas plant therefore can produce valuable outputs which can be used in the household activities.

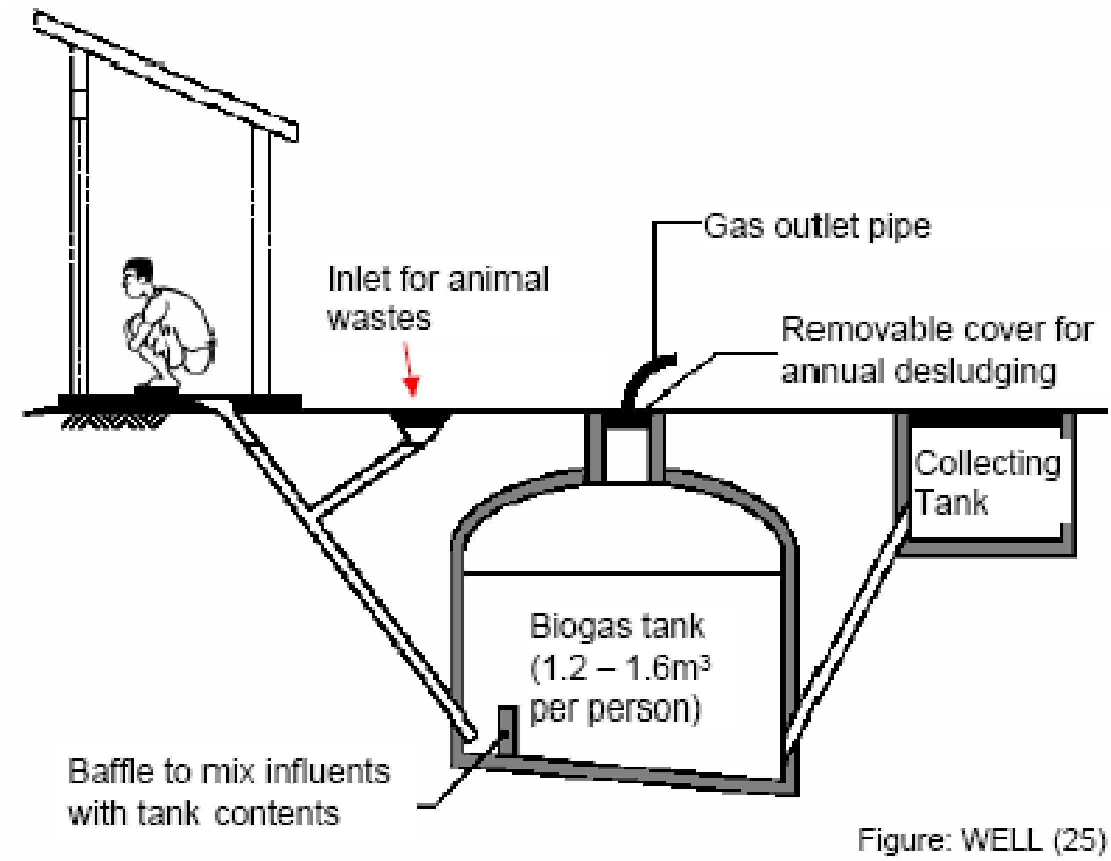


Figure 11 : Biogas plant [22]

4. The orphanage

4.1 Location and surroundings

The orphanage is located in a small tribal village called Sarangada in the Khandamal district of Orissa State, India. Khandamal was a part of the Phulbani district and received independent status on 1st January 1994. The district is located between 19.34'N and 20.50'N latitude, and 80.30'E and 84.48'E Longitude.[13] The altitude varies from 300 to 1100m above sea level. [14]

Sarangada is approximately 211Kms from Bhubaneshwar the capital city of Orissa and approximately 35 Kms from G.Udayagiri. The area of the village is 554.37 Acres (approx.1.4 sq.Km).[15] The village is remotely located and is sparsely connected with transportation. It is surrounded by hilly forest and farm lands. The Orphanage is located on the outskirts of the village and at the foot hills of the surrounding mountains.

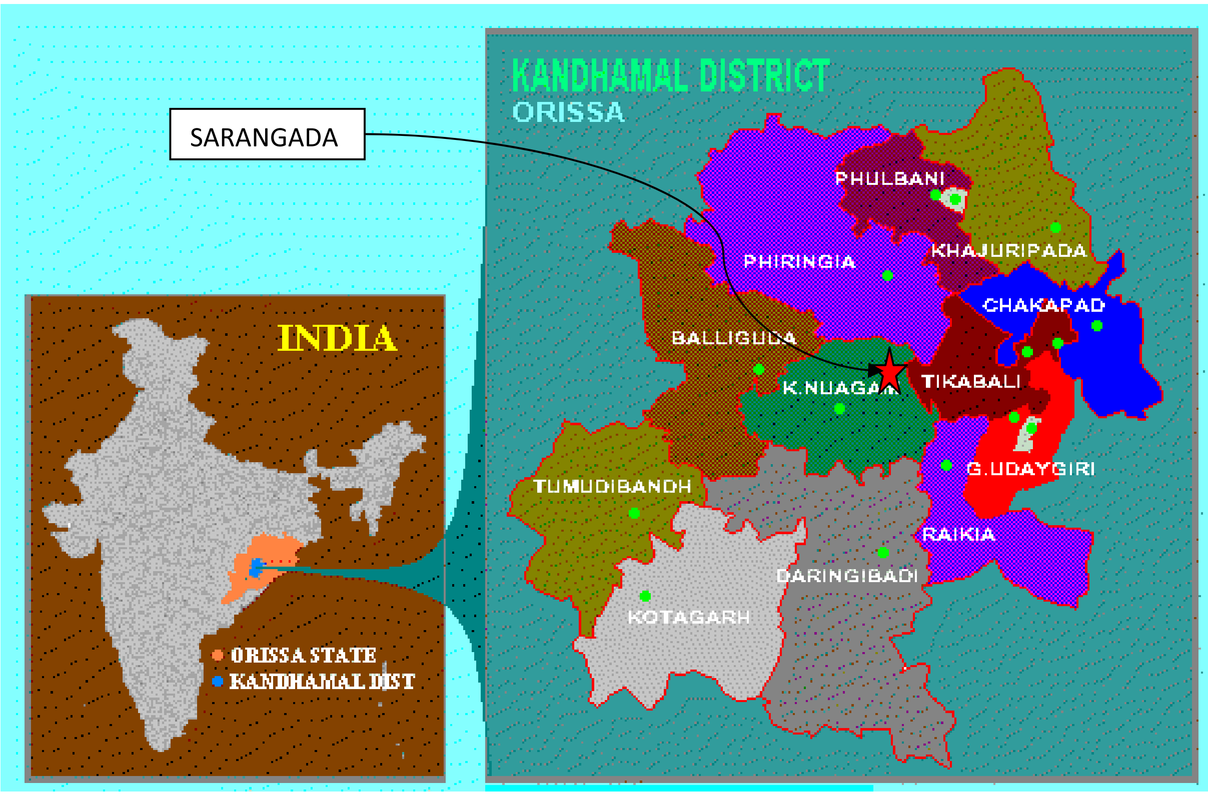


Figure 12 : Location Map of Sarangada [16]

4.2 Natural conditions

The weather of Sarangada is warm and dry due to its location in the interiors of the state. The maximum temperature of the district is 45.5°C during summer and 2°C during winter. The region enjoys four season namely the spring, the summer, the rainy and the winter. Due to mountainous topography the district receives heavy rainfall. The average yearly rainfall of the district is 1587mm.[13] The village has red sandy loam soil[31] which makes less impermeable. As rice cultivation is done in this soil, the soil infiltration rate is very low. The ground water table is at a depth of 20m close to the orphanage1. The water level falls down drastically during summer while the water level rises during Rainy season in the well. Water is not scarce, however if not judiciously used can lead to water scarcity. The agriculture in the neighbouring areas is mainly rice cultivation and mango, banana and papaya tree plantations are very common.

Figure 12 : Orphanage: front yard (left) and the backyard (right)

4.3 Social and Economic conditions

The population of the Khandamal district in the year 2001 is approx. 650,000 inhabitants and the population density is 81 inhabitants per sq.km. There are around 1008 females for every 1000 males and the literacy rate is 52.95%. [13] The district derives its name from the Khanda tribe and most of the villagers belong to the schedule caste(SC) and schedule tribes (ST). The language spoken by this tribe is Kui which is a dialect of Oriya Language.

Sarangada being a remote tribal village the literacy rate is much lower. One of the major reasons of illiteracy is the poor economic conditions. Majority of the population are below the poverty line and the per capita annual income is Rs. 3864/- (64.4€[2]) . Only a small portion of the villagers own agriculture land for cultivation. They are seasonal labourers and work as labour for construction activity when an opportunity arises. The rest of the population earns their livelihoods collecting fire wood and other forest products from the surrounding forests. Fire wood is used as cooking fuel by almost 90.5% of the population. The family size is 5.3 people per household. Only about 4.83% of the populations have their own toilets and

[1] Information from Project Engineer , Mr. Jay Kumar, PWD Orissa.
[2] 1 Euro = 60 Indian Rupees(as on 25 April 2008)

about 92.7% of the people depend on ground water for their daily needs. About 71.83% of the population lives in Kacha houses.[30]

Majority of the people living in this area are Hindus and Christians forms the minority. Both the communities lived in harmony until recent communal clashes based on religious differences were reported in December 2007 in the villages and the surrounding areas of Khandamal district.

4.4 Cultural habits

The tribes display a strong sense of gender separation. Almost all the people defecate in the open due to lack of proper sanitation facility. The areas of defecation for men and women are segregated. Also most of the people do not have shower cubicles and they shower in the open close to the ground water wells. The shower timings are segregated for the men and the women.

Also the majority of the population being Hindus, they worship the Holy Cow. People consider the cow dung and urine sacred, and they do not have inhibitions to handle it. Cow dung is used for various purposes. Composted cow dung is used in the fields. Cow dung cakes are dried and used as fuel with firewood during cooking. It is also used as a plaster for the walls and flooring material for the mud house construction. Urine on the other hand is used as holy water for spiritual purification and sprinkled on the houses. However human feces are considered unclean and bad, and therefore excreted away from the house.

The people are religious, conservative and blindfolded due to illiteracy. The people have a strong interaction with their environment and tend to worship the forests and farms. However the glorification of the forests and farms as Gods has lead to the belief that they are self recuperative irrespective of the harm caused. The children of the orphanage as well as the staff are more liberal and open-minded due to literacy and the constant interactions with the foreign volunteers which has led to exchange of ideas through interpersonal interactions.

4.5 Existing sanitation infrastructures

The village lacks basic infrastructure for sanitation. Toilets and showers are non-existent in the households. Very few households, public toilets and schools have toilets which are the pour flush type with a septic tank. Almost all the people defecate in the open in the forest, farms, bushes etc

4.6 Demand for improved sanitation

Due to the poor economic condition of the people the need for improved sanitation is not a priority of the people. The more important needs being food and shelter for living. There is general unawareness of improved sanitation and children tend to grow with the notion that defecation should be done in the open bushes and is a safe way of sanitation.

4.7 Legal framework

The authorities do not prescribe any standard of sanitation for tribal village households and therefore no legal formalities are involved. But community sanitation projects need approval from the local authorities.

4.8 Inhabitants of the orphanage

There are 60 female children from the age of 3yrs to 14yrs who live with 7 staff members in the orphanage. A calf is a new member to this huge family. All the children go to public school and the staff members are literate. Summer camps are organized in the orphanage and foreign volunteers visit the orphanage during this time. The volunteers spend time and participate in the daily activities of the orphanage.

5. Ecological sanitation toilet alternatives

5.1 Selection of Alternatives

There are various types of ecological sanitation technologies available for toilets. Each type of sanitation system has its own advantages and disadvantages. Depending on specific situation, the advantages and disadvantages are evaluated and the best sanitation technologies are adopted.

Far evaluating the best suited sanitation technology for the orphanage, 4 type of sanitation technologies are selected depending on the treatment of waste water. They are as follows:

1) Pour flush toilets with Septic tank (Conventional)
2) Pour flush toilet with double Leach pit (Pit Type)
3) Urine diversion dehydrating toilet (Dehydration)
4) Pour flush toilet with Biogas system (Anaerobic)

To evaluate these system a conceptual design of each system is made and then evaluated for the following Objectives.

1) Technical
2) Economic
3) Environmental
4) Health
5) Social

As these designs are conceptual designs, professional expertise needs to be seeked while constructing the best choice alternative.

5.2 Design of Pour flush toilet with Septic tank

The design of a septic tank is guided by the following principles:

1) ‘To provide sufficient retention time for the sewage in the tank to allow separation of solids and stabilization of liquid;
2) To provide stable quiescent hydraulic conditions for efficient settlement and flotation of solids;
3) To ensure that the tank is large enough to store accumulated sludge and scum;
4) To ensure that no blockages are likely to occur and that there is adequate ventilation of gases’ [19]

For designing toilets the following considerations are made.

1) Sewage retention time (A) assumed to be 24 hours.
2) Number of people to be served (P) by the septic tank is 60 children and 6 adults(staff).
3) Sewage flow per person (q) is assumed as 10 litres of water flushed with a bucket in a day. [28]
4) Number of years before desludging (N) is considered to be 5 years.
5) The rate of sludge and scum accumulation is taken as 25 litres per person per year. [19]. As the feces production of children is half that of the adult, 2 children are considered as 1 adult.
6) Minimum number of toilets required is assumed to be 2 toilets.

5.2.1 Design calculations for septic tank

Capacity required for 24 hours liquid retention is

A = P x q litres (refer Annexure V)

A = 66 x 10

A = 660 litres

Capacity required for sludge and scum storage (B) is

B = P x N x F x S (refer Annexure V)

B = 36 x 5 x 1 x 25

B = 4,500 litres

Therefore the total capacity of the septic tank (C) is

C = A + B

C = 660 + 4500

C = 5,160 litres i.e 5200 litres approximately

Assuming the length of the septic tank to be 3m and the breath to be 1 m, the min depth of the tank is worked out to be 1.7 m

Total depth of the tank = min depth + 0.3 m (headboard) = 1.7 + 0.3 = 2 m

5.2.2 Design of Soak pit

The following assumptions are made for the design of a Leach pit

1) Sewage retention time (A) assumed to be 24 hours.

2) Number of people to be served (P) by the Leach pit is 60 children and 6 adults (staff).
3) Sewage flow per person (q) is assumed as 10 litres of water flushed with a bucket in a day. [28]
4) Number of years of storage capacity (N) is considered to be 1 year.
5) The rate of sludge and scum accumulation is taken as 25 litres per person per year. [19]. As the feces production of children is half that of the adult, 2 children are considered as 1 adult.
6) As the soil is sandy loam red soil. Infiltration rate of soil (IR) is low and considered to be 25 litres per m² [19]

5.2.3 Design calculations for a Soak pit

The capacity design is done similar to the septic tank

Capacity required for 24 hours liquid retention is

A = P x q litres (refer Annexure V)

A = 66 x 10

A = 660 litres

To soak the water in the soil, the surface area of the pit should be = A / IR = 26.4 m²

Assuming a length of 4m and a breath of 3 m, the min depth of the pit with a surface area of 26.4m² works out to be 2m.

Therefore depth of Leach pit = head board + Min depth of pit

= 0.50 + 2

= 2.5 m.

5.3 Design of Pour flush system with Leach Pit

The following assumptions are made for the design of a Leach pit

1) Sewage retention time (A) assumed to be 24 hours.
2) Number of people to be served (P) by the Leach pit is 60 children and 6 adults (staff).
3) Sewage flow per person (q) is assumed as 10 litres of water flushed with a bucket in a day. [28]
4) Number of years of storage capacity (N) is considered to be 2 year.
5) The rate of sludge and scum accumulation is taken as 25 litres per person per year. [19]. As the feces production of children is half that of the adult, 2 children are considered as 1 adult.

6) As the soil is Sandy loam red soil. Infiltration rate of soil (IR) is considered to be 25 litres per sq. m [19]

7) Minimum number of toilets required is assumed to be 2 toilets.

5.3.1 Design calculations for a Leach pit

The capacity design is done similar to the septic tank

Capacity required for 24 hours liquid retention is

A = P x q litres (refer Annexure V)

A = 660 litres

Capacity required for sludge and scum storage (B) is

B = P x N x F x S (refer Annexure V)

B = 36 x 2 x 1 x 25

B = 1800 litres

To soak the water in the soil, the surface area of the pit should be = A / IR = 26.4 m²

Assuming a length of 4M and a breath of 3 M , the min depth of the pit with a surface area of 26.4m² works out to be 2M.

Therefore depth of Leach pit = head board + Min depth of pit + depth for sludge storage

= 0.5 + 2 + (1.8/12)

= 2.65 m i.e 2.75m approximately.

5.4 Design of Urine diversion Dehydrating toilet

The following assumptions are made for designing a UDD toilet

1) Number of people to be served (P) by the UDD is 60 children and 6 adults (staff).

2) Daily feces generation is considered to be 0.02 litres per child per day. [8]

3) Number of years of storage capacity (N) is considered to be 1 year.

4) The amount of cover material used is 0.2 litres per person per day. [8]

5) Minimum number of toilets required is assumed to be 2 toilets. The total users of each toilet can vary between 30 to 35 users per day.

6) The daily urine production can be assumed to be 1 litre per person per day. [8]

5.4.1 Design calculations

The daily accumulation of feces and cover material person is = (0.2 + 0.02) x 35 = 7.7 litres per day i.e. approximately 8 litres

Yearly accumulation of feces and cover material is = 8 x 365 = 2,920 litres i.e Minimum 3 m^3 is required for storage capacity.

Assuming a toilet size of 1.5m x 2 m, the depth of the feces storage should be 1 m.

Daily urine production is = 66 x 1= 66 litres per day i.e approximately 70 litres.

Weekly urine production is = 70 x 7 =490 Litres i.e 0.5 m^3 approx.

Assuming a storage time of 4 weeks approximately 5 plastic containers of 500 litres are required.

5.5 Design of Pour flush system with Biogas system

The following assumptions are made for the design of Biogas plant.

1) Number of people to be served (P) by the Biogas plant is 60 children and 6 adults (staff).
2) Daily feces production is considered to be 0.2 Kg per child per day. [8]
3) Minimum number of toilets required is assumed to be 2 toilets.
4) Cow Dung produced by one cow is 10 Kg.[29]

5.5.1 Design calculation for biogas plant (refer Annexure VI)

feedstock from	No. Of producers	quantity per person per day in Kgs [29]	total Daily production in kgs	gas production per kg in m^3 [29]	total gas production in m^3
Children	60	0.2	12	0.07	0.84
Adults	6	0.4	2.4	0.07	0.168
Cow	1	10	10	0.036	0.36
Total			**24.4**		**1.368**

Therefore a Biogas plant with a biogas capacity of 1.5 m^3 is feasible.

5.6 Process of analysis

Analysis is made for each of the 5 objectives. For each objective criteria and indicators are identified for evaluation. The criteria are then evaluated by the indicators for each alternative separately. The evaluation of the indicators is either qualitatively or quantitatively. The qualitative evaluation is based on a performance; very high, high, medium, low, nil. It has to be noted that 'very high' and 'high' represents good, beneficial and positive qualities while poor, nil represent bad, harmful and negative qualities.

In the next step the indicators are scored as per their performance. Qualitative indicators are scored as follows:

Very high = 5

High = 4

Medium = 3

Low = 2

Nil = 1

The quantitative indicators are scored based on comparison and graded 5 as the highest positive score and 1 as the lowest negative score.

The score of the indicators are added to find the score of the criteria. In order to balance all the criteria they are divided by the number of indicators used to evaluate a criteria. Thus the performance of each criteria have the same parameter. This process is again repeated with all criteria to evaluate the objective. Weights can also be given to the criteria as per its significance.

The resultant scores of all the alternatives are then compared to see the final performance of each alternative for hat specific objective

This method is applied for each alternative and objective separately. The final results of each objective are then compiled in the chart of multi-criteria analysis to identify the best choice alternative of all the four options.

6. Case studies

6.1 Case Study 1: Gothamaha Primary school[3]

6.1.1 Project Details :

- Promoter : Government of Orissa.
- Location : Sarangada, Orissa(India)
- School type : Day school with hostel accommodation
- School capacity: 200 students + 20 staff
- Hostel accommodation : 200 students
- Type of technology applied : Pour flush toilet with Septic tank
- No of toilets : 4
- Cost of Construction: Rs. 65,000/- (750 €)
- Constructed year : 2007
- Status : Not yet commissioned

Figure 13 : Septic tank and soak pit

[3] Information based on Interview with Mr. Jay Kumar (Project Engineer, PWD) and Visual inspect ion

6.1.2 Observations

1) Pour flush type of toilet with septic tank is a commonly adopted system by the government of Orissa in all public schools throughout the state of Orissa.
2) Water supply for flushing the toilet is from the ground water well located in the centre of the toilet and shower Block.
3) Plastic buckets used to pour water for flushing the toilets.
4) Greywater from the shower is directly connected to the soak pit
5) As it is a standard practice to construct toilets with septic tanks by the government, no evaluation surveys were made while opting for this technology.
6) The consideration of the soil infiltration rate has not been considered an standard soak pit is constructed which can lead to over flowing soak pit.
7) The septic tank alternative offers no maintenance which makes it the favoured alternative amongst other sanitation technologies.
8) Impacts of desludging is ignored

6.2 Case Study 2 : Private toilet of villagers[4]

6.2.1 Project Details:

- Promoter : WHO (World Health Organisation)
- Location : G.Udayagiri, Orissa (India)
- Family size :5-6 people
- Type of technology applied : Pour Flush Toilet with double Leach pit
- No. of toilets : 1 per family
- Cost of Construction : Rs. 10,000/- (167€)
- Public –private contribution : The investment cost of the toilet was subsidized 90%by WHO and 10% was private contribution of each family.

[4] Information based on Interview with Mr. Chabila Naik (resident), G. Udayagiri, Orissa.

6.2.2 Observations

1) As majority of the population was lived below the poverty line and earned less than Rs. 6,000/- per year, they could not afford the contribution of Rs. 1,000/-. Very few such toilets were constructed.
2) The constructed toilets were overused leading to flooding which was interpreted as failure of the system. Many such toilets have been abandoned.
3) The importance of changing of connection from the first leach pit to the second leach pit was not properly understood.

6.3 Case Study 3 : Navsarjan Primary boarding school at Rayka village [8]

6.3.1 Project Details

- Promoter: Navsarjan Trust.- An Ahmedabad based NGO working for the upliftment of the Dalit , Tribals and the poor all over Gujrat.
- Consultants : SEECON gmbh (Switzerland)
- Location : Rayka villaga, Dhandhuka Taluka, Gujarat(India).
- No of Users : 210 children and 10 staff
- Type of Technology applied : Double vault Urine Diversion Dehydrating toilets (UDD)
- Number of toilets : 8
- Year of construction : 2007
- Cost of construction : 12,000/- (200 €)

6.3.2 Observations

1) The toilets enjoy a high level of acceptability as it is introduced among children who are more open to newer concepts. Also as it is a boarding school, the children are less exposed to contradictory opinions from the family and the community.
2) The toilets are very well maintained and supervised owing to which the system works efficiently and there is no bad odour from the toilets.
3) The toilets are cleaned and washed everyday which makes them attractive to the users.
4) Stake holder involvement in the decision making process is important.

5) Awareness raising and capacity building has contributed to its social acceptance. General acceptance from the community takes time.

Figure 14 : UDD toilets , inside (left); toilet block (right) [8]

Figure 15 : UDD toilets, shower (left), outside view (right) [8]

6) Conservation of drinking water and reuse of water have been very effectively achieved through this project.

7) The grey water and the composted feces is used in the nearby fields.

6.4 Case Study 4: Cow Dung based Bio gas Plant

6.4.1 Project details :

- Location: Sarangada, Orissa (India)
- Family size : 6
- No of cows : 3
- Type of Technology used : Biogas plant
- Toilets: toilets not connected to Biogas Plant
- Year of construction : 1995
- Funded by : the investment cost was 100% subsidized by the government.

6.4.2 Observations

1) 15 Biogas plants were constructed by the government in the year 1995. Only one of the 15 biogas plant is still functional
2) The failure of the other biogas plants was due to death of animals, reduction in the production of gas, leakage in the structure which was not repaired, choking of the pipe etc.
3) The only one functional bio gas plants is functioning efficiently. It was designed for a capacity of 1.5 M^3
4) The gas generated is available for cooking for approximately 1.5 to 2 hours everyday using a 4 inch burner stove.
5) The family cooks rice and vegetables on the biogas stove. But they also use fire wood based traditional cooking for preparing the Chapattis (Indian bread). Cooking Chapattis is a time intensive activity as only one bread can be cooked at a time.
6) The Biogas slurry is used in the banana plantation and this has improved the yield.
7) The slurry kept in the open to dry sometimes causes mosquito hazards.

Figure 16 : Biogas plant [Top] ; Biogas stove [bottom left]; Bio slurry plantation [bottom right].

6.5 Learnings from the Ecosan technology case studies

1) Ecosan Technologies play an important role in closing the nutrient loop. It therefore ensures soil quality and food security.
2) The ecosan technologies when applied to rural areas with no sanitation facilities generates a sense dignity amongst users. Especially women feel a sense of security.
3) These technologies are more attractive as they can provide economic benefits. However when the economic benefits are small and spread over a long period of time, these technologies tend to loose their attractiveness. Technologies which provide regular benefits at short intervals of time are very attractive to individual users.
4) The ecosan technologies through capacity building and regular use change the attitude of the users towards feces and urine from being a waste to being a resource.
5) It offers poor farmers a source of generating income through waste and can help in elevating the financial conditions.
6) Ecosan technologies when being introduced to users of conventional systems needs to address the objective of comfort and convenience.
7) Sufficient number of toilets and urinals needs to be provided to reduce the inconvenience of waiting.
8) Manual handling of feces and urine is a source of discomfort and ecosan technologies should address this issue.
9) Systems should be upgraded based on the comments of the users.
10) Capacity building is very important and needs persistent efforts to spread awareness.
11) Children and women have a larger acceptability to these systems.
12) Failures tend to spread misconceptions of the system and needs to be addressed by professionals.

7. Technical analysis

7.1 Criteria and Indicators for evaluation

To evaluate the performance of each system the following criteria and indicators are identified

1. Simplicity of construction – the ease of construction determines the scale of the project and the involvement required in the project. To evaluate this criterion, it is subdivided into the following indicators:
   1.1. Easy availability of materials – some technologies involve materials which are not easily available and incur high transportation cost, have lead time and can prolong a small construction activity.
   1.2. Simplicity of design – some technologies require professional assistance for designing the system. This indicator evaluates the need of professional expertise.
   1.3. Need of skilled labour/professional guidance for construction - some technologies require specialized labour for construction. This indicator evaluates such needs.
2. Simplicity of operation – the ease of operation develops user comfortability. This criterion is measured in terms of the need of training and guidance required for its use.
3. Simplicity of Maintenance – Maintenance plays an important role in technical evaluation as it is a repetitive activity and depending on the complexity it could require trained professionals. This criterion is evaluated by the following indicators
   3.1 Need of trained labour – some technologies can be labour intensive and complex. The need to have special dedicated labour for maintenance can increase the yearly maintenance costs.
   3.2 Frequency of maintenance – the frequency of maintenance determines how labour intensive the system is. This indicator evaluates such the frequencies.
4. System stability – External forces and internal forces can make the systems unstable and is subjected to failure. The system can then have adverse effects. To evaluate this criterion the following indicators are used:
   4.1 Risk of failure – failures can happen due to various reasons. However some systems are very sensitive and prone to failure due to small errors. This indicator evaluates such risks.
   4.2 Effect of failure – Some systems can have an isolated impact on failure while some systems can have dissipated impact. Some systems have a short term impact while some others have a long term impact. This indicator evaluates such effects.
5. System Durability – this criterion is evaluated by the indicator ‘lifespan of the system’.
6. Space requirement – many technologies require large area for its setup. Land being a scarce resource it needs to be conserved. The area requirement of the system is the indicator for this criterion.

7.2 Technical analysis for Alternative 1 : Pour flush toilet with septic tank

S.No	Criteria and Sub criteria	Indicators Performance Qualitative[5] or Quantitative
1	Simplicity of construction	
1.1	Easy availability of materials As this type of toilet is built on conventional lines and connected to a septic tank and a soak pit, no special constructional materials are used.	High
1.2	Simplicity of design As the design of this system includes a conventional toilet, a septic tank and soak pit, the design of this system needs professional expertise.	Medium
1.3	Need of skilled labour/professional guidance for construction The construction of conventional toilets, septic tank and soak pits is a moderately standard activity and does not require specialised labour.	High
2	Simplicity of operation	
2.1	Need of training and guidance As the toilet does not incorporate source separation and works on conventional lines, no training is required	Very High
3	Simplicity of Maintenance	
3.1	Need of trained labour The system does not need special maintenance. But the users have to be informed of not using any chemicals for cleaning the toilet. No trained labour is required for maintenance. Desludging can be a labour intensive activity	Medium
3.2	Frequency of maintenance	5 years

[5] Qualitative performance : Very High (+), High, medium, low, Nil (-)

S.No	Criteria and Sub criteria	Indicators Performance Qualitative[5] or Quantitative
	Desludging activity for this system is considered to be once in 5 years	
4	System stability	
4.1	Risk of failure The risk of failure of this system could be due to clogging of the drain pipe or by flooding of the soak pit with rain water.	High
4.2	Effect of failure Clogging of drain can be repaired, however the flooding of the pit with rain water can paralyze the entire system temporarily till	Medium
5	System Durability	
5.1	Lifetime of the system This system can be used for almost a period of 20 years	20 years
6	Space requirement	
6.1	Area requirement The space requirement of this toilet is around 10 to 15 m²	10 to 15 m²

7.3 Technical analysis for Alternative 2 : Pour flush toilet with Leach pit

S.No	Criteria and Sub criteria	Indicators Performance Qualitative[6] or Quantitative
1	Simplicity of construction	
1.1	Easy availability of materials As this type of toilet is built on conventional lines and connected to 2 pits where the water is discharge, no special constructional materials are used and the material is easily available	High
1.2	Simplicity of design As the design of this system includes a conventional toilet and 2 pits for storage of discharged wastewater, the design of this system is very simple.	High
1.3	Need of skilled labour/professional guidance for construction The construction of conventional toilets and pits is a standard activity and does not require skilled labour	High
2	Simplicity of operation	
2.1	Need of training and guidance As the toilet does not incorporate source separation and works on conventional lines, no training is required. However yearly maintenance operation has to be properly explained.	Medium
3	Simplicity of Maintenance	
3.1	Need of trained labour The system does not need special maintenance. However the users have to be informed of not using any chemicals for cleaning the toilet. No trained labour is required for maintenance.	Very High

[6] Qualitative performance : Very high (+), high, medium, low, Nil(-)

S.No	Criteria and Sub criteria	Indicators Performance Qualitative[6] or Quantitative
3.2	Frequency of maintenance As the pits require approximately 1 year for complete decomposition, the pits are accessed once in two years.	1 year
4	System stability	
4.1	Risk of failure The risk of failure of this system could be due to clogging of the drain pipe or by flooding of the pit with rain water.	Medium
4.2	Effect of failure Clogging of drain can be repaired, however the flooding of the pit with rain water can paralyze the entire system temporarily	Medium
5	System Durability	
5.1	Lifetime of the system As the system alternates between the two pits this system has a longer life time of around 25 years	25 years
6	Space requirement	
6.1	Area requirement The space requirement of this toilet is around 10 to 15 m^2	m^2

7.4 Technical analysis for Alternative 3 : Urine Diverting Dehydrating Toilet (UDD)

S.No	Criteria and Indicators	Performance Qualitative[7] or Quantitative
1	Simplicity of construction	
1.1	Easy availability of materials This toilet requires material similar to the conventional toilet except the squatting pan which can be cast in site in the cement slab or an FRP/ ceramic pan can be installed. The FRP/ ceramic pan are specialized items and not easily available.	Medium
1.2	Simplicity of design This system needs special design considerations as source separation is involved and proper segregation and storage of waste is required	Low
1.3	Need of skilled labour/professional guidance for construction Semi skilled labour is required to cast the pan on site or installing the FRP/ceramic pans.	Medium
2	Simplicity of operation	
2.1	Need of training and guidance Proper training and guidance is required to the user as errors such as use of anal cleaning water can lead to a failure in the system.	Medium
3	Simplicity of Maintenance	
3.1	Need of trained labour Special considerations are required while maintaining the UDD toilets as the waste has to be maintained at certain special conditions. Sometimes trained labour can be beneficial.	Medium

[7] Qualitative performance : Very high (+), high, medium, low, Nil(-)

S.No	Criteria and Indicators	Performance Qualitative[7] or Quantitative
3.2	Frequency of maintenance The toilets require regular maintenance to provide required conditions to the dehydrating chamber; the Urine containers need to be replaced at regular intervals and the soak pits for grey water needs cleaning	Everyday
4	System stability	
4.1	Risk of failure The risk involved in this system could be the discharge of anal cleaning water into the dehydrating chamber, leakage of urine.	Medium
4.2	Effect of failure The above mentioned failure of the toilet can be controlled by adding bulking material such as ash, soil, wood chips, saw dust etc to absorb the water; urine leak can be fixed ; soak pits can be cleaned.	Medium
5	System Durability	
5.1	Lifetime of the system This system can be used for almost a period of 25 years	25 years
6	Space requirement	
6.1	Area requirement The space requirement of this toilet is not large even though apart from the toilet block it needs space for the storage of Urine and soak pits	6 to 12 m^2

7.5 Technical analysis for alternative 3 : Flush toilet with Biogas Plant

S.No	Criteria and Indicators	Performance Qualitative[8] or Quantitative
1	Simplicity of construction	
1.1	Easy availability of materials Most of the material for construction is easily available	High
1.2	Simplicity of design The system needs proper design considerations and needs professional intervention. Improper design can lead to failure of the system	Low
1.3	Need of skilled labour/professional guidance for construction Skilled labour is required to construct the dome of the bio gas plant. Specialized labour in dome construction is required.	Low
2	Simplicity of operation	
2.1	Need of training and guidance Proper training and guidance is required to the user as errors can lead to a failure in the system	Low
3	Simplicity of Maintenance	
3.1	Need of trained labour As special conditions within the biogas plant are to be maintained the system requires trained labour for maintenance of this system	Medium
3.2	Frequency of maintenance The Bio gas plant requires cleaning and maintenance twice yearly	Half yearly
4	System stability	

[8] Qualitative performance : Very high (+), high, medium, low, Nil(-)

S.No	Criteria and Indicators	Performance Qualitative[8] or Quantitative
4.1	Risk of failure This system fails when there is reduction in the quantity of waste water than the designed capacity while also the specified balance of mixture is required. Clogging of the digester and low temperatures during winter can cause possible failures. Also leak in the structure can cause technical failure.	Medium
4.2	Effect of failure The above mentioned failure of the toilet can be controlled by ensuring a steady supply of waste to the plant. Also regular maintenance can prevent clogging of the system while use of hot water can help activate the bio gas generation during the winter season. Therefore the effects are short lived. Repair and maintenance is required for technical failure.	Medium
5	System Durability	
5.1	Lifetime of the system This system can be used for more than a period of 15 years	15 years
6	Space requirement	
6.1	Area requirement The space requirement of this toilet is quite large as it involves the construction of toilet, the bio gas plant and refuse drying beds	15 to 25 m²

7.6 Comparison of all alternatives

Sr.no	Criteria and Indicators	Performance				Score[9]			
		Qualitative or Quantitative							
		Alt 1	Alt 2	Alt 3	Alt 4	Alt 1	Alt 2	Alt 3	Alt 4
1	**Simplicity of construction**								
1.1	Easy availability of materials	High	High	Medium	High	4	4	3	4
1.2	Simplicity of design	Medium	High	Low	Low	3	4	2	2
1.3	Need of skilled labour/professional guidance for construction	High	High	Medium	Low	4	4	3	2
2	**Simplicity of operation**								
2.1	Need of training and guidance	Very High	Medium	Medium	Low	5	3	3	2
3	**Simplicity of Maintenance**								
3.1	Need of trained labour	Medium	Very High	Medium	Medium	3	5	3	3
3.2	Frequency of maintenance	5 years	1 year	Everyday	Half yearly	5	4	2	3
4	**System stability**								
4.1	Risk of failure	High	Medium	Medium	Medium	4	3	3	3

[9] Score : Very High (5), High (4), Medium (3), Low (2), Nil (1)

Sr.no	Criteria and Indicators	Performance				Score[9]			
		Qualitative or Quantitative							
		Alt 1	Alt 2	Alt 3	Alt 4	Alt 1	Alt 2	Alt 3	Alt 4
4.2	Effect of failure	Medium	Medium	Medium	Medium	3	3	3	3
5	**System Durability**								
5.1	Lifetime of the system	20 years	25 years	25 years	15 years	4	5	5	3
6	**Space requirement**								
6.1	Area requirement	10 to 15 Sq.m	10 to 15 Sq.m	6 to 12 Sq.m	15 to 25 Sq.m	4	4	3	3

7.7 Performance of each alternative

Sr. no	Criteria and Indicators	Ratings(A)			
		Total score of each criterion			
		Alt 1	Alt 2	Alt 3	Alt 4
1	Simplicity of construction	11.00	12.00	8.00	8.00
2	Simplicity of operation	5.00	3.00	3.00	2.00
3	Simplicity of Maintenance	8.00	9.00	5.00	6.00
4	System stability	3.50	3.00	3.00	3.00
5	System Durability	4.00	5.00	5.00	3.00
6	Space requirement	4.00	4.00	3.00	3.00

Sr. no	Criteria and Indicators	Ratings(B=A/no of indicators) Average score of each criterion			
		Alt 1	Alt 2	Alt 3	Alt 4
1	Simplicity of construction	3.67	4.00	2.67	2.67
2	Simplicity of operation	5.00	3.00	3.00	2.00
3	Simplicity of Maintenance	4.00	4.50	2.50	3.00
4	System stability	1.75	1.50	1.50	1.50
5	System Durability	4.00	5.00	5.00	3.00
6	Space requirement	4.00	4.00	3.00	3.00

Sr. no	Criteria and Indicators	Ratings(C=B/no of criterias) Average score of each criterion			
		Alt 1	Alt 2	Alt 3	Alt 4
1	Simplicity of construction	0.61	0.67	0.44	0.44
2	Simplicity of operation	0.83	0.50	0.50	0.33
3	Simplicity of Maintenance	0.67	0.75	0.42	0.50
4	System stability	0.29	0.25	0.25	0.25
5	System Durability	0.67	0.83	0.83	0.50
6	Space requirement	0.67	0.67	0.50	0.50

Sr. no	Criteria and Indicators	weight	Ratings(D=C x Weight)			
			Weighted score of each criterion			
			Alt 1	**Alt 2**	**Alt 3**	**Alt 4**
1	Simplicity of construction	0.5	0.31	0.33	0.22	0.22
2	Simplicity of operation	1	0.83	0.50	0.50	0.33
3	Simplicity of Maintenance	1	0.67	0.75	0.42	0.50
4	System stability	1	0.29	0.25	0.25	0.25
5	System Durability	1	0.67	0.83	0.83	0.50
6	Space requirement	0.5	0.33	0.33	0.25	0.25
	Total	**5**	**3.10**	**3.04**	**2.51**	**2.10**

7.8 Therefore overall final performance of all the Alternatives is as follows

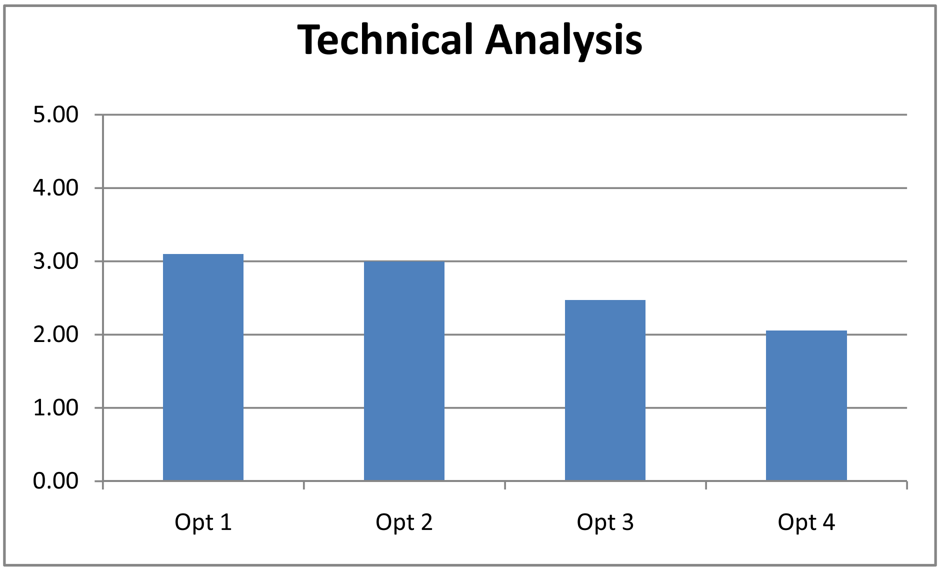


Figure 17 : Technical analysis performance graph

Alternative 1 is the most suitable alternative technically which is followed closely by alternative 3 while Alternative 4 has the least technical suitability.

8. Economic analysis

8.1 Criteria and Indicators for evaluation

The economic evaluation of the different alternatives is based on Cost benefit analysis performed for each alternative.

The criteria for evaluation are as follows

1) Total investment – this criterion evaluates the scale of investment involved depending upon the paying capacity of the NGO. The indicator of evaluation is Indian Rupees.
2) Yearly expenditure – this criterion evaluates the scale of the yearly costs involved depending upon the paying capacity of the NGO. The indicator of evaluation is Indian Rupees.
3) Financial benefits involved – the financial benefits involved for each alternative vary and are evaluated in Indian Rupees.
4) Break even time – the break even time in this case can be defined as the time required for the benefits of the alternative to accumulatively recover the investment and all other associated costs. The indicator for evaluating this criterion is the No of years.

8.2 Cost benefit analysis for Alternative 1 : Flush Toilet with septic tank

1. Investment costs – the cost involved in setting up a Flush toilet with Septic are following

    1.1 Construction cost of a flush toilet = Rs. 19,638/- (refer Annexure I)

    1.2 Construction cost of Septic Tank = Rs. 11,545/- (refer Annexure II)

    1.3 Construction cost of Soak Pit = Rs. 16,626/- . (refer Annexure II)

2. Yearly expenditure

    2.1 Rate of interest on investment – the interest earned on the amount invested if kept in a bank. The present rate of interest on fixed deposits is 8%. Therefore the interest earned on the investment in a bank would be Rs. 3,825/-

    2.2 Depreciation cost of Toilet structure – assuming the life span of the flush toilet to be approximately 25 years, the percentage of depreciation would be 4%. The depreciated cost of the Flush toilet would be Rs. 786/-

    2.3 Depreciation Cost of Septic tank – assuming the life span of a Biogas plant to be approximately 25 years, the percentage of depreciation would be 4%. Therefore the deprecated cost of the Septic tank per year would be Rs. 462/-

2.4 Depreciation cost of Soak pit – assuming the life span of the leach pit to be 25 years, the percentage of depreciation works out to be 4% and the cost of depreciation per year would be Rs. 665/-.

2.5 Maintenance cost – The maintenance cost for a septic is almost nil. Maintenance of chocked drain pipe once or twice a year might be required. However the septic tank needs to be desludged once in 5 years. As the de-sludging trucks are not present in the vicinity of the village, the deslugging activity needs to be carried out manually. The contents of the pit (approximately 4500 litres) needs to be transferred to another pit. Approximately a pit of 8 M³ needs to be dug to dispose the scludge and scum which would require 4 labours days i.e. Rs. 220/- (Rs. 55/-.per labour day [23]) The desludging of the contents of the septic tank would require 10 labour days and would require expensive labour to perform this activity i.e Rs. 750(i.e Rs. 75/-per labour day[23]). Therefore the total maintenance cost for 5 years would be Rs. 970/- and per year it would be Rs.194/-

3. Income and savings - The Septic tank has no financial benefits.
4. Break Even time

A	Investment	Cost in Euros	Cost in Rupees
1	Construction cost of 2 flush toilets	327.00	19,638.00
2	Construction cost of Septic Tank	192.00	11,545.00
3	Construction cost of Soak pit	277.00	16,626.00
	Total Investment (A)	**797.00**	**47,809.00**
B	**Yearly Expenditure**	0.00	
1	Rate of interest on investment	64.00	3,825.00
2	Depreciation cost of Toilet structure	13.00	786.00
3	Depreciation Cost of Septic Tank	8.00	462.00
4	Depreciation cost of Soak Pit	11.00	665.00
5	Maintenance cost	3.00	194.00
	Total yearly expenditure (B)	**99.00**	**5,931.00**
C	**Yearly income and savings**	0.00	0.00
	Total yearly income and savings (C)	**0.00**	**0.00**
	Yearly benefits (D = C-B)	-99.00	-5,931.00
	Break even time (A/D)	**-8.00 years**	**-8.00 years**

As the break even time is negative, it implies that this alternative will incur a LOSS and the money invested cannot be recovered.

5. Rate of Interested earned - as the investment would incur a loss no interest would be earned on the investment.

8.3 Cost benefit analysis for Alternative 2 : Flush toilet with a Leach Pit

1. Investment costs – the cost involved in setting up a Flush toilet with Septic are following
   1.1. Construction cost of a flush toilet = Rs. 19,638/- (refer Annexure I)
   1.2. Construction cost of Leach Pit = Rs. 33,252/- . (refer Annexure II)
2. Yearly expenditure
   2.1. Rate of interest on investment – the interest earned on the amount invested if kept in a bank. The present rate of interest on fixed deposits is 8%. Therefore the interest earned on the investment in a bank would be Rs. 4,231/-
   2.2. Depreciation cost of Toilet structure – assuming the life span of the flush toilet to be approximately 25 years, the percentage of depreciation would be 4%. The depreciated cost of the Flush toilet would be Rs. 786/-
   2.3. Depreciation cost of Leach pit – assuming the life span of the leach pit to be 25 years, the percentage of depreciation works out to be 4% and the cost of depreciation per year would be Rs. 1330/-.
   2.4. Maintenance cost – The soak pit has recurring maintenance cost involved in opening the pit once the feces is composted every year. The retrieval work involves 2 labour days and costs Rs.110/- (Rs.55/-per labour day [23]).
3. Income and savings
   3.1. Composted manure –The feces of an adult consists of 4.55kg of Nitrogen, 0.58Kg of Phosphorous and 1.27Kg of Potassium which adds up to 6.4Kg per year. Let us assume only 50% i.e 3.2Kg per year nutrient contribution for a child. The total yearly contribution of nutrients by 60 children works out to be 192kg and for 6 adult staff members it is 38.4Kg per year. Therefore the total nutrient production of the orphanage is 230.4Kg. The composted feces not only contains N, P and K but also oxygen, hydrogen etc. Therefore the amount of nutrients in the composted feces for a family of 6 (2 adults and 4 children) corresponds to 75 Kg of NPK 25-2-6 fertiliser which costs Rs. 10/- per Kg. [27]. The nutrients produced by the orphanage is therefore equivalent to 630 Kg of NPK 25-2-6 fertiliser and costs Rs. 6803/-
4. Break Even time

A	Investment	Cost in Euros	Cost in Rupees
1	Construction cost of 2 flush toilets	327.00	19,638.00
2	Construction cost of 2 Leach pits	554.00	33,252.00
	Total Investment (A)	**882.00**	**52,890.00**
B	**Yearly Expenditure**		
1	Rate of interest on investment	71.00	4,231.00
2	Depreciation cost of Toilet structure	13.00	786.00
3	Depreciation cost of Leach Pit	22.00	1330.00
4	Maintenance cost	2.00	110.00
	Total yearly expenditure (B)	**108.00**	**6,457.00**
C	**Yearly income and savings**		
1	Cost of Compost	113.00	6803.00
	Total yearly income and savings (C)	**113.00**	**6803.00**
	Yearly benefits (D = C-B)	6.00	346.00
	Total investment at the end of 1st year (A+B)	987.00	59,237.00
	Break even time {(A+B)/D}		**171.12 years**

The break even time of 171.12 years translates to 171 years and 1 months. The initial retention time of approximately 1year which is economically unproductive, needs to be added to this break even time. Therefore the Break even time for the total investment and connected costs is 172 years and 1 months.

5. Rate of interest – the rate of interest earned on the investment after a period of 172 years and 1 months would be 0.6% per annum.

8.4 Cost benefit analysis for Alternative 3 : Urine Diversion Dehydrating Toilet (UDDT)

1. Investment costs – the cost involved in setting up a Flush toilet with Septic are following
   1.1. Construction cost of a flush toilet = Rs. 38,477/- (refer Annexure III)
2. Yearly expenditure
   2.1. Rate of interest on investment – the interest earned on the amount invested if kept in a bank. The present rate of interest on fixed deposits is 8%. Therefore the interest earned on the investment in a bank would be Rs. 3,078/-
   2.2. Depreciation cost of Toilet structure – assuming the life span of the UDD toilet to be approximately 25 years, the percentage of depreciation would be 4%. The depreciated cost of the UDD toilet would be Rs. 1539/-
   2.3. Maintenance cost – A person is required for half hour every day for maintenance of this system as it needs management of urine. The labour wage is approximately Rs.7 per hour derived from the labour rate of Rs. 55 per day. [23]. Therefore the total maintenance cost for the year would be Rs. 1,260/-
3. Income and savings
   3.1. Composted manure – Rs.6803/- (refer 7.3. Point 3; sub point 3.1)
   3.2. Cost of fertilizer equivalent of Urine – Urine which is rich in nitrogen content can replace fertilizers used in plants. A family of 5 using the Urine generated replaces 50 Kg of fertilizer for the plants worth Rs.450/- every year [25]. Therefore the cost per litre of urine is approximately Rs. 0.23/- per litre. The total volume of urine generated by the children and staff of the orphanage is 19710 litres. the total savings on the cost of fertilizer is Rs.4,533/-. Also it needs to be noted that the during the initial retention time, urine is not used and has zero economic benefits. This additional time needs to be added to the break even time.
4. Break Even time

A	**Investment**	**Cost in Euros**	**Cost in Rupees**
1	Construction cost of 4 Urine Diversion Dehydrating (UDD) Toilet (including vertical flow organic soak filter)	680.00	40,822.00
2	Cost Plastic containers for urine storage	83.00	5,000.00
	Total Investment (A)	**764.00**	**45,822.00**
B	**Yearly Expenditure**		
1	Rate of interest on investment	61.00	3,666.00
2	Depreciation cost of Toilet structure	27.00	1633.00
3	Depreciation cost of toilet storage containers	3.00	200.00

4	Cost of painting the steel door	5.00	270.00
5	Maintenance cost @15 hours per month	21.00	1260.00
	Total yearly expenditure (B)	**117.00**	**7,029.00**
C	**Yearly income and savings**		
1	Cost of Compost	113.00	6803.00
2	Cost of fertilizer equivalent of urine	76.00	4,533.00
	Total yearly income and savings (C)	**189.00**	**11,336.00**
	Yearly benefits (D = C-B)	72.00	4,308.00
	Total investment at the end of 1st year (A+B)	881.00	52,851.00
	Break even time {(A+B)/D}		**12.27 years**

The break even time of 12.27 years which translates to 12 years and 3 months. The initial retention time of approximately 1year which is economically unproductive, needs to be added to this break even time. Therefore the Break even time for the total investment and connected costs is **13 years and 3 months.**

It is to be noted that only 2 toilets of the 4 toilets are in use at any given time. The remaining 2 toilets can be used as shower areas by covering the pit with a slab. When the cost of only 2 toilets is considered at an investment cost of 60% of the cost of 4 toilets, the break even time is 6 years and 6 months (5 years and 6 months + 1 economically unproductive year).

5. Rate of interest – the rate of interest earned on the investment after a period of 11 years would be 9.4% per annum. The rate of interest considering only 2 toilets after a period of 6 years 1 month would be 21.25%.

8.5 Cost benefit analysis for Alternative 4 : Bio gas Plant

1 Investment costs – the cost involved in setting up a bio gas plant are following

- 1.1 Construction cost of a flush toilet = Rs. 19,638/- (refer Annexure)
- 1.2 Construction cost of Bio Gas plant (1.5 M^3) = Rs. 10,594/- (refer Annexure : average cost of 1M^3 and 2M^3 plant)
- 1.3 Piping and stove cost = Rs. 1,750/- [22]. As the piping and stove would need to be replaced once after 10 years, the investment cost of this sub criterion is doubled i.e. Rs.3,500/-

2 Yearly expenditure

2.1 Rate of interest on investment – the interest earned on the amount invested if kept in a bank. The present rate of interest on fixed deposits is 8%. Therefore the interest earned on the investment in a bank would be Rs. 2,699/-

2.2 Depreciation cost of Toilet structure – assuming the life span of the flush toilet to be approximately 25 years, the percentage of depreciation would be 4%. The depreciated cost of the bio gas plant would be Rs. 786/-

2.3 Depreciation Cost of bio gas plant – assuming the life span of a Biogas plant to be approximately 20 years, the percentage of depreciation would be 5%. Therefore the deprecated cost of the bio gas plant per year would be Rs. 530/-

2.4 Depreciation cost of piping and stove – assuming the life span of the piping and gas stove to be 10 years, the percentage of depreciation works out to be 10% and the cost of depreciation per year would be Rs. 350/-

2.5 Painting cost – the cost involved to paint the pipe every year is Rs. 350/- [22]

2.6 Maintenance cost – a person is required for half hour every day for maintenance of this system as it needs maintenance of input slurry, stirring of existing slurry in the plant and maintenance of output slurry. The labour wage is approximately Rs.7 per hour derived from the labour rate of Rs. 55 per day. [23]. Therefore the total maintenance cost for the year would be Rs. 1,260/-

3 Income and savings

3.1 Cost of Bio gas – the cost of Bio gas is derived from the equivalent cost of LPG gas. A 14.6 kg cylinder of LPG costs Rs.300/- (market price) the bio gas equivalent of LPG (Butane) is 0.4kg per m^3 of biogas. Therefore approximately 15 cylinders are equivalent to the Bio gas produced by the plant in one year. The total income due to bio gas production is Rs.4,470/-. Also it needs to be noted that the during the initial retention time, no gas is produced and has zero economic benefits. This additional time needs to be added to the break even time.

3.2 Cost of fire wood saved - Approximately 2 bundles of firewood are used every week to cook food for the children in the orphanage. Each bundle of fire wood costs Rs.100/- . As the bio gas plant meets approximately 50% cooking energy needs of the orphanage, there is a saving of Rs. 100/- every week and Rs. 5,200/- every year.

3.3 Cost of Biogas manure – As the Biogas manure (output slurry) of the biogas plant is rich in Nitrogen and potassium, it has an equivalent effect of artificial fertilizers. Approximately 24Kg of biogas manure is produced by a 2 M^3 plant [24]. Assuming the input-output ratio remaining the same, a 1.5 m^3 plant would produce a biogas manure of 18Kg. the price of 1 kg of BgM is Rs.0.30 per Kg(2003) [24] and at an inflation of 5% every year the rate is Rs. 0.38/- per Kg(2008). Therefore the cost of Biogas manure is Rs. 2,497/- per year. However it is to be noted that as the biogas manure is in the liquid state it cannot be sold unless dried, while the biogas manure is very effective when in the liquid state.

4 Break Even Analysis

A	Investment	Cost in Euros	Cost in Rupees
1	Construction cost of 2 flush toilets	327.00	19,638
2	Construction cost of Bio Gas plant (1.5 M^3)	177.00	10,594
3	Piping and stove cost	58.00	3,500
	Total Investment (A)	**562.00**	**33,732**
B	**Yearly Expenditure**		
1	Rate of interest on investment	45.00	2,699.00
2	Depreciation cost of Toilet structure	13.00	786.00
3	Depreciation Cost of bio gas plant	9.00	530.00
4	Depreciation cost of piping and stove	6.00	350.00
5	Painting cost	6.00	350.00
6	Maintenance cost @15 man hours per month	21.00	1,260.00
	Total yearly expenditure (B)	**100.00**	**5,974.00**
C	**Yearly income and savings**		
1	Cost of Bio gas	75.00	4,470.00
2	Cost of fire wood saved	87.00	5,200.00
3	Cost of Biogas manure	42.00	2,497.00
	Total yearly income and savings (C)	203.00	**12,167.00**
	Yearly benefits (D = C-B)	103.00	6,193
	Break even time (A/D)		**5.45 years**

The break even time of 5.45 years translates to 5 years and 5.5 months. The initial retention time of approximately 1.5 months which is economically unproductive, needs to be added to this break even time. Therefore the Break even time for the total investment and connected costs is 5 years and 7 months.

5 Rate of interest – the rate of interest earned on the investment after a period of 5 years and 7 months would be 18.36% per annum.

8.6 Comparison of all alternatives

Sr.No	Criterion	Performance of Indicators			
		Alt (1)	Alt (2)	Alt (3)	Alt (4)
1	Investment (in Rupees)	47,809	52,890	45,822	33,732
2	Yearly expenditure (in Rupees)	5,931	6,457	7,029	5,974
3	Yearly income and savings	0	6,803	11,336	12,167
4	Break even (in Years)	-8	172 yrs-1month	13 yrs - 3months	5yrs-7months
5	Rate of interest on investment	0%	0.6%	9.40%	18.36%

Sr.No	Criterion	Performance of Indicators			
		Initial Score of Criteria[10] (A)			
		Alt (1)	Alt (2)	Alt (3)	Alt (4)
1	Investment (in Rupees)	2	4	2	4
2	Yearly expenditure (in Rupees)	3	4	2	3
3	Yearly income and savings	1	3	5	5
4	Break even (in Years)	1	1	3	5
5	Rate of interest on investment	1	1	3	4

[10] Score : Very High (5), High (4), Medium (3), Low (2), Nil (1)

Sr.No	Criterion	Performance of Indicators Average Score of Criteria (B=A/ no of criteria)			
		Alt (1)	**Alt (2)**	**Alt (3)**	**Alt (4)**
1	Investment (in Rupees)	0.4	0.8	0.4	0.8
2	Yearly expenditure (in Rupees)	0.6	0.8	0.4	0.6
3	Yearly income and savings	0.2	0.6	1	1
4	Break even (in Years)	0.2	0.2	0.6	1
5	Rate of interest on investment	0.2	0.2	0.6	0.8

Sr.No	Criterion	Weight	Performance of Indicators Final score			
			Alt (1)	**Alt (2)**	**Alt (3)**	**Alt (4)**
1	Investment (in Rupees)	1	0.4	0.8	0.4	0.8
2	Yearly expenditure (in Rupees)	0.75	0.45	0.6	0.3	0.45
3	Yearly income and savings	0.75	0.15	0.45	0.75	0.75
4	Break even (in Years)	1.25	0.25	0.25	0.75	1.25
5	Rate of interest on investment	1.25	0.25	0.25	0.75	1
	Total	**5**	**1.5**	**2.35**	**2.95**	**4.25**

8.7 Final performance of all the Alternatives

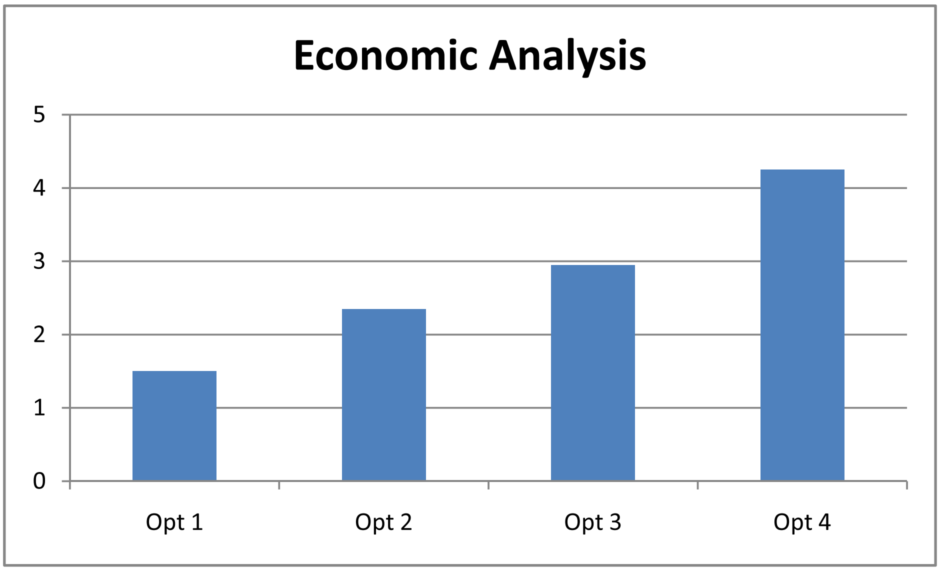


Figure 18 : Economic analysis performance graph

Alternative 4 is the most suitable alternative economically. Alternative 3 ranks the second most suitable alternative and the difference alternative 4 and alternative 3 is large. Alternative 2 ranks 3rd while alternative 4 has the least economic suitability.

9. Environmental analysis

9.1 Criteria and Indicators for evaluation

One of the most effective ways of evaluating the environmental impacts of the selected alternatives is to conduct a Life cycle assessment of each alternative. Life cycle assessment can evaluate the alternatives in terms of Energy consumption/generation water consumption, air emissions, global warming potential etc. The results of life cycle assessment can actually provide substantial information whether the said environmentally friendly technologies are truly environmental friendly. However due to time constraint and lack of information, life cycle assessment of the alternatives could not be performed and are not a part of the environmental analysis.

Following criteria have been identified for performing environmental and health analysis of the selected alternatives.

1. Ground water safety – one of the most important indicator of environmental analysis is the evaluation of ground water contamination potential of each alternative. This criterion evaluates the ground water safety qualitatively.
2. Water conservation – water being a scarce resource needs conservation. The growing usage of ground water is responsible for the lowering of the ground water table. This criterion is evaluated qualitatively.
3. Energy generation potential – Some of the alternatives have the potential of producing energy which can be used as Bio fuels. Use of bio fuels can reduce the dependency on fossil fuels and thus contribute to sustainable development. This criterion is evaluated qualitatively.
4. Ground cover – greater the ground coverage, lesser is ground water recharge. This criterion evaluates quantitatively the effective ground coverage of each system in terms of its area(m^2).
5. Return of nutrients – one of the important aspects of ecosan is to close the loop of the nutrient cycle by its efficient return to the soil. Return of nutrients reduces dependencies on artificial fertilizers and improves the soil quality naturally. This criterion is evaluated qualitatively.
6. Preservation of trees – deforestation for want of fire wood is a common feature of the tribal life of Sarangada. This criterion evaluated how the alternative can prevent deforestation and preserve forest life.

9.2 Impact assessment of Alternative1 : Pour flush type toilet with septic tank

Sr. No	Criteria	Performance of indicator qualitative[11] or quantitative
1	Ground water safety The risk of contamination of the ground water is almost nil. However during the rainy season there could be a possibility of ground water table to rise and water to enter the soak pit which could contaminate the water. But as the soak pit has a depth of only 2 meters, this possibility is very rare.	medium
2	Water conservation As the gradient of the inlet pipe cannot be increased much, more water is required for flushing. This system is therefore very water intensive. However the water used for flushing recharges' the ground water through the soak pit.	Low
3	Energy generation potential No energy is produced in this system.	Nil
4	Ground cover Approximately 10 m² area of ground is covered in this system. As the area covered is low this system has a higher quantitative ranking	Medium
5	Return of nutrients Very little nutrients are returned to the soil depending on the desludging technique	Low
6	Preservation of trees This system does not contribute to the preservation of forests.	Nil

[11] Qualitative performance : Very High (+), High, medium, low, Nil (-)

9.3 Impact assessment of Alternative 2 : Pour flush type toilet with Leach pit

Sr. No	Criteria	Performance of indicator qualitative[12] or quantitative
1	Ground water safety The risk of ground water contamination is higher during the rainy season as there is possibility of ground water to enter the leach pit.	Medium
2	Water conservation This is a water intensive system and therefore does conserve water. However the water used for flushing recharges' the ground water through the leach pit.	Low
3	Energy generation potential There is no energy potential in this system	Nil
4	Ground cover Approximately 10 sq m of ground coverage is required for this system. The performance of this indicator is therefore medium	Medium
5	Return of nutrients The nutrients are returned back to the soil every year	High
6	Preservation of trees This system does not contribute towards preserving forests. However the compost can be used for growing more trees	Low

[12] Qualitative performance : Very High (+), High, medium, low, Nil (-)

9.4 Impact assessment of Alternative 3 : Urine diversion dehydrating toilet

Sr. No	Criteria	Performance of indicator qualitative[13] or quantitative
1	Ground water safety This system does have any impact on ground water except in case of flooding which is very unlikely in this area.	high
2	Water conservation Water conservation is this system is very high as there is source separation and the grey water is used for gardening.	Very High
3	Energy generation potential There is no potential for energy generation	Nil
4	Ground cover This system uses only 6 m^2 area for its toilets. There fore the performance of this system is high.	High
5	Return of nutrients. The nutrients are returned to the soil from composted feces and urine and has very high quality.	Very high
6	Preservation of trees This system does not directly help preserve trees but helps tree plantation.	Low

[13] Qualitative performance : Very High (+), High, medium, low, Nil (-)

9.5 Impact assessment of Alternative 4 : Pour flush type toilet with Bio gas plant.

Sr. No	Criteria	Performance of indicator qualitative[14] or quantitative
1	Ground water safety This system does not have ground water pollution potential as the outlet slurry treated slurry is very already disinfected in the anaerobic process.	High
2	Water conservation The system requires less water as the inlet pipe from the toilet can have a very steep gradient. Also amount of flushing water has to be limited not to dilute the system.	Medium
3	Energy generation potential This system has energy potential in the form of bio gas.	High
4	Ground cover Approximately $16m^2$ area of ground is covered in constructing this system.	Low
5	Return of nutrients. The biogas slurry is very rich in nutrients and is a very good soil conditioner.	Very high
6	Preservation of trees As this system provides an alternative for wood as a cooking fuel, it helps preserve the trees	High

[14] Qualitative performance : Very High (+), High, medium, low, Nil (-)

9.6 Comparison of all alternatives

Sr. No	Criteria	Performance of indicator			
		Alt 1	**Alt 2**	**Alt 3**	**Alt 4**
1	Ground water safety	medium	Medium	high	High
2	Water conservation	Low	Low	Very High	Medium
3	Energy generation potential	Nil	Nil	Nil	High
4	Ground cover	Medium	Medium	High	Low
5	Return of nutrients.	Low	High	Very high	Very high
6	Preservation of trees	Nil	Low	Low	High

Sr. No	Criteria	Performance of Indicators			
		Average score [15](B=A/no of criteria)			
		Alt 1	**Alt 2**	**Alt 3**	**Alt 4**
1	Ground water safety	2	3	4	4
2	Water conservation	3	3	5	3
3	Energy generation potential	1	1	1	4
4	Ground cover	3	3	4	2
5	Return of nutrients.	2	4	5	5
6	Preservation of trees	1	2	2	4

[15] Score : Very High (5), High (4), Medium (3), Low (2), Nil (1)

Sr. No	Criteria	Performance of Indicators Average score (B=A/no of criteria)			
		Alt 1	Alt 2	Alt 3	Alt 4
1	Ground water safety	0.33	0.50	0.67	0.67
2	Water conservation	0.50	0.50	0.83	0.50
3	Energy generation potential	0.17	0.17	0.17	0.67
4	Ground cover	0.50	0.50	0.67	0.33
5	Return of nutrients.	0.33	0.67	0.83	0.83
6	Preservation of trees	0.17	0.33	0.33	0.67

Sr. No	Criteria	Weight	Performance of Indicators Weighted score			
			Alt 1	Alt 2	Alt 3	Alt 4
1	Ground water safety	1.25	0.42	0.63	0.83	0.83
2	Water conservation	1.00	0.50	0.50	0.83	0.50
3	Energy generation potential	0.75	0.13	0.13	0.13	0.50
4	Ground cover	0.50	0.25	0.25	0.33	0.17
5	Return of nutrients.	1.00	0.33	0.67	0.83	0.83
6	Preservation of trees	0.50	0.08	0.17	0.17	0.33
	Total score	**5.00**	**1.71**	**2.33**	**3.13**	**3.17**

9.7 Final performance of all the alternatives

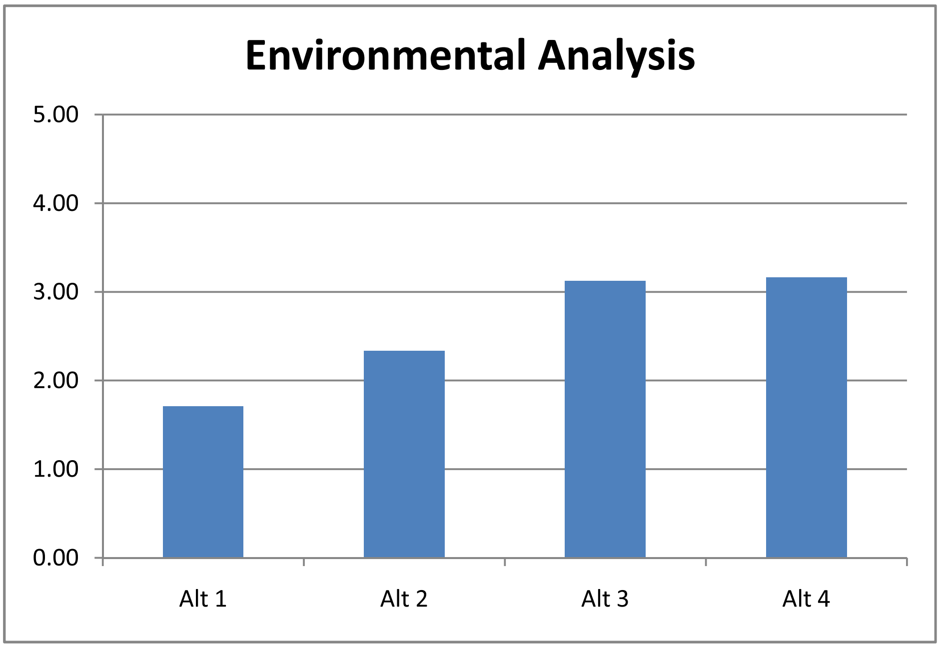


Figure 19 : Environmental analysis performance graph

Alternative 4 is the most suitable alternative environmentally followed closely by Alternative 3. Alternative 4 has the least environmental suitability.

10. Health analysis

10.1 Criteria and Indicators for evaluation

Health and hygiene is the core of any sanitation system. A sanitation system that fails to satisfy this basic objective fails as a system completely. Following criteria have been identified to evaluate this objective.

1. Prevention of odour – Foul smell from the sludge can create unhealthy conditions for living. This criterion evaluates the extent of prevention of odour of each alternative qualitatively.
2. Improved hygienic conditions for user – this criterion evaluates the quality of hygiene each system offers to its users.
3. Control of infection and diseases – one of the main aims of sanitation is to prevent the spread of infections and diseases. This criterion evaluates the effectiveness of each system to control the spread of infections and diseases qualitatively.
4. Health risk due to failure of system – this criterion evaluates the possible health risk due to failure of the system
5. Health risk while emptying the system – this criterion evaluates the possible risk involved while emptying the system.

10.2 Analysis of Alternative 1 : Pour flush system with Septic tank

Sr. No	**Criteria**	**Performance of Indicator qualitative[16] or quantitative**
1	Prevention of odour As the toilet has a water seal there is no odour present in the toilet. The septic tank if properly sealed can also be odour free.	High
2	Improved hygienic conditions for user This system offers very good hygienic conditions for the users.	Very High
3	Control of infection and diseases This system can effectively control the spread of infections and diseases.	High

[16] Qualitative performance : Very High (+), High, medium, low, Nil (-)

Sr. No	Criteria	Performance of Indicator qualitative[16] or quantitative
4	Health risk due to failure of system Failure of the septic tank can lead to overflowing of the contents causing possible health risk	Low
5	Health risk while emptying the system As the desludging activity is performed by lanour it has high health risk to them	Nil

10.3 Analysis of Alternative 2 : Pour flush system with Leach Pit

Sr. No	Criteria	Performance of Indicator qualitative[17] or quantitative
1	Prevention of odour As the toilet has a water seal there is no odour present in the toilet. The septic tank if properly sealed can also be odour free.	High
2	Improved hygienic conditions for user This system offers very good hygienic conditions for the users.	Very High
3	Control of infection and diseases This system can effectively control the spread of infections and diseases.	High
4	Health risk due to failure of system The failure of this system can cause the contents of the leach pit to overflow which can pose health risks	Low

[17] Qualitative performance : Very High (+), High, medium, low, Nil (-)

Sr. No	Criteria	Performance of Indicator qualitative[17] or quantitative
5	Health risk while emptying the system As the pit is opened after the contents are composted there is very low risk in the handling of the contents.	High

10.4 Analysis of Alternative 3 : Urine diversion Dehydrating toilet

Sr. No	Criteria	Performance of Indicator qualitative[18] or quantitative
1	Prevention of odour Proper precautions needs to be taken to prevent odour	Medium
2	Improved hygienic conditions for user This system offers very good hygienic conditions for the users.	High
3	Control of infection and diseases Proper precautions need to be taken to prevent infection and diseases.	Medium
4	Health risk due to failure of system The failure can be caused due to dilution of the feces which can be controlled by adding more filler material. Spilling of urine does not pose much health risk.	Medium
5	Health risk while emptying the system The health risk involved is low as the feces is composted and free of pathogens	High

[18] Qualitative performance : Very High (+), High, medium, low, Nil (-)

10.5 Analysis of Alternative 4 : Pour flush system with Biogas system

Sr. No	Criteria	Performance of Indicator qualitative[19] or quantitative
1	Prevention of odour As the toilet has a water seal there is no odour present in the toilet. The septic tank if properly sealed can also be odour free.	High
2	Improved hygienic conditions for user This system offers very good hygienic conditions for the users.	Very High
3	Control of infection and diseases The toilet is effective in preventing the spread of infection and diseases but the Biogas slurry can form breeding grounds for mosquitoes and the spread of diseases .	Medium
4	Health risk due to failure of system The failure of the system would lead to improper anerobic treatment of the waste leading to the biogas slurry containing some pathogens.	Low
5	Health risk while emptying the system The emptying of the system is done gradually over the retention time of the plant therefore the risk involved is not very high	Medium

[19] Qualitative performance : Very High (+), High, medium, low, Nil (-)

10.6 Comparison of all Alternatives

Sr. No	Criteria	Performance of Indicators			
		Alt 1	Alt 2	Alt 3	Alt 4
1	Prevention of odour	High	High	Medium	High
2	Improved hygienic conditions for user	Very High	Very High	High	Very High
3	Control of infection and diseases	High	High	Medium	Medium
4	Health risk due to failure of system	Low	Low	Medium	Low
5	Health risk while emptying the system	Nil	High	High	Medium

Sr. No	Criteria	Performance of Indicators			
		Initial Score[20] (A)			
		Alt 1	Alt 2	Alt 3	Alt 4
1	Prevention of odour	2	2	3	2
2	Improved hygienic conditions for user	1	1	2	1
3	Control of infection and diseases	2	2	3	3
4	Health risk due to failure of system	2	2	3	2
5	Health risk while emptying the system	1	4	4	3

[20] Score : Very High (5), High (4), Medium (3), Low (2), Nil (1)

Sr. No	Criteria	Performance of Indicators			
		Average score (B=A/no of criteria)			
		Alt 1	Alt 2	Alt 3	Alt 4
1	Prevention of odour	0.67	0.67	1.00	0.67
2	Improved hygienic conditions for user	0.33	0.33	0.67	0.33
3	Control of infection and diseases	0.67	0.67	1.00	1.00
4	Health risk due to failure of system	0.40	0.40	0.60	0.40
5	Health risk while emptying the system	0.20	0.80	0.80	0.60

Sr. No	Criteria	Weight	Performance of Indicators			
			Weighted score			
			Alt 1	Alt 2	Alt 3	Alt 4
1	Prevention of odour	1.00	0.80	0.80	0.60	0.80
2	Improved hygienic conditions for user	1.00	1.00	1.00	0.80	1.00
3	Control of infection and diseases	1.25	1.00	1.00	0.75	0.75
4	Health risk due to failure of system	1.00	0.40	0.40	0.60	0.40
5	Health risk while emptying the system	0.75	0.15	0.60	0.60	0.45
	Total	**5.00**	**2.80**	**2.80**	**2.15**	**2.55**

10.7 Final performance of all the Alternatives

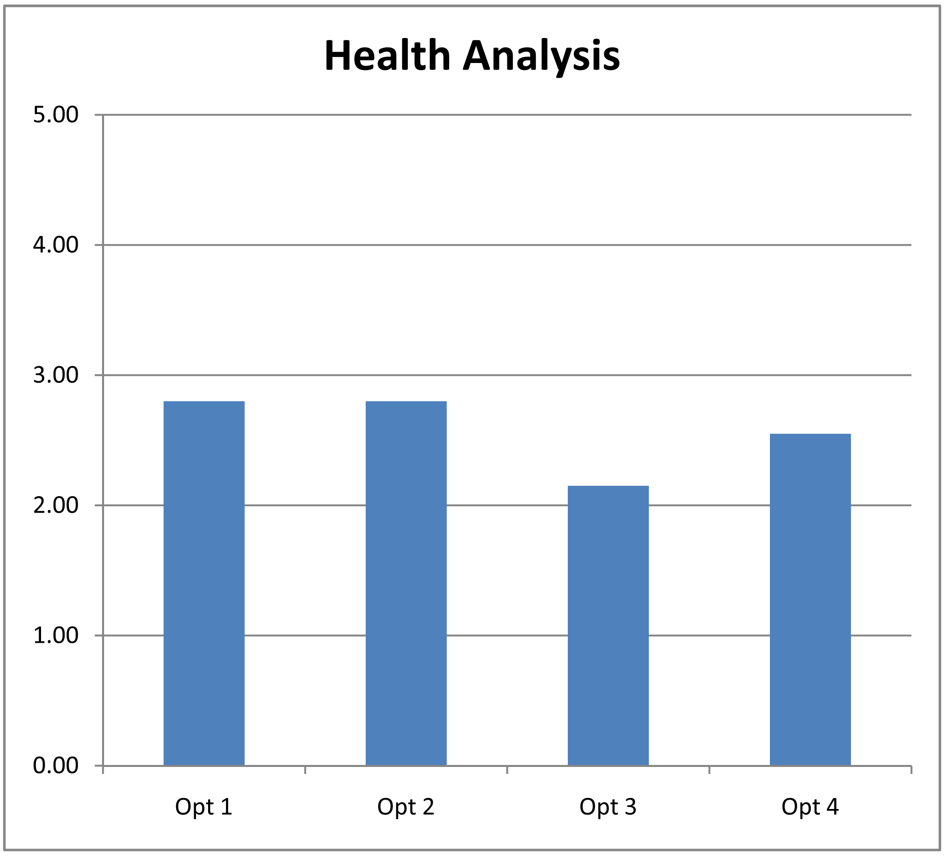


Figure 20 : Health analysis performance graph

From the above graph it can be seen that Alternative 1 and Alternative 2 are most suitable alternatives hygienically followed by alternative 4. Alternative 3 has the least Hygienic suitability.

11. Social analysis

11.1 Social and cultural scenario

11.1.1 Attitude

The attitude of the local community towards excreta and urine is negative and perceive it as dirty. People perceive it as unhealthy and unhygienic and needs to be cast away from the home. The major reasons of this perception being odour, colour, social upbringing and religion. The development of such an attitude is throughout the childhood and change can be possible if the perception of the children towards feces and urine as a resource can be established.

11.1.2 Cultural habits

The cultural habits mould the personality of human beings and the habits form an integral part of the life so much so that people do not realize it. One such instance is that even though the local community perceives excreta as dirty and to be casted away, they do not realize that they use hands without inhibitions for anal cleaning. People tend to urinate in the bushes with the cognition that they are watering the plants.

11.1.3 Religion

The main religion of the community is Hinduism. Hinduism is divided into 4 classes based on the profession which is inherited from the family, viz.

1) Brahmins - The priests(The highest caste)
2) Kshatriyas, - The warriors
3) Vaishnavas - Traders
4) Shudras –Labourers (the lowest caste also known as untouchables)

The Brahmins since ages have glorified their holiness to the extent that they considered it unholy to be touched by the Shudras or even drink water from the well used by the lowest caste people. The Shudras earned their livelihood doing small jobs, one among which was to clean the toilets.

Even though the caste system is slowing dissolving, it is still a part of rural community in a subdued state. The perception towards excreta and urine is therefore also connected to human dignity. To handle excreta manually, is to associate oneself to a particular community/caste. This makes the community less responsive to handle feces and urine.

Figure 21 : Religious group parading on the streets

Even though the children of the orphanage do not have a specific religion, the children tend to accept the religion of the staff members who are mostly Hindus. However as they are born without a religion their caste is unknown and therefore less significant.

11.1.4 Gender

Gender plays an important role in the acceptability of the toilets. Females are more tolerant than men as they are responsible for hygiene of the house and have handled the feces of their children. Moreover the need of privacy is felt much more by the female population than the men. Design of toilets also plays an important role when in public use. The toilet needs to be segregated for both the sexes and the entry to the women's toilet should not be visible to the public.

11.1.5 Acceptability

The community by large is open to the concept of using a toilet, however due to poor economic conditions it is not a priority. Therefore the toilet reflects affordability and a sign of improved standard of living. Convenience, comfort and immediate investment are important factors while making a choice of the type of sanitation. Reuse of toilet waste is still not an acceptable concept.

The constant interactions of the children with foreigners who spend time with them in the orphanage during the work camps has made the children and staff more acceptable to cultural differences and new concepts. A capacity building exercise was conducted by myself with the children and staff on 'the need of sanitation'. The response of the children and staff was encouraging and they were keen on using the toilet facility.

11.2 Criteria and indicators for evaluation

The following Criteria and indicators have been identified for evaluating the social acceptability of the alternatives.

1. Convenience
   1.1 Comfort
   Comfort plays an important role in the decision to use toilet. If uncomfortable to use the toilet may not be used again. This criterion is judged qualitatively
   1.2 Attractiveness
   The toilet system needs to be attractive to generate a sense of pride and an improved standard of living apart from the ecofriendly concept of ecological sanitation. This criterion is evaluated qualitatively.
   1.3 Gender compatibility
   The toilet design should be suitable to both the sexes, especially women and children as in this case. The criterion is evaluated based on the design suitability to both the sexes.
2. Suitability to the local culture – taking into consideration the cultural aspects of the community this criterion evaluates the suitability of the system for the local community qualitatively.
3. Acceptability by stake holders and local community
   3.1 Children – acceptability of the system by the children qualitatively
   3.2 Staff – acceptability of the system by the staff qualitatively
   3.3 Local community – Acceptability of the system by the Local community qualitatively
4. System perception
   4.1 Complexity – the perception of the locals qualitatively
   4.2 Compatibility – the perception of the locals qualitatively
   4.3 Reuse – the perception of the locals qualitatively

11.3 Acceptability of Alternative 1 : Pour Flush type toilet with Septic tank

Sr. No	Criteria	Performance of Indicator qualitative[21] or quantitative
1	Convenience	
1.1	Comfort This system is very comfortable to use	High
1.2	Attractiveness As the system can be kept clean and no fecal matter is seen, this system rates high on attractiveness	High
1.3	Gender compatibility This system can be easily used by both the sexes. However special consideration of design based on anthropometric data for children needs to be incorporated.	High
2	Suitability to the local culture	High
3	Acceptibility by stake holders and local community	
3.1	Children	High
3.2	Staff	High
3.3	Local community	High
4	System perception	
4.1	Complexity As the system does not any special considerations for use this system has low complexity and performs high in the evaluation	High

[21] Qualitative performance : Very High (+), High, medium, low, Nil (-)

Sr. No	Criteria	Performance of Indicator qualitative[21] or quantitative
4.2	Compatibility	High
4.3	Reuse attractiveness	Low

11.4 Acceptability of Alternative 2 : Pour Flush type toilet with Leach pits

Sr. No	Criteria	Performance of Indicator qualitative[22] or quantitative
1	Convenience	
1.1	Comfort This system is very comfortable to use	High
1.2	Attractiveness As the system can be kept clean and no fecal matter is seen, this system rates high on attractiveness	High
1.3	Gender compatibility This system can be easily used by both the sexes. However special consideration of design based on anthropometric data for children needs to be incorporated.	High
2	Suitability to the local culture	Very high
3	Acceptibility by stake holders and local community	

[22] Qualitative performance : Very High (+), High, medium, low, Nil (-)

Sr. No	Criteria	Performance of Indicator qualitative[22] or quantitative
3.1	Children	High
3.2	Staff	High
3.3	Local community	High
4	System perception	
4.1	Complexity As the system does not any special considerations for use this system has low complexity and performs high in the evaluation	High
4.2	Compatibility	High
4.3	Reuse attractiveness	Medium

11.5 Acceptability of Alternative 3 : Urine diversion dehydrating Toilet

Sr. No	Criteria	Performance of Indicator qualitative[23] or quantitative
1	Convenience	
1.1	Comfort This system is not very comfortable to use	Low
1.2	Attractiveness	Low

[23] Qualitative performance : Very High (+), High, medium, low, Nil (-)

Sr. No	Criteria	Performance of Indicator qualitative[23] or quantitative
	As the fecal matter is seen in this system, it loses its attractiveness	
1.3	Gender compatibility This system is compatible to both the genders when a ceramic pan is used however while casting the pan onsite special considerations in design needs to be made as per the gender.	Medium
2	Suitability to the local culture	Low
3	Acceptibility by stake holders and local community	
3.1	Children	Medium
3.2	Staff	Medium
3.3	Local community	Low
4	System perception	
4.1	Complexity As special considerations are required for use of this system toilet, it is slightly complex and performs low in the evaluation	Low
4.2	Compatibility	High
4.3	Reuse attractiveness	Medium

11.6 Acceptability of Alternative 4: Pour flush toilet with Biogas plant

Sr. No	Criteria	Performance of Indicator qualitative[24] or quantitative
1	Convenience	
1.1	Comfort This system is very comfortable to use	High
1.2	Attractiveness As the system can be kept clean and no fecal matter is seen, this system rates high on attractiveness	High
1.3	Gender compatibility This system can be easily used by both the sexes. However special consideration of design based on anthropometric data for children needs to be incorporated.	High
2	Suitability to the local culture	High
3	Acceptibility by stake holders and local community	
3.1	Children	High
3.2	Staff	High
3.3	Local community	High
4	System perception	
4.1	Complexity As the system does needs special considerations for operation of the Biogas plant, it is slightly complex and performs moderately in the evaluation	Medium

[24] Qualitative performance : Very High (+), High, medium, low, Nil (-)

Sr. No	Criteria	Performance of Indicator qualitative[24] or quantitative
4.2	Compatibility	High
4.3	Reuse attractiveness	High

11.7 Comparison of all alternatives

Sr. No	Criteria	Performance of Indicators				Performance of Indicators[25]			
		Alt 1	Alt 2	Alt 3	Alt 4	Alt 1	Alt 2	Alt 3	Alt 4
1	Convenience								
1.1	Comfort	High	High	Low	High	4	4	2	4
1.2	Attractiveness	High	High	Low	High	4	4	2	4
1.3	Gender compatibility	High	High	Medium	High	4	4	3	4
2	Suitability to the local culture	High	Very high	Low	High	4	5	2	4
3	Acceptability by stake holders and local community								
3.1	Children	High	High	Medium	High	4	4	3	4
3.2	Staff	High	High	Medium	High	5	4	3	3
3.3	Local community	High	High	Low	High	5	4	2	3

[25] Score : Very High (5), High (4), Medium (3), Low (2), Nil (1)

Sr. No	Criteria	Performance of Indicators				Performance of Indicators[25]			
		Alt 1	Alt 2	Alt 3	Alt 4	Alt 1	Alt 2	Alt 3	Alt 4
4	System perception								
4.1	Complexity	High	High	Low	Medium	4	4	2	3
4.2	Compatibility	High	High	High	High	4	4	2	4
4.3	Reuse	Low	Medium	Medium	High	2	3	3	2

Sr.no	Criteria and Indicators	Ratings(A) Total score of each criterion			
		Alt 1	Alt 2	Alt 3	Alt 4
1	Convenience	12	12	7	12
2	Suitability to the local culture	4	5	2	4
3	Acceptability by stake holders and local community	14	12	8	10
4	System perception	10	11	7	9

Sr.no	Criteria and Indicators	Ratings(B=A/no of indicators) Average score of each criterion			
		Alt 1	Alt 2	Alt 3	Alt 4
1	Convenience	4.00	4.00	2.33	4.00
2	Suitability to the local culture	4.00	5.00	2.00	4.00
3	Acceptability by stake holders and local community	4.67	4.00	2.67	3.33

4	System perception	3.33	3.67	2.33	3.00

Sr.no	Criteria and Indicators	Ratings(C=B/no of criterias)			
		Average score of each criterion			
		Alt 1	Alt 2	Alt 3	Alt 4
1	Convenience	1.00	1.00	0.58	1.00
2	Suitability to the local culture	1.00	1.25	0.50	1.00
3	Acceptability by stake holders and local community	1.17	1.00	0.67	0.83
4	System perception	0.83	0.92	0.58	0.75

Sr.no	Criteria and Indicators	weight	Ratings(D=C x Weight)			
			Weighted score of each criterion			
			Alt 1	Alt 2	Alt 3	Alt 4
1	Convenience	1.25	1.25	1.25	0.73	1.25
2	Suitability to the local culture	1	1.00	1.25	0.50	1.00
3	Acceptability by stake holders and local community	1.5	1.75	1.50	1.00	1.25
4	System perception	1.25	1.04	1.15	0.73	0.94
	Total	**5.00**	**5.04**	**5.15**	**2.96**	**4.44**

11.8 Final performance of all the Alternatives

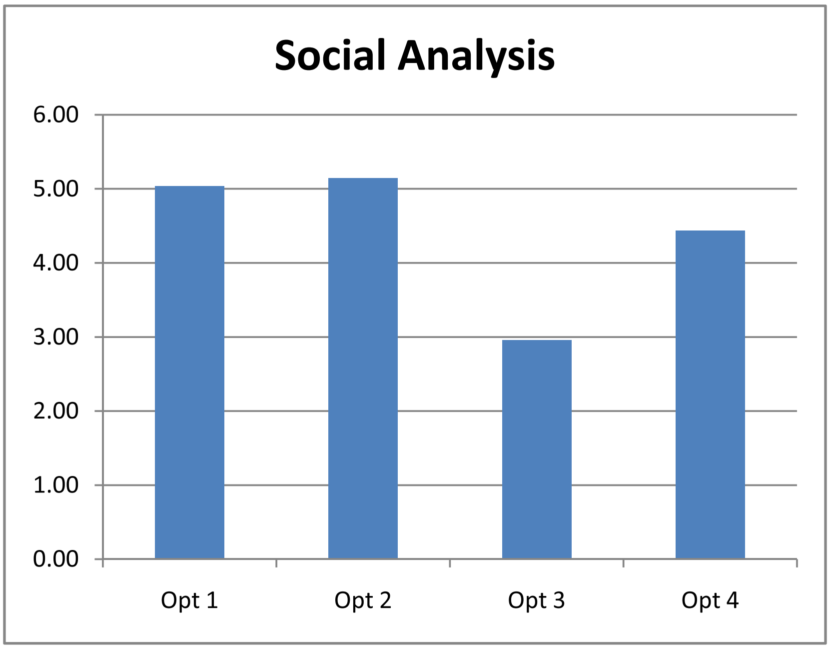


Figure 22 : Social analysis performance graph

From the above graph it can be seen that Alternative 2 is the most the socially acceptable followed closely by Alternative 1. The Alternative 4 ranks third while Alternative 3 has very low social acceptability.

12. Results of the study

12.1 Multi criteria evaluation (MCA)

Multi criteria evaluation is a structured methodology in a decision making process to identify the best alternative among a set of alternative alternatives. In projects which aim at achieving several objectives, best alternative can be identified by evaluating each objective in terms of a set of identifiable criteria and indicators. These indicators can be quantitative or qualitative in nature which can be transformed into rated values of performance. These rated values need to be normalized to make them comparable with the other criteria and objectives. The objectives, criteria and indicators can be internally given weights depending upon its importance to the decision making process. The final performance of the objectives provides insights into the performance of all the alternative alternatives and the possible best choice alternative amongst them.

12.2 Performance of the Alternatives in MCA

The results of the evaluations in the earlier chapters is summarized as below

Sr. No	Type of Analysis	Performance of Indicators			
		Initial total score of Criteria			
		Alt 1	Alt 2	Alt 3	Alt 4
1	Technical Analysis	3.10	3.00	2.47	2.06
2	Economic Analysis	1.85	2.65	2.95	4.25
3	Environmental Analysis	1.71	2.33	3.13	3.17
4	Health Analysis	2.80	2.80	2.15	2.55
5	Social Analysis	5.04	5.15	2.96	4.44

Sr. No	Type of Analysis	Weight	Performance of Indicators			
			Weighted score			
			Alt 1	Alt 2	Alt 3	Alt 4
1	Technical Analysis	0.75	2.32	2.25	1.85	1.54
2	Economic Analysis	1.25	2.31	3.31	3.69	5.31
3	Environmental Analysis	1.00	1.71	2.33	3.13	3.17
4	Health Analysis	1.00	2.80	2.80	2.15	2.55
5	Social Analysis	1.00	5.04	5.15	2.96	4.44
	Total	**5.00**	**14.19**	**15.84**	**13.78**	**17.01**

From the above evaluations the performance of the 4 alternatives can be seen in the graphs below

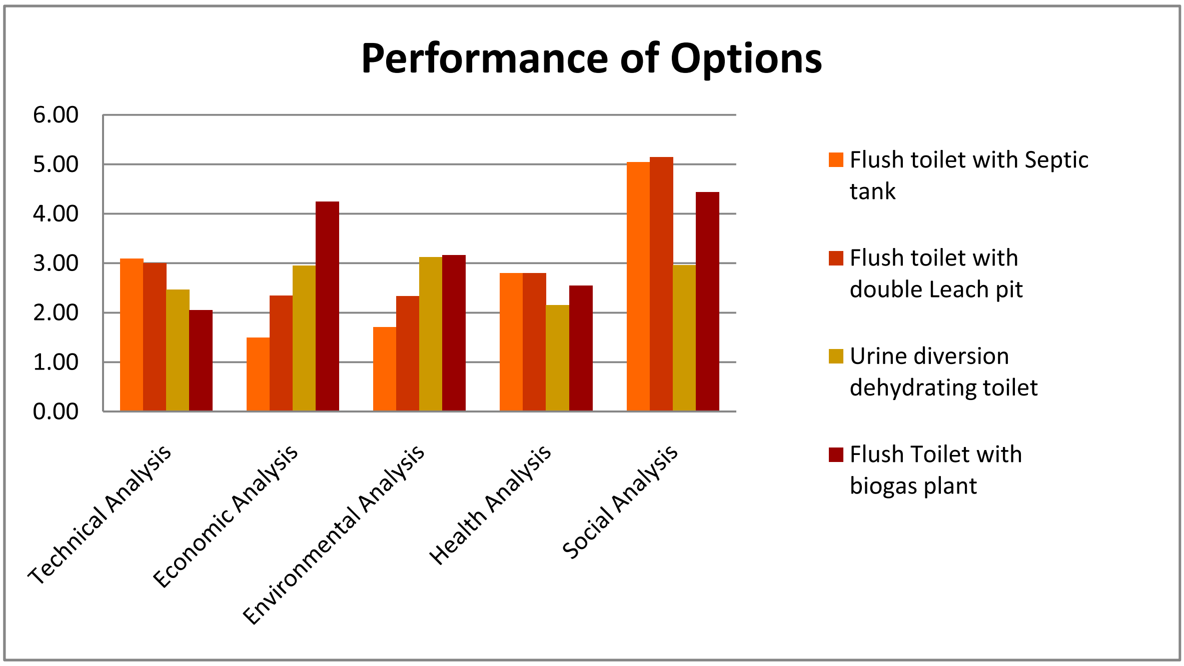


Figure 23 : Performance of alternatives for different objectives

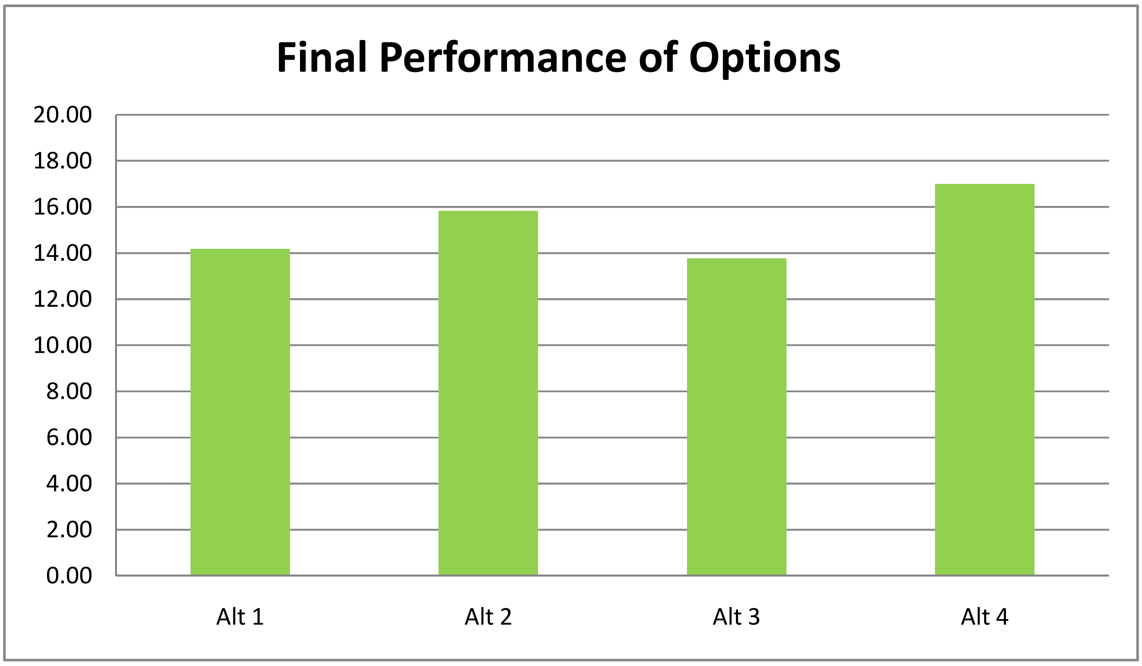


Figure 24 : Final performance of Alternatives

From the above results it can be seen that the performance of all the alternatives is competitive and the difference between the performances is not large. The following is the ranking of the alternatives as per their score.

1) Alt 4 : Flush toilet with Biogas plant
2) Alt 2: Flush toilet with Double Leach pit
3) Alt 1: Flush Toilet with Septic tank
4) Alt 3 : Urine diverting dehydrating toilet

Alternative 4 i.e. Flush toilets with a Biogas plant performs has the lowest impact potential which is followed closely with the Flush toilet with the double Leach pit. The impact potential of the remaining 2 alternatives is almost 20% higher than least impact alternative and therefore need not be considered. The impact potential of the Flush toilet with double leach pit is less than 10 % higher than that of alternative of a Flush toilet with a Biogas Plant

It is however important to note that economic affordability plays a pivotal role in the decision making process. The feasibility is based on the affordability of the NGO as a stake holder in this project.

As is seen in from the analysis Alt 4 has low technical suitability. These technical shortcomings need to be addressed before the decision to implement this best choice option needs to be taken. The performance of this option is low in simplicity of construction, maintenance and operation. As the biogas scheme is implemented nationwide in India and there are functional biogas plants within the vicinity of the orphanage, the possibility of support from the local organizations for capacity building, guidance and professional expertise for construction needs to be ascertained.

12.3 Best suited alternative

The results of the multi-criteria analysis indicate that the pour flush toilet with the bio gas plant has the least impact and the best choice alternative of all the 4 alternatives. This alternative does not only provide hygienic and safe disposal of feces and urine but also provides some additional benefits as mentioned below.

1. Biogas is provided free of cost for cooking, electricity etc.
2. The biogas generated replaces the use of firewood partially as a cooking fuel and therefore reduces the expenditure of the orphanage.
3. The use of biogas as cooking fuel also reduces the deforestation of forests for firewood.
4. The biogas slurry can be used in banana plantation, papaya plantation etc which can provide the orphanage with food.
5. The output of the plantation can also generate income for the orphanage.
6. The nutrients present in the excreta and urine are returned back to the soil increasing its fertility.
7. Working on the plantation along with their studies can train the children in the farming trade which can help them in future.
8. The use of waste to generate biogas, manure and income not only motivates the children in reuse of resources but will also help them to develop their scientific aptitudes.
9. It will help the children to overcome their negative perception of excreta and urine and will make them more acceptable to other ecological sanitation technologies in the future.

12.4 Recommendations

1. Investing in a few more cows and a bigger size biogas plant can produce more biogas thus eliminating the partial dependency on fire wood as cooking fuel. The additional biogas can also be used as lighting for the orphanage with gas lamps reducing the electrical expenses. The cows will provide with milk which can be used by the children and can also be used to generate income by selling milk and milk related products.
2. Regular maintenance of toilets and biogas plant should be done to maintain the attractiveness of the toilets. The toilets should be odour free and hygienic.
3. Capacity building of the biogas plant should be done to increase the acceptability of the toilets. For effective capacity building the stake holders should be taken to visit a similar model project which helps to build confidence in the system.
4. The capacity building should be a periodic activity and needs to meet the concerns of the users and modifications should be made where ever required in the system.
5. Active participation of the children and the staff in the activities is important to develop a sense of responsibility towards the system.

6. There are schemes implemented by the Government of India which provide financial assistance for installing biogas plants which can subsidize the investment costs and make the investment more lucrative.
7. Design of the toilets needs to ensure privacy for the women, anthropometric dimensions suitable for children, proximity of biogas container to the kitchen, proximity of the biogas slurry beds to the plantations, proximity of the animal stables to the biogas plant, visual seclusion of the Kitchen from the biogas plant, proper slope of the drain pipe connecting the toilets to the biogas plant to reduce the usage of flush water.
8. Professional expertise should be sought for the selection and construction of biogas plant and for providing guidance on its operations.
9. Considerations to be made while selecting the type of biogas plant are space requirements, availability of material, costs, gas pressure, ease of maintenance, ease of operation, visual attributes of the biogas slurry, effects during winter, effects of reduction in waste input, effect of dilution on gas generation and the biogas plant life.
10. Modification of the existing kitchen is required to ensure sufficient ventilation to the biogas stove.

12.5 Evaluating the possible spread effect

Biogas plants have been used for more than 2 decades in rural India. Most of these biogas plants are cow dung based which provide biogas for cooking and the biogas slurry is used in the fields. Majority of the population of the Sarangada village are Hindus by religion. As the Hindus consider the Cow as a holy animal, people do not have inhibitions while handling the excreta and urine of the cows. Therefore the acceptability of the Biogas plants based on cow dung is very high. However the biogas plant fed with cow dung and human excreta might not be the same. This discomfort is due to perception, cognition and visual of excreta as bad, unhygienic and ugly. Changing the perception and cognition of the people is a slow and gradual process which can be achieved through capacity building exercises. The visual discomfort needs to be addressed by technological advancement. If the biogas slurry does not have visual traces of suspended excreta the visual discomfort is curtailed. Many of the technologies claim to provide biogas slurry free of suspended excreta which make them more acceptable by the people. Such technologies can foster the spread of biogas plants fed with human excreta and animal dung. Moreover as the benefits of a biogas plant based on cow dung are already seen or experienced by the people, it makes it easier to convince the benefits of excreta reuse along with cow dung. Also as the benefits from the biogas plants are faster as compared to other ecological sanitation technologies the motivation to use it is higher.

Biogas plants have tremendous potential of improving the living conditions of the villagers. If the investment costs are partially or totally subsidized by the government, economic and other benefits can be reaped by the households using it. A family is supplied with a continuous supply of manure for the fields which improves the yield of the fields. A community based biogas plant can provide employment opportunities to the villagers. The ecological benefits of this system would include the return of the nutrients back to the soil increasing soil fertility without any harmful effects as in fertilizers and protection of water bodies and ground water from contamination. The reduction in the use of firewood as coking fuel can reduce deforestation activities and consequent effects of soil erosion. Denser forests will ensure protection of wildlife which has been constantly entering into the human settlements. This system would provide better health and hygiene and reduce the number of deaths caused due to unhygienic sanitation. It would improve human dignity and can help reduce the social injustice done to the poor and lower class people due to the caste system. The use of renewable sources of energies would reduce the possible use of fossil fuels for daily needs will make the village self sustainable. If such a project can be implemented at a village level, the reduction of greenhouse gases and the growth of the trees and forests qualify for carbon credits which can be traded for monetary benefits.

For the promotion of this ecological sanitation technology, capacity building exercises play an important role along with the government intervention to subsidize the investment costs.

13. Summary

The year 2008 has been proclaimed as the ‘World Sanitation Year’ by the World Health Organisation. Lack of sanitation has claimed the lives of millions of people in the past few decades. The growing scarcity of water is questioning the use of sanitation technologies that use fresh drinking water for flushing the toilets. The growing dependency on artificial fertilizers for improving the soil fertility is giving rise to harmful genetic disorders. There is therefore an urgent need to consider technologies which provide a common solution to all these problems.

Ecological sanitation technologies provide onsite solutions for improved sanitation, for reduction in the use of water and for improving soil fertility naturally. These technologies aim at closing the loop of different materials involved in sanitation by recycling them.

Act!Orissa is a Berlin based NGO supporting an orphanage in Sarangada village, Orissa, India. In its effort to improve the infrastructure of the orphanage, the NGO intends to construct toilets for the children for which they wish to conduct a feasibility study to evaluate the possibility of incorporating ecological sanitation technologies.

In this feasibility study, various ecological sanitation toilet technologies have been studied and 4 possible alternatives have been shortlisted for the orphanage. They are

1. Alt 1 : Pour flush toilet with septic tank
2. Alt 2 : Pour flush toilet with double leach pit
3. Alt 3 : Urine diversion dehydrating toilet
4. Alt 4: Pour flush toilet with biogas plant

Toilets and other waste processing infrastructure for each alternative were conceptually designed. Case studies similar to the alternatives were studied which provided information on experiences with each alternative. These four alternatives were then evaluated for technical, economic, environmental, health and social objectives.

In the technical analysis it was observed that the Alt 1 had the highest technical suitability followed by Alt 2, while Alt 4 was the least technically suitable alternative. Contradictory to these results the economic analysis revealed that Alt 4 was the most economically viable alternative followed by Alt 3, while Alt 1 had the least economic suitability. The environmental analysis showed similar results as the economic analysis. Alt 4 had the highest environmental suitability followed closely by Alt 3, while Alt was the least environmentally friendly alternative. However in the health analysis, it was observed that Alt 1 and Alt 2 had similar performance and provided the highest degree of health security followed by Alt 4 while Alt 3 had the lowest performance. Similar results were observed in the social analysis. The results of all the 5 objectives were then given weights as per their importance and cumulated in multi-criteria analysis chart.

The results of the multi-criteria analysis identified Alt 4 i.e Pour flush toilet with biogas plant was the best choice alternative of all the 4 alternatives for the orphanage. This alternative provided the most sustainable sanitation solution to the Orphanage and the community.

14. Conclusion

Sanitation for the orphanage is a very crucial aspect of the health of the children and staff. Hygienic sanitation can be provided to the orphanage through a variety of available alternatives which can be characterised as the ‘flush and forget’ type technologies and the ecological sanitation technologies. The ‘flush and forget’ types of technologies are illogical as they tend to export the problem from one place to another while in ecological sanitation, the toilet waste is first sanitised and then the nutrients are returned back to the soil from where they have been derived.

Ecological sanitation technologies are of various types and suited to specific situations such as number of users, climatic conditions, geological conditions, water availability, density of the settlement, type of reuse, social acceptability, cultural suitability, environmental benefits, economic benefits, technical suitability etc. These technologies are not only very competitive to the conventional technologies in terms of investment costs but also provide high rate of interest on the investment which is almost nil for conventional technologies.

The above analysis of 4 different possible alternatives of sanitation for the orphanage, the alternative ‘ pour flush toilet with biogas plant’ is the most suited technology based on technical, economic, social, environmental, health and social analysis. This system is therefore not only the most suited alternative of sanitation but also the most sustainable sanitation solution for the orphanage and the local community.

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Annexures

Annexure I : Pour flush type toilet

Annexure II : Septic tank and soak pit

Annexure III – Urine Diversion dehydrating toilet

Annexure IV – Biogas plant

Annexure V – Design of Septic tank

Annexure VI – Design parameters of Biogas plant

Annexure VII – Maintenance of Biogas plant

Annexure I : Pour Flush toilet

Construction cost of a Pour flush type toilet

Sr.No	Items	Amount in Rupees
	Sub structure	
1	Excavation	110.00
2	Brick masonary work including labour	5,149.00
3	Plastering including labour	178.00
4	PCC for foundation and plinth slab including labour	1,239.00
5	Providing and fixing of Orissa pan with necessary connections	2,500.00
	Total	**9,175.00**
	Super structure	
1	Brick masonary work including labour	3,431.00
2	Plastering including labour	1,201.00
3	Providing and fixing roofing sheets	1,590.00
4	Providing and fixing wooden doors with necessary fittings	3,180.00
5	Electrical works with labour	1,060.00
	Total	**10,463.00**
	Total cost of 2 Toilets	**19,638.00**
	Total cost of 2 Toilets in euros	**327.00**

Note:

- The above costs does not include any transportation costs and profits.
- The above costs are based on the 'Schedule of rates – 2006' prescribed by the government of Orissa for the year 2006-2007 by the Works Department
- Wherever Schedule rates were unavailable for certain materials, market rates are incorporated based on interview with Architects.
- 1 Euro = 60 Indian Rupees (as on 25th April 2008)
- The costs of smaller projects are usually higher due more wastage of material and higher over head costs.

Annexure II : Septic tank with soak pit

Construction cost of Septic tank

Sr.No	Item	Amount in Rupees
1	Excavation and filling	550.00
2	Brickwork including labour	6,861.00
3	RCC footing and cover slab and PCC	2,869.00
4	Plastering including labour	894.00
5	Piping	371.00
	Total	**11,545.00**
	Total in euros	**192.00**

Construction cost of a Soak pit/Leach Pit

Sr.No	Item	Amount in Rupees
1	Excavation and filling	660.00
2	Brickwork including labour	10,937.00
3	RCC cover slab	3,086.00
4	Plastering including labour	844.00
5	Piping	350.00
6	Gravel	750.00
	Total	**16,626.00**
	Total in Euros	**277.00**

Note:

- Same as Annexure I

Annexure III – Urine Diversion dehydrating toilet

Construction cost of a Urine Diversion Dehydrating Toilet

	Items	Amount
	Sub structure	
1	Excavation	220.00
2	Brick masonary work including labour	6,774.00
3	Plastering including labour	244.00
4	RCC and PCC for foundation, ground slab and plinth slab including labour	4,155.00
5	Providing and fixing of prefabricated pan with necessary connections	6,000.00
6	Steel doors	2,200.00
7	Providing and fixing piping for urine collection and Grey water	150.00
8	Pit cover stone slab	400.00
	Total	**20,143.00**
	Super structure	
1	Brick masonary work including labour	7,253.00
2	Plastering including labour	1,626.00
3	Providing and fixing roofing sheets	2,400.00
4	Providing and fixing wooden doors with necessary fittings	6,000.00
5	Electrical works with labour	2,000.00
6	Vent pipe with fly mesh	1,400.00
	Total	**20,679.00**
	Total cost of 4 Toilets	**40,822.00**
	Total cost of 4 toilets in euros	**680.00**
	5 x 250 Litre plastic containers for urine storage @ 200 Rs each	**1,000**
	Considering a lifetime of the containers to be 5 years, the plastic containers need to purchased every 5 years in a period of 25 years	**5,000**

Note:

- The above costs does not include any transportation costs and profits
- The above costs are based on the 'Schedule of rates – 2006' prescribed by the government of Orissa for the year 2006-2007 by the Works Department and from SEECON [25]
- Wherever Schedule rates were unavailable for certain materials, market rates are incorporated based on interview with Architects.

Annexure IV – Biogas plant

Cost of a Biogas plant

Size of Plant M³	Quantity of cow dung required (Kgs)	No. of cattle required	No. of persons food can be cooked	Estimate cost of Denabandhu Model 2003	Estimate cost of Denabandhu Model 2008 @5% inflation every year	Cost in Euros
1	25	2 – 3	3 – 4	7,100/-	9,062/-	151.00
2	50	4 – 6	5 – 8	9,500/-	12,125/-	202.00
3	75	7 – 9	9 – 12	11,300/-	14,422/-	240.00
4	100	10 – 12	13 – 17	13,800/-	17,613/-	294.00
6	150	12 – 20	18 - 25	18,200/-	23,228/-	387.00

Annexure V – Design of Septic tank

Septic tank design [19]

The minimum capacity required for 24 hours' liquid retention is:

A = P x q litres

where

A = required volume for 24 hours' liquid retention;
P = number of people served by the tank;
q = sewage flow per person (litres per person per day).

Volume for sludge and scum storage

The volume required for the accumulation of sludge and scum depends upon the factors discussed in Chapter 5. Pickford (1980) suggested the formula:

B = P x N x F x S

where

B = the required sludge and scum storage capacity in litres;

N = the number of years between dislodging (often 2-5 years; more frequent dislodging may be assumed where there is a cheap and reliable emptying service);

F = a factor which relates the sludge digestion rate to temperature and the dislodging interval

S = the rate of sludge and scum accumulation which may be taken as 25 litres per person per year for tanks receiving WC waste only, and 40 litres per person per year for tanks receiving WC waste and sullage

Number of years between desludging	**Value of F Ambient temperature**		
	> 20 °C throughout year	**> 10°C throughout year**	**< 10 °C during winter**
1	1.3	1.5	2.5
2	1.0	1.15	1.5
3	1.0	1.0	1.27
4	1.0	1.0	1.15

Annexure VI – Design parameters of Biogas plant

Design parameters for Bio gas plant

Potential gas production from different feed stocks [29]

Type of Feedstock	Gas yield/kg (m^3)	Normal manure availability per animal per day (kg)	Gas yield per day (m^3)
Dung :			
Cattle	0.036	10	0.36
Buffalo	0.036	15	0.54
Pig (approx 50 kg)	0.078	2.25	0.18
Chicken (approx 2 kg)	0.062	0.18	0.011
Human excreta (Adult)	0.07	0.4	0.028

Quantity of cattle dung required for feeding of different sizes of biogas units [29]

Size of plant (m^3)	Amount of wet dung required daily (kg)	Approximate number of adult cattle heads
1	25	2
2	50	4
3	75	6
4	100	8
6	150	12
8	200	16
10	250	20
15	375	30
20	500	40

Quantities of biogas consumed for different application [29]

Use	Specification	Quantity of gas consumed (m^3/hr)
Cooking	2" burner	0.33
	4" burner	0.47
	6" burner	0.64
	per person per day	0.24 m^3/day
Gas lighting mantle lamp of	100 Candle Power	0.13
Duel fuel engine	75-80% replacement of diesel oil per B.H.P.	0.5
Electricity	1 kWh	0.21

Household burner: 200 - 500 l/h

Some figures of gas consumption from India: Boiling 1 l of water: 40 l; boiling 5 l of water 165 l; cooking 500 grice: 140 l; cooking 1000 g rice: 175 l; cooking 350 9 pulses: 270 l; cooking 700 g pulses: 315 l

Due to the limitation that the costs of various items being noted in different years, a rate of inflation has been assumed. The rate of inflation is growing steadily in the past few years.

As the rate of inflation ranges from 4% to 6% between 2004 and 2007, an average rate of 5% per year is assumed for calculating the present costs.

Annexure IV - Maintenance and Care of Biogas Plant [29]

‘The Deenbandhu plant is simple to operate and handle as far as the beneficiaries are concerned. The following simple guidelines for general care and maintenance will increase the operational life and working efficiency of the Deenbandhu plant several-folds.

• The gate valve should be opened only when the gas has to be actually used.

• Before opening the valves, one must ensure that all the preparation for cooking have been made. This would avoid the unnecessary, wasteful consumption of gas.

• The air injector should not be closed very tightly on the side of the burner. The inflow of the air should be adjusted properly in the injector.

• The outlet tank of the plant should never be left uncovered. In addition to the above, the daily, weekly, monthly, yearly and five yearly care and maintenance should be done as per the schedule given below.

Daily

• Add the recommended quantity of raw material.

• Use proper slurry mixture.

• Use clean feedstock, free from soil, straw, etc.

• Clean the mixing tank before and after use.

Weekly

• Use a long bamboo pole for stirring the slurry through the outlet tank.

• Clean gas burners and other appliances.

• Open the tap of the manual moisture trap to drain off moisture condensed in the pipeline.

• The nozzle of the biogas lamps should be properly cleaned.

Monthly

• Remove digested slurry from the slurry collection tank to the compost pit.

• If compost pits are provided next to the outlet tank, then check the level of slurry in it. If filled, divert the slurry to the next compost pit.

• Check gate valve, gas outlet pipe and gas pipes fittings for leakage.

• Check the pipe of the moisture trap (water removal system) for any possible leakage.

Annually

• Check for gas and water leaks from pipe and appliances.

• Repair the worn-out accessories.

• Replace damaged or non-working accessories. Open the gate valve and remove all the gas from the plant. After this, check the level of slurry in the outlet chamber. If the slurry level is above the second step counted from the bottom in the outlet chamber, (i.e. above the initial slurry level), remove it up to the second step.

Five Yearly

• Empty the plant and clean the sludge and in organic material from the bottom of the plant.

• Give a through check to the entire gas distribution system for possible leakage.

• Repaint the ceiling of the dome and gas storage chamber with black enamel paint.

• Recharge (reload) the plant with fresh slurry. ‘