BIOSAN LATRINE FOR REFUGEE CAMPS

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Abstract

Provision for energy needs, safe water supply and sustenance of environmental quality are among the topmost challenges facing the present human society. Water and sanitation inadequacies also hinder economic and social development, constitute a major impediment to poverty alleviation, and inevitably lead to environmental degradation. Conditions are worse for conflict/disaster hit areas where a large human population is suddenly gathered, such as in refugee camps. Various technologies for sanitation, which may be suitable for post-disaster or post-conflict phases, have been developed.

This study analyses the technological, environmental and economical suitability of the BIOSAN technology, in the post-disaster reconstruction. The BIOSAN technology is a hybrid of the ventilated improved pit-latrine (VIP) and sewerage technologies, and integrates the advantages of the two technologies while minimizing their shortcomings and enhancing the human quality of life.

This study follows a BIOSAN technology model designed and constructed at the Kakamega Provincial General Hospital, in Western Kenya. The technology is very appropriate for institutional sanitation and is therefore, considered suitable for refugee camps in the intermediate emergency phase of a disaster or conflict event. Apart from providing an environmentally friendly sanitation, the technology also aims to harvest methane to be used as source of energy.

Keywords: BIOSAN latrine; energy; environment; and refugee camps

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INTRODUCTION

Overview of development in the field of sanitation

Water supply and sanitation systems in the world's developing countries are not very well developed. The conditions seem to be deteriorating because of high poverty levels, low economic development and high growth rate of human population. In certain major cities in Africa, for example, it is estimated that as many as two thirds of the population are without adequate sanitation (Water Solidarity Network, 1994). The world health organization figures for 1998 showed that only 67 percent of the combined urban population of the developing countries had adequate facilities for excreta disposal.

Presently half of the human community has no access to any type of sanitation (WHO and UNICEF, 2000). The rest of the humanity relies on conventional approaches to sanitation, which fall into one of two categories: water borne systems and pit latrines. Both 'flush and discharge' and 'drop and store' technologies were built on the premises that the waste is suitable for disposal and have little economic value. Consequently, the environment is polluted, resources are lost, and a wide array of health and environmental problems result. It is no doubt some of the emerging and unexplained illness could have a link with the deteriorating environment.

Sewerage system is suitable for communities with more than 75 litres of water per capita per day. It requires piped water system, high design standards, high investment, maintenance and operation costs. The conventional latrine technologies include: basic improved traditional latrine, Ventilated Improved Pit Latrine (VIP), double Vault Compost Latrine, bored hole latrine, and the pour-Flash Latrine with leaching pit. The characteristics and requirements of the pit-latrine system are that: do not require water for operation, low investment, operation and maintenance costs. The latrine should be located such that not to pollute groundwater and downstream of the residential areas with respect to wind direction.

In attempt to overcome the disadvantages of the conventional sewerage and latrine systems other technologies have been developed and tried in different parts of the world. In Nigeria, for example the shallow sewerage system was found appropriate except in areas with shallow piezometric water levels to avoid risk of faecal contamination of groundwater (Adelegan and Ojo, 1999). In South Africa (Austin and Van Vuuren 1999, Holden and Austin 1999) the urine diversion technology has been tried and is still under evaluation, though positive results have already been realized. The source separation of urine and faeces has been found successful in some developed countries (Schonning 2002). However, by using the Quantitative Microbial Risk Assessment (QMRA), Schonning (2002) found out that the risk of viral injection is very high which requires careful handling of the waste. In Ethiopia, ECOSAN (ecological Sanitation) toilet technology that enables the recycling of human waste mixed with household wastewater and organic waste has been successful (Terrefe and Edstrom 1999).

Problems in refugee camps

An emergency, which is a description of the crisis that arises when a community has great difficulty in coping with a disaster, may be classified – in a case of a refugee emergency – into five phases: immediate, stabilization, recovery, settlement and resolution phases. The last three phases may take more than two years and are characterized with camp-needs such as construction of more durable shelters and support facilities, installation of piped water supply, improved sanitation, health education campaigns, agricultural support, schooling, vocational training and income generating activities.

Disasters and conflicts have resulted into sudden mass movement of people from volatile areas and concentrated in refugee camps. The numbers of people uprooted by wars has increased dramatically in the last two decades of 1985 – 2005. For instance nearly 300,000 Somalis have sought refugee and about 4.5 million Sudanese were uprooted, of which 475,000 have lived as refugees in the neighboring countries (US Committee for Refugees, 2003).

Most refugee camps are supposed to have 10,000 people. However, camps have hundreds of thousands, as it was with Rwandan camps in Congo in mid 1990's when one of which grew to 600,000 (Cameron, 2002). Refugee camps are supposed to be temporary but unresolved conflicts often make it difficult for refugees to go back home, and camps remain for decades. For instance, the Kakuma camp in Kenya was established in 1992 and is still having refugees due to unresolved conflicts in refugees' home countries.

Conditions in most refugee camps across the world have been found not suitable for humanitarian conditions. The situation is worse in developing countries where, incidentally, most of the refugee camps are located. Donor nations provide fewer contributions, forcing the agencies to just maintain basic services such as health care, shelter and food and implement critical budget cuts on other programs. In Tanzania, which has over 500,000 refugees, programs to improve ailing water systems, construction of new latrines, maintain health services, road repairs have been curtailed.

Most refugee camps are in poor nations of Africa and Asia - and they economically burden local societies, economies, and ecosystems, leading to problems. Sometimes refugees are given food that require considerable cooking, prompting energy related problems such as deforestation. Most of the refugee settlement locations do not have the a significant water supply.

While refugee human needs must take precedence over environmental concerns in times of crisis, the link between human welfare and the environment is becoming more apparent. The environmental resources affected by the presence of refugees include forests, land, water and biodiversity through deforestation, soil erosion, loss of wildlife, depletion of biological diversity, contamination of surface and ground water, poor sanitation, poor waste disposal, over-extraction of ground water and over-cultivation of farmlands.

Refugees use most of the wood from forest as fuel. Survey of Western Tanzania found that refugees used an average of 2.8kilograms of wood per person per day, where local communities used just 1.7kilograms per person per day (UNDP 2005). Soil erosion is commonly observed in and around refugee camps due to destruction of vegetation cover and unsuitable cultivation techniques. For instance soil erosion is a serious problem in and around refugee camps in Karago in Tanzania and Goma and Bukavo camps in DRC. The main threat to freshwater is direct pollution of watercourses by wastewater and waste thrown into the river, laundry washed directly in the flowing river, pollution by infiltration from latrines. Environmentally safe disposal of human, medical and solid wastes is a significant problem in most refugee camps. In Kibumba camp in the Goma region of the DRC, excavation of pit-latrines was difficult due to underlying volcanic rock.

Because the use of woodfuel impacts both the society (gathering wood exposes women and children to violence and requires much time that could better used for education or wage earning) and environment – alternative fuel is necessary. Commonly used camp kerosene is very dangerous causing carbon monoxide poisoning and is easily sold through black markets.

This paper presents a technology, BIOSAN latrine, which is suitable for institutional sanitation. The technology is proposed for refugee camps that have sanitation problems and lack of water and energy supply.

BIOSAN TECHNOLOGY

BIOSAN latrine is in principle the center part of a sanitary biogas unit for safe human faeces disposal, degrading the excreta anaerobically, thus producing biogas and digested substrate that may be utilized as fertilizer. BIOSAN Latrines are designed as integral fixed-dome biogas plants where up to 6 latrines can be installed around a dome.

Biolatrine sanitation (BIOSAN) technology is an integration of the conventional sewerage system and pit-latrine, with an objective of maximizing the advantages and minimizing disadvantages of the two systems, while deriving the economic and financial benefits from the technology. BIOSAN consists of a pit-latrine, digester, gas chambers and delivery systems, as represented in figure 1. The underground part of the pit-latrine is joined directly to the digester, which is divided into two compartments by the baffle wall. The underground pit-latrine, the digester, the gas chambers, and the gas delivery systems are constructed such that they are watertight and gastight.

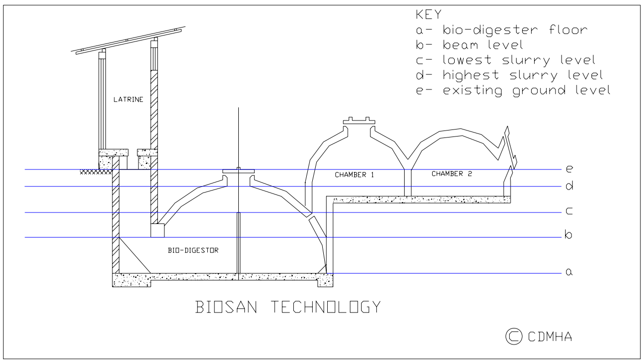

Figure1: Cross-section view of the BIOSAN Latrine

The human waste (excreta), which is the major input in the system, is introduced into the system through the pit-latrine. The waste moves by gravity into the first compartment and then overflows over the baffle wall into the second compartment. The digester is emptied after filling up. The system starts generating biogas when the slurry level creates a seal in the pit-latrine.

The performance of Biogas technology whose objectives are; the cost-effective provision of sanitation and production of energy) depends on the following factors: microbes, plant design, construction materials, climate, chemical and microbial characteristics of inputs. Several factors influencing the design of the system and gas generation include; temperature, pH, loading rate, retention time and toxicity.

The optimum pH value for generation of biogas is between 6 and 7. However, it has been found that the pH reduces in the initial stages of digestion but starts rising towards the end to about 7.2 and 8.2, when biogas production level is stabilized. The methanogenic bacteria operate in an optimum temperature of 35^oC. Satisfactory gas production takes place in the mesophilic range, between 25^o to 30^o C. Loading rate is the amount of raw materials fed per unit volume of digester capacity per day. If the plant is overfed, acids will accumulate and methane production will be inhibited. If the plant is underfed, the gas production will also be low. Retention time (detention time) is the average period that a given quantity of inputs remains in the digester to be acted upon by the methanogens. The retention time is calculated by dividing the total volume of the digester by the volume of daily inputs. The retention time is also dependent on the temperature: the higher the temperature, the lower the retention times. Mineral ions, heavy metals and the detergents are some of the toxic materials that inhibit the normal growth of pathogens in the digester. Small quantity of minerals and heavy metals , such as sodium, potassium, calcium, magnesium, ammonium and sulphur, copper, nickel, chromium, zinc, lead in small quantities are essential for the growth of bacteria but their higher concentration is toxic.

Advantages of using BIOSAN latrine are numerous: they are run without water – not as flush toilets, thus substantially reducing water demand and related cost. The urine provides sufficient fluid. The latrine can be operated without major maintenance demand for 10-20 years. The chances of contaminating groundwater or surface water are very minimal. Biogas is a low-cost substitute for the fuelwood commonly used in the rural areas and refugee camps. The technology is cheaper compared to the conventional pit-latrine and sewerage system, in the long term and short-term respectively. BIOSAN latrine may only be appropriate solution if at least 25 people are connected to its use making the technology very appropriate for places with high populations such as refugee camps and public and learning institutions. Once a year, a tank lorry has to pump out the settled and partially stabilized sludge for further treatment, such as composting, before being used as fertilizer.

CHEMICAL AND PHYSICAL PROCESSES AND ENERGY POTENTIAL

Respiration and photosynthesis are two major processes that sustain life on the planet earth. When green parts of the plant are exposed to light under suitable conditions of temperature and supply of water, use carbon dioxide from the atmosphere and release oxygen to it. This gaseous exchange is opposite to that which occurs during respiration. In photosynthesis the carbohydrates are synthesized from carbon dioxide and water by the chloroplast of living plants cells in the presence of light, oxygen being the product of reaction.

$$6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2 \qquad (1)$$

As result of this process radiant energy of sunlight is stored up as chemical energy in the molecules of carbohydrates (Biomass, such as wood, crops, and organic waste). Biomass is fuel that liberates heat when it reacts with oxygen. Biomass fuel might be burned to liberate energy in a power plant or they may be fermented to yield higher-grade fuels such as methane.

The feed material for BIOSAN latrine is human excreta (faeces and urine). The production and constituents of excreta per capita per day varies with the climate, type of food and age. In Africa and Europe faeces production is between 130 – 500 g (wet weight) per capita per day, while in Europe is about 100 – 200 g per capita per day. Most adults produce between 1 – 3litres of urine per day.

Human waste materials, which consist mainly of carbohydrates, lipids, proteins and inorganic materials is released in the pit latrine and then moves into the first chamber of the digester. Digestion process takes place in the digester. The process consists of hydrolysis, acidification and then methanization. In the hydrolysis stage, the large molecular complex substances are solubilized into simpler one with the help of extra cellular enzyme released by the bacteria. Example, the cellulose consisting of polymerized glucose is broken down to dimetric, and then to monometric sugar molecules (glucose) by cellulytic bacteria. In the acidification stage, the monomer from stage one is fermented under anaerobic conditions into various acids. The principal acids produced in this process are acetic, propionic acid, butyric acid and ethanol. Methanogic bacteria, in the methanization stage, process the principal acids to produce methane. The reaction is expressed by the chemical equations:

$CH_3COOH \rightarrow CH_4 + CO_2$ (2)

Acetic acid → methane + carbon dioxide

$2CH_3CH_2OH + CO_2 \rightarrow CH_4 + 2CH_3COOH$ (3)

Ethanol + Carbondioxide → Methane + Acetic acid

$CO_2 + 4H_2 \rightarrow CH_4 + 2H_2O$ (4)

Carbondioxide + Hydrogen → Methane + Water

An average of 1 kg of wet faeces (12% dry matter content, DMC) produces about $0.054m^1$ of biogas, while 1 litre of urine produces about $0.009m^1$ of biogas. Biogas, which is a mixture of constituent gases shown in table 1, is produced by methanogenic bacteria while acting upon biodegradable materials in anaerobic conditions.

Therefore, based on the $35,846kJ/m^1$ energy potential of methane, the potential production of energy per person per day is 750 kJ and 600kJ in Africa and Europe respectively.

Table 1: Gas constituents of biogas

Substance	**Symbol**	**Per cent**
Methane	CH_4	50 - 70
Carbon-dioxide	CO_2	30 – 40
Hydrogen	H_2	5 – 10
Nitrogen	N_2	1-2
Water vapor	H_2O	0.3
Hydrogen sulphide	H_2S	Traces

BIOSAN PROJECT IN WESTERN KENYA

Project Background

BIOSAN project at Kakamega Provincial General Hospital (KPGH), in Western Province, Kenya, is the first model in the country. Figure 2 shows the geographical location of the project (blue spot). The project was funded by Barclays Bank of Kenya, Kakamega branch, in collaboration with Western University College of Science and Technology (WUCST). The Centre for Disaster Management and Humanitarian Assistance (CDMHA) implemented the technology transfer. The model is to be used for monitoring the performance of the technology in the local climatic conditions.

KEY

● Location of the BIOSAN unit

Figure 2: Geographical location of BIOSAN Latrine Technology in Kenya

Design and construction of the project

The unit, whose design economic life is 20 years, was designed to serve a human population of 150 persons per day. Loading rate and retention time were also considered in the design of the project. Considering the local climatic conditions a retention period of 45 days seemed desirable. Therefore the minimum volume of bio-digester of $12m^3$ was to be provided based on the expected 2 litres or 1 kg of faeces per capita per day. With the $30m^3$ bio-digester for the plant the loading rate of the unit is $5Kg/m^3$. Three number cubicles and VIP type of pit-latrine was provided to serve the patients, hospital staff and the general public. Figure 3 shows the BIOSAN latrine project at the Kakamega Provincial General Hospital, Kenya.

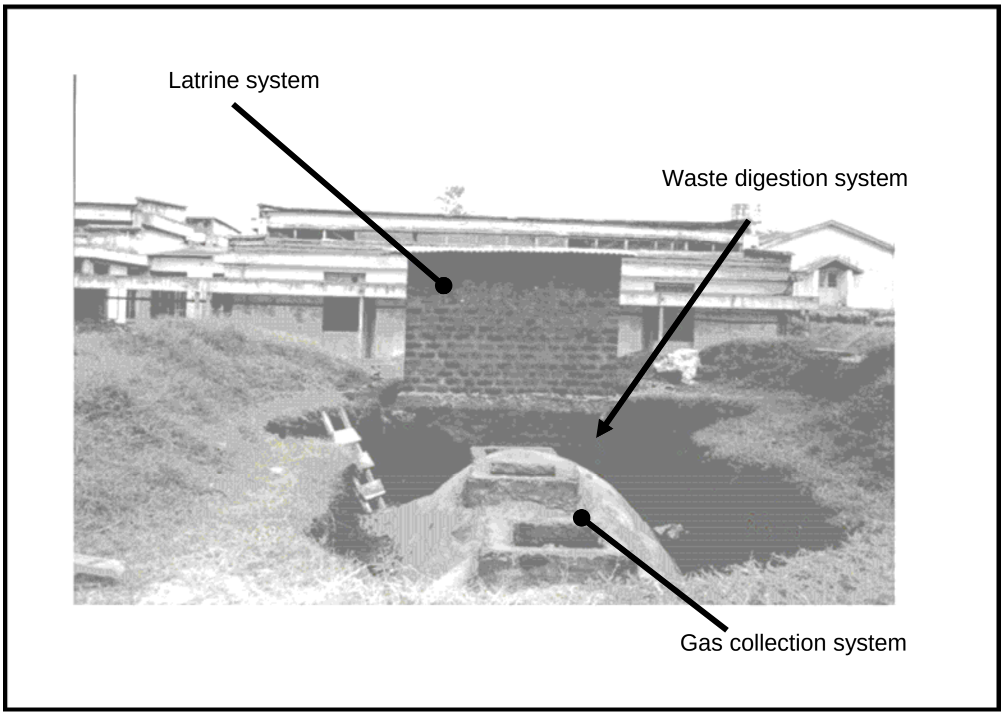

Figure 3: BIOSAN Latrine unit at Kakamega Provincial General Hospital in Kenya

Locally available materials such as stones, sand, soil, bricks, and timber contributed significantly to the low project cost. Imported and/or factory manufactured materials were the most expensive of all the construction materials: cement being the most costly material with the 17% of the total construction cost. Services, labour and transport also made the project cost high. Figure 4 shows the total investment cost for individual items for the BIOSAN plant at KPGH. A total of Kshs 205,500.00 was invested in the project.

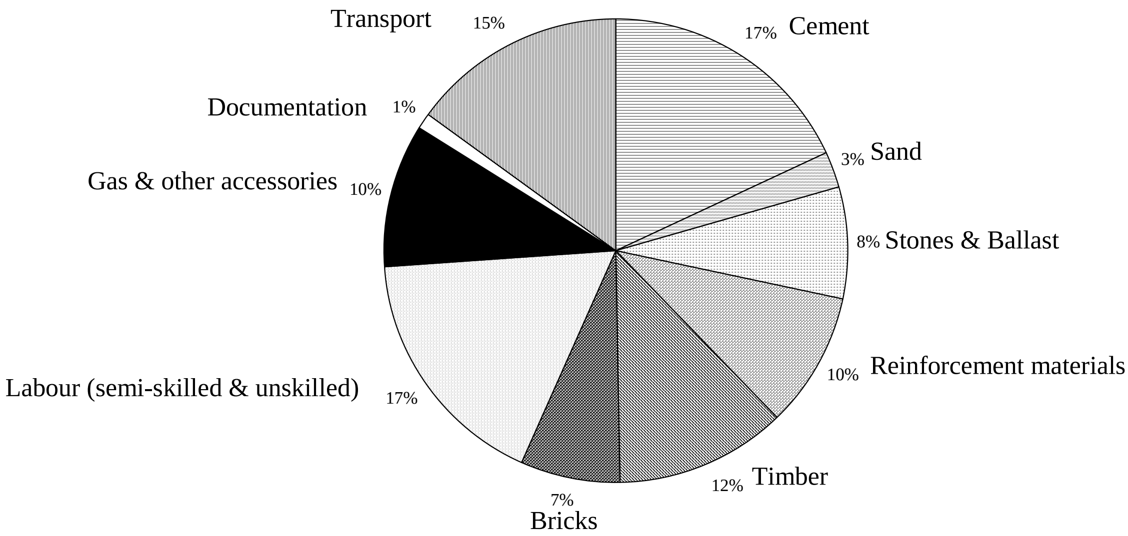

Figure 4: Cost Distribution of a BIOSAN Latrine Unit at KPGH

Energy Potential and Benefit Cost Analysis

Not all the benefits of a BIOSAN unit can be readily priced or even compared with the price of similar products or services in the market. For example it is difficult to put money value on the protected stratospheric ozone layer due to reduced emission of methane (a greenhouse gas) in the atmosphere. Even though there are economic tools that can be used to assign money value to such benefits, they are complicated to apply (FAO, 2000).

The BIOSAN model at KPGH has provision to harvest the gas and package it in suitable containers. The packaged gas will be used in a wider user base: hospitals, schools laboratories, lighting and emergency fuel supply.

For simplicity purposes, the cost-benefit analysis of the present project, with respect to energy generated and used for kitchen (cooking) purposes has been considered. Most of the rural household and institutions use firewood for cooking. For this assumption, it is the quantity and value of firewood saved that becomes the benefits of the biogas plant. Problems associated with collection, storage and use of firewood are avoided by the availability of gas. These are the most appreciated benefits of the BIOSAN technology in terms of reducing the hard work of women who are responsible for most of these activities. The heavy reliance on fuel wood has caused not only irresponsible damage to the sustainability of agriculture and ecosystems in Kenya but also increased workload of rural women and large number of children, mostly girls, who have to allocate work time for fuel wood collection. Table 3 shows the effect of using biogas energy instead of firewood for a kitchen worker.

The relationship between the quantity of gas produced from the BIOSAN unit, the amount of firewood saved, and the values of such savings presented below were based on the following data: -

Population use per day	150
Waste (faeces) collected per day	$0.3m^3$
Biogas produced per day per fresh waste	$5.0m^3$
Energy potential of biogas	$24,500kJ/m^3$
Firewood energy potential	8000kJ/Kg
Firewood equivalence of $1m^3$	3.0Kg
The cost of firewood	Kshs 4.00/Kg

Therefore the unit would save about 20Kg of firewood per day and 7 tones per year.

Table 3: The effect of biogas plant on the workload of a kitchen worker.

SN	**Activity**	**Saving in Time (hrs/day)**
1	Cleaning of the latrine	(-) 0.50
2	Collection of firewood	(+) **2.00**
3	Cooking	(+) **1.00**
4	Cleaning of cooking utensils	(+) **0.75**
	Total	**3.25**

Note: the data on labour and energy saving is from experience while other data is theoretical

From Table 3 it is seen that about 3.25 hours of labour will be saved per day if biogas is used in the kitchen instead of firewood. The results consider the time required cleaning the BIOSAN facility daily. The labour time saved can be used for leisure or for other economic activities. We value the labour time saved by assuming that the labour may be directly sold into the local labour market. The valuation of labour saved is based on the existing rate of employment and market wage rate for the unskilled labour as shown below: -

$$Y = \frac{T \times 365 \times P}{8} \qquad (5)$$

Where, Y: Value of saving in time per year
T: Net saving in time per day (3.25)

8: Working hours per day
P: Current market wage rate for unskilled worker (Kshs 250.00)
365: Total number of days in a year

Therefore, the value of saving in time is about Kshs 37,500.00

The worthiness of the BIOSAN project was assessed by three investment discounting criteria: Net Present Value (NPV), Internal Rate of Return (IRR), and Benefit Cost Ratio (BCR).

$$NPV = \sum_{t=1}^{n} \frac{C_t}{(1+r)^t} - I \qquad (6)$$

Where, C_t : Cash flow at the end of year t, (Kshs 60,500.00)
n : Economic life of the project (20 years)
r : Discount rate, (16%)
I : Initial investment (Kshs 205,500.00)

NPV for the project is Kshs 150,230.00

Table 4: Theoretical financial Analysis of BIOSAN unit at KPGH with reference to cooking

	YEAR/BENEFITS	0	1	2	3	4 to 20
Indirectly Priced						
	Saving firewood	30,000.00	30,000.00	30,000.00	30,000.00	30,000.00
	Saving time/labor	37,500.00	37,500.00	37,500.00	37,500.00	37,500.00
Sub-total		**67,500.00**	**67,500.00**	**67,500.00**	**67,500.00**	**67,500.00**
COSTS						
	Investments	205,500.00				
	Operation	-	6,000.00	6,000.00	6,000.00	6,000.00
	Maintenance	-	1,000.00	1,000.00	1,000.00	1,000.00
Sub-total		**211,500.00**	**7,000.00**	**7,000.00**	**7,000.00**	**7,000.00**
NET BENEFIT (LOSS)		**(151,500.00)**	**60,500.00**	**60,500.00**	**60,500.00**	**60,500.00**

NPV = 150,230.00, Discount rate = 16%, IRR = Above 27.5%,

CONCLUSION

BIOSAN latrine technology is environmental friendly sanitation facility, conserving the environmental resources. Chances are high that the technology would be widely acceptable and viable, socially and economically, in many communities. It provides a cntinuos and cheap source of energy. Locally available materials are used in construction of the technology. Do not require water, hence suitable for rural and urban communities; public, learning and social institutions.

There are circumstances where well meaning aid organizations have provided advanced technological devices, best food-stuffs, new expensive materials that do not match economic, cultural and geographical realities of the situation. Properly combined today's best innovative practices can often provide for basic human needs – clean water, food, sanitation, shelter, security, medical care and education – in ways that support poor populations, check the spread of poverty-inducing conditions, and restore vital habitat and infrastructure.

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