Modification of Existing EcoSan Toilets in Rural Bangladesh

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Modification of Existing EcoSan Toilets in Rural Bangladesh

A thesis report submitted to the department of Civil Engineering of Khulna University of Engineering & Technology (KUET), Khulna, Bangladesh in partial fulfillment of the requirements for the degree of

"Master of Science in Civil Engineering"

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Declaration

This is to certify that the thesis work entitled "**Modification of existing EcoSan toilets in rural Bangladesh**" has been carried out by **Shuvo Ramo Saha** in the Department of Civil Engineering, Khulna University of Engineering & Technology, Khulna, Bangladesh. The above thesis work or any part of this work has not been submitted anywhere for the award of degree or diploma.

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Abstract

Sanitation, one of the most vital parts in environment is a great concern for the developing countries in the world. Bangladesh is one of the most threatened countries of climate change due to its vulnerable geographical location which led to severe water and sanitation crisis. Common features of defecation facilities in the country include pit toilets with or without water seal, hanging toilets, direct pit pour-flash toilets, toilets with septic tank, urine diversion toilets etc. The health burden associated with poor sanitation condition is staggering and hence there is a dire need of holistic approach to call for hygienic, eco-friendly and sustainable sanitation technology. EcoSan toilets are found as one of the most appropriate and proven technological options, as these are cost effective, environment friendly as well as socially sound. Eco-San toilet is a urine diversion toilet and based on the idea that urine, feces and water are resources in an ecological loop. The toilet has a special squat plate in which urine is diverted through the pipe and thus separated from the feces which fall directly downwards into a vault. Wooden ash is added to cover the feces after every visit and thus feces is dried out for which easier handling and transferring is possible. The urine can be collected separately, making it available as a liquid fertilizer. Also the solid component, being semi dry, it does not smell so much and its potential as a fly breeding medium is much reduced compared to the mixes of urine and feces. Eventually, the feces become completely composted. Moreover, it does not need to use water for cleaning and flashing. However, Eco-san has a great potential to contribute safely in transforming human urines and faces into organic fertilizers for eco-friendly agriculture and producing food-crops.

This study had been carried out in Banshbaria village in Keshabpur Upazila of Jessore District due to its high vulnerability to water logging. From geographical perspective, the village was located in the catchments of river "Kobadak". This village was named EcoSan village because 94 no. of EcoSan toilets had been installed in this village by foreign agencies from 2008 to 2012. Due to siltation, the river spread over adjacent area of the village is gradually losing its flow capacity. As a result, the waterlogged condition in the monsoon had damaged the management and safe disposal of human excreta in this area. Pit latrines with various types of super-structure as well as open spaces used for defecation are usually flooded in the rainy season which cause pollution to water sources in the area. The villagers had been suffering from water borne diseases like diarrhea, dysentery, skin diseases with fever, etc. It was found that they were extremely demanded of improved sanitation options (toilets) for safe disposal of human excreta in waterlogged condition. Specific objectives of the study were to (1) study the field performance of existing EcoSan toilets regarding its socio-economic acceptance by rural population in Bangladesh; (2) identify the technical problems in the operation and maintenance of EcoSan toilets; (3) investigate any possible

contamination of groundwater/surface water resources around the EcoSan toilets; and (4) Design modification of EcoSan toilets for its sustainable development in rural Bangladesh.

A detailed field survey was carried out in the study area to investigate the level of socio-economic acceptance of EcoSan toilet by rural population. Social acceptance of the EcoSan toilet was found to be 31.25% on the basis of various operation and maintenance aspects in real field situation such as waterlogged condition, religious aspect, recycling of human urine and feces into organic fertilizers for agriculture, children and elderly people users, etc. On the other hand, considering the chemical properties of nutrients in urine and feces derived fertilizer, equivalent profit of recycled human excreta was found to be BDT 286.28/EcoSan user/year. EcoSan toilets were treated as a source of business through community based organization (CBO). This study revealed that the medical cost and income loss after installation of the EcoSan toilet was far less than it was before. The EcoSan toilet users were also found to be well-practiced in hygiene behaviors.

Several technical problems in operation and maintenance of the existing EcoSan toilets were identified in this study. The major operational difficulties include: removing lid of defecation hole before defecation; being transferred from defecation place to anal washing place; adding ash into feces chamber and placing the lid over the hole. Moreover, the identified maintenance problems include: cleaning the evaporation bed, replacing the corroded heat panel, removing the blockage in pipes, extracting the feces from vault, etc.

Various surface/ground water samples were collected around EcoSan toilets and water quality parameters were analyzed to investigate any contamination of surrounding water sources. Water quality parameters were selected in two categories: a) physicochemical such as pH, SO_4^{2-}, PO_4^{3-}, NO_3^-, DO, BOD_5, COD and b) microbiological such as total coliform, fecal coliform, and E.coli. Experimental results of pH, SO_4^{2-}, PO_4^{3-}, NO_3^- in both surface/ground water were found to be satisfactory within the acceptable limit of Bangladesh standards. BOD_5 value was higher in surface water than groundwater but COD value was lower in surface water in comparison to groundwater. Microbiological water quality was better in groundwater than surface water. The DO level was found to be little bit low.

A modified design of the existing EcoSan toilet was proposed to minimize the operation and maintenance difficulties in the prevailing system. In the modified design, users need not to being transferred from defecation place to anal washing place and hence would use the toilet at one sitting. Finally, it can be concluded that the EcoSan toilets have great potentials for its promising application in the context of rural Bangladesh.

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CHAPTER 1
INTRODUCTION

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1.1 Background

Bangladesh is a densely populated country in the world where most of the rural populations do not have access to safe and reliable toilets. At present, sanitation in rural areas of Bangladesh is getting worse gradually due to inadequate facilities of human excreta management through the traditional way, a great concern of environmental sanitation. However, pit toilets with or without water seal, hanging toilets, direct pit pour-flash toilets, toilets with septic tank, urine diversion toilets etc. are common feature in rural sanitation having no master plan of management for collection, transportation and disposal of human excreta. Conventional pit latrines have certain limitations especially in densely populated rural areas with risks of contamination in groundwater (Niemezynowicz, 1996). The key objective of a sanitation system is to shield and endorse human health by providing and maintaining a clean environment without fecal contamination and by adopting measures that break the cycle of disease transmission. The system should be technically appropriate, economically feasible, socially acceptable and institutionally manageable which are factors that all affect the health outcomes to achieve the direct effects of containment and reduction of pathogenic organism. Human health and environmental impact are interlinked. For this rationale, it is necessary to have not only improved toilet but also sanitary management of human excreta. Improved sanitation relates with requirements for the better living environment, including water quality conservation, sustainable agriculture, poverty alleviation and reduction of health risk.

Bangladesh is known as one of the most susceptible countries across the globe under natural calamity. The southern, south-western and coastal areas of Bangladesh remain submerged for long periods every year, especially during the monsoon season due to the vulnerable geographical setting and climate change. Both human interruptions upon nature and climate change are responsible for the water logging problems in the South-West region of Bangladesh. People in these areas have been coping with waterlogged condition for generations. Water logging has been disrupting livelihoods of about one million people in Bangladesh during past two decades. Every year on an average 20% area of Bangladesh are inundated due to annual flood and this is common and normal phenomenon (Morshed and Sobhan, 2009). In Bangladesh, every year, a huge number of sanitation facilities are damaged or destroyed due to natural disasters like flood and cyclone. There is a huge demand for flood resistant, appropriate, socially and culturally accepted technological options for safe disposal of human excreta in the flood prone areas. However, there are limited technological options for sanitation for flood prone areas (Morshed and Sobhan, 2009).

The present study has been conducted in Banshbaria village in Keshabpur Upazila of Jessore District due to its high vulnerability to water logging for last seven years. From geographical perspective, the village is located in the catchments of river "Kobadak". Historically, the river has been affected by regional and political decision which was, in most cases, detrimental to the hydrological condition of the region. Due to the siltation of the river, three unions such as Trimohini, Sagardari and Bidyanandakathi in the western part of Keshabpur are affected. As a result, the river has lost its flowing capacity due to sedimentation. Every year the river spreads over the adjacent area of these villages due to heavy rainfall during the monsoon season. Almost eight months in a year most of the land area which is monotonously flat and low elevated is inundated. As a result, the impact of waterlogged condition had smashed the management and safe disposal of human excreta. For defecation, people use the pit latrines with different types of super structure, open spaces, direct pit pour flash toilets, hanging toilets etc. which were very unhygienic and responsible for pollution of sub-surface soil and groundwater in rural areas. People of the study area had pit latrines but those latrines were not suitable to use because pits were sunk by water in rainy season. For this condition, they had been suffering by water borne diseases like diarrhea, dysentery, skin diseases with fever etc. It was found that they were extremely demanded of improved sanitation options (toilets) for safe disposal of human excreta. Since 2009, several NGOs (Non-Government Organizations) with foreign collaboration had been establishing EcoSan (Ecological Sanitation) toilets in the waterlogged areas (Saha *et al.*, 2012)

EcoSan is an approach to avoid the disadvantages of conventional wastewater system which is based on water as transport medium for collection and transport of human excreta via a sewer system. It includes wastewater treatment and disposal, vector control and other disease prevention activities that mean proper management of human feces and urine (Mashauri and Senzia, 2000). The EcoSan toilet uses a special pedestal or squat plate in which urine enters the front part of pedestal and then diverted through the pipe and thus separated from the feces which fall directly downwards into a vault or container. Some wood ash is added to cover the feces after every visit. This covers the deposit and helps to dry out the surface of the feces and makes them easier to handle and transfer. The distinct advantage of this method is that the urine can be collected separately, making it available as a liquid fertilizer. Also the solid component, being in semi dry state, is much easier to handle and safer from the beginning, even if it does initially contain pathogens. Being semi dry, it does not smell so much and its potential as a fly breeding medium is much reduced compared to the mixes of urine and feces. Eventually, the feces become completely composted (Morgan, 2007).

EcoSan applies the fundamentals of ecology and takes the non-hazardousness, decrement as well as resources recovery of human excreta as the guiding principles for the construction of ecological facilities, and the rational utilization of non-hazardous treated human excreta as useful resources, so as to achieve the purpose on health protection of human beings and ecological balance (Shunchang 2002). Nevertheless, EcoSan is a cycle or a system or a closed-loop system which treats human excreta as a resource where excreta are processed on site until they are free from pathogen and sanitized excreta are recycled by using them for agriculture purposes. EcoSan is the appropriate method of human excreta management, where this might be used as both organic matter and fertilizer. Bangladesh is predominantly based on agriculture that is highly intensive and also subsistence of people to meet up demand of food security. Due to intensive cultivation excess use of chemical fertilizer and pesticides without application of organic matter, soil is losing organic content day by day. The low organic content is considered as one of the main reasons for low productivity of soils (Rahman, 2003). The crucial need for proper content of organic matter in soil should be top emphasized in view of the low organic matter content. Alternatively, to meet up demand of food, more inputs are used in form of fertilizer, pesticides, insecticides and irrigation, therefore a tremendous pressure in put on natural balance. A time has come now to look into overall problem of the indiscriminate use of pesticides and chemical fertilizer. Now agriculturist, policy planner and farmer also feel a great demand of organic farming for productivity, stability and sustainability of agriculture in rural Bangladesh. Organic farming is currently termed as ecological farming based solely on organic inputs, which have the potentials to reduce some of the negative impacts on conventional agriculture on the environment. Due to realize the crucial need of organic matter in soil and lack of alternative source of organic matter, human excreta should be used as fertilizer for its high nutrient content in Bangladesh agriculture.

There is a cruel cycle in which lack of sanitation relates with poverty, as increased health risk caused by unhygienic environment might increase the medical expenditure and lose job chance. Sanitation relates deeply with the living environment in rural area of Bangladesh. As arsenic contamination of groundwater is a serious issue for health risk, it is necessary to keep alternative water source for drinking. Improper management of defecated human excreta will cause surface water pollution, which will restrict water resource to use for safe drinking water. There is the natural nutrient cycle, into which excreta of the living things are taken, and human excreta are not exception. The natural nutrient cycle will keep health of soil and food production. In Bangladesh, the soil condition of agricultural farms has been deteriorated due to the application of chemical fertilizer for a long time. Moreover, there are predictions that it is difficult to keep nitrogen and phosphorus fertilizer. The production of nitrogen fertilizer is related to the energy crisis in this country and phosphorus is one of the depleting natural resources in the world. Therefore, the necessity of utilizing human excreta as fertilizer or a soil conditioner is increasing. It is noted that deviating human excreta from the natural nutrient cycle will hamper sustainable food production. So, EcoSan is the concept of dry sanitation, an innovative approach and viable solution to the problems caused by conventional sanitation because its benefits and advantages are successfully conveyed correctly shown through knowledge sharing and capacity building. Therefore, benefits related with improvement of sanitation and agricultural product is expected, if EcoSan functions as normally. When the products from a sanitary system should be considered as potential resources either for food production or for energy generation, the health issues and aspects of risk reduction need to be accounted for in addition to the benefits of nutrient recovery. Figure 1.1 shows a typical model of EcoSan toilets that had been constructed in many rural areas of Bangladesh for safe management of human excreta.

Figure 1.1 Typical feature of EcoSan toilet with its squat plate in study area

Proper sanitation positively affects the individual's nutritional status, diseases resistance, income opportunities, self-esteem, personal security, etc. Enhanced opportunities for improved livelihoods can be achieved through eco-system based sanitation with radical perspective on gender balance, social development, agricultural production and sustainability (Chowdhury, 2006). Sanitation is one of the key factors of sustainable development. In order to be sustainable, a sanitation system has to be not only economically viable, socially acceptable and technically/institutionally appropriate, but also should protect the environment and natural resources (Langergraber and Weissenbacher, 2010). The benefits of EcoSan toilets are well-known: it does not need water to function; it protects the environment; and allows the nutrients in human feces and urine to be returned to the soil as fertilizer (Winblad and Simpson-Hébert, 2004). EcoSan toilets are increasingly recognized as realistic alternatives to provide safe sanitation and thereby reduce the health risks associated with poor sanitation.

1.2 Objectives of the study

Aspire of the study was to explore social acceptance, operation and maintenance problem and modified design of existing EcoSan toilet in rural Bangladesh for good management of human excreta. The specific objectives of this study are outlined below:

a) To study the field performance of existing EcoSan toilets regarding its socio-economic acceptance by rural population in Bangladesh;

b) To identify the technical problems in the operation and maintenance of EcoSan toilets;

c) To investigate any possible contamination of groundwater/surface water resources around the EcoSan toilets; and

d) Design modification of EcoSan toilets for its sustainable development in rural Bangladesh.

1.3 Structure of the dissertation

The study has been offered in eight distinct chapters comprising different aspects of this study (Figure 1.2). The chapters expose the socioeconomic acceptance of the EcoSan toilets among rural people, possible contamination of groundwater / surface water surrounding the toilets, operation and maintenance problems and the modification of existing design of EcoSan toilets for safe sanitation.

Chapter-1 gives a general explanation that concerns the approach of EcoSan toilets in rural areas of Bangladesh with coverage for safe sanitation and good management of human excreta through systematic way.

Chapter-2 comprises of a comprehensive literature review encompassing the global sanitation practices in developing country especially Bangladesh; concept of ecological sanitation (EcoSan) in Bangladesh perspective; and EcoSan in rural areas through planning, promotion, education and training, institutions, financial aspects and codes and regulations.

Chapter-3 contains elaborate description of the materials, analytical methods, and experimental procedures and design modification employed in this study along with the fundamental principles underlying those.

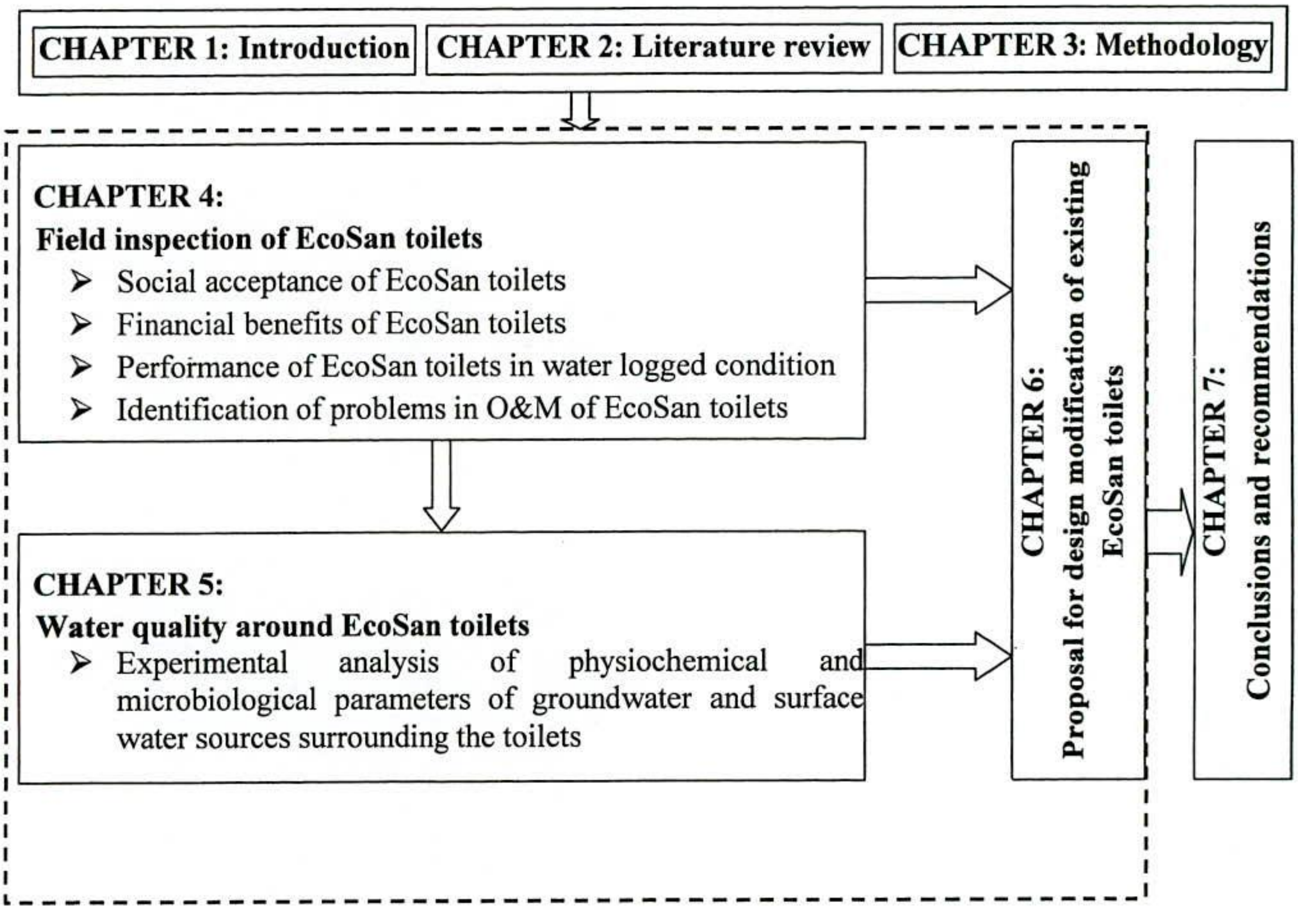


Figure 1.2 Structure of the dissertation

Chapter-4 provides an assessment of social acceptance and economic aspect of existing EcoSan toilets through analyzing social, operational and maintenance problems in using the toilets, performance of those toilets in water logged condition and economic relations among annual income of users, fertilizer profit and medical expenses including income loss due to illness. Shortly, it also describes socioeconomic performance of EcoSan toilets at field level.

Chapter-5 introduces the experimental test result of water quality parameters of surface water (ponds) and groundwater (shallow tube-wells) nearby the EcoSan toilets. Two types of parameters; physiochemical and microbiological parameters of both surface water and groundwater were introduced for laboratory analysis to identify any probable contamination.

Chapter-6 elucidates the modification of existing design of EcoSan toilets to change the operating system through developing an arrangement of frame where urination, defecation and anal washing will be occurred mutually at a same place but urine, feces and anal washing water will not get mixed with each other.

Chapter-7 draws final conclusions based on logical reasoning of the field investigations and water quality analysis and also provides a few recommendations for future related studies.

An annotated reference list of the literatures cited in the dissertation follows the last chapter.

There are four specific objectives in this study, which were outlined earlier in section 1.2 in this chapter. The first and the second objectives are addressed in chapter 4. Chapter 5 is aimed to elucidate the third objective of this study. The fourth objective is discussed in chapter 6. Based on the investigations in the preceding chapters, finally, overall conclusions and recommendations are provided in chapter 7.

CHAPTER 2

LITERATURE REVIEW

CHAPTER 2

LITERATURE REVIEW

2.1 General

2.1.1 Global sanitation practices

An estimated 2.6 billion people or 39% of the world's population require access to improved facilities for safe disposal of human excreta, such as a basic pit latrine, a toilet connected to a septic tank or piped sewer system or a composting toilet according to the World Health Organization (WHO) and the United Nations Children's Fund (UNICEF). In low-income regions, people are most vulnerable to infection and disease, only one in two people is covered by improved sanitation. More than 1.0 billion people still practice open defecation. Coverage in Sub-Saharan Africa and Southern Asia is just 31% and 33%, respectively. While the global population in 2006 was about equally divided between urban and rural dwellers, more than 7 out of 10 people living without improved sanitation are rural inhabitants (WHO/UNICEF, 2010).

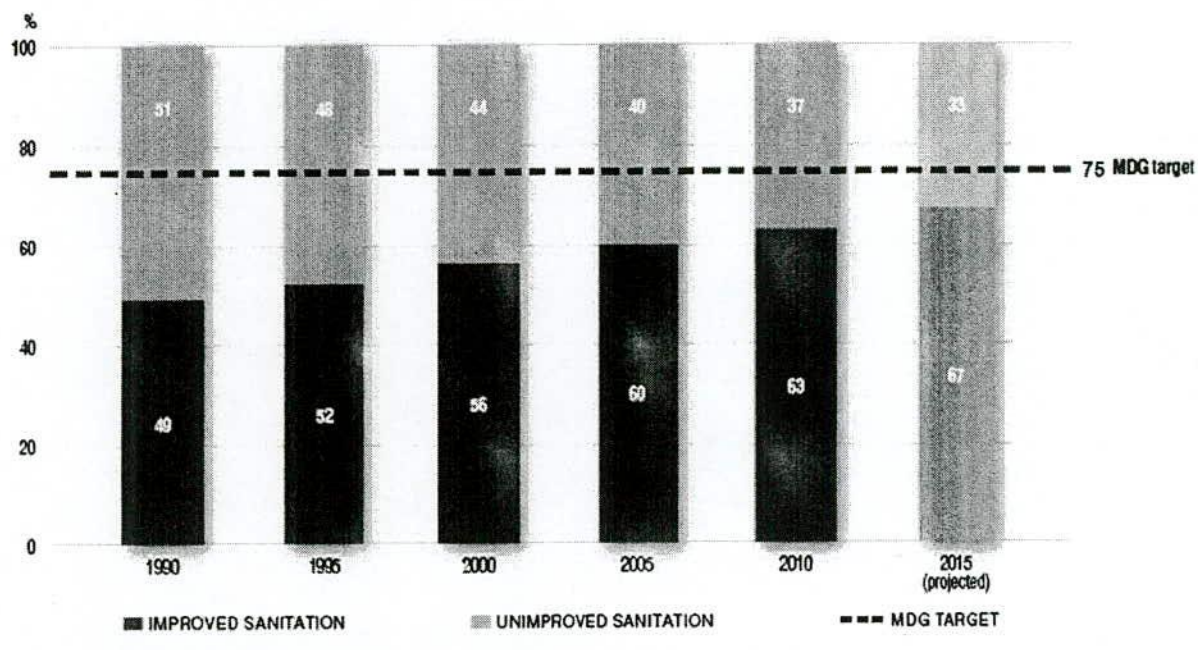


Figure 2.1 Trends in global sanitation coverage 1990-2010, projected to 2015

Though it is unlikely that the world will meet millennium development goal (MDG) sanitation target by 2015, encouraging progress is being made. Globally, 63% of the population use improved sanitation facilities, an increase of almost 1.80 billion people since 1990 shown in Figure 2.1. This means that we are within 10% of being 'on track'. At current rates of progress, we will reach 67% coverage in 2015, better than previous projections but still far from the 75% needed to reach the target. Unless the pace of change in the sanitation sector can be accelerated, the MDG target may not be reached until 2026. If current trends continue, the world will not meet the MDG sanitation target. In 2010, an estimated 2.5 billion people were still without improved sanitation.

Figure 2.2 shows that 15% of world population in 2010 still practice open defecation, defined as defecation in fields, forests, bushes, bodies of water or other open spaces. This represents 1.1 billion people. Though the proportion of people practicing open defecation is decreasing, the absolute number has remained at over 1.0 billion for several years, due to population growth (UNICEF/WHO, 2012).

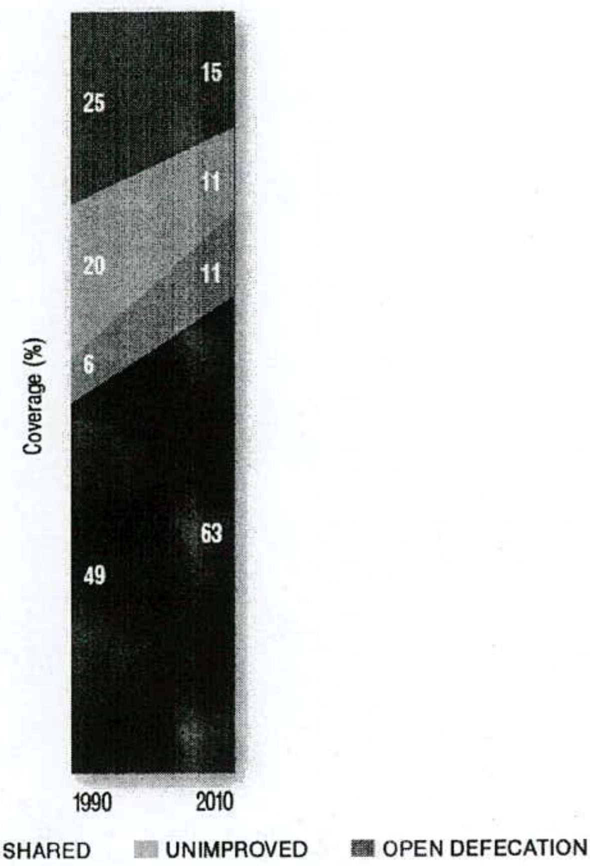


Figure 2.2 Trend in the proportion of the global population using improved, shared or unimproved sanitation or practicing open defecation, 1990-2010 (UNICEF/WHO, 2012)

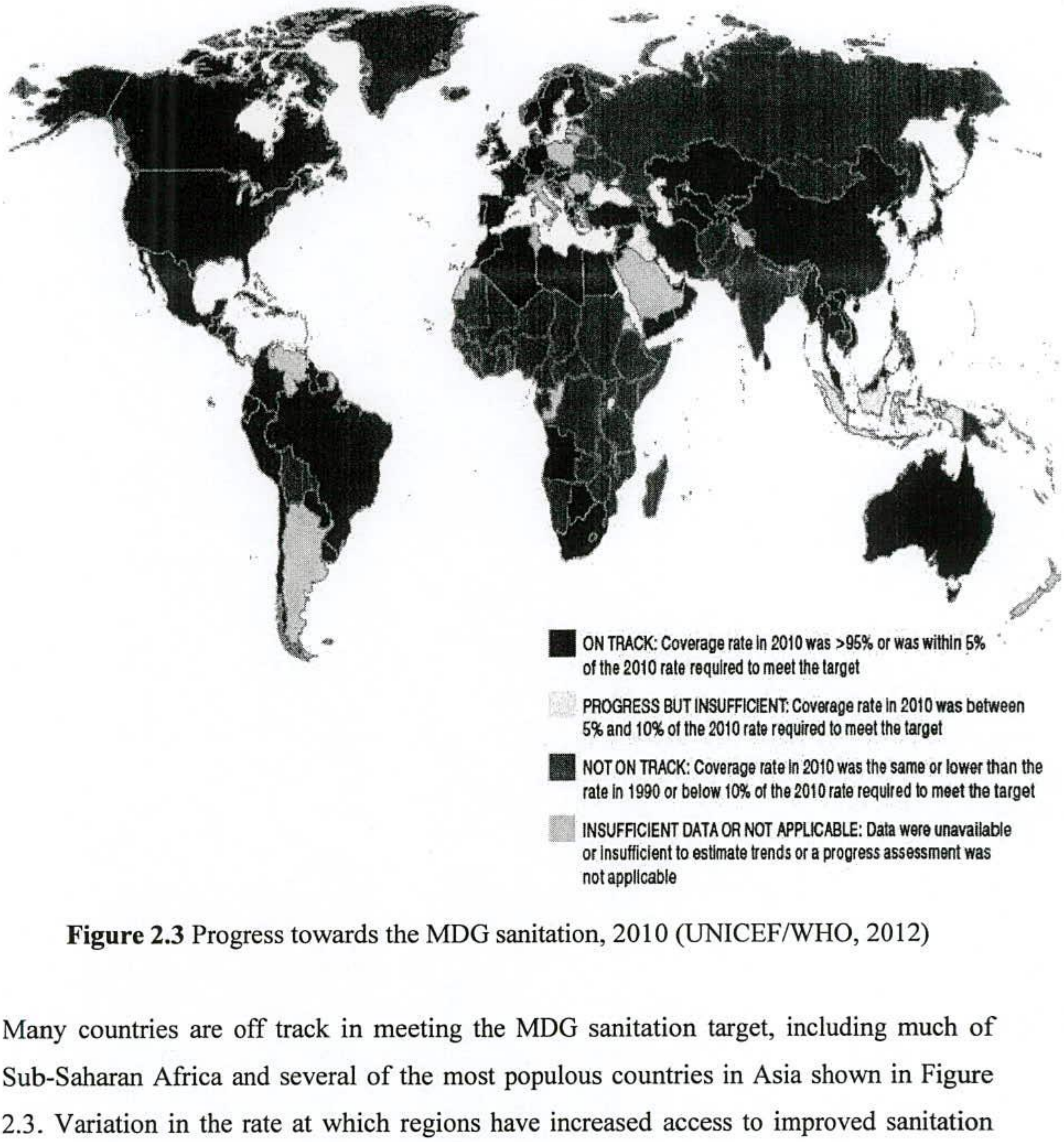


Figure 2.3 Progress towards the MDG sanitation, 2010 (UNICEF/WHO, 2012)

Many countries are off track in meeting the MDG sanitation target, including much of Sub-Saharan Africa and several of the most populous countries in Asia shown in Figure 2.3. Variation in the rate at which regions have increased access to improved sanitation facilities is striking in Figure 2.4. Eastern Asia added 39 % points in coverage between 1990 and 2010. Unlike drinking water, no region has experienced decreas in coverage (UNICEF/WHO, 2012).

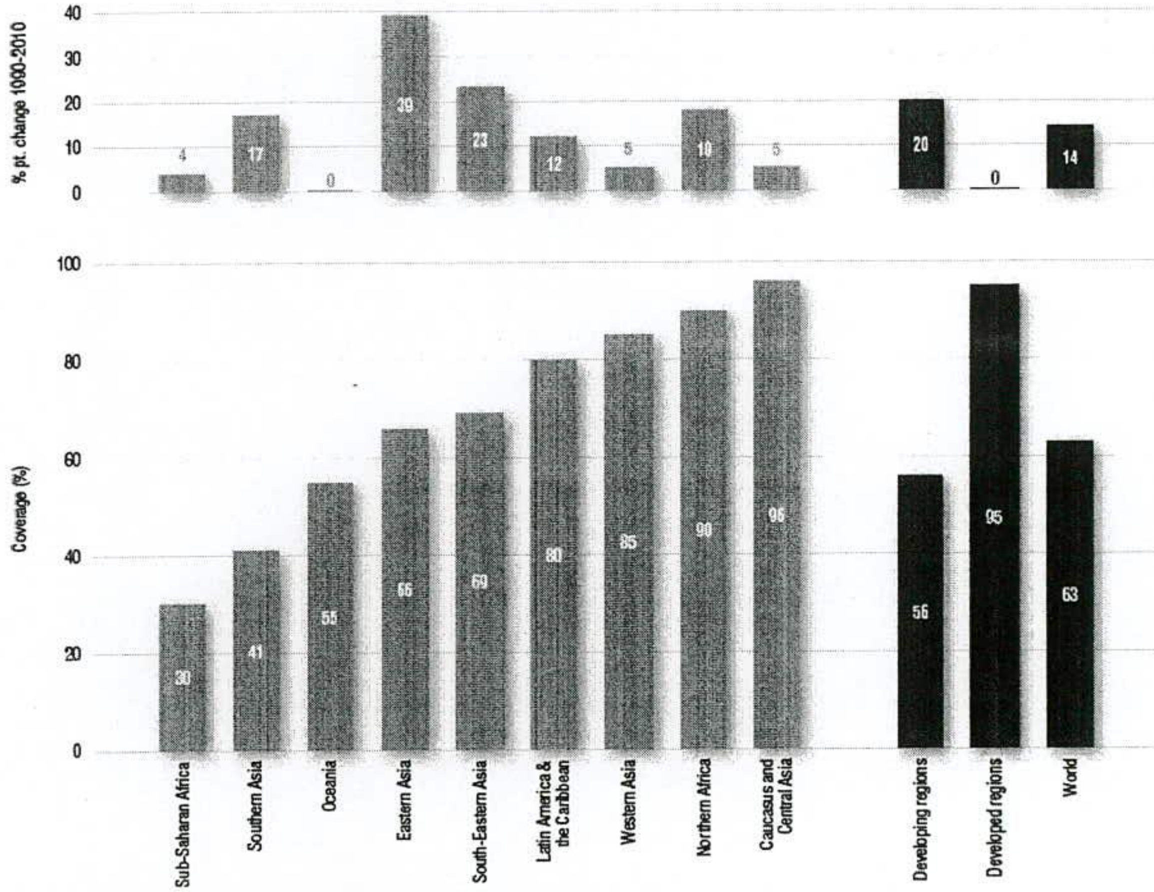


Figure 2.4 Use of improved sanitation facilities by MDG region in 2010 and %-point change 1990-2010 (UNICEF/WHO, 2012)

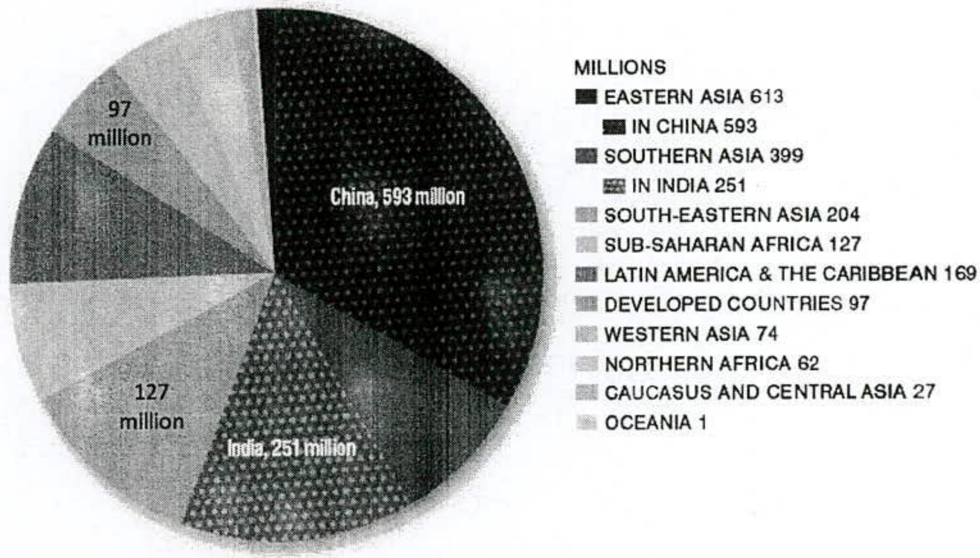


Figure 2.5 Number of people who gained access to improved sanitation from 1990 to 2010, by MDG region (millions) (UNICEF/WHO, 2012)

Figure 2.5 represents the number of people who gained access to improved sanitation facilities since 1990, by MDG region. Progress in China and India is highlighted, since these two countries represent such a large proportion of their regional populations. While China has contributed to more than 95% of the progress in Eastern Asia, the same is not true for India in Southern Asia. Together, China and India contributed just under half of the global progress towards the MDG target in sanitation. Four out of ten people who have gained access to improved sanitation since 1990 live in China or India (UNICEF/WHO, 2012).

2.1.2 Sanitation in developing countries

Trends in sanitation coverage by region show marked differences, as illustrated in Figure 2.6. Southern Asia and Sub-Saharan Africa still struggle with low coverage (41% and 30%, respectively). However, the two regions differ significantly from one another in the proportions of populations using facilities other than those classified as 'improved'. In Sub-Saharan Africa, 45% of the population uses either shared or unimproved facilities, and an estimated 25% practice open defecation. In Southern Asia, the proportion of the population using shared or unimproved facilities is much lower and open defecation is the highest of any region. Although the number of people resorting to open defecation in Southern Asia has decreased by 110 million people since 1990, it is still practiced by 41% of the region's population, representing 692 million people. Sub-Saharan African has not made the same progress in reducing open defecation. In fact, it has decreased by only 11% since 1990. With population growth, this means that the number of people practicing open defecation has actually increased by 33 million. That said, Sub-Saharan Africa has the highest proportion of people using some sort of unimproved sanitation of any region (these are facilities that fall short of being 'improved' and are unimproved, shared or public). This proportion is growing, suggesting that the demand for sanitation is on the rise.

Far more countries have sanitation coverage of less than 50 percent than water coverage of less than 50 percent. As with water, most of the countries with low sanitation coverage are in Sub-Saharan Africa. However, several populous countries in Southern Asia also have low rates of improved sanitation.

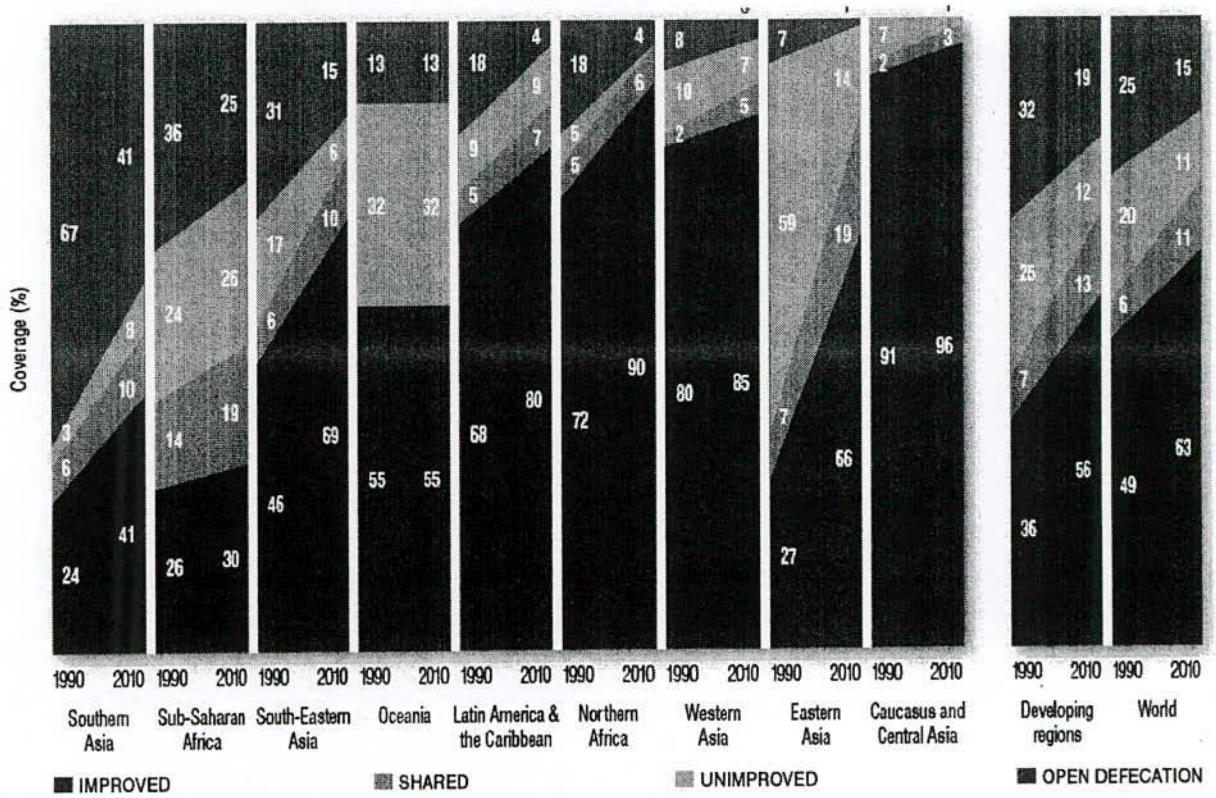


Figure 2.6 Sanitation coverage trends by developing region, 1990-2010 (UNICEF/WHO, 2012)

The majority of those practicing open defecation (949 million) live in rural areas. Open defecation in rural areas persists in every region of the developing world, even among those who have otherwise reached high levels of improved sanitation use. For instance, the proportion of rural dwellers still practicing open defecation is 9% in Northern Africa and 17% in Latin America and the Caribbean. Open defecation is highest in rural areas of Southern Asia, where it is practiced by 55% of the population.

Open defecation is, however, decreasing in all regions, in both urban and rural areas. About 234 million fewer rural dwellers were practicing open defecation in 2010 than in 1990. Those that continue to do so tend to be concentrated in a few countries, including India, where 626 million people practice open defecation (59% of the global total). Shared sanitation is defined as sanitation facilities of an otherwise acceptable type that are shared between two or more households, including public toilets. Sanitation facilities that are shared among households, whether fully public or accessible only to some, are not considered improved according to the definition used for the MDG indicator (UNICEF/WHO, 2012).

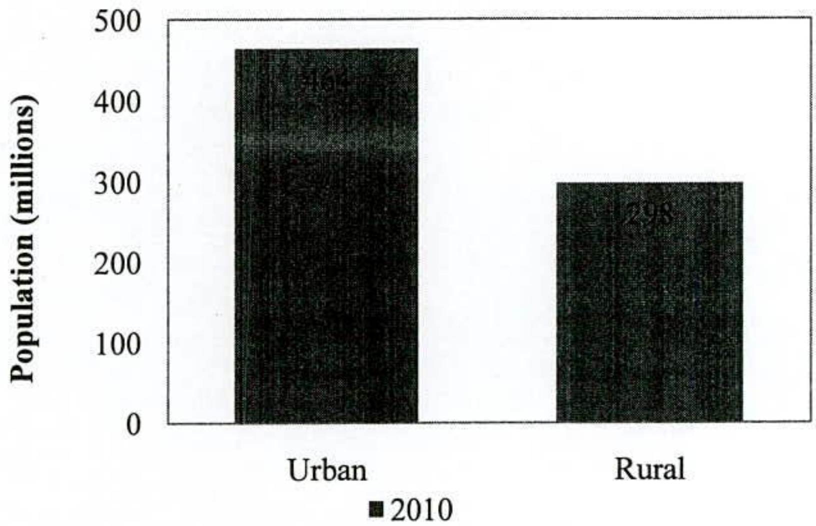


Figure 2.7 Population sharing sanitation facilities by urban and rural areas, 2010 (millions) (UNICEF/WHO, 2012)

The reason stems from concerns that shared facilities are unacceptable both in terms of cleanliness (toilets may not be hygienic and fully separate human waste from contact with users) and accessibility (facilities may not be available at night, or used by children, for instance). However, it is also recognized that, globally, the number of people using shared sanitation is growing: The number of users has increased by 425 million since 1990 – increasing from 6% of the global population to 11% in 20 years. In many countries, particularly in crowded urban areas, shared sanitation is the only viable option for those wishing to avoid open defecation; in rural areas, families often keep costs down by sharing latrines between one or more households with family ties. The UNICEF/WHO joint monitoring programme (JMP) task force on sanitation is exploring the issue of shared sanitation as part of its mandate. Shared sanitation is predominantly an urban phenomenon, and over 60% of people using this type of facility live in urban areas are shown in Figure 2.7.

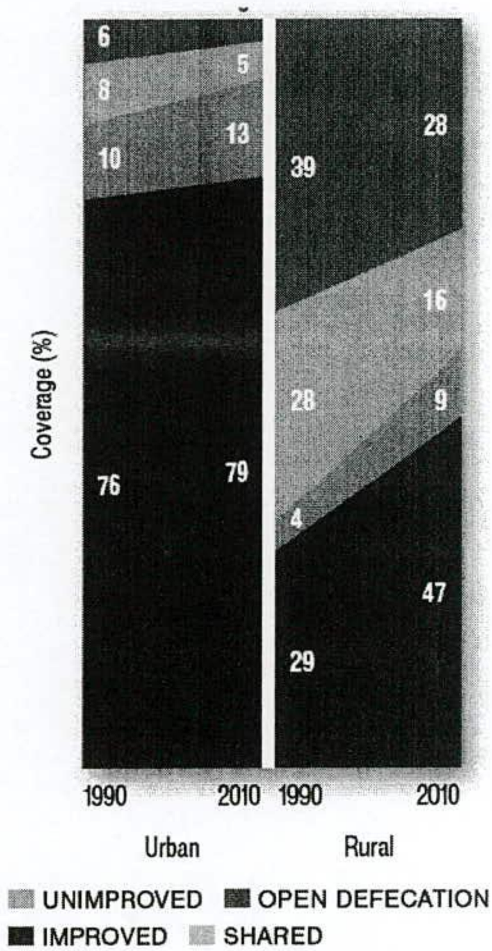


Figure 2.8 Sanitation coverage trends by urban and rural areas, 1990-2010 (UNICEF/WHO, 2012)

The disparities in rural and urban sanitation are even more pronounced than those in drinking water supply. Globally, 79% of the urban population uses an improved sanitation facility, compared to 47% of the rural population showing Figure 2.8.

In rural areas, 1.8 billion people lack access to improved sanitation, representing 72% of the global total of those unserved. However, a great deal of progress has been made in rural areas since 1990; 724 million rural dwellers have gained access to improved sanitation while the number of people unserved in urban areas has grown by 183 million.

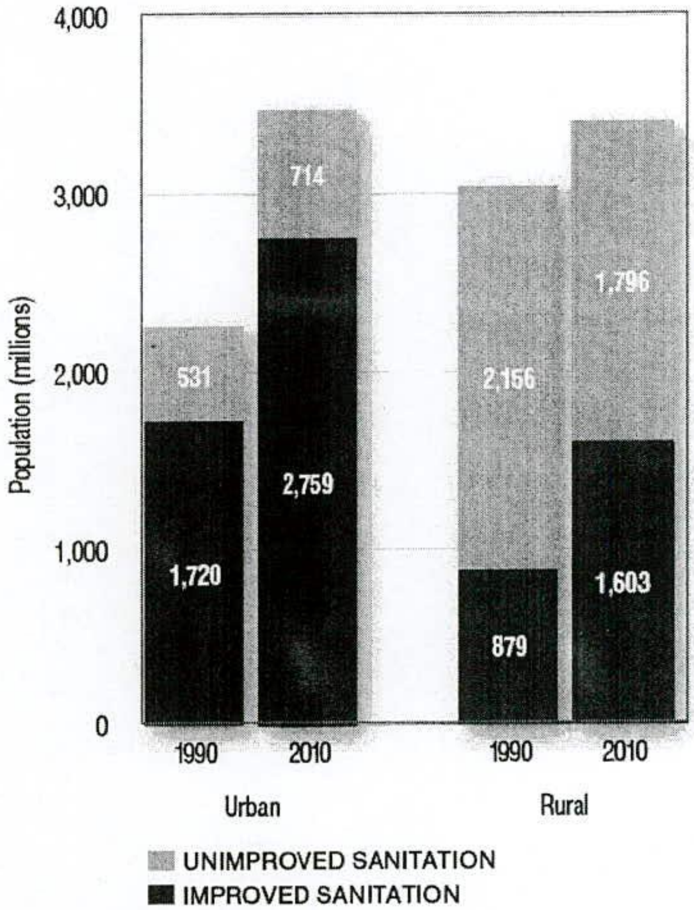


Figure 2.9 Population using improved or unimproved sanitation by urban and rural areas, 1990-2010(millions) (UNICEF/WHO, 2012)

A significant number of rural dwellers have moved away from open defecation, doing so at a higher rate than urban dwellers. In 2010, 105 million people practiced open defecation in urban areas, representing 3% of the urban population. As with drinking water, the number of urban residents using unimproved facilities increased from 1990 to 2010, at a time of rapid growth in urban areas. The number of people using unimproved facilities in rural areas decreased, but in 2010 was still two and a half times that of urban areas illustrated in Figure 2.9.

Large parts of the developing world have sanitation coverage of 50% or less in rural areas, including much of Sub-Saharan Africa and several populous countries in Southern Asia. The number of countries with less than 50% coverage in urban areas is much lowers (UNICEF/WHO, 2012).

Table 2.1 Proportion of the population using improved, shared or unimproved sanitation facilities or practicing open defection in countries where the rate of shared sanitation use is 25% or more (UNICEF/WHO, 2012).

Name of the Country	Improved Sanitation (%)	Shared Sanitation (%)	Unimproved Sanitation (%)	Open defecation (%)
Ghana	14	58	9	19
Bolivia	27	36	14	23
Congo	18	34	40	8
Gabon	33	34	32	1
Malawi	51	33	8	8
Nauru	65	31	4	0
Mongolia	51	28	9	12
Democratic Republic of the Congo	24	27	40	9
Kenya	32	27	27	14
Sierra Leone	13	27	32	28
Zimbabwe	40	27	6	27
Bhutan	44	26	26	4
Bangladesh	56	26	15	4
Liberia	18	25	12	45
Nigeria	31	25	22	22

2.1.3 Sanitation practice in Bangladesh

In Bangladesh, about 16% of 90 million rural population use sanitary latrines. In addition, another 22% use the so-called home-made pit latrines that are constructed by placing a squatting slab made of bamboo over a manually dug pit. Many consider this home-made pit latrine as not fully sanitary. People are now conscious of using latrine and about 61% of the total population has access to some form of latrine. Of about 30 million urban dwellers sanitation coverage is only about 42%. In urban areas range of on-site option such as septic tanks, single and double pit pour-flash latrines are used. Conventional sewerage systems are used only in parts of Dhaka and cover only 18% of the city's 8.5 million people (Ahmed and Rahman, 2003).

A study conducted on households having no latrines depicted interesting results of defecation practices by males, females and children in a rural community (LGED, 1989). The results shown in Table 2.2 indicate variation in defecation practices between males and females and between adults and children.

Table 2.2 Defecation practices by those who do not have a latrine

Places used for defecation	Males (%)	Females (%)	Children (%)
Landlord's latrine	2.6	2.6	1.5
Neighbour's latrine	14.4	27.2	2.6
Roadside drain	1.5	0.5	6.1
Open field	46.2	29.2	71.4
River, water bodies	12.3	12.8	8.7
Jungle	12.8	27.7	8.7
Public toilet	10.2	0	1

As indicated in Table 2.2, the % of children defecating in the open fields is found to be very high because children defecate more frequently than adults. Furthermore, some parents instruct them not to use a latrine either because the pit might be unsafe for the children or because the pit would be filled up too soon. Females more frequently use neighbors latrine (27.2%) and are much more accustomed to defecate in the jungle (27.7%) than their male counterparts (14.4% use neighbor's latrine and 12.8% defecate in the jungle). For children's defecation, public toilets are seldom used. There is a gender variation among the adults in using public toilets. Women do not use public toilets at all, while males do (10.2%), because of the lack of privacy.

People in general have very poor understanding about the relationship between health and sanitation. Rural sanitation suffers much from poor understanding of the health benefits of sanitary latrines. Latrines are used for reasons of convenience and privacy rather than health reasons. In slum areas, situation is deplorable. The sanitary condition of slums is miserable and inhuman. Most of the slum dwellers have literally no latrines, only a few have pit or hanging latrines. They often defecate in open fields, in the bushes, near the roads, in the drains or on the riversides. The problem is acute with female residents who have to wait till sunset for defecation or use a neighbour's latrine, if available.

The nationwide baseline survey, conducted in 2003 revealed that lack of money and lack of awareness are the prime reasons for not having a latrine. It was also found that some people (4%) prefer open defecation than using a latrine. Reasons for not having a latrine by the households according to the baseline survey 2003 are given in Table 2.3 (Ahmed and Jahan, 2008).

Table 2.3 Reasons reported for not having a latrine

Area/ Region	No. of households with no latrines	Reasons for not having a latrine %			
		Lack of money	Lack of awareness	Lack of space	Preference for open defecation
Rural	85,95,626	73	25	10	4
Urban	3,86,925	80	21	18	3
National	89,82,551	73	25	11	4

There is difference in defecation practices between male, females and children. There are some significant gender variations in defecation habits as well as there are variation between adult and children.

Latrine type and income

There is a relationship between latrine types and income. It was found that households with low annual income usually do not have any sanitary latrine, while households having high income often acquire sanitary latrines or few unsanitary latrines for use. The households of the lowest income group either have no latrine or only have unsanitary latrines.

Latrine type and education

There is a linear relationship between the level of education of the people and the type of latrines they use. It was observed that, there is an increase of use of sanitary latrines as they progress on the educational ladder.

Defecation practice of the households having no latrine

Defecation practice of adults and children vary according to social groups. The males and females of the households having no latrine usually use neighbor's latrines for defecation. They are also accustomed to defecate in the jungle. The children usually defecate in the open fields. The % of children defecating in the open fields is found very high because they defecate more frequently than the adults and some parents instruct them not to use a latrine since the pit will fill up to fast. For children's defecation, public toilets are seldom used. There is a gender variation among the adults in using public toilets. Women folks do not prefer to use public toilets mainly because of the lack of privacy.

Children's defecation practices

The children below 5 years in households either having a latrine or no latrine defecate in the open homestead compound. This is either due to the high altitude of the latrine door, or the squatting plate is so desired that it is difficult for children to squat comfortably. It is unrealistic to expect that children should use a fixed place for defecation, while their parents defecate indiscriminately. Many mothers do not feel the necessity to enforce strict rules on children's defecation practices, because they opine that children's faces do not produce offensive smell, and their feces are less harmful than those of adults. There is hardly any difference between households with a latrine and those without latrine in this respect. Children's feces are generally disposed of by washing in the water bodies and throwing in the jungle. Sometimes feces are also washed under tube-well or thrown in the yard.

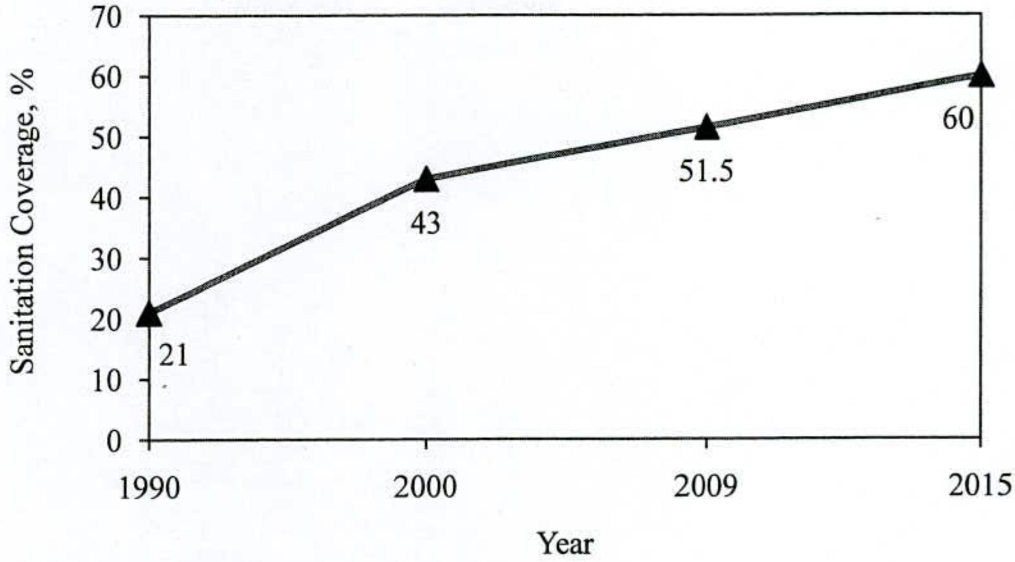


Figure 2.10 Trends in sanitation coverage 1990-2015 (BBS/UNICEF, 2010)

By Government standards some 51.5 percent of households in Bangladesh are using a hygienic sanitation facility. Within the divisions, Chittagong shows the best performance with 62% of households using a hygienic sanitation facility, while Sylhet has the worst performance with 43%. There is no marked variation between rural and urban locations when the Bangladesh standard is used. Household access to improved sanitation increases slightly to 54.1% when the JMP (Joint Monitoring Programme) definition is applied. In the slums only 8.5% of households are using an improved sanitation facility as per the JMP standard, as a result of the large proportion of households that share a toilet. When the Government standard is applied, this proportion rises to 12%. The MICS (Multiple Indicator Cluster Surveys) 2009 found that the proportion of households practicing open defecation fell from 7.5% in 2006 to 5.7% in 2009. Based on the current trend, the sanitation coverage will reach 61% in 2015 which would put Bangladesh on track to achieve its MDG target of 60%. However, the Government's goal of 100% sanitation coverage by 2013 will not be achieved on current trends shown in Figure 2.10 (BBS/UNICEF, 2010). Progress of sanitation in Bangladesh is being confined due to some problems which are described below (Ahmed and Rahman, 2003):

Housing density

Single pit latrines are suitable for use in rural areas and low density urban areas up to about 300 people per ha. It is difficult to be more precise in general terms, as local factors, such as average household size, housing design, plot layout and area, have large influence. At higher densities alternating twin pit latrines may be feasible, but other options such as small bore sewers, community latrines etc. may be more appropriate solution.

Water supply service level

In areas where water use is low (less than 30l/c/d) and where water has to be hand carried from public standpipes, tube-wells or communal wells, pit latrines are technically feasible sanitation option.

Operation and maintenance

In all latrines, cleanliness is of the utmost importance. Squatting slabs easily become fouled and pour flash bowls may block up. Fouled and unhygienic pit latrines are found all over the country, often because they have been constructed in communities previously accustomed to defecation on the open ground who have also had inadequate health education. Fouled pit latrines become a focus of diseases transmission and may create health hazard. Water seal, the essential part of the sanitary latrine often breaks down. Sometimes, other garbage thrown into the pan blocks the latrine. Often it is observe that necessary action has not taken by individual households when the pit fills up. Sometimes, the pits are very shallow and filled up too soon for households to get into the habit of using latrines. As a results, they prefer to go back to open defecation to avoid the inconvenience of frequent cleaning or change of pits.

Insect breeding

Pit latrines usually become breeding sites for sites for files. Files that visit a pit latrine to reed or feed carry pathogens and promote diseases transmission. If the pits are wet, these may also become breeding sites of mosquitoes.

Soil permeability

Soils with permeability below 2.5mm per hour (for clays) are unsuitable for pit latrines, as the liquid fraction of the excreta is unable to infiltrate into the soil.

Groundwater pollution

The deposition of excreta in pits may pollute water sources, particularly wells, tube-wells, ponds etc. located nearby. The danger of pollution increases if the pit is dug down to the water Table or to fissured or weathered rock. Bacteria will not penetrate more that 1-2 m in most unsaturated soil, but they have been known to travel about 10 m in common soil and over 100 m in gravel below the water Table and in rock fissures. In general, the bacterial contamination may spread as far as the distance travelled by the groundwater itself in ten days. Where it is necessary to avoid any risk of fecal contamination of groundwater, there should be at least 2 m of soil depth between bottom of the pit and the water Table surface. A shallow tube-well should not be sunk within 10 m of a pit latrine.

2.2 Concept of ecological sanitation (EcoSan)

Ecology is the scientific study of the relationships of living organisms with each other and with their natural environment. Topics of interest to ecologists include the composition, distribution, amount (biomass), number, and changing states of organisms within and among ecosystems. Ecosystems are composed of dynamically interacting parts including organisms, the communities they make up, and the non-living components of their environment. Ecosystem processes, such as primary production, pathogenesis, nutrient cycling, and various niche construction activities, regulate the flux of energy and matter through an environment. These processes are sustained by the biodiversity within them. Biodiversity refers to the varieties of species in ecosystems, the genetic variations they contain, and the processes that are functionally enriched by the diversity of ecological interactions.

Ecology is an interdisciplinary branch of biology. The word "ecology" was coined in 1866 by the German scientist Ernst Haeckel (1834–1919). Ancient Greek philosophers such as Hippocrates and Aristotle laid the foundations of ecology in their studies on natural history. Modern ecology transformed into a more rigorous science in the late 19th century. Evolutionary concepts on adaptation and natural selection became cornerstones of modern ecological theory. Ecology is not synonymous with environment, environmentalism, natural history, or environmental science. It is closely related to physiology, evolutionary biology, genetics, and ethology. An understanding of how biodiversity affects ecological function is an important focus area in ecological studies (Wikipedia-ecology).

In the broadest sense, sanitation deals not only with the collection, storage, treatment, disposal, reuse or recycling of human excreta (feces and urine), but also the drainage, disposal, recycling, and re-use of wastewater and storm water, and household, industrial, and hazardous solid waste.

The Joint Monitoring Programme (JMP) for Water Supply and Sanitation defines improved sanitation and unimproved sanitation in terms of the facilities for the disposal of human excreta. Improved sanitation includes a private flush or pour-flush toilet or latrine connected to a piped sewer system or septic system, a simple pit latrine with water seal, a ventilated improved pit (VIP) latrine or a composting toilet. Unimproved sanitation includes any other flush or pour-flush latrine, pit latrine without water seal, bucket latrines, a hanging latrine, any public or shared facility or open defecation.

"Sanitation" refers to the principles and practices relating to the collection, removal or disposal of human excreta, household wastewater and refuse as they impact on people and the environment. The main objective of a sanitation system is to protect and promote human health by providing a clean environment and breaking the cycle of disease. In order to be sustainable, a sanitation system has to be not only economically viable, socially acceptable and technically and institutionally appropriate, but should also protect the environment and the natural resources (SuSanA, 2008).

2.2.1 Definition of EcoSan

Ecological sanitation (EcoSan) is a concept that treats various types of waste generated by us as a resource which can be safely collected, treated and reused to prevent pollution of water bodies and the environment. Currently, various types of EcoSan practices such as promotion of EcoSan toilets, compost pits, bio-gas plants, reed-beds for treatment of waste water, etc., are being taken up to treat waste generated by us in a ecologically sound manner.

EcoSan is a holistic approach to sanitation and water management based on the systematic closure of local material flow-cycles. According to the EcoSan philosophy, sanitation problems could be solved more sustainably and efficiently if the resources contained in excreta and wastewater were recovered and used rather than discharged into the water bodies and the surrounding environment. The concept thus recognizes human excreta and water from households not as waste but as resources that can be recovered, treated where necessary and safely used again

EcoSan is based on three basic principles of preventing pollution rather than pollute and then undertake costly treatment options, sanitizing the urine and the feces for recycling and use safely the nutrients found in human excreta in agriculture and horticulture. The EcoSan concept is based on liquid separation system which recycles all the outputs in a hygienic manner through on-site sanitation that minimizes contamination risks. It produces three outputs, namely, feces, urine and anal wash water.

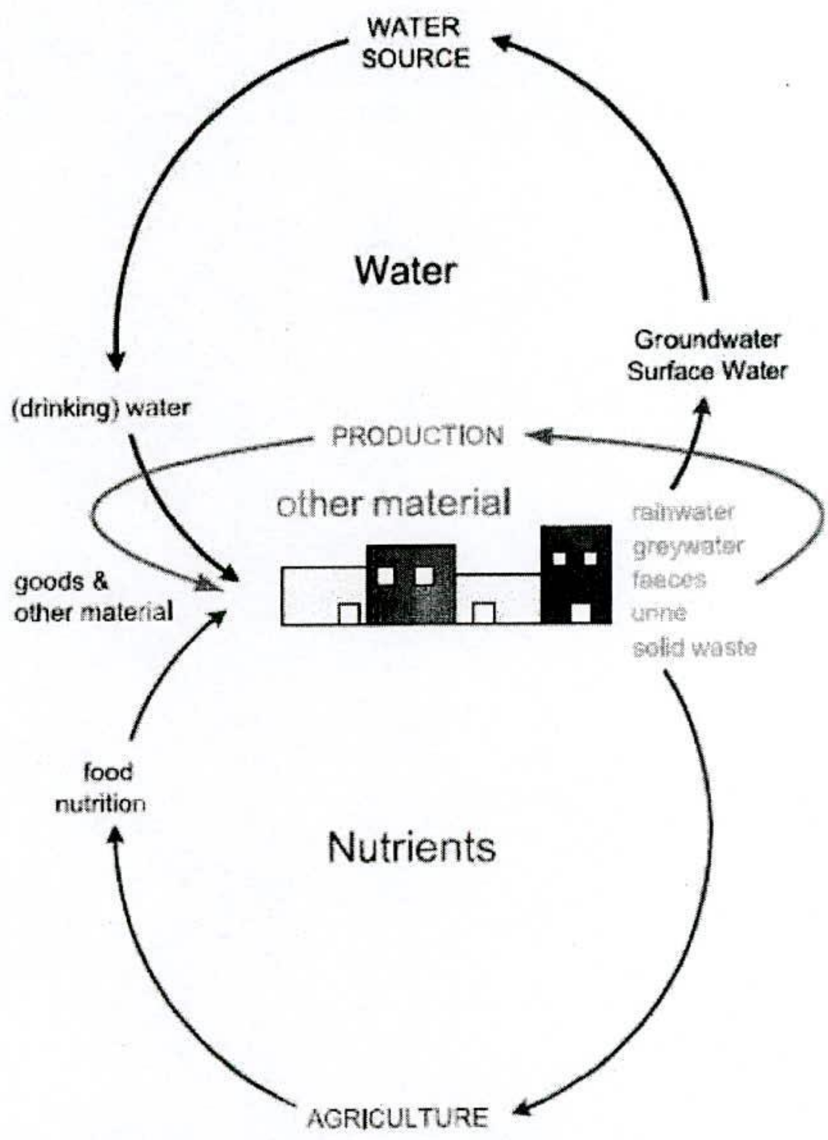


Figure 2.11 Resources-oriented or ecological sanitation system

Resources-oriented or ecological sanitation systems are an approach to avoid the disadvantages of conventional wastewater systems which are based on (drinking) water as transport medium for collection and transport of human excreta via a sewer system. In resources-oriented sanitation systems, human excreta and water from households are recognized as a resource which should be made available for re-use. These systems are based on the closure of material flow cycles and on collecting and treating the different wastewater flows separate to optimize the potential for reuse shown in Figure 2.11. When implementing resources-oriented sanitation systems single technologies are only means to an end and are not resources-oriented by itself but only in relation to implemented sanitation system. The applied technologies may range from natural wastewater treatment techniques to compost toilets, simple household installations to complex, mainly decentralized systems, but will include also low-cost sewerage and on-site sanitation systems (Langergraber and Müllegger, 2005).

2.2.2 Advantages of ecological sanitation

If this vision of ecological sanitation could be realized, then it would confer a great many advantages to the environment, households and families and to municipalities (Winblad and Simpson-Hébert, 2004). The advantages are focused below.

Advantages to the environment and agriculture

- If ecological sanitation could be adopted on a large scale, it would protect our groundwater from fecal contamination.
- Less water would be consumed.
- Farmers would require less expensive commercial fertilizer, much of which today washes out of the soil into water, thereby contributing to environmental degradation. EcoSan allows us to make the fertilizer of urine and feces that enrich the soil properties.
- Urine is rich in nitrogen that source of ammonia, main content of urea. Urine can be diluted with water and put directly in vegetable gardens and agricultural fields. Human feces can be turned into a valuable soil conditioner. With EcoSan, we can replenish the soil for agricultural use. Returning human urine and sanitized feces to soils on a regular basis has the potential to replenish soil nutrients to levels at which productivity will become sustainable.

- Recycling human excreta would reduce the greenhouse effect if practiced on a large scale as part of a comprehensive programme to increase the carbon content of soils. Returning sanitized human excreta to degraded lands would play a significant role in this process by increasing the amount of carbon in the soil, enhancing soil fertility, increasing plant growth and hence the amount of CO_2 fixed from the atmosphere through photosynthesis.

Advantages to households and neighborhoods

- No matter how unpleasant the immediate environment may be, individual households can improve their conditions considerably by adopting an EcoSan system. Many of the options available are relatively inexpensive and not difficult to build. Households can immediately have the privacy, convenience and aesthetic advantages of an odorless toilet, attached to or even built right into their homes, however small. This is of course particularly important for women. Groups of households with access only to public toilets and open defecation can improve their neighborhood dramatically.
- The health benefits of toilets are usually not an important selling point for consumer acceptance. However, some consumers may find it attractive to know that if a large area of their community can be made more sanitary, the likelihood of diarrhoea and worm infections will decrease, leading to overall better health and better study results for school children.
- The emptying of ordinary pit toilets and the sludge removal from septic tanks is messy, expensive and technically difficult. EcoSan systems based on dehydration or decomposition reduce the volume of material to be handled and transported and result in a dry, soil-like, completely inoffensive and easy-to-handle product. As the toilet is built completely above ground there is easy access to the sanitized feces for recycling and easier management of contents for pathogen destruction.
- A great problem of building toilets in some areas is the subsoil and groundwater conditions. In some areas the ground is too hard for digging. In other areas the water-Table is close to the surface. Both conditions prevent or make difficult the construction of pit toilets, VIP toilets or pour-flush toilets. As EcoSan toilets can be built entirely above ground, they allow construction anywhere a house can be

built, they do not collapse, they do not destabilize the foundations of nearby buildings and they do not pollute the groundwater.

- Jobs can be created for builders and for collectors of urine and sanitized feces. These products can be sold to farmers or households could use them to grow food. An entire mini-economy could potentially develop around EcoSan systems, especially in urban areas.

Advantages to municipalities

More than half the world's population lives in urban areas, a number projected to reach 5.1 billion by 2030; about 98% of the increase will occur in developing countries.

- Municipalities all over the world are experiencing greater and greater difficulty in supplying water to households and neighborhoods. In many cities water is rationed and supplied only a few hours a day. Wealthier households collect this water in large tanks while the poor queue up at public taps to receive their daily ration. EcoSan systems reduce the use of these scarce water resources and may result therefore in a more equitable allocation of water to rich and poor households.
- A major advantage of EcoSan systems is that they have the potential to increase sustainable sanitation coverage of the unserved more quickly than any other method. Municipal governments are under increasing pressure to provide sanitation coverage for the entire urban population. Even if there is political will, the options available are severely limited owing to lack of water and/or money (for flush-and discharge systems) and lack of space and/or difficult ground or groundwater conditions (for drop-and-store systems).
- Modifying these installations so that they do not contaminate the subsoil and groundwater requires capacity building that remains to be developed. The EcoSan options are in general affordable to the poor and have almost no recurrent costs for operation and maintenance. In most cases Eco-toilets require no excavation; do not depend on water and pipe networks; can be used even in congested areas; and, as the units have no odor when properly looked after, can be placed anywhere (even inside a house and on upper floors). EcoSan is an inexpensive and attractive alternative to expansion of sewerage systems.

Figure 2.12 A neighborhood with an ecological sanitation system.

Each household has its own dehydrating or composting toilet attached to the house. There is urine diversion and the processing chamber is solar heated. Municipal workers collect urine, primary processed feces and kitchen wastes and take them to the neighborhood's own eco-station (Winblad and Simpson-Hébert, 2004).

Finally, EcoSan systems allow, even favor, decentralized urban waste-to-resource management. The burden for guaranteeing a well functioning urban sanitation system is taken from the municipal government and transferred to the neighborhood level where citizens can monitor conditions and take direct action when necessary. The role of municipal government then becomes regulatory with the goal of safe guarding public health. Figure 2.12 is an example of a municipal with ecological sanitation system.

2.2.3 Ecological sanitation in Bangladesh perspective

Table 2.4 List of EcoSan toilets constructed in rural areas of Bangladesh

Division	District	No. of EcoSan	Working NGOs	Total
Dhaka	Dhaka	3	DSK	229
	Gazipur	107	PAB, BASA, JADE, SPACE	
	Manikganj	60	SPACE, JADE	
	Munshiganj	25	JADE, SPACE	
	Jamalpur	10	Water AID, DAM	
	Narayanganj	5	DSK	
	Narshingdi	18	PAB, BASA	
	Tangail	1	PAB, BASA	
Chittagong	Bandarban	89	Water Aid, PAB, CUB, Green Hill, SPACE	319
	Comilla	200	BARD, JADE	
	Chittagong	10	BASA	
	Rangamati	20	Water Aid, Green Hill, YPSA	
Khulna	Jessore	185	JADE, SPACE, IDO, AAN	246
	Satkhira	52	JADE, SPACE, NGF, RPEDS	
	Meherpur	9	SPACE	
Rajshahi	Chapainawabganj	48	PAB, SPACE	152
	Naogaon	57	JADE, SPACE, SKUS	
	Sirajganj	47	Oxfam, MMS	
Barishal	Bhola	2	CUB, DAM	107
	Barguna	100	Tdh	
	Noakhali	5	BASA	
Sylhet	Moulovibazar	12	PAB, BASA	52
	Sunamganj	40	PAB, BASA	
Rangpur	Rangpur	61	PAB, CC	217
	Gaibandha	87	Oxfam, PAB, SSUS, SPACE	
	Kurigram	69	Oxfam, CUB, SSUS, DAM, Tdh	
	Total	**1322**		**1322**

A summary of constructed EcoSan toilets was shown in Table 2.4. From the Table, it was found 1322 no. EcoSan toilets were constructed in rural areas of Bangladesh. Those toilets were implemented and funded by Government and non-government organizations as well as foreign agencies, involved in promoting EcoSan toilets in Bangladesh. EcoSan toilets had already been constructed in 26 districts of 7 divisions in Bangladesh. In those areas organic fertilizer was produced from the toilets and used as an alternative to chemical fertilizer with good management of human excreta. From the Table, it is observed that Comilla district and Chittagong division carries highest coverage of EcoSan toilets of 200 and 319 no., respectively. Lowest coverage with 1 toilet in Tangail district and 52 toilets in Sylhet divisions was found in the Table.

Table 2.5 EcoSan toilets distribution by implementing organizations

Implementing organization	EcoSan toilet Constructed
BARD	80
BASA	15
CUB-DAM	4
CUB-SPACE	20
DAM	5
DSK	8
Green Hill	19
JADE	78
JADE-BARD	114
JADE-SPACE	28
JADE-SPACE-AAN	20
JADE-SPACE-IDO	42
JADE-SPACE-NGF	26
JADE-SPACE-RPEDS	26
JADE-SPACE-SKUS	40
JADE-CBO	10
MMS	47
PAB-BASA	117
PAB-CC	61
PAB-SPACE	148
SPACE	185
SPACE-YPSA	6
SSUS	98
Tdh-Lausanne	120
WSP-WB-DAM	5
Total	**1322**

Table 2.5 presented a summary of EcoSan toilets that were implemented by national and international agencies in rural areas of Bangladesh. Some organizations acted as patron

supporting the local NGOs financially. Some organizations were found to implement the toilets directly. The highest number of EcoSan toilets implemented by contribution of single organization 'SPACE' was 185 while 148 numbers of toilets were constructed by joint contribution of PAB-SPACE.

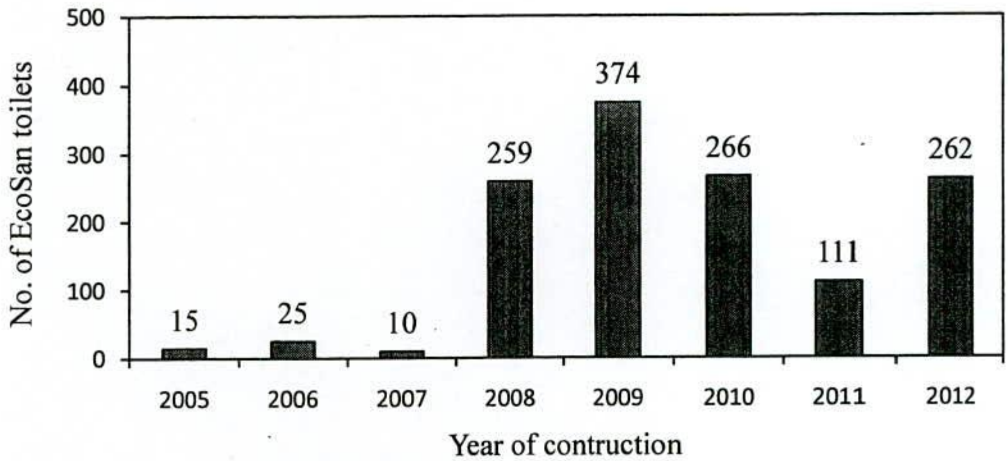


Figure 2.13 Progress of EcoSan toilets year by year

Progressive trend of EcoSan toilet was shown in Figure 2.13. From the Figure, it was observed that implementation of the toilets was started from 2005 and continued till 2012. So, it was understood that the number of EcoSan toilets were increased every year at different rate. Those toilets were implemented by many types of projects funded by foreign agencies.

Households remain steady in no. of 125 in the village of South Banshbaria from year 2009 to 2011. Census data on the prevalence of toilets in the area shows an improved % of household sanitation with the EcoSan toilets in Figure 2.14. Result of pre-survey showed 58 out of 125 no. of households (46.40%) had no fixed toilet for defecation and 56 out of 125 no. of households (44.80%) used pit toilets with 2 (1.60%) no. of EcoSan toilet. So it is concluded that sanitation facilities was very poor in 2009. Lack of awareness about good sanitation, superior health protection and well hygienic environment is main reason for this problem. In one word, they were unknown to ecological sanitation. In 2011, rate of open defecation has been significantly reduced from 46.40% to 12% with ecological concept through providing EcoSan toilets. After passing two years (in 2011), sanitation facilities have been improved than previous situation in 2009. Recently, 61 families (49%

of total families) are using EcoSan toilets when rate of using pit latrines and open defecation is 35% and 12% respectively. They are well known to use the toilet and its benefits. The toilet has achieved good response in the area and surrounding the village. Most of them have constructed the toilet very closed to their houses. They are well practiced to keep the toilet neat and clean. They are also capable to motivate others about the sanitation concept through benefit analysis of the toilets. However, the families who have no EcoSan toilets yet are not capable due to economic and land scarcity (Saha *et al.*, 2012).

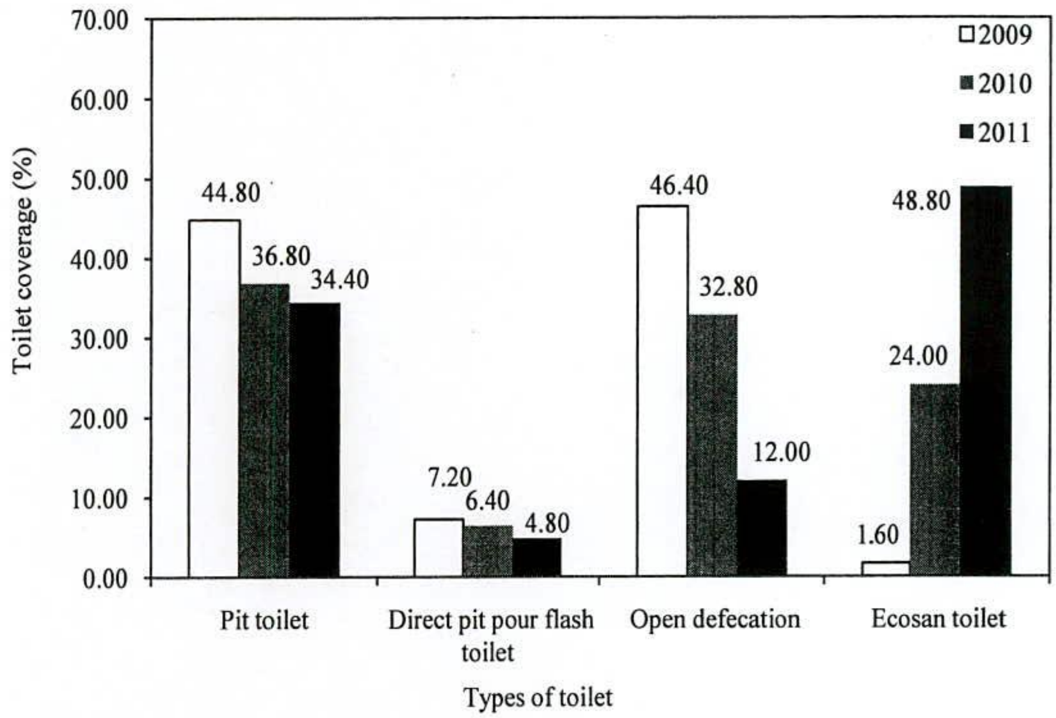


Figure 2.14 Improvement of household sanitation in South Banshbaria from 2009 to 2011

Figure 2.15 shows how the improvement in living environment by appropriate sanitation would relate with safe water supply, sustainable agriculture and poverty alleviation. Appropriate sanitation solution will resolve the vicious cycle of lack in sanitation and poverty. At aiming resource recycle, sanitation is improved through controlling of pathogenic bacteria relating with surface water quality conservation and human excreta utilization that makes agriculture sustainable through chemical fertilizer reduction and mitigation of soil deterioration. Accessibility to safe drinking water is improved based on water quality conservation for which diseases occurrence is reduced by medical cost reduction and income generation. Sustainability of agriculture reduces cost for fertilizer and maximizes the production. Reduction of the burden on the household finance is occurred through reducing expense of medical and fertilizer and increasing income source and agricultural products. Finally, poverty is alleviated through reduction of burden on household finance and malnutrition prevention health.

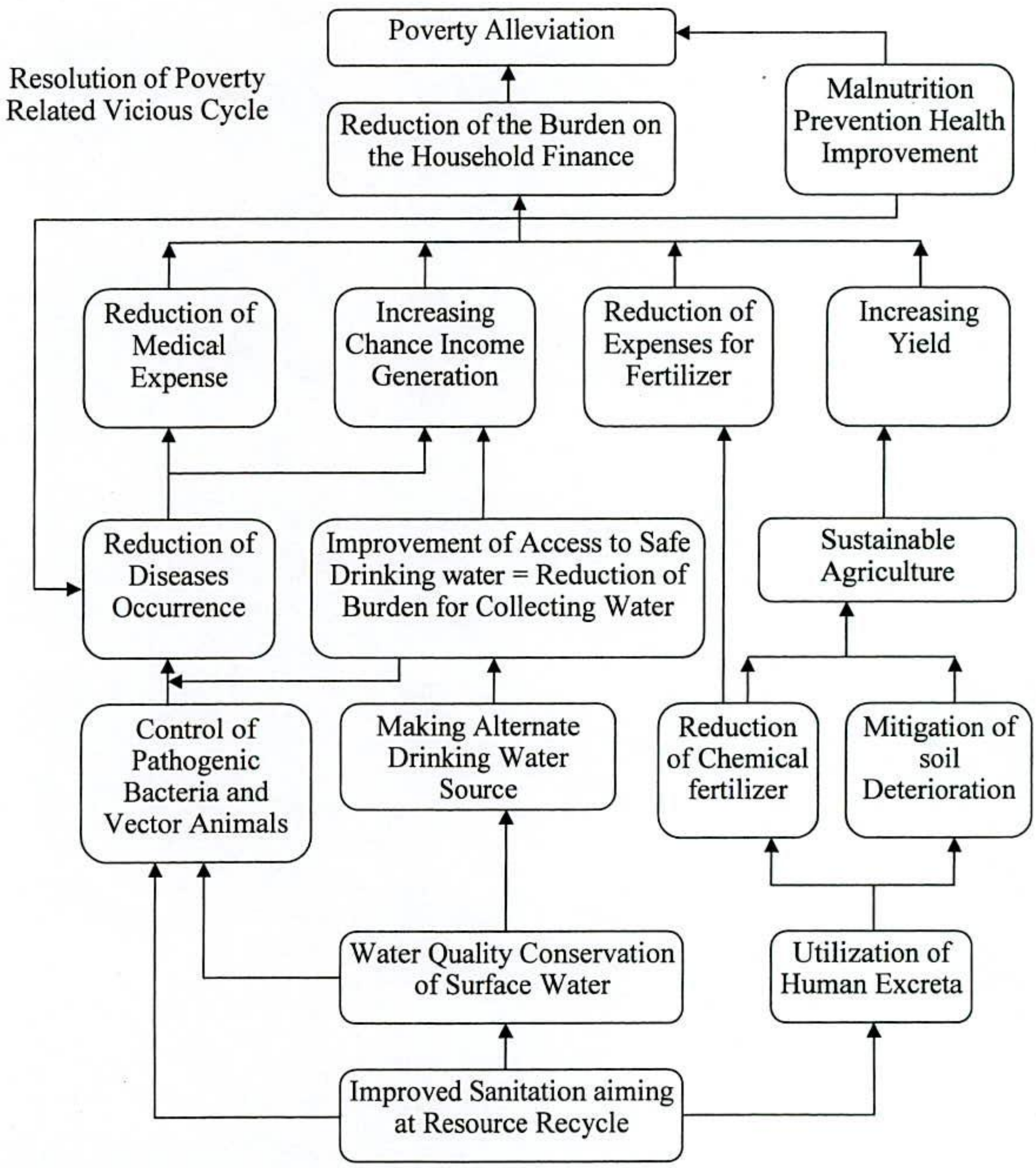


Figure 2.15 Flow diagram of relationship between living environment and improved sanitation (Sakai *et al.*, 2008)

2.2.4 Operation and maintenance of EcoSan toilets

Operation and maintenance (O&M) is the key for the sustainability after implementing any imaginative aim, project and establishment. According to this, it can be said that sanitation is an inventive plan and/or process which would be implemented through different types of project. So, O&M is most important for sanitation, basically in rural areas. Therefore, O&M of resources-oriented sanitation systems is one of the vital points of research. Monitoring of the implemented pilot projects plays an important role to obtain more information of the O&M on household level and involvement of the private sector. In practice, O&M of sanitation system receives less attention compared to the design and construction or is sometimes even completely neglected. Especially in developing countries, O&M of decentralized sanitation systems is discounted to a great extend. Neglected O&M and non-functioning systems have consequences towards such as damage of the environment and compromising people's health. However, there is lack of adequate information on O&M requirements and data on costs for different resources-oriented sanitation systems regarding collection, transport, treatment and utilization of the sanitized products (Bräustetter, 2007). Furthermore, there is no evidence of community based approaches of O&M being rolled out in a city (Sohail *et al.*, 2001). In the study of this research on O&M had been performed using similar methods including baseline studies, a two-day workshop on O&M research focusing on methods and research question and hypothesis development, and conducting on-site research using (semi-) structured interviews, focus group discussions which were important for the development of service chains, i.e. transportation, treatment and use of feces and/or urine produced from EcoSan toilets. Additionally, financial implications and the acceptance of reuse–oriented sanitation systems were investigated. In this circumstance, a field inspection was done to find out technical problems in O&M of their EcoSan toilets of last three years.

2.2.4.1 Definition of operation and maintenance

O&M refers to all activities needed to operate, maintain and manage a sanitation system, including the collection, transport, treatment and reuse and/or final disposal of the different sanitation products. Operation refers to the daily activities of running and handling infrastructure that involves the major operations required to use the service and correct handling of the facilities by users to ensure the long life of the service (Sohail *et al.* 2001). Maintenance on the other hand involves the activities required to sustain existing assets in a serviceable condition (WHO, 2000) and includes preventive, corrective and crisis maintenance (Brikké, 2000). Basic maintenance activities consist of the inspection of the technical and operational function.

Good toilets are based on good design and availability as much as they are on good management and maintenance (Greed, 2003, Gershernson and Penner, 2009). An effective and efficient O&M requires a clear organization and financial management with explicit responsibilities. Neglecting that can easily lead to dramatic results such as closing down of public toilets or the deterioration of treatment plants. Proper management of O&M needs further a budget to carry out the necessary tasks. However, municipality budgets often do not specify funds for O&M of sanitation systems (IRC, 1997). Funds are rather spent on activities which are more visible than on ones which are not recognized immediately. Thus it is recommended to allocate a separate budget for routine O&M including funds which allow major replacements, upgrading and extensions. This budget should to a large extend be generated from the users of municipal infrastructure services.

2.2.4.2 Necessity of operation and maintenance

A question, why operation and maintenance is important may be raised on O&M of EcoSan toilets. The answer to this question seems to be very simple: Without a well designed O&M strategy, the constructed infrastructure will sooner or later break down. But the identification of the reasons behind provide a wide range of answers and range from deficiency of training and awareness raising, a lack of skilled labor, high operating costs, excessive repair and replacement expenses, etc. Additionally, the technical options chosen are not always the best suited to the environment in which it shall be operated. Other reasons are closely related to donor financed projects, which often aim on construction of hardware, because it is simpler and less time consuming. They end after a certain period, leaving behind constructed infrastructure, but rarely a strategy for O&M of the systems. It is therefore obligatory that effective and efficient O&M of sanitation systems has to be seen in a holistic conceptual framework. The best way is to consider O&M already during the planning stage and not when it becomes apparent. Tasks and responsibilities have to be made abundantly clear and divided among the actors/stakeholders e.g. between the municipality, community based organizations (CBOs), users and the private sectors (Müllegger and Freiberger, 2010).

2.2.4.3 How to use EcoSan toilet

The EcoSan families were using the existing toilets according to sequential steps that are shown in Figure 2.15 and given below:

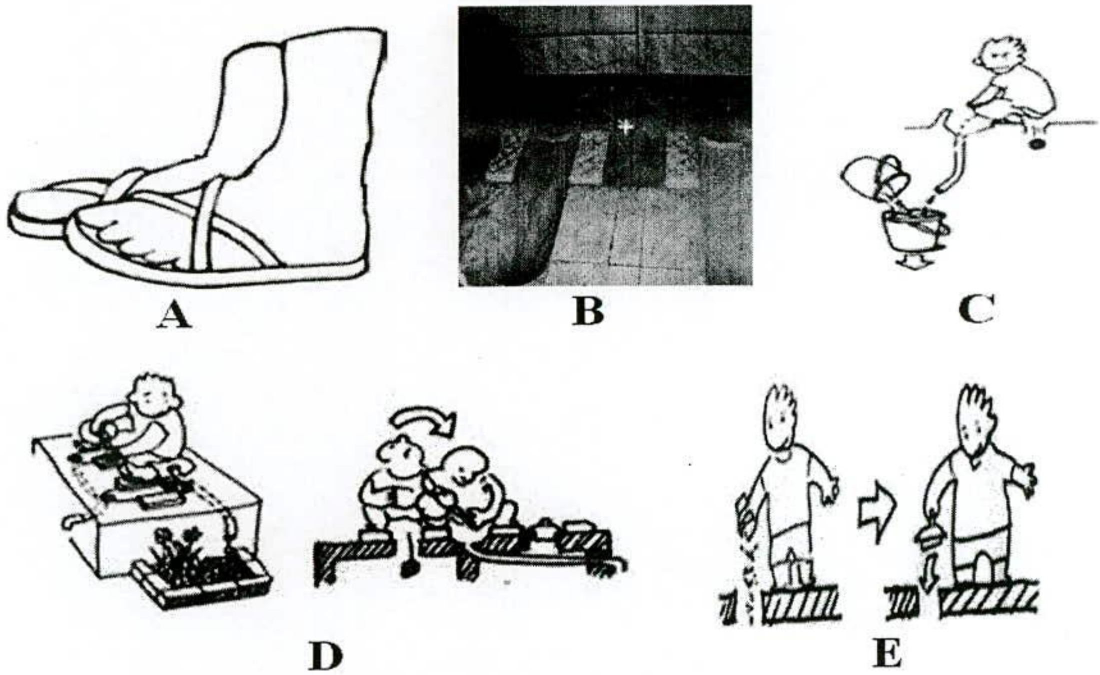


Figure 2.16 A view of activities to use EcoSan toilet (Takamura, 2011)

- At first, they entered into the toilet with sandal that were available at entrance of the toilet (Figure 2.16 - A).
- After entering into the toilet, they opened the cover of defecation hole and put it beside the hole (Figure 2.16 - B).
- Then they sat on the defecation hole easily and carefully so that feces directly fall in the vault and urine drops on the slope in front to be gathered in separated plastic container (Figure 2.16 - C).
- After defecation, they moved to anal washing place (middle of two defecation hole) (Figure 2.16 - D).
- Before leaving the toilet, they added ash over the feces and covered the hole (Figure 2.16 - E).
- After leaving the toilet, wash their hand properly with soap or other cleaning substances (detergent powder, ash etc).

Some precautions that have to be considered to use the EcoSan toilets are shown in Figure 2.17 and described below:

Users have to be attentive when they will enter into the toilet for defecation. The attentiveness is most important to use the toilet for children, aged person and relatives (who are unknown to EcoSan toilet) so that any disturbances are not occurred in the toilet. In the Figure 2.17, picture A, B and C shows the right way of using the toilet marked by circle and picture D, E and F shows the disturbances marked by cross that had been occurred. Picture A, B and C correspond to anal washing, urination and pouring water through anal washing pipe, respectively. Alternatively, picture D, E and F are symbolized for defecation at anal washing place, urination into defecation hole and pouring water into defecation hole, respectively. In the Figure 2.17, picture 1 and 2 indicate using left and right feces chamber of an EcoSan toilet, respectively at a time which is not a system of using the toilet. One chamber has to be used at single time and after filling first chamber, second chamber have to be used. So, it is recommended that users should mention and follow the steps for proper usage of EcoSan toilets. As a disturbance, if any of the following happens:

- Water goes into the feces chamber.
- Flies are found in the vault.
- Bad smell comes out the toilet.

Ash/sawdust has to be added into the chamber instantly. Ash will absorb the water, kill the flies/insects and make the toilet odorless for which ash is very important substance in maintenance of EcoSan toilet shown in Figure 2.18.

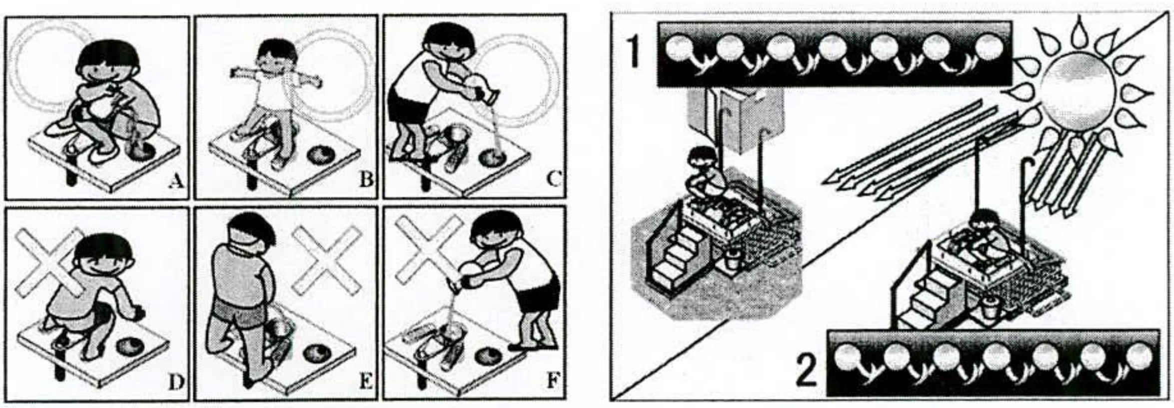


Figure 2.17 Precautions for using EcoSan toilet (Takamura, 2011)

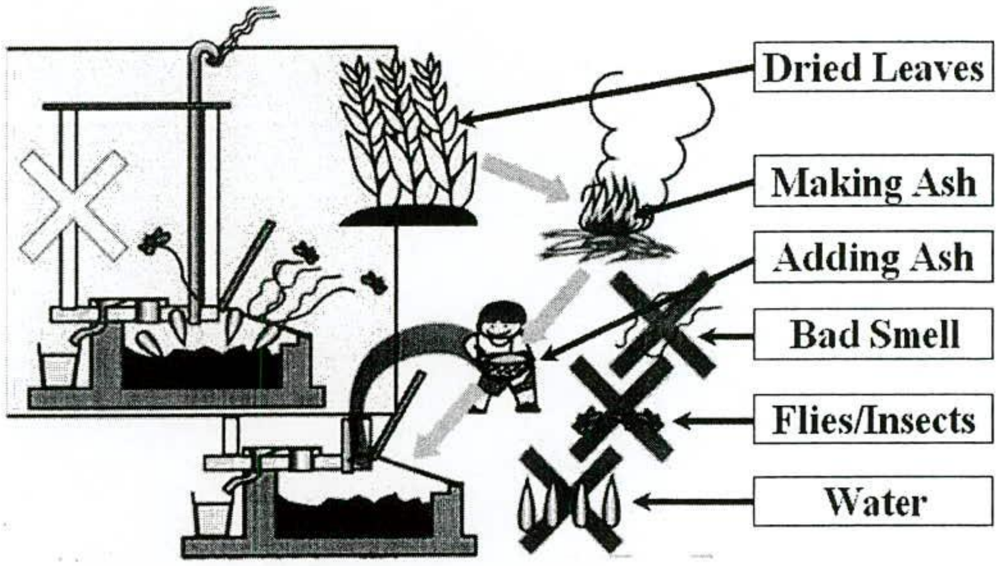


Figure 2.18 Positive contribution of ash in EcoSan toilet (Takamura, 2011)

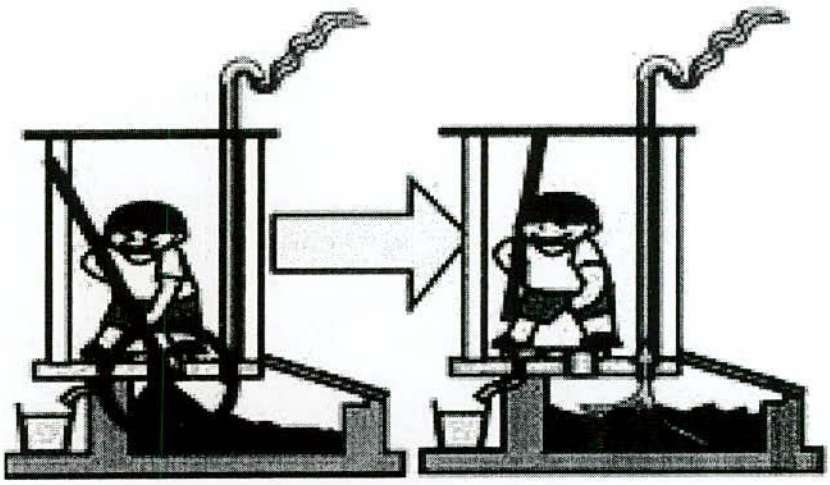


Figure 2.19 Spreading the feces into chamber (Takamura, 2011)

When the deposition of feces into the chamber gets a shape of pyramid, a piece of bamboo or branch of tree is needed to demolish the peak of the pyramid and spread the feces all over the place in the vault showing in Figure 2.19. It may be occurred once in a month. However, the stick should be heavy and kept at any corner inside the toilet for further usage in future. If the stick is not kept inside the toilet, pathogens will pollute the environment where the stick will be kept. So, users should be careful about this.

2.2.4.4 Urine and its application in farmland

Urine may be safely disposed of through infiltration, or preferably used as a fertilizer for crop production. Urine contains the majority of nutrients that are excreted from humans.

The concentration of nutrients in urine varies depending on diet, gender, and climate and water intake. Out of the total amounts excreted by humans, roughly 80% of nitrogen, 60% of potassium and 55% of phosphorus of is excreted with urine. The health related parts of the reuse guidelines for urine are based on storage time and temperature. Because of its high pH, stored urine should not be applied directly on green leafy plants surfaces. Rather, it should be:

- Mixed undiluted into soil before planting;
- Poured into shallow furrows and covered immediately (once or twice during the growing season); and
- Diluted several times and used frequently (twice weekly) poured around plants.

Roughly a square meter of cropland can be fertilized with one day's urine from 1 person (1 to 1.5L) (Stenstrom T.A. *et al.*, 2011). Urine, generally believed to be sterile, accumulates in the plastic containers where it also goes through some form of treatment. The pH changes that occur due to ammonia pressure kills off some bacteria making the urine relatively safe. When the 25 liter urine containers are full they are removed from the holding chambers, closed and stored for at least two months before being applied in the field.

Collection of urine

After urination, urine was collected into the plastic container or jar besides the EcoSan toilet. However, urine was gathered mixed with water into the container because people are habituated to use water after urination in perspective of Bangladesh. The urine was channeled by a network of pipes and stored into a container of which capacity was 25 L. Pipes from the toilet into the urine container should run along the walls of the toilet. Only 10cm of the link pipe into the urine container should be in the container to ensure that pipes are not dislodged when trying to remove the container.

Removing urine container and its transportation

Users should always check whether the urine container is full or not and this is done regularly by looking into the container. It has been shown that an average family of 6 people fills one 25 liter container per week, all losses considered. When the urine container is full, it must be removed from its seat. To remove the container, disconnect the link pipe from the toilet first. The lid of the container should be closed tightly. Then the container was carried to the field by lifting it vertically up to place on shoulders or van or bicycle. In the study area, normally men or boys carry the urine to the field. Carrying urine to the field is a job which can be shared by both males and females.

Storage of urine

Proper storage of collected urine is very important to minimize the loss of nutrients. Urine should be stored in a translucent dark container as opposed to a transparent container, and in a dark place. The urine containers should be stored in a cool place (e.g a shed or under a granary) until it is reused. The urine may be stored for a minimum of two months before it is applied to crops. During storage the following processes take place:

- Ammonia vaporization occurs which generate pressure and this helps to kill some pathogenic organisms.
- The pH of urine changes from acidity to alkalinity (pH of about 8 to 9). This also kills off pathogens.

Application of urine

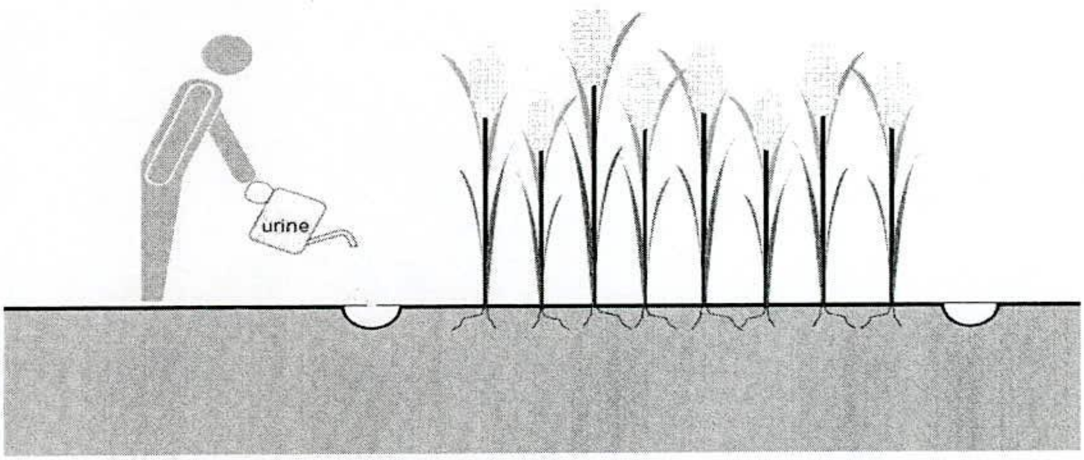


Figure 2.20 A general sketch of land application of urine (Stenstrom T.A. *et al.*, 2011)

Figure 2.20 represents a general view of application of urine in crop fields. Urine should be applied into the soils not on top and at a distance of at least 15cm from the plant. 50 ml dose of urine applied when the crop is 4 weeks old has been shown to cause plant growth and good yield. Urine is poured into a small container usually a graduated 5 liter plastic cup. It can also be poured in a 750ml bottle and then poured to the plant or crop. In study area, concentrated urine was applied to each crop getting mixed with water at urine and water ratio of 1:10. Water mixed urine (just after urination) was applied to each crop at urine and water ratio of 1:5. A hole is dug with a stick or hoe handle into the ground 5cm from the crop or seed. The hole should be at least 10cm and not more than 20cm deep. Urine should be poured into the hole and covered with soil immediately to minimize losses due to evaporation.

Hygiene issues that should be considered during field application of urine are outlined below:

- Remove the urine containers or temporarily disconnect the pipe leading into the urine container and pour some warm water through the urine chambers on a weekly basis, allow the water to run to waste or into a soak away.
- Any drops of urine or fecal matter that accidentally soil the seat should be wiped off immediately, otherwise this will discourage the next user from sitting on it.
- Male users should be encouraged to use the mono urinal usually situated on the side of the toilet.
- When cleaning the Urine diversion toilets avoid pouring water into the fecal and urine chambers.
- All cleaning water should be channeled into a soak away and always prevent pools of water near the toilet.
- Always have a hand washing facility near each EcoSan toilet if it's not constructed with the toilet.
- Users must wash their hands with soap after using the toilet.
- If water has been accidentally poured in the fecal chamber, pour ash-soil mixture enough to absorb the excess water.
- If the flies are found in the feces vault, ash will be added
- If bad odor comes out the chamber, dry ash is necessary to make dehydrated in the chamber for which toilet will be odorless.

2.2.4.5 Feces and its application in farmland

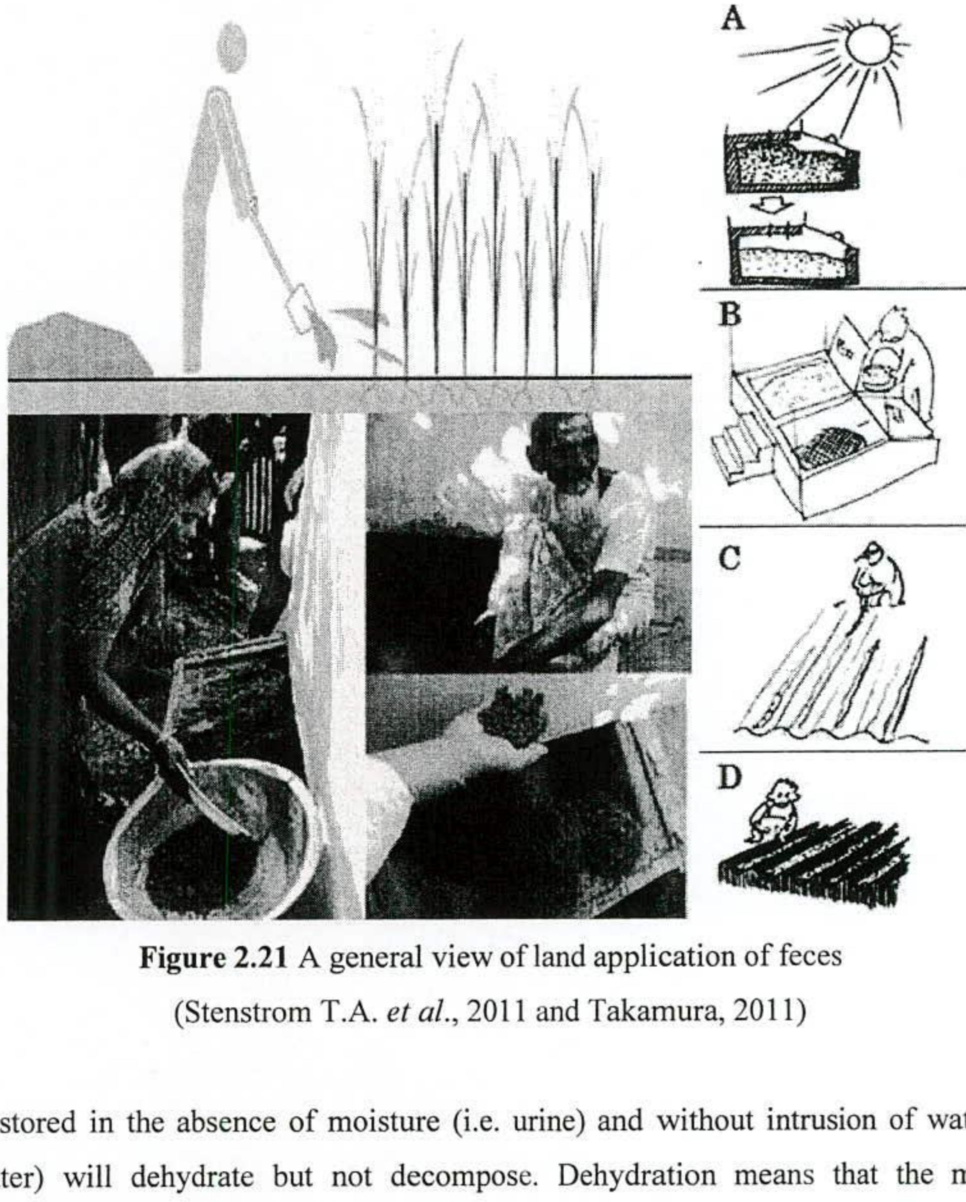


Figure 2.21 A general view of land application of feces (Stenstrom T.A. *et al.*, 2011 and Takamura, 2011)

Feces stored in the absence of moisture (i.e. urine) and without intrusion of water (i. e rainwater) will dehydrate but not decompose. Dehydration means that the moisture naturally present in the feces partly evaporates and/or is absorbed by the addition of a drying material (e.g. ash, sawdust, lime). After dehydration, feces have reduced in volume by about 75% and appear as a humus-like substance. The shells and carcasses of worms and insects that also dehydrate will remain in the dried feces. The dehydrated feces may be buried in pits, or incorporated into the soil on farms for crop production as a fertilizer and soil conditioner if pre-treatment requisites are adhered to. For agricultural application, the material should be worked into the soil before planting or sowing. The fecal matter goes through a primary treatment process in the vault. This primary treatment makes the fecal matter relatively safe and easy to use in agriculture. Absence of urine from the vault makes the fecal matter odorless. It is believed that odor in mixing toilets is caused by a bacteria, *Bacterium ureae*, found in urine. This bacteria feeds on fecal matter and odorous gases are some of its by-products. Ash has a great affinity for moisture; as soon as it comes in contact with feces. It quickly absorbs all the moisture in the feces making them completely dry. Ash has a direct bactericidal effect when it comes in contact with bacteria thereby immediately reducing the bacteria load in the fecal matter. The addition of ash changes the pH of the fecal matter from acidic to alkaline. Most common pathogenic bacteria are cannot grow in alkaline conditions. Infective and reproductive stages of bacteria require moisture. Removal of urine from feces retards growth and multiplication of bacteria including pathogens. Some bacteria form spores under hostile conditions to regenerate themselves later. Figure 2.21 shows the processing of fertilizer from human feces, removing feces from the chamber and land application. A, B, C and D are the symbol of such activities; drying feces in the vault by solar heat, removing feces from the vault, keeping feces on the yard to get dry and application of feces in form of organic fertilizer in agriculture field shown in Figure 2.21.

Collection and storage of feces

In the study area, volume of each vault was 0.47 m^3 which took about 12 months to be fulfilled if adult (able to defecate in the toilet) member was 4 nos. per family. Feces were removed from each vault when another vault was fulfilled. In this period, fecal matter has been kept in the vault with addition of enough wood ash or lime. In this case, feces were removed at 24 month intervals. During removing feces from the vault, a long handled shovel was used and feces were spread out on the yard in the sunlight for 7 days to make completely dry so that temperatures were raised to 50°C to kill off the spore forming bacterial now activated. After drying, feces were collected and stored into black poly plastic bags for field application. The manure can be put into the trenches or pits and covered with soil before planting seedlings. Further treatment and quantity enhancement can be achieved through composting can be enhanced through moisturizing. This process activates the flora and fauna essential for decomposition including spores.

2.2.4.6 Maintenance of EcoSan toilet

Management issues

- When a new EcoSan toilet is built at home the household head should gather all family members and explain how the toilet is used.
- A builder or health worker may also be invited to help the household head to explain the operations and functions of the toilet.
- The family should make an effort to appreciate and understand the Urine Diversion toilet and its link to ecological sanitation.
- Each family should collect all the ash that they produce throughout the week and sieve it to remove all the charcoal, charcoal is the main culprit in causing pipe blockages.
- Every household member should make an effort to leave all the feces and urine at their home not in the bush.
- The family should target to use the nutrients for production and every member should contribute.
- If there was a pit toilet at home this should be closed so that all the nutrients are captured for use in agriculture when the season comes.
- Visitors to the home where an EcoSan toilet is in place should be taught on how the toilet functions and its operation and maintenance.
- The family should make a commitment to use treated sanitized human excreta as manure and fertilizer for crop production.
- All household or family members should take turns in monitoring the hygiene of the toilet.
- Where ash is not available the household can make arrangements to go and collect it from boilers or brick molding ovens or simply use top soil or agricultural lime.
- All household members and visitors should be encouraged to use the urine diversion toilet to ensure that a maximum amount of urine and feces is harvested for use in crop and tree production.
- Children should be taught and supervised by the mother, father or elder brother or sister on how to use the EcoSan toilets.
- Children should sit on the pedestal and should not squat or stand on it.
- It should be mentioned that fecal matter should be directed into the bigger chamber and urine into the small container.

- Every user should make an effort to direct urine and feces to go where it should go.

Technical issues

- The ash should be mixed with soil at 1:3 so as to stabilize the ash and ensure that it does not produce a lot of dust.
- Soil is a good source of natural flora and fauna to initiate further bacterial action when the fecal matter goes through the composting process.
- Anal cleaning material should be put into the fecal channel as these have been responsible for many of the blockages.
- A bucket full of sieved ash and a pouring cup should always be available in the toilet.
- To cover the deposited fecal matter, sufficient ash should be sprinkled on top of the fecal matter after each visit to the toilet; care must be taken to make sure that ash does not sprinkle into the urine channel.
- Air vent pipe should be attached with feces chamber.
- Users should be careful to disallow water entering into the chamber through any leakage of heat panel and defecation hole.
- Urine and anal washing water passing pipes may be blocked with solid particles; charcoal, tissue paper etc. however, ash was found into the urine pipe network especially if enough care is not being taken when sprinkling them over the fresh feces.
- Urine itself causes blockages due to a salt compound that is formed as a result of the chemical reactions of the urine's mineral contents, a process called mineral calcification.

2.2.4.7 Checklist

Monitoring is the most important lesson for sustainability. For monitoring activity, a format is necessary to record the information. According to this, EcoSan toilets are one kind of hardware of which regular monitoring is most essential. Regular monitoring may be once or twice in a month, dependent on field situation. Practically, the monitoring work is included with activities of private sectors that follow a monitoring format named checklist. A checklist of EcoSan toilets is shown in Table-A in Annex-I.

2.2.4.8 Checking points

Monitoring of EcoSan toilets is not only task of private sectors or NGOs but also responsibility of the every user. Some items that have to be checked by user regularly are mentioned in Table-B in Annex-I.

2.2.4.9 Repairing parts and methods

Removing the blocks in pipe

If the pipe through which urine and anal washing water come out the toilet may be blocked by ash, deposition of salt, tissue paper etc. To remove the blocks, following methods are applicable:

- Urine blockages will always be formed, they can however be minimized by increasing the urine pipe diameter to as big as 38mm.
- Make pipe connections from the toilet to the urine container as short as possible.
- Take a 2mm diameter flexible wire and use it to remove the blockage. If you can't remove it, pour sodium hydroxide liquid that dissolves blockage due to calcification into a spongy or jelly like substance which can be pushed through using a prodding wire.
- Pour warm water through the urine pipe and urinal at least once in a week
- Make a narrow drain after removing pipes shown in Figure 2.22.

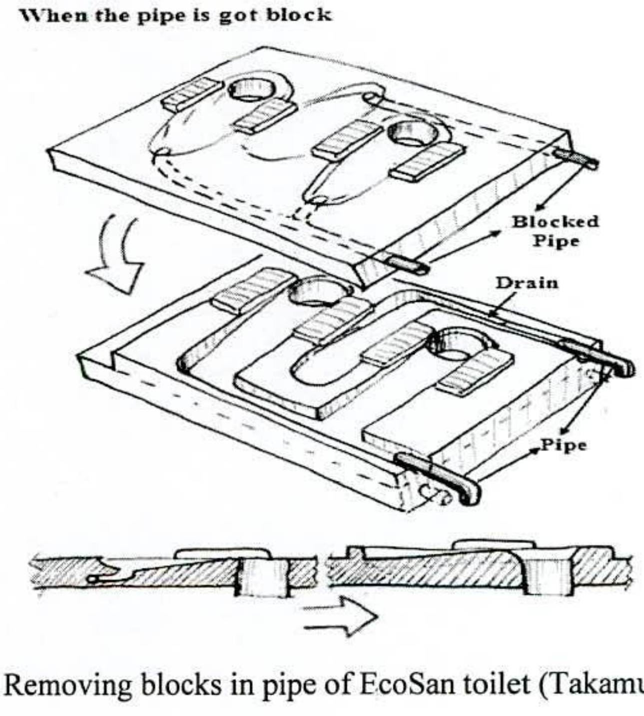


Figure 2.22 Removing blocks in pipe of EcoSan toilet (Takamura, 2011)

Repairing outer part of pipes

A part of pipes that is open outside the toilet may be broken accidentally by following ways:

- Beating on the pipe.
- Trying to bend the pipe.
- Cow may thrust on the pipe if cow is present at user home.
- Someone may cut it.
- Someone may stand on it to keep something on roof.

If the pipes may be broken, they may be repaired by different methods shown in Figure 2.23 and described below:

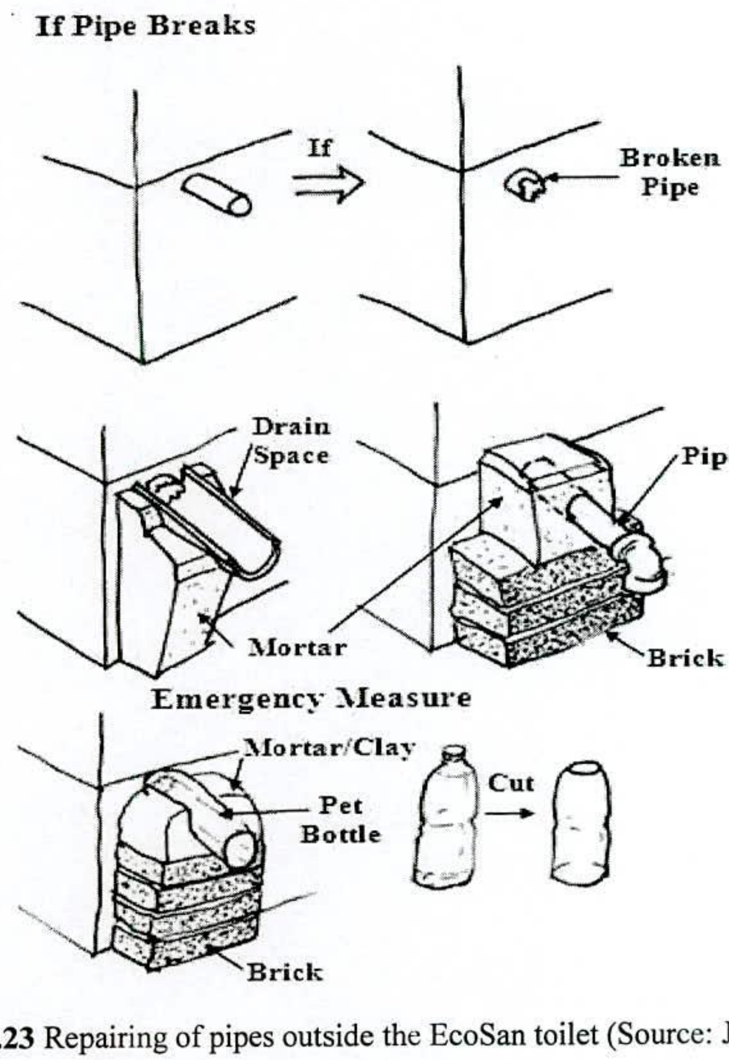


Figure 2.23 Repairing of pipes outside the EcoSan toilet (Source: JADE, 2011)

- Make a short drain joining with broken part by providing support of bricks.
- Adding a new piece of pipe with broken part and providing support of bricks.
- Cut a plastic bottle at both ends and add the bottle looking a piece of pipe. Provide a support of brick and mortar.

2.3 Ecological sanitation in rural areas

2.3.1 Planning

Typically in the past, planning for sanitation and water supply systems in rural areas and small towns took place at higher levels of government, at state, regional and municipal levels and decisions were communicated to the administrative levels below. However, in recent years there has been recognition that, when planning begins at the local level and moves upwards and when communities have more choice, there is a greater chance of achieving sustainable systems. This is because the systems are planned in accordance with local ecological conditions and local cultural practices.

Community management of rural and small town water supply systems is now common in many parts of the world. Water committees are formed at the start of new projects and they participate in the design of the new scheme. Experience shows that sustainability is more likely when users feel a sense of ownership of the systems because they selected the design, participated in construction and made key decisions along the way. The same principle can be applied to EcoSan systems. Local government authorities and local community groups should form partnerships to lead sanitation programs. Sanitation committees can be formed in communities to lead in the planning and implementation and to develop a sense of ownership and responsibility for community sanitation.

2.3.2 Promotion, education and training

A sure method for failure of a rural ecological sanitation program is to put it in place without the participation of the intended users and without proper instruction. Roll of participation is illustrated by the example: In 1992–94, in a project financed by IDB, the government of El Salvador built 50,263 LASF toilets. The total investment at that time was USD 12.5 million. The toilets were built by contractors without community participation and little or no community training. A sample survey of 6,380 families carried out in 1994 showed that 39% of the toilets were used adequately, 25% were used inadequately and 36% were not used at all. These findings led to the development of a hygiene education strategy that focused on personalized education for all family members through home visits, participation of organized women in the implementation of the whole educational process, education materials and user-friendly monitoring and evaluation. After the completion of the first education module, the % of proper use increased to 72%, and the toilets that were being used improperly or were not being used at all decreased to 18% and 10%, respectively. The lesson learnt from this whole process was that the problems of non-use or improper use are not as a result of the technology itself but because of the interaction between technology and user. Promotion should therefore be on a personal and family basis, in order to provide advice on the spot. The need for behavioral changes, proper use and maintenance should be stressed.

Roll of women

It is particularly important that women are included in the empowerment and promotion process right from the beginning. Women are the ones normally responsible for the household water supply, sanitation, and hygiene and food preparation. They generally also play a major role in the education of the children in regard to health and hygiene issues. Their views and concerns must be expressed and integrated into the program design as well as in detailed design decisions. Special effort should be made to assure that the toilet designs take into account women's special privacy and security requirements and are usually appropriate for women, men and children.

Roll of model families

Long-term success of EcoSan system will depend on the credibility with potential users. It must be shown to work and accepTable to respected local leaders and opinion makers for the system to be an integral part of local culture. A visit to a well-functioning EcoSan toilet in a neighbor's home is one of the best ways to convert nonbelievers.

Local grassroots organizations

It is generally best to work through local organizations that are successful and well known within the community. Such organizations might include community water committees or health committees.

Local government

In the long run, the support of local government will be essential for designing and installing the necessary infrastructure for supporting EcoSan systems on a meaningful scale. It can be well worth the investment to take community leaders on study tours to other communities and countries so that they can see for themselves and be convinced that EcoSan systems do work.

Pilot projects

The history of technology transfer has many examples of programs that went wrong when planners or politicians tried to go too fast without adequate attention to user participation and understanding. EcoSan is no exception. It is advisable to begin with experimental small-scale pilot projects through which different EcoSan devices may be assessed. During this phase the social aspects of the approach can be refined while demonstrating to a broader audience that the technology works. Broad dissemination requires in addition that hardware, if any, should be available in the market. In the pilot phase, regular follow-up at the household level is required.

2.3.3 Institutions

Institutional arrangements for sanitation vary from country to country. Health authorities are the responsible for rural sanitation. What seems to be universally true is that sanitation lags behind all other sectors in development and often gets the poorest budget and has the weakest strategy. EcoSan offers an opportunity to strengthen the sanitation sector in rural development by forming an alliance with rural agriculture, rural development and rural households. Rural EcoSan programs are much more focused around the household, and thus within one rural community households may choose different EcoSan systems for themselves depending upon their preferences. Households lacking spacing and wanting indoor toilets may choose double-vault desiccating toilets with urine diversion. Other households may want to stick with a pit latrine but collect their urine for fertilizer. Whatever the choice, the institutional arrangement should provide back-up and support for families in implementing their choices. At least one local institution should have a field agent capable of visiting households, speaking at schools and rural organizations, such as farmer's associations or women's clubs, and providing information and answering questions. There should also be arrangements for continuous monitoring and evaluation of the EcoSan systems in operation for safety and to record benefits.

2.3.4 Financial aspects

EcoSan systems need not be expensive to build because for dehydrating and composting types and the soil composting types:

- The entire device is built above ground – there is thus no need for digging and lining of pits.
- As urine is diverted and no water is used for flushing the volume of the processing chambers is small.
- The contents of the processing chambers are dry, which means that there is no need for expensive water-tight constructions.
- The pits are only 1.0–1.5 m deep since they need only hold excreta for about a year;
- The shallow pits are generally not lined and often only require a ring beam at the top;
- Special pans or seat-risers are not required.
- EcoSan systems are usually cheaper than flush toilet systems built to the same standards of quality.

Experience from rural sanitation programs around the world indicates that subsidies are often an impediment to progress in getting sanitation coverage. Either all households should be subsidized or none should be. Subsidies frequently indicate that households cannot afford to build the type of toilet that has been selected (without community involvement) by authorities from outside the community. Families should be able to select an option that they can afford. Costs can be influenced by the type of toilet system, choice of building materials, financing arrangements, as well as whether paid labor or self-help owner constructed.

2.3.5 Codes and regulations

Although rural areas of developing countries may have codes and regulations for sanitation from colonial times, they are rarely enforced. In many developing countries sanitation coverage is so poor that governments are still working on getting any hygiene improvements no matter how simple. Some countries may have regulations against the recycling of human excreta in agriculture (Winblad and Simpson-Hébert, 2004).

CHAPTER 3
METHODOLOGY

CHAPTER 3
METHODOLOGY

3.1 Research strategy

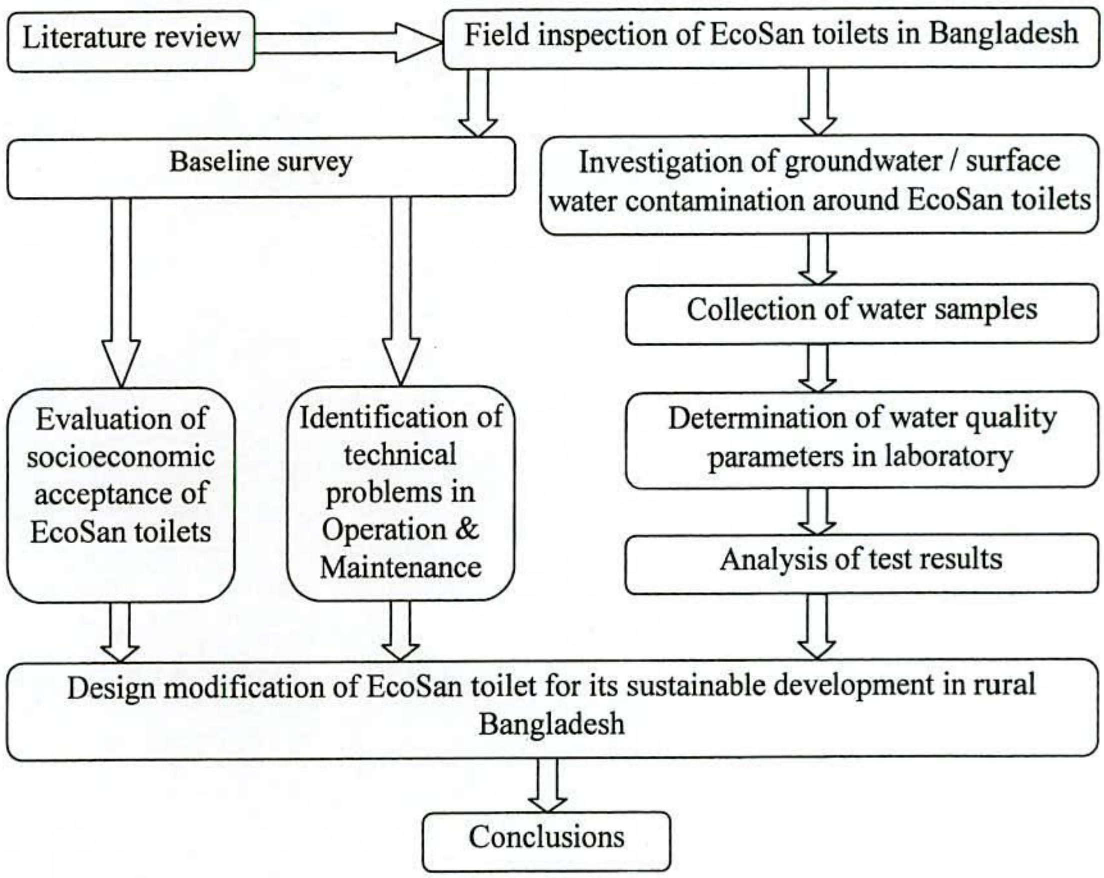


Figure 3.1 Flowchart showing the sequential steps in the research work

At the beginning of this study, a detailed field survey was carried out to imagine the level of performance and to assess the suitability of existing EcoSan toilets in rural areas of Bangladesh and further modification for the long-term sustainability. A baseline survey as a part of field inspection was conducted to evaluate the socioeconomic acceptance of EcoSan toilets and indentify the problems in its operation and maintenance in rural areas. As an another part of field inspection, investigation of groundwater and surface water sources such as shallow tube-wells and ponds surrounding existing EcoSan toilets was carried out to ensure the probable contamination by analyzing laboratory experiment results of water quality parameters. Finally, the existing design was modified to increase the socioeconomic acceptance and to make easy and comforTable in its operation and maintenance for sustainable development.

3.1.1 Field inspection of EcoSan toilets

A field survey was conducted in the study area named village of Banshbaria in Keshabpur upazila under Jessore district where 94 EcoSan toilets have already been installed (Figure 3.2). One questionnaire was prepared for the users of EcoSan toilets considering different information such as general socio-economic condition, operation and maintenance of EcoSan toilets, benefits of land application of urine and feces in EcoSan process, hygiene practice and aesthetic view of EcoSan toilets and recommendation on existing EcoSan toilets.

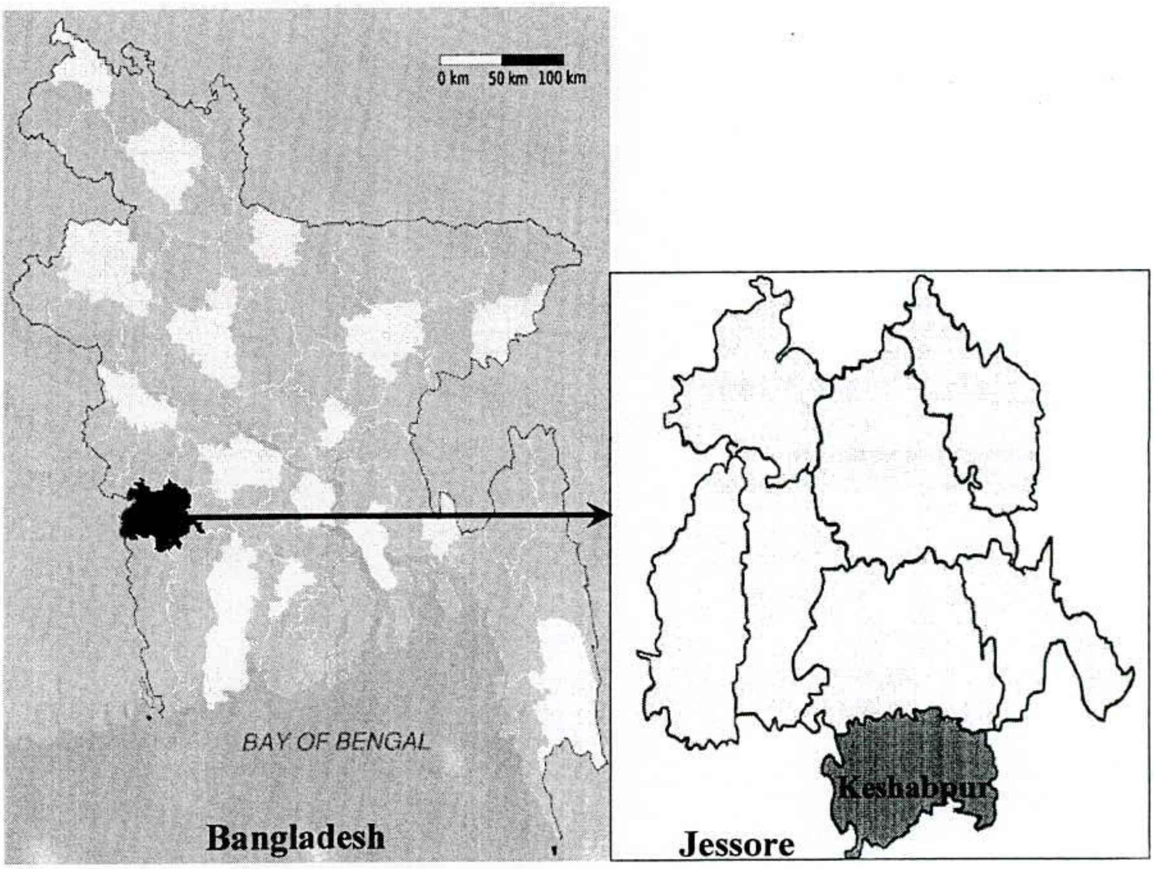


Figure 3.2 Location map of study area

A sample of 40 households who have EcoSan toilet in the village was selected. Household interviews were conducted in the households of the community. This was done with assistance of a guide from the study area to locate the household respondents' homes. In cases where the household head or landlord was not present, any adult in the household was interviewed. Data was collected using a structured questionnaire comprising both open-ended and close-ended questions. Questions from the questionnaire were read out to the respondent. The respondent's responses to the questions were then recorded in spaces provided in the questionnaire. For open ended questions, the respondent was at liberty to give multiple answers and also to bring to discussion other issues he/she thought are relevant to the questions. While close ended questions necessitated the respondents to rank, accept by indicating either yes or no answers. Each household interview took about 30 minutes, including an introduction of the study and the researcher, interview of the respondent, and visit to the toilet facility. The questions were prepared in English language but translated into Bengali language. However, some respondents were not willing to give information or be interviewed because they were busy at their work place while others were simply not interested because they have been interviewed several times by other researchers and that they have not seen any changes as a result. This necessitated a lot of convincing explanations by the interviewer to let those respondents accept to be interviewed.

3.1.1.1 Evaluation of socio-economic acceptance of EcoSan toilets

Socio-economic determinants like social values and structure, income and resource constraints and education play a dominant role. Human health related behavior is not only determined by a complex mix of their knowledge, beliefs, attitudes, norms, and customs. Without the resources to construct and maintain sanitation facilities, it is difficult to attain level of personal, domestic and environmental hygiene conductive to health. Resources relate not only to money, but also to the availability of land, time, material, and technical and management skills for achieving improved facilities. Hygiene behavior and the prevention of water and sanitation related diseases are influenced by socio-economic factors, such as proper housing, nutrition, clothing, education, and time.

To evaluate the social and economic benefits of EcoSan toilets is first objective of the study. Evaluation of socio-economic acceptance was done by questionnaire survey including personal information (name of toilet owner, father's/husband's name, sex, age, religion, level of education, occupation and no. of children), socio-economic information (monthly income, income source, having farmland or not, level of satisfaction using

EcoSan toilet, occurrence of flood, medical expense, loss in income due to illness, benefit of urine and feces). To capture the attention of agriculture stakeholders it is important to show that human excreta contain a substantial amount of plant nutrients. EcoSan toilet treats as resource recovery through converting human excreta (urine and feces) into organic fertilizer that is used as replacement of chemical fertilizer in the agricultural field. Urine is applied in vegetable and crop fields after dilution (mixed with water according to ratio). Urine is a source of ammonia gas that is raw material of urea, chemical fertilizer. The amount of nitrogen and phosphorous in human excreta can be calculated from protein consumption (Jönsson *et al.*, 2004).

3.1.1.2 Identification of problems in O & M

Identification of technical problems in existing EcoSan toilets is the second objective of this study. Through the questionnaire survey, technical problems in operation and maintenance of EcoSan toilets had been identified. Aesthetic view including surrounding environment of EcoSan toilet will be noted. Suitability of EcoSan toilets in rural areas will be found out depending on users' recommendation. In the context of the toilets, users are responsible for the development, construction, management, operation and maintenance of the buildings and structures, as well as the continuous monitoring of technical functions. Operation includes procedure of using the toilets; open the defecation hole by removing lid, adding wooden ash or saw dust into the vault to cover the feces, covering the hole, transferring to anal washing place being ensure not to use water at the same place of defecation. Maintenance means protection or repairing some essential parts of the structure for sustainable development. For operation and maintenance, practice of cleaning of the toilet acts an important task. The cleaning routine consists of: emptying the feces vault, cleaning the facilities (equipment, floors, walls, etc.), re-stocking hygienic articles (soap, toilet paper) and monitoring the functions of the equipments. Cleaning personnel have the task of cleaning the toilets after each use.

3.1.2 Investigation of ground/surface water contamination around EcoSan toilets

Investigation of any contamination of water resources around EcoSan toilets is the third objective of the research work. Some EcoSan toilets were built nearby ponds and shallow tube-wells for which it was needed to investigate the possible contamination of these water sources. A sampling was carried out from 30 water sources including 10 ponds and 20 shallow tube-wells nearby the toilets in two times; dry season and rainy season in a year. Samples of water were collected for laboratory test of physicochemical parameters (pH, SO_4^{2-}, PO_4^{3-}, NO_3^-, BOD_5, COD, DO) and microbiological parameters (Fecal coliform, E. coli and Total coliform). Laboratory analysis was conducted in Environmental Engineering Laboratory, KUET, Khulna.

3.1.2.1 Collection of water samples

Collection of water sample from any type of water sources is called water sampling that was occurred in the study area. According to research work, water samples were collected from existing surface water and groundwater sources; ponds and shallow tube-wells respectively surrounding EcoSan toilets. Water samples were collected in both dry and wet seasons ; first one was in February, 2012 and second was in July, 2012. Point of sources was selected randomly based on nearest distance between water source and toilet. For microbiological test, samples were collected in thio-bags which were stored in icebox to control the temperature (20°C) of water during sampling period. Sampling bottles were used for taking water for physicochemical analysis.

However, BOD bottles of 300ml were used only for sampling to analysis Five-Day Biochemical Oxygen Demand (BOD_5). To minimize sample degradation, samples were chilled without freezing at 4°C temperature. It is optimum to start the BOD_5 analysis immediately after sample collection to minimize changes in bacterial concentration. The maximum holding time of a sample to be analyzed for BOD is 24 hours. Each sample was collected into two BOD bottles; one for testing initial Dissolve Oxygen (DO_i) and another for testing final Dissolve Oxygen (DO_f) after 5 days. After collection, all samples were sent to Environmental Engineering Laboratory, KUET, Khulna.

3.1.2.2 Laboratory analyses of collected water samples

For the test of microbiological parameters, a medium (food for bacteria) that was made one day before water sample collection is essential. the food for bacteria was kept in refrigerator under controlled temperature. Main component of food was m FC Broth Base for fecal coliforms and XM-G Agar for E. coli and total coliforms. Water samples were kept in the icebox until the test was completed.

For the test of physicochemical parameters, samples were prepared by guidelines as per respective parameters. For phosphate analysis, samples were preserved by adjusting the pH to 2 or less with concentrated Sulfuric Acid (about 2 ml per liter) and storing at 4° C temperature. Before analysis, samples were warmed to room temperature and adjusted pH to 7 with 5.0N Sodium Hydroxide Standard Solution. Samples were stored by cooling to 4°C (39 °F) or lower and warmed to room temperature before analysis for sulfate analysis. For nitrate analysis, samples were preserved by adding concentrated Sulfuric Acid (about 2 ml per liter) and storing at 4° C temperature. Before analysis, samples were warmed to room temperature and adjusted pH to 7 with 5.0N Sodium Hydroxide Standard Solution. For the BOD_5 analysis, samples were allowed to warm to 20 ± 3°C before starting the test. It was mentioned that pH value of 6.5 to 7.5 was required for bacterial growth. Consequently, sulfuric acid or sodium hydroxide may need to be added to the dilution water to lower or raise the pH, respectively. For measuring chemical oxygen demand (COD), samples were preserved by acidification to pH ≤ 2 using concentrated Sulfuric Acid in room temperature.

Dehydrated FC Broth Base was suspended in proportioned purified water to make growth medium that was boiled in water bath and cooled at room temperature in Petri dish for cultivating and enumerating fecal coliforms indicated blue dye by the membrane filtration technique incubating at 44.50 ± 0.5 °C temperature for 24 ± 2 hours. Powder form of XM-G Agar was mixed well with distilled water in proper ratio to make the medium in Petri dish for screening test of E. coli and total coliforms that decomposes the substrate of X-GLUC to produce blue dye and MAGENTA-GAL to produce red dye, respectively incubating at 35-37 °C temperature for 20 ± 2 hours by the membrane filtration technique.

Dissolved oxygen concentration was measured by DO meter. The meter was calibrated by shaking tap water to make the water fully saturated. After standardization, probe was entered into sample water. Reading was taken after being stabilized. Sensor of probe was washed with distilled water after every experiment. The procedure was repeated two times; for initial DO and final DO after incubating at 20 °C temperature for five days to measure BOD. For the determination of COD, 2.50 ml sample water, 1.50 ml digestion solution and 3.50 ml sulfuric acid reagent were mixed into culture tubes of 16 x 100 mm by capping tube tightly which were heated in block digester to 150 °C temperature and refluxed for 2 hours. After cooling at room temperature and adding 0.05 to 0.10 ml ferroin indicator, titration was completed with 0.10M ferrous ammonium sulfate solution (FAS) changing color from blue-green to reddish brown.

After storing program number in spectrophotometer for the sulfate analysis, SulfaVer 4 Reagent Powder Pillow was added to 10 ml of sample water and dissolved indicating white turbidity due to presence of sulfate. After five minutes reaction time, calibration was done by blank sample and sample water was inserted to measure the value of sulfate concentration. For the nitrate analysis by spectrophotometer, NitraVer 5 Reagent Powder Pillow was added to 10 ml of sample water and dissolved. After five minutes reaction time, calibration was done by blank sample and sample water was inserted to measure the value of nitrate concentration. Phosphate analysis was same as sulfate and nitrate with difference in reagent and reaction time; PhosVer 3 and two minutes.

3.2 Analytical methods

Laboratory analysis for the concentration of sulfate, nitrate and phosphate in sample water was carried out by spectrophotometer **(DR/2500 Spectrophotometer/HACH/USA)** which allows the detection limits 2 to 70 mg/l, 0.30 to 30.0 mg/l and 0.06 to 3.50 mg/l, respectively. For the high concentration of these parameters in the analytical procedure, dilution factor was applied. Before determining the value of pH, the meter was calibrated with the standard solution of pH 4.0 and pH 7.0. However, sensor of the probe of pH meter (**Sensoin2/HACH/USA**) should keep saturated with distilled water for accuracy in result. DO meter (**HQ40d multi/HACH/USA**) was applied to determine dissolved oxygen (DO) concentration of water samples. The method was also used for determining biochemical oxygen demand (BOD) that is a difference between initial DO and DO after five days. Chemical oxygen demand (COD) was measured applying Closed Reflux Titrimetric method. For analysis of microbiological parameters; fecal coliforms, E. coli, total coliforms, Membrane Filtration (MF) method in which the sample is filtered and the filter is placed on a pad containing growth media was applied. After incubation of filtrated growth media, the filter is examined for the growth of the target organism.

3.3 Design modification of EcoSan toilet

Good toilets are not only based on good design but also ensure good management and maintenance practices. Although, EcoSan toilet is regarded as safe sanitation and thereby reduces the health risks, but its success is largely dependent on the ease of operation and maintenance by the rural population. The environmental condition, tradition and culture, socio-economic acceptance, etc. are the key factors to be considered in designing the region specific EcoSan toilets for its long-term sustainability. In this context, a modified EcoSan toilet was developed. Final recommendation was given for the sustainable EcoSan toilet in rural Bangladesh.

CHAPTER 4

FIELD INSPECTION OF ECOSAN TOILETS

CHAPTER 4

FIELD INSPECTION OF ECOSAN TOILETS

4.1 Background

Several organizations, including government and non-government agencies as well as some international agencies, are involved in promoting and increasing level of responsiveness on EcoSan technology and its benefits among professionals and policy makers. Despite positive development on this technology and its effective use, there remains a lot of work to be done before a real paradigm shift in sanitary provision can occur whereby people do not equate sanitation to merely access to toilets but rather to total and ecologically sound sanitation. In the study of local context, the performance of EcoSan toilets and its users on technical and financial aspects are documented. The population of Banshbaria was remaining under environmental pollution and health risks, caused of poor sanitation. This situation requires a new approach for sustainable Ecological Sanitation (EcoSan) that treats human excreta as a valuable source, protects the environment and conserves valuable drinking water. So, social acceptance of EcoSan toilets is vital to build a sustainable and comfortable technology. To gain information on social acceptance and economic aspects along with identifying problems in operation and maintenance of EcoSan toilets, a survey was carried out in Banshbaria, rural area of Bangladesh where EcoSan toilets had been installed. Objective of the survey work is to find out how do they use the EcoSan toilet, what do they like or dislike about the various aspects of using it, what do they think that could improve the EcoSan for future installation and how they would get benefit using the toilet.

4.2 Methodology

EcoSan families were surveyed based on household visits and focus group discussions which were used in addition to survey. Total no. of families was 425 in which 94 households (22%) were using the EcoSan toilet in the study area. For the research work, 40 out of 94 no. of EcoSan families were surveyed. EcoSan families were filtered based on some criterion such as those toilets of which maintenance was being run well had been used for minimum two years with good operation, users who feel some problems in operation and maintenance, toilets that are properly scattered among those families based on agriculture, users who had used both urine and feces as fertilizer in the agricultural field at least one time or more and understood its convenience, toilets were affected by flood etc. The families were asked according to a questionnaire including users' identity with their education level, occupation and income per month, satisfactory level on the toilets, and benefit analysis from the toilets during the survey. On an average, the family was made of approximately 5 persons with children. The smallest and highest no. of members per family was 3 and 10, respectively found in the study area. During the field inspection, the users were asked only how much money they spent when they had been suffering from diarrhea, dysentery, fever, skin diseases etc. before and after the installation of EcoSan toilets.

4.3 Results and discussion

4.3.1 Concept development on sanitation

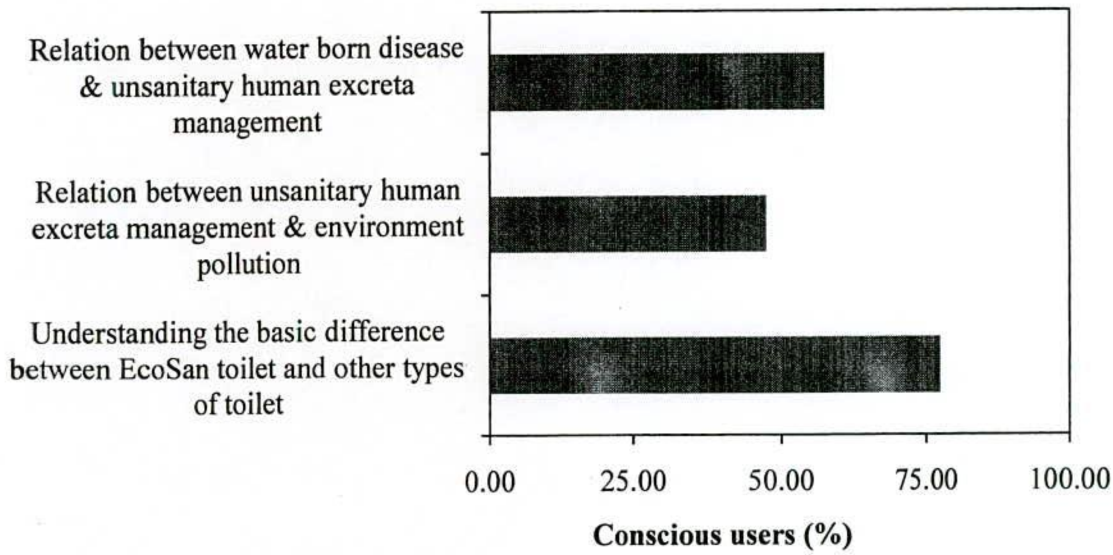


Figure 4.1 Awareness on ecological sanitation among the EcoSan users

Figure 4.1 represents the consciousness on ecological sanitation among the users who are already using the EcoSan toilets. Figure 4.1 focuses that the concept had been increased along with a period of using the toilet. Alternatively, EcoSan toilets increased consciousness on sanitation among the users accompanied with its usages because the toilet was built on the concept of ecological sanitation. But, sanitation concept had not only been increased based on behavior of using good toilet but also had been depended on literacy. So, education status of EcoSan families was found 38.97% in the study area.

During the field investigation, it was found that literate people were 76 out of 195 total members of surveyed EcoSan family. Each family had one to five educated members including student of primary school, high school and college. It was also found that only three members had already passed college. However, 5 out of 40 EcoSan families that had no educated person were identified. In the circumstances, the rate of literacy was not so good compared to the national average level of 51.8 %. As a result, the illiteracy was hampering the consciousness on their life style especially sanitation with hygiene practice and safe drinking water related to good health. Nevertheless, they were struggling with the poverty which badly affects the level of education. It was a way wherein children who went to school could learn important lessons/articles on sanitation practice and safe drinking water. It is truly said that there is a possibility to become wise on sanitation and hygiene behavior; what is the meaning of sanitation, why hygiene practice is necessary, how can be developed the practice, how does the good toilet improve their health, what are benefits of safe drinking water, why do they suffer from water born diseases etc. in school education. After learning these lessons, they can share these with their parents at home. Thus, the consciousness among family members may be developed on sanitation and safe water supply. But the possibility of this way is not so many due to fewer rate of literacy. On the other hand, many national and international organizations arranged so many workshops or training, advertisements, cultural programs etc. on sanitation and safe drinking water supply in the study area through which rural families learnt regarding to these points. More than one national and/or international NGO already trained the beneficiaries in this village arranging many workshops and/or training programs on sanitation, hygiene practices and safe drinking water having maximum illiteracy according to survey result. The Figure 4.1 illustrates that increased rate of consciousness among them after using the toilet for last three years and participating at so many workshops. Three key points were outlined below showing in the Figure 4.1.

- Understanding the basic difference between EcoSan toilet and other types of toilet was based on following tasks:
  - Management system of human excreta
  - Resource recovery
  - Replacement of open defecation
  - Suitability in using during water logged/flood period

- Relation between unsanitary human excreta management and environment pollution including contamination of soil, water and air through pit toilets and open defecation.
- Relation between waterborne disease and unsanitary human excreta management as well as polluted water badly affects the human health though diarrhea, dysentery, skin disease, etc.

4.3.2 Application of EcoSan fertilizer in agriculture

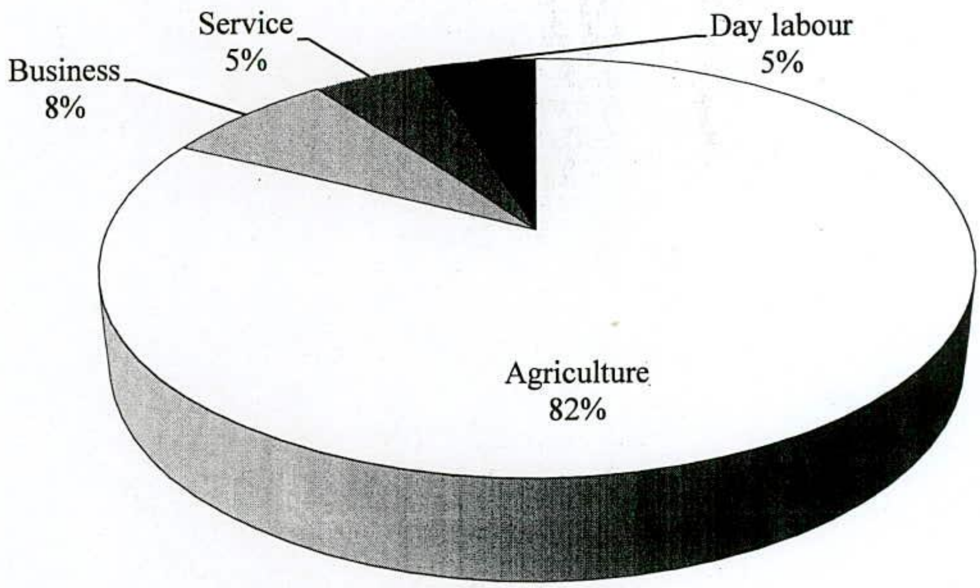


Figure 4.2 Occupational classification of EcoSan users

Figure 4.2 shows that users of EcoSan toilets had various occupations such as agriculture, business, service and day labor. More than 80% of the users were directly related to agriculture in occupation. Nevertheless, agriculture is the focal occupation of the toilet users. Except agriculture, three types of occupation were found among the EcoSan users of which 5% in services, 5% day labors and 8% in business activities. Due to illiteracy, they were not well occupied in services. In the field investigation, it was found that about 40% EcoSan families cultivate own farmland and 60% of them cultivate others' farmland though most respondents practiced agriculture as their primary occupation. About 44% of users had own agricultural land less than 100 decimals whereas minimum area of own land was 50 decimals. The remaining 56% percent were owner of greater than 100 decimals with maximum 200 decimals individually. According to land area, almost all of the EcoSan users can be categorized as small farmers. This study revealed that their main profession was agriculture in which EcoSan fertilizer was being used to produce different types of crops, vegetables and fruits. EcoSan fertilizer was originated form of human excreta. Urine and feces was one kind of organic fertilizer as a replacement of chemical fertilizer; urea and phosphate. The application of EcoSan fertilizer in agriculture was found to be highly acceptable in the rural community of the study area.

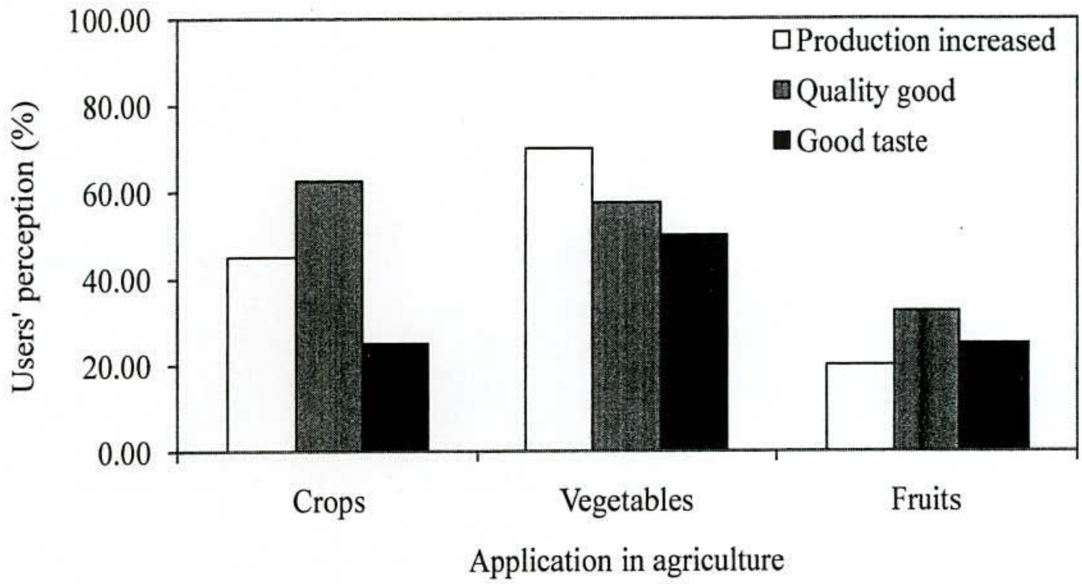


Figure **4.3** Users' perception on land application of urine

In EcoSan toilet, human excreta get changed into organic fertilizer, called EcoSan fertilizer. On the other hand, collected urine from EcoSan toilets are mixed with water at ratio around 1:5~10 (urine: water) and applied in the agricultural field as a substitute for urea. On an average, a container of 25 lit was fulfilled within one week if family member was 6. After getting fulfilled, the container was shifted to field of agriculture and urine was applied mixing with water. Sometimes urine was poured directly from the container into irrigation channel through which urine spread over the land with water. Again, urine was poured directly in rice or jute field where water gets deposited during monsoon period. Furthermore, urine was applied at fruit plants after making the soil loose. They applied urine at 15 days interval in same plants. As a result, they got more production, better quality, and better taste of fruits. The farmers understood the difference between urine and chemical fertilizer. After realizing the positive effects of urine application, they were satisfied with the EcoSan toilets. In Figure 4.3, effects of urine on different types of agriculture; crops, vegetables and fruits are shown. This result is qualitative measurement which was recorded as the level of users' perception. In case of vegetable, production rate was higher than other types of agriculture. Users recommended that they got more quantity than previous when they used only chemical fertilizer in same land. Now-a-days, they are using the EcoSan fertilizer with chemical fertilizer. In this circumstance, quantity of chemical fertilizer had been reduced at presence of EcoSan fertilizer. One criterion out of three, quality of crops, vegetables and fruits carried peak value. Quality means color of leaves and growth rate, observed by them was good. According to users' judgment, taste of rice, vegetables and fruits was good although rate of this perception was fewer than others.

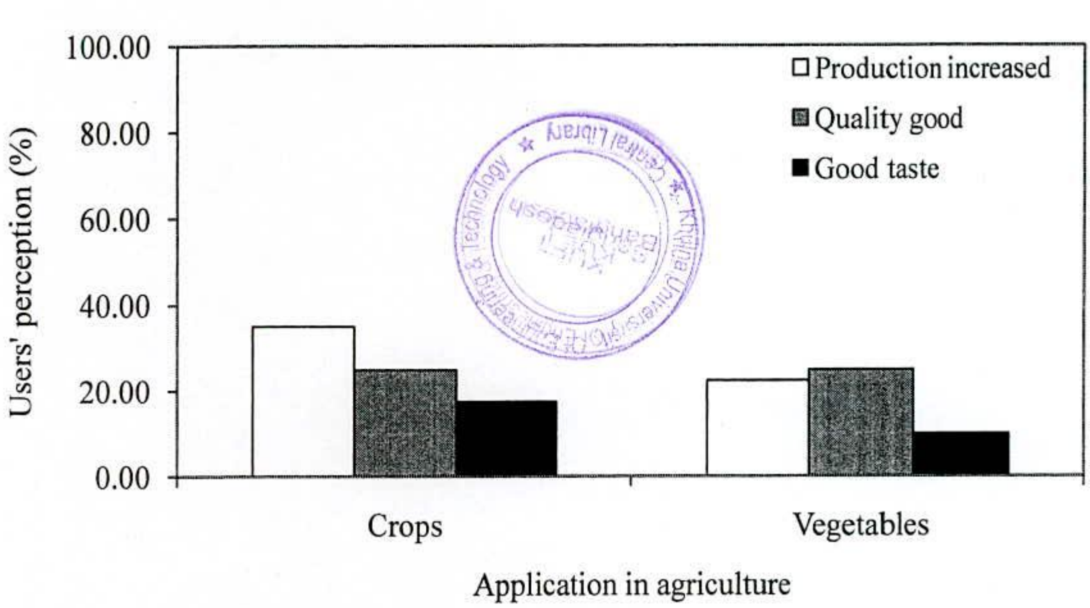


Figure **4.4** Users' perception on land application of feces

On the other hand, EcoSan feces-fertilizers were applied in the agricultural fields of crops and vegetables and the users were found to be moderately satisfied with the levels of production and its quality (Figure 4.4). The aesthetic and social views of the community people were found to be the major obstacles for using EcoSan feces-fertilizers in the agriculture. After a long detention time of approximately six months in EcoSan toilets, feces-ash fertilizers were removed from the storage chamber and dried in the sun. After drying, it was turned into powder form. Then the dried feces-fertilizers get stored in plastic bags for using in the agriculture. After making the soil loose, dried feces-fertilizers were spread over the land and thoroughly mixed with soil.

4.3.3 Financial benefits of EcoSan toilets

Human excreta contain various nutrients such as nitrogen, phosphorus and potassium which are valuable for agriculture. The contents of excreta composed of urine and feces are shown in Table 4.1.

Table 4.1 Nutrients in urine and feces (Harada, 2006)

Nutrients	Urine (500L/person/year) gm/person/day	Feces (50L/person/year) gm/person/day
Nitrogen	11.0	1.50
Phosphorus	1.0	0.50
Potassium	2.50	1.0
Pathogens	Little	Much

Based on the available data in Table 4.1, the following estimation indicates the amount of nutrients (kg) that are wasted from human excreta per person per year (Table 4.2 and Table 4.3).

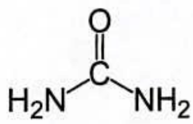
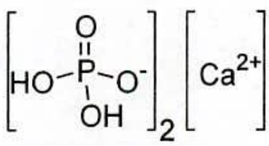
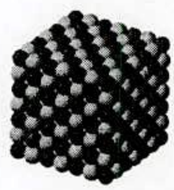
Table 4.2 Quantity of nutrients in urine

Nitrogen	Phosphorus	Potassium
$=11\frac{gm}{person*day}$	$=1\frac{gm}{person*day}$	$=2.5\frac{gm}{person*day}$
$=11*365\frac{gm}{person*year}$	$=1*365\frac{gm}{person*year}$	$=2.5*365\frac{gm}{person*year}$
$=4.015\frac{kg}{person*year}$	$=0.365\frac{kg}{person*year}$	$=0.913\frac{kg}{person*year}$

Table 4.3 Quantity of nutrients in feces

Nitrogen	Phosphorus	Potassium
$=1.50\dfrac{gm}{person*day}$	$=0.5\dfrac{gm}{person*day}$	$=1\dfrac{gm}{person*day}$
$=1.50*365\dfrac{gm}{person*year}$	$=0.5*365\dfrac{gm}{person*year}$	$=1*365\dfrac{gm}{person*year}$
$=0.55\dfrac{kg}{person*year}$	$=0.18\dfrac{kg}{person*year}$	$=0.365\dfrac{kg}{person*year}$

Table 4.4 Information on the commonly used fertilizers along with their nutrient contents

Name of Fertilizer	Structure of Chemical Bonding	Chemical Formula	Molar mass. (gm/mol)	Nutrient (%)
Urea		$CO(NH_2)_2$	60.06	$N=\dfrac{2*14}{60.06}*100=46.62$
Triple Super Phosphate		$Ca(H_2PO_4)_2$	234.05	$P=\dfrac{2*30.974}{234.05}*100=26.47$
Muriate of Potash		KCl	74.5513	$K=\dfrac{39.08}{74.5513}*100=52.42$

The financial profits through using EcoSan feces and urine fertilizers were estimated in Table 4.5 and 4.6 below:

Table 4.5 Equivalent profit of using EcoSan urine-fertilizer

Name of Nutrients	Quantity of nutrient produced by urine (kg/person/year)	Equivalent commercial fertilizer produced by urine (kg/person/year)			Market price of Urea/TSP /MP (BDT/kg)	Equivalent profit of fertilizer produced by urine (BDT/person/year)
		Urea (46.62 % N)	TSP (26.47 % P)	MP (52.42 % K)		
Nitrogen (N)	4.015	8.61	--	--	20.00	172.20
Phosphorus (P)	0.365	--	1.38	--	25.00	34.50
Potassium (K)	0.913	--	--	1.74	16.00	27.84
Total Profit (BDT)						234.54

Table 4.6 Equivalent profit of using EcoSan feces-fertilizer

Name of Nutrients	Quantity of Nutrient Produced by Feces (kg/person/year)	Equivalent Commercial Fertilizer Produced by Feces (kg/person/year)			Market price of Urea/TSP /MP (BDT/kg)	Equivalent Profit of fertilizer Produced by Feces (BDT/person/year)
		Urea (46.62 % N)	TSP (26.47 % P)	MP (52.42 % K)		
Nitrogen (N)	0.55	1.18	--	--	20.00	23.60
Phosphorus (P)	0.18	--	0.68	--	25.00	17.00
Potassium (K)	0.365	--	--	0.696	16.00	11.14
Total Profit (BDT)						51.74

Both urine and feces contain nitrogen, phosphorus and potassium but urine is rich in quantity for which urine is more effective than feces. Depending on the result, it is understood that both urine and feces act as a replacement of chemical fertilizer. According to this study, Table 4.5 and 4.6 represent the profit earned from the fertilizer in form of urine and feces, respectively. The profit is equivalent to chemical fertilizer that was calculated based on current market price of the fertilizer. The amount of equivalent fertilizer was estimated and finally equivalent price of fertilizer was determined in Table 4.5 and 4.6. This estimation suggests that a person can produce 9.79 kg urea, 2.06 kg TSP, and 2.436 kg MP fertilizer annually which is equivalent to BDT 286.28. For example, if an

EcoSan family is comprised of 5 persons, they could gain an estimated BDT 1431.4 annually through using faces and urine fertilizers for the agricultural production.

Alternatively, if the EcoSan toilet owner has no opportunity to use the fertilizer (EcoSan product), he can sell the fertilizer to a farmer at local market price and get profit. If the toilet owner does not sell the fertilizer, he will get profit which is replacement of chemical fertilizer. Thus, EcoSan was made a source of business. Nonetheless, EcoSan acts as an alternative of resource recovery. Tables 4.5 and 4.6 represent the way through which EcoSan users will be benefited financially.

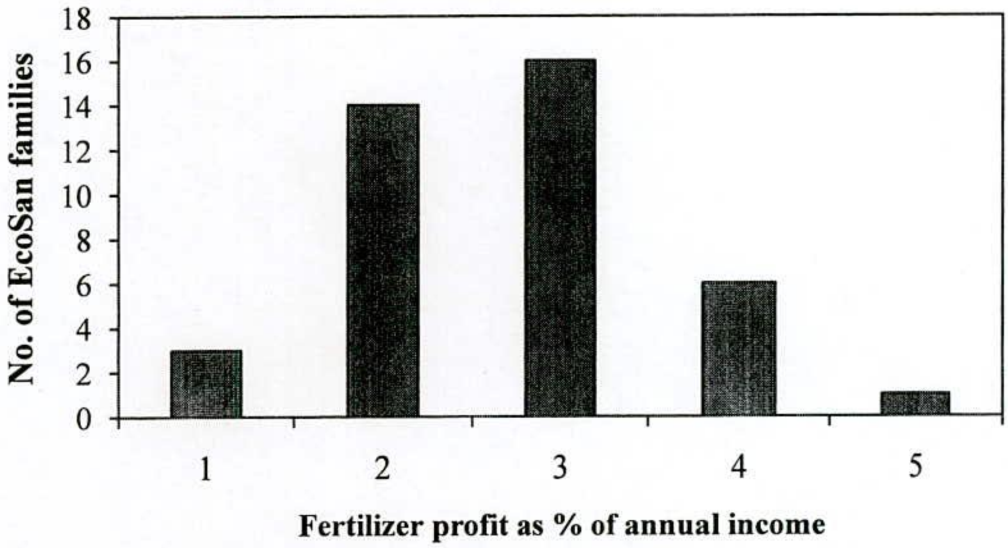


Figure 4.5 Percentage of fertilizer profit from EcoSan to annual income of EcoSan family

Baseline survey in the study area identified that the maximum and minimum incomes of the EcoSan families were around BDT 11000.00 and BDT 3000.00 per month, respectively. Average income was found approximately BDT 5712.50 per family per month. Participation of women in family income was seen completely absent. Women in each family were found to be involved with indoor activities only. On the other hand, an earning from EcoSan toilet alone was estimated BDT 286.28 per person annually according to local market price of equivalent chemical fertilizers. Figure 4.5 shows the percentage of fertilizer profit earned from EcoSan toilet to total annual income of EcoSan family. Annual income may be increased and/or decreased depending on family members because new earner may be joined in the family and/or sudden loss may be occurred in their income. It is mentioned that the village stands beside the river "Kobadak". So, maximum farmland areas, nearest the river remain under water for six to seven months in every year for which they were not able to grow the crops in the same field more than single time per year. In brief, agricultural business is being seriously hampered due to water logging situation.

Figure 4.6 presents a plan of sanitation business in rural areas through EcoSan toilets where organic fertilizer is produced. The Community Based Organization (CBO) was responsible for the business through marketing human excreta that was purchased from EcoSan toilet users and sold to poor farmer. According to this goal, the CBO encouraged the villagers to deposit money on regular basis in amount of BDT 20.00 per month which was recorded in cash book. Cash was then deposited in savings account in bank by CBO committee. The CBO collects loan from the bank account to purchase the excreta and/or compost from EcoSan households. Then the CBO sold the compost to farmers through which CBO got profit and pay back loans to the bank. Finally, farmers who have no EcoSan toilet were benefited using the fertilizer in the crop fields. Especially, feces of each chamber were sold at price of BDT 500.00 by the user who had no way to use it. In this case, the user got profit of feces and had no expense for cleaning the chamber i.e. benefited financially in two ways.

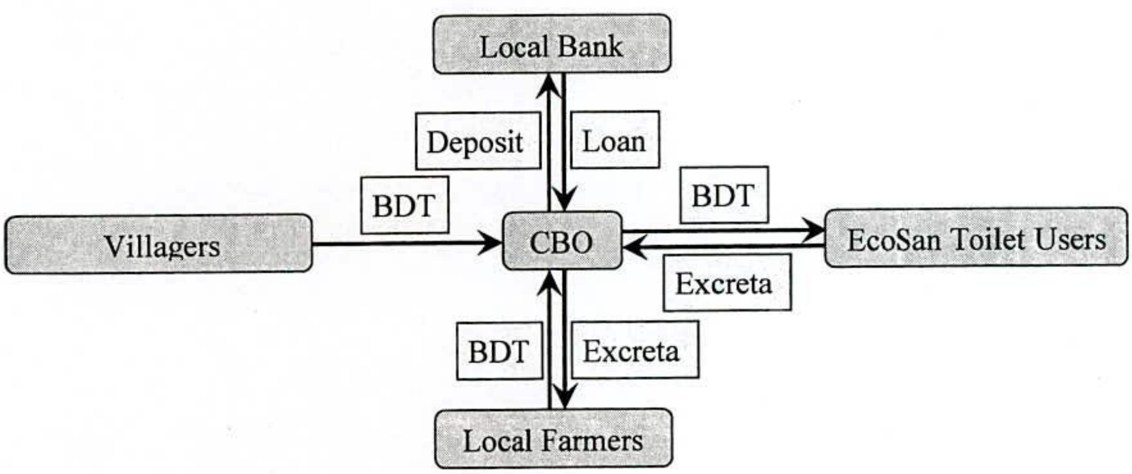


Figure 4.6 Diagram of the rural Sanitation as a Business

Figure 4.7 shows the statistical feature of EcoSan families who had been using the toilets for last three years in medical point of view. Maximum, minimum and mean value of medical expense, income loss and summation of these expenses both before and after installation of the toilets were shown in the Figure. From the Figure, it is understood that the medical expense was more before installing the toilets but the expense was reduced after installing the toilets. For the same reason, income loss was reduced after installing the toilets. In the Figure, it is observed that cumulative sum of medical expense and income loss due to illness was so much when the EcoSan toilet was absent in the family. But the Figure means that the toilets reduce this type of expenses. This improvement was possible due to increasing the no. of EcoSan toilets and concept of ecological sanitation among the users. Reducing income loss indicates positive attribute of the toilets. It is described that the medical cost including doctor's fees, medicine cost, pathological test etc. varied from BDT 1000.00 to BDT 2400.00 before installing the toilets and after installing the toilets, the cost varied from BDT 100.00 to BDT 1000.00 in EcoSan families. The average medical cost was BDT 1542.50 and BDT 552.50 before and after installing the toilets. On the other hand, mean value of income loss due to illness was BDT 680.00 and BDT 370.00. So it is understood that the EcoSan toilet reduced the medical expense and income loss i.e. the technology is positive to increase and save the profit in the family after installing EcoSan toilets.

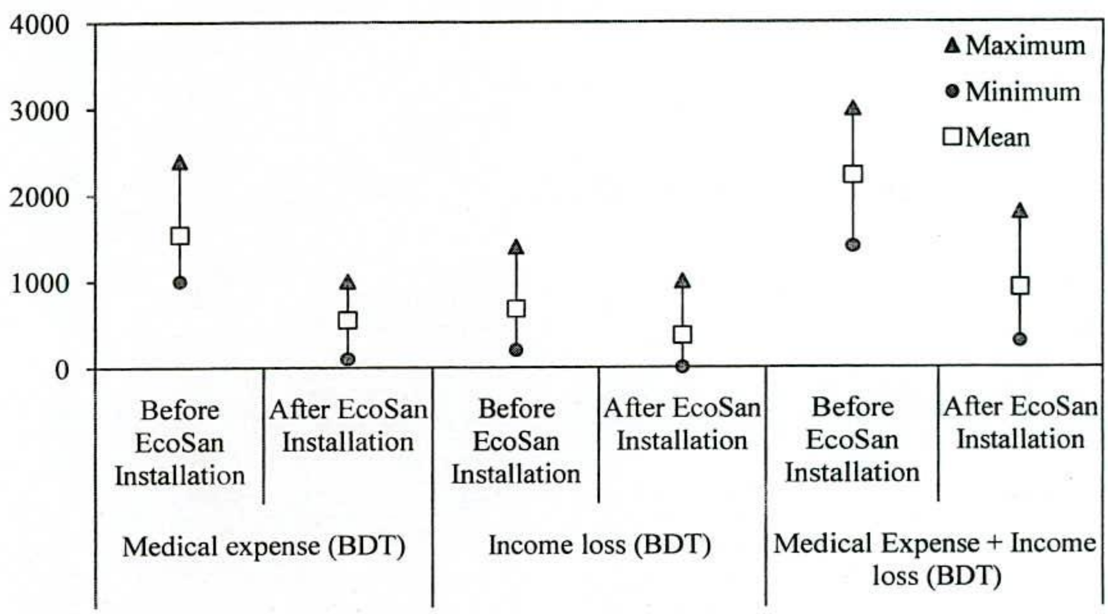


Figure 4.7 Variation on yearly expenses of EcoSan families before and after installation of toilet

Figure 4.8 focuses the percentage of medical expense to yearly income of EcoSan families before and after installing EcoSan toilets in the study area. In the Figure, X-axis denotes the percentage of medical expense to annual income with respect to no. of EcoSan families indicating in Y-axis. EcoSan toilets had been being installed since 2008 to 2010 through different projects implemented and supported by international organizations and foreign donation, respectively. No. of installed EcoSan toilets were depended on budget of the projects. Form he Figure, it is observed that medical cost of maximum families was 1.0% of annual income after installation of EcoSan toilets although medical cost varied from 0.50% to 2.50% of annual income. Alternatively, medical cost was limited from 1.50% to 4.00% of annual income but maximum cost was 2.50% of annual income before installing the toilets. After all, it is focused that the percentage was lowest after installing the toilets because EcoSan toilets replaced the pit toilets without water seal and open defecations through which human bodies were affected by microorganisms. From the result of this Figure, it is understood that medical expense was reduced from 2.50% to 1.0% of 13 families. However, another observation is that no. of families was increased from 13 to 17 with respect to range of 2.50% to 1.0%. The percentage was dependent on both medical expense and annual income. The percentage may be increased or decreased changing one parameter with respect to other parameter. According to this result, it was found that EcoSan toilet may increase no. of families within low range of medical cost.

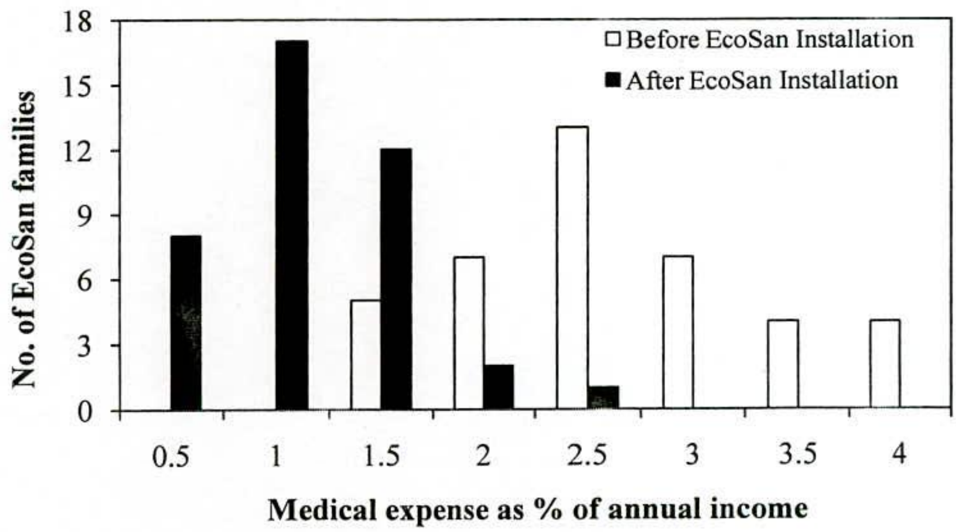


Figure 4.8 Distributions of percentage of medical expense to yearly income for EcoSan toilet users

During the field investigation, it was identified that the people were hampered financially due to their illness in two ways; medical expense and income loss for absent in daily work. Figure 4.9 shows the comparative analysis on total diseases relating costs (medical expense plus income loss due to illness) of EcoSan families with respect to their monthly income before and after installation of the toilets. Medical expenses of poor families were found high when they had no EcoSan toilets and after installing the toilets, the cost became less. This Figure shows the possibility that EcoSan toilets alleviated the burden of medical expenses on poor families.

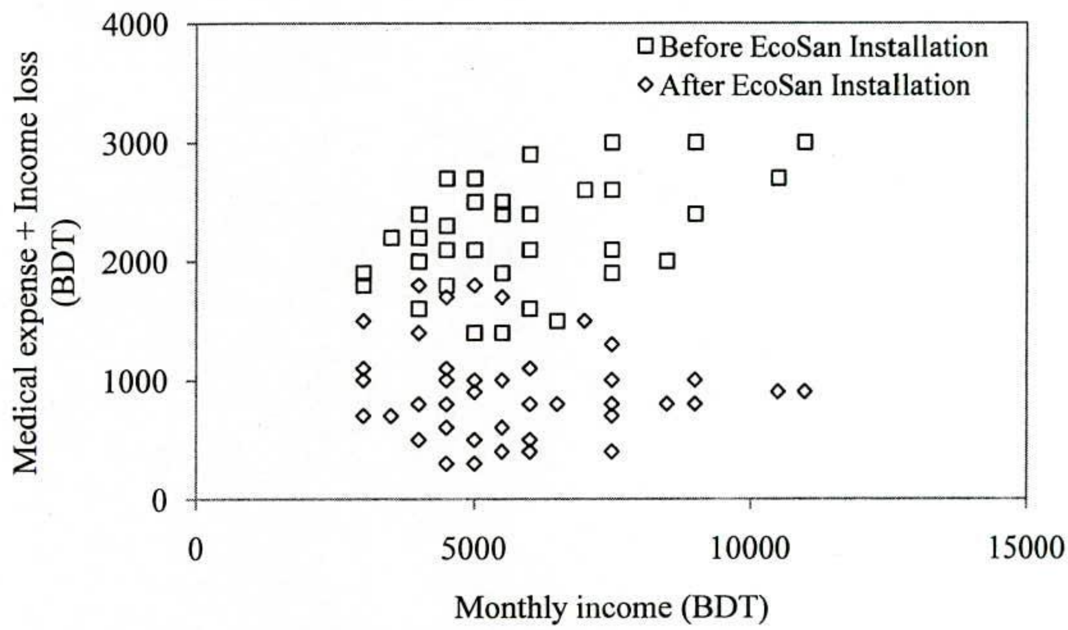


Figure 4.9 Relationship between monthly income and total diseases relating cost of users before and after installation of EcoSan toilet

It is known to all that unhygienic sanitation is the source for different types of diseases which roughly affect the human health through contamination of pathogenic organisms. For this reason, everybody should be well practiced with hygiene behaviors including washing vegetables with safe water before cooking, brushing teeth, covering food after cooking and drinking water vessel, washing hand before meal and after defecation in every time that were found among the users of EcoSan toilets during the field investigation (Figure 4.10). It was observed that EcoSan families were well-practiced (above 65%) with hygiene behaviors. They were known to cover the meal and drinking water vessels, washing hands with soap before meal and after defecation, use poTable water in washing vegetables, keep the teeth clean through brushing regularly. The fluctuation of those behaviors was occurred due to raising awareness among the users varied because perception of the concept on ecological sanitation to them was not equal. The hygiene practices were developed by raising awareness among them for ensuring the usages of the toilets. It was found from the observation that users were accepting the practices in conjunction with the EcoSan toilets because they were trying to feel their weakness in sanitation practice on which their physical stability was depended.

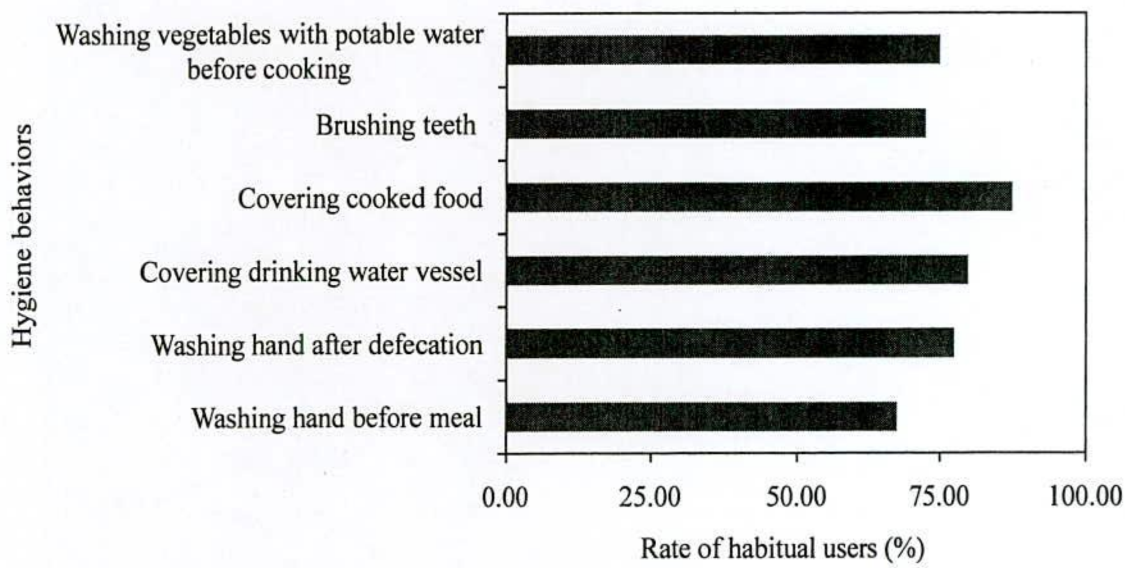


Figure 4.10 Hygiene practice of EcoSan families in the study area

4.3.4 Performance of EcoSan toilet in water logged condition

EcoSan toilet is a structure which was built completely on the ground level. It has two portions, one is lower portion called Feces chamber and another is upper portion called defecation place. Feces chamber is the most important part of the structure. During construction period, the chamber is made water proof carefully so that no water enters in it i.e. there is no scope that human feces get mixed with water. The feces chamber is made of bricks and well sealed with cement mortar at the bottom and side walls. The front faced and backside wall of the chamber is typically 2 ft 6 inch and 2 ft high, respectively from the ground level. An impermeable base is constructed underneath the feces chamber. In this process, a compacted sand layer is provided on the leveled ground followed by 3 inch brick flat soling and 3 inch cement concrete. Finally, both inside and outside of the chamber are plastered with neat cement finishing (Figure 4.11).

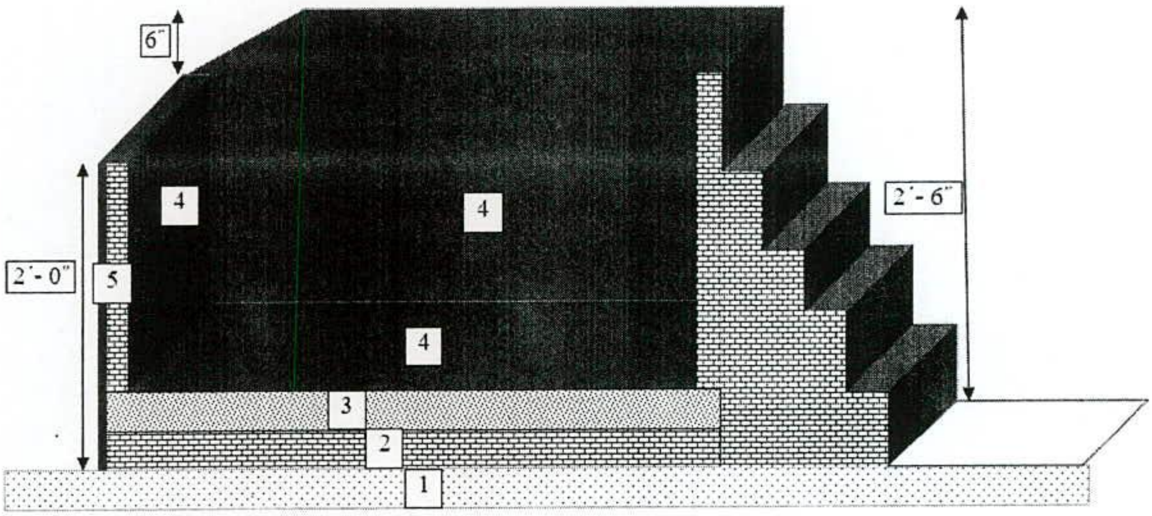


Figure 4.11 Construction stages of feces chamber

The village had been inundated in last August, 2011. Shelters, toilets (both EcoSan and non-EcoSan), yards, cowsheds, agricultural lands of the inhabitants in the village were waterlogged for more than three months. The people who lived in the area faced a vulnerable situation because water spread over the area. Water stayed at varying depth due to tidal effect in the flood prone area. Water depth fluctuated when flow-tide and ebb-tide had occurred through the nearest river "Kabodak". For this reason, water depth surrounding the toilet varied. The water depth was measured from the ground level (base of the toilet) along the height of the structure (Figure 4.12). Identification (ID) of toilet has been expressed by the name of village (in short) with serial no. For example, SB-1 means toilet no. 1 in South Banshbaria (SB). From Figures 4.11 and 4.12, it is clearly understood that EcoSan toilet is a sustainable option in waterlogged area because maximum depth of water surrounding the toilet was 38 cm where height of feces chamber was 60 cm and water had no scope to enter into the feces vaults which was sealed both outside and inside with neat cement finishing.

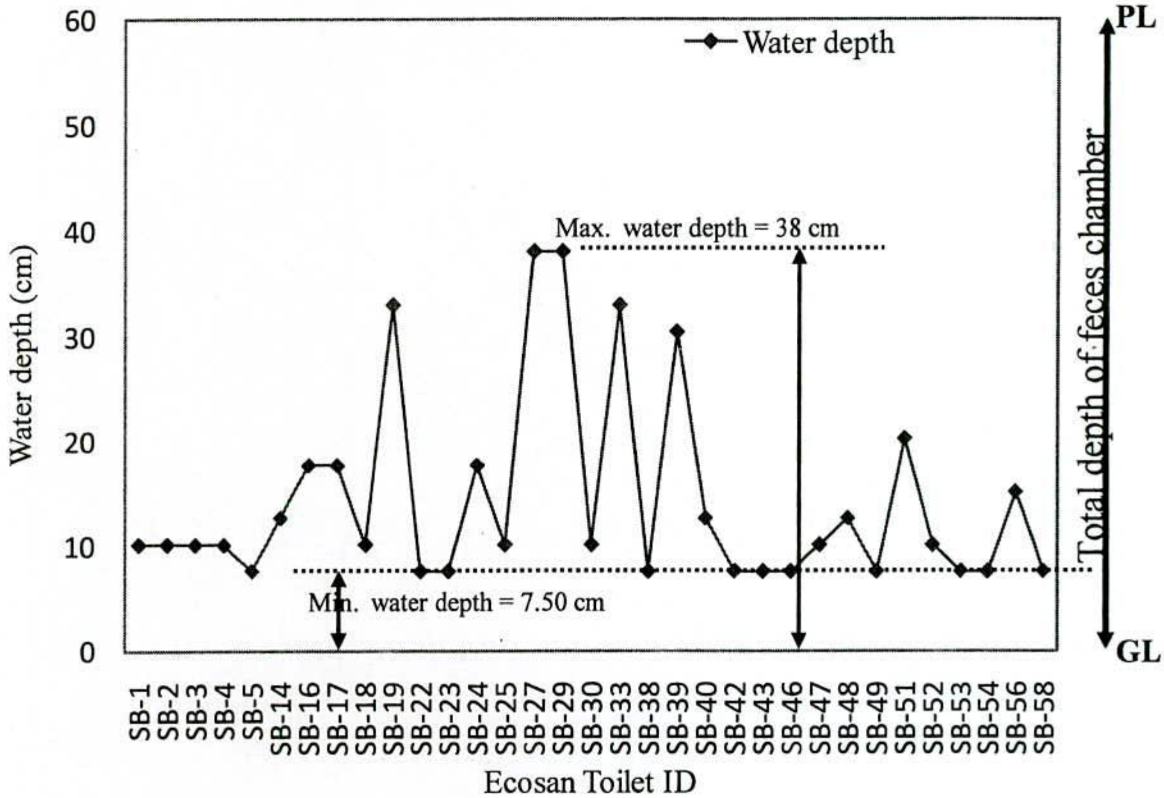


Figure 4.12 Water depths surrounding the EcoSan toilet during flood, 2011

Pit latrine is the most common and low-cost option in the technology of sanitation. In rural Bangladesh, more than 90% latrine is typically pit latrine. Culturally, people of Bangladesh use water to clean themselves after defecation. Therefore, urine, anal cleansing water and excreta are being accumulated in the single pit, which causes rapid fill up of the pit and subsequent return to open defecation due to lack of replacement space. In flood prone areas, overflowing pit latrines pose a high health risk. Thus, surface water gets mixed with a large range of pathogenic organisms of viral, bacterial, parasitic, protozoan and helminthes origins present in human excreta. The major problem of sanitation in flood-prone areas is surface water contamination and loss of accessibility to the latrine. Figure 4.13 indicates the common feature of pit toilets in the study area during flood. It is realized that this type of toilet was absolutely useless and unhygienic. Bad smell, mixing of water and human excreta, risky structure were the problems of pit toilets. Most of flood affected people both EcoSan users and non-EcoSan users used EcoSan toilets during the inundation period in the study area.

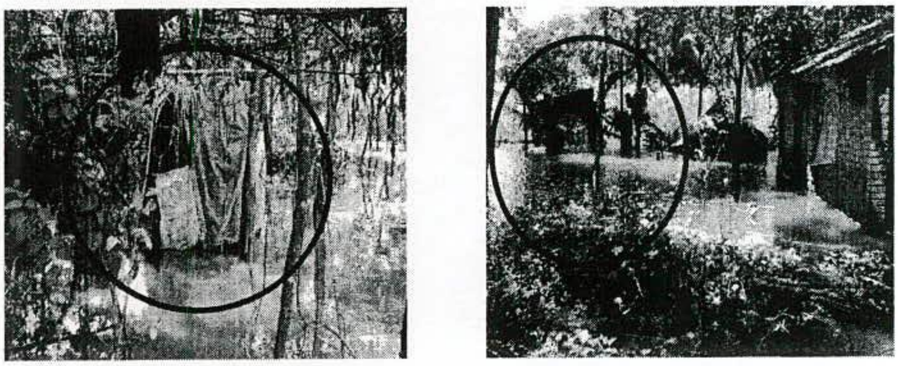


Figure 4.13 Pit toilets in the study area during flood, 2011

EcoSan toilets had been constructed in the study area in 2008. After construction, this was first time that faced flood. So, it was a big challenge about its importance and sustainability in water logging area. EcoSan toilets were used successfully during the last flood period when other types of toilets were completely useless as shown in Figure 4.13. EcoSan toilets had been constructed on the raised ground levels. Feces chamber was 2 ft high above ground level as shown in Figure 4.11. The defecation place is 2 ft 6 inch high above the ground level. Flood level did not exceed the height which was presented in Figures 4.12 and 4.14, respectively. During the flood period, inside of chamber was dry because no water entered into it although water remained surrounding the structure as shown in Figure 4.14. Thus, water pollution was not occurred by the toilet because human excreta did not get mixed with water. EcoSan users were informed that wooden ash will be applied to feces to be dried in the chamber if the water enters. About one year later, the dried feces turn into organic fertilizer. Covering and drying up feces with ash removes foul odor and eliminates the generation and infestation of flies and other insects, which can mediate contact between fecal pathogens and human.

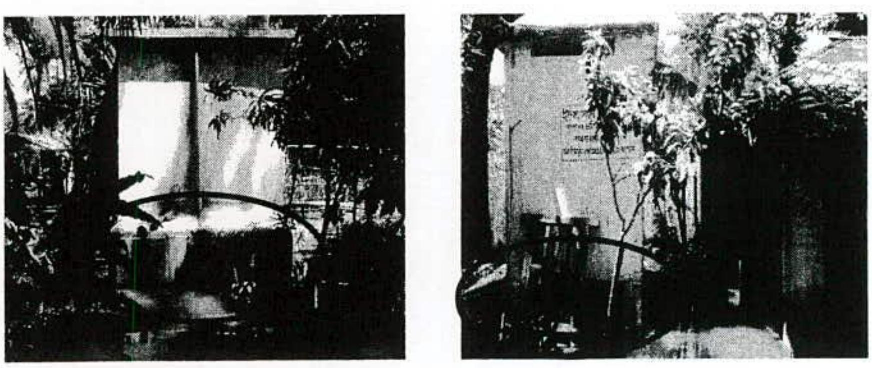


Figure 4.14 EcoSan toilets in the study area during flood, 2011

4.3.5 Problems of EcoSan toilets

4.3.5.1 Social Problems

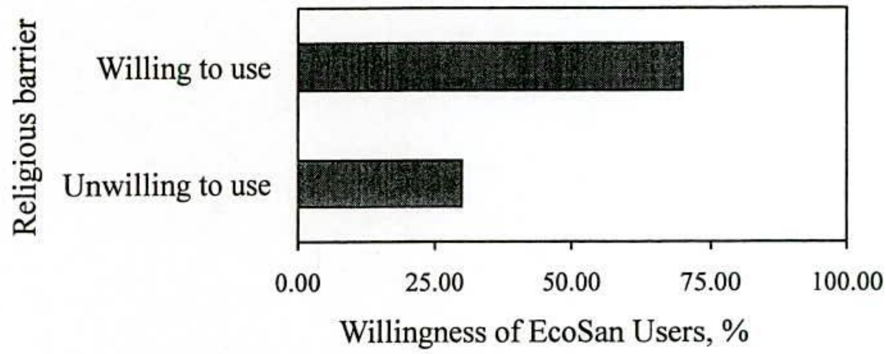


Figure 4.15 Religious hesitations to use EcoSan toilets

In the field investigation, it was found that 87.50% users were Muslim where Hindu were 12.50%. It was noted that one hesitation was created among Muslim users of EcoSan toilet. Some of them were feeling disturb to use the toilet. Religious persons expressed that the toilet was not appropriate to use for them. However, relatives of some users also had same perception. According to their opinion, drops of urine rebound back to human body when fall on the floor during urination which hampers the preparation for prayer. So, the observation was that the floor was made at slop which was not properly good. It can be mentioned that urination place was made on floor during casting. Based on the religious peoples' complain, the issue was recorded in questionnaire form as a social problem. It was found that 30% of Muslim EcoSan families had been suffering from the doubt (Figure 4.15).

As a social problem, another observation was found that users were good practiced in using the toilets but new comers at their home as relatives, friends or visitors who were unknown to the toilets had faced difficulties to use the toilets. It was observed that they got hesitation with the new technology of EcoSan toilet which was completely unknown to them. According to the users' comment, new comers felt uneasy to use the toilets. They did not know how to use the toilet, what were the rules of operation and maintenance, what were the benefits of adding ash into feces chamber, what were the demerits of mixing water into the feces vault, etc. For solving these types of problem, users had to provide instructions to their relatives while they went to the toilets. This problem was considered as a social problem because the relatives or new comers act a vital role to increase the value of social acceptance of EcoSan toilets. Shortly, it is said that perception of EcoSan toilets among the rural users depends on the satisfaction of relatives showing in Figure 4.16. During the field investigation, 65% users replied that their relatives did not feel comfortable to use the toilets. Relatives of 22.50% users used the toilet with little hesitation. A few users, 12.50% declared that their relatives and friends used the toilet easily.

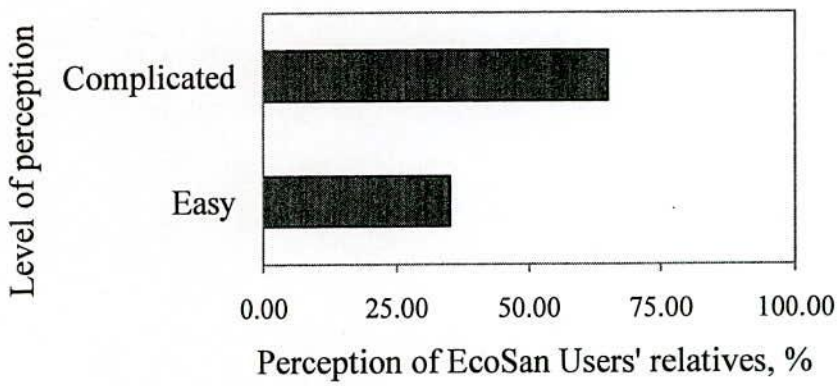


Figure 4.16 Level of satisfaction among EcoSan toilet users with their relatives

4.3.5.2 Operational problems

The toilets were generally well accepted by rural users in the study area. The users appreciate the absence of odor and flies when the toilets are well operated and managed. As a part of field investigation, the toilets were observed to find out technical problems in operation and maintenance. According to operating system, the tasks that were marked as problem to users are outlined below:

- To remove cover of defecation hole before defecation
- To be transferred from defecation place to anal washing place
- Adding ash into feces chamber
- To cover the defecation hole

In Figure 4.17, it is exposed that the problems of being displaced for anal cleansing after defecation and operating the lid over the defecation hole before and after defecation carry the highest disliking of users around 70%. On the other hand, about 50% users had been suffering for difficulties of adding ash into feces hole. From the Figure, it was found that about 50% users were common among those problems but difficulties of displacement for anal washing and difficulties in operation of lid were 17.50% more. They were greatly demanded for modification of easy operation. According to users' opinion, if all tasks were accomplished at same place, operation of toilet would be easy to all. They want to use the toilet with a good combination where nobody will change the place. Thus, it is clearly understood that social acceptance of the toilets in the rural areas mostly depended on the design modification.

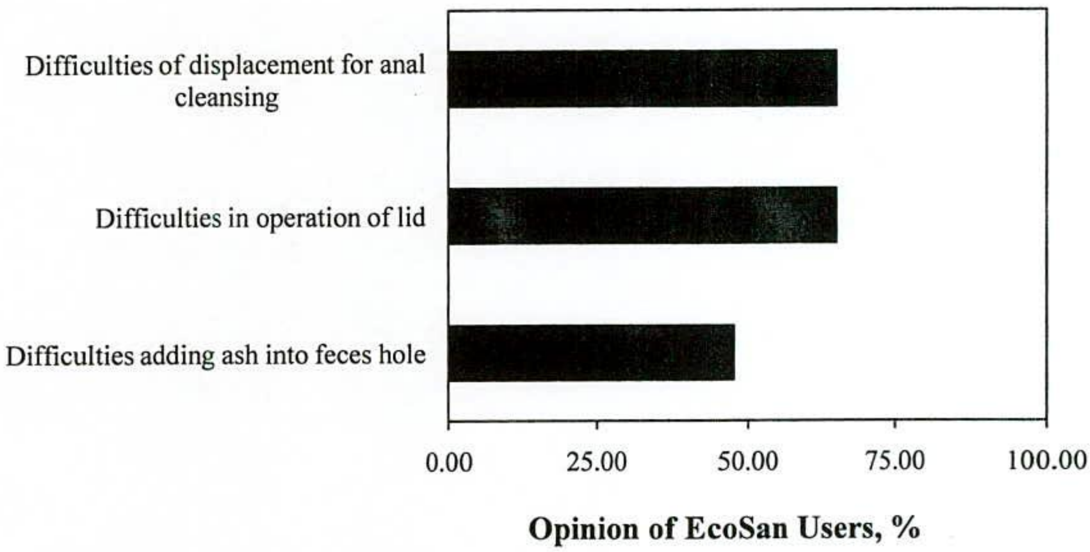


Figure 4.17 Problems of adult users in operation

During the field investigation, some users made complain that EcoSan toilets were not suitable for children and/or elderly people. They need help from family members. Children usually had problems such as pouring water into feces hole, falling leg into feces hole, forgetting to remove cover, mistakes of adding ash over the feces into the vault. It was difficult for the elderly people to follow all the sequential steps of using the EcoSan toilets. Figure 4.18 shows the rate of perception among the users through the attitudes of children and elderly people who were unable to use the toilets without assistance from family members. Among those, main problem of users (above 62.50 %) was found to be the risk of falling leg into the feces hole. Thus, modification of EcoSan toilets with regards to solving the above operational difficulties would be imperative for its long-term sustainability.

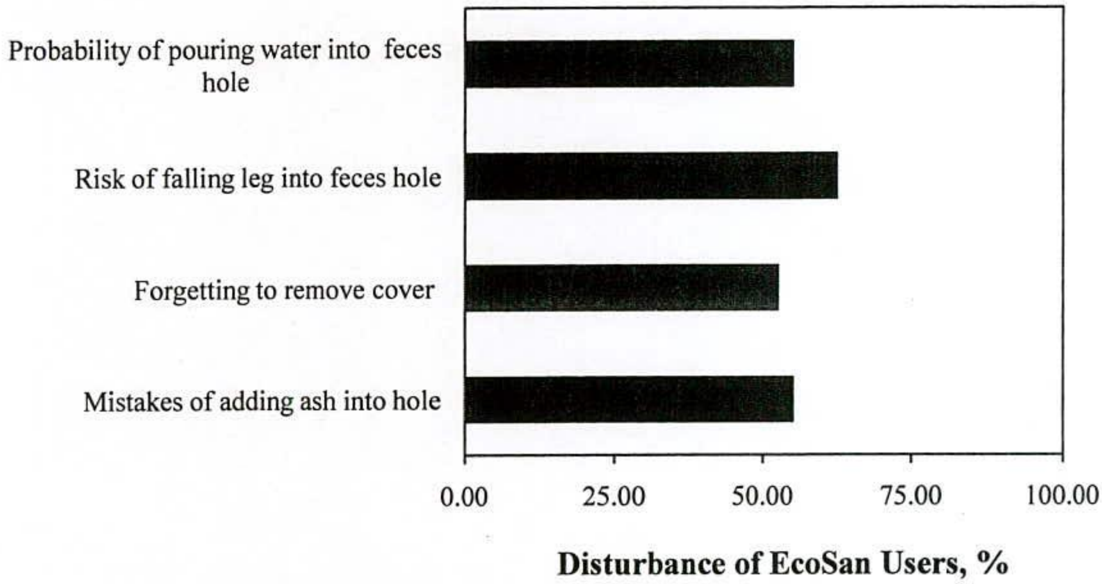


Figure 4.18 Problems of children/elderly people in EcoSan operation

4.3.5.3 Maintenance problems

During the field investigation, following problems were found in maintenance of EcoSan toilets in the study area (Figure 4.19):

- To clean the evaporation bed
- To replace the corroded heat panel
- To remove the ash in the pipes when it gets block by pieces of paper or ash
- Removing the feces from the vault
- Operation of urine container

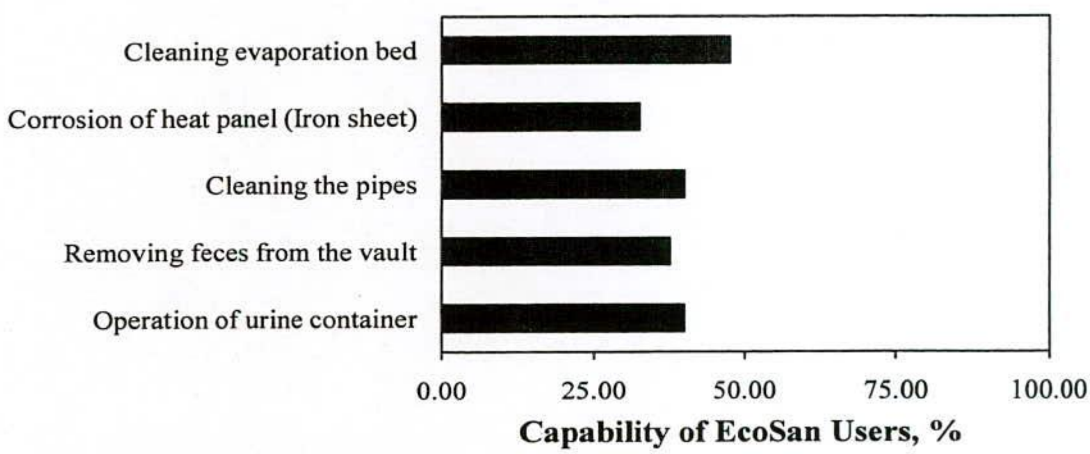


Figure 4.19 Difficulties in maintenance of the EcoSan toilets

Maintenance of EcoSan toilets depends on the nature of users and frequency. Evaporation bed of EcoSan toilet was an important part through which anal cleansing water passes into ground. It was made of brick chips at top layer and sand bed was provided at the bottom layer. After continuous using, intermediate pores in the brick chips got blocked by algae and dust. Sometimes, a thinner layer of algae, clay, etc. accumulated upon the layer for which water might not pass through it. Water logging in the evaporation bed was deemed a big problem with regards to proper functioning of this unit. The users who were not willing to clean the bed were found to be 47.50%. Heat panel, made of iron sheet, covering the feces vault was provided at the backside of the toilet. It protects the ingress of rainwater and transmits heat into the vault for which it was called heat panel. In presence of air, corrosion occurs and hence damages some portion of the heat panel sheet. Due to corrosion, plain sheet became porous through which rainwater entered into the vaults. Around 32.50% users did not show any interest to repair the heat panel. The pipes through which anal cleansing water and urine came out the toilets might be blocked by pieces of charcoal, tissue papers or any other things. 40% users were found that they did not maintain the pipes at smooth working. At regular frequency, pipes should be cleaned. Removing feces from the vault might be occurred in a year. Around 37.50% users were not willing to remove the feces by themselves. On the other hand, 40% users did not aesthetically feel good to use the urine in the agricultural lands due to its obnoxious smell.

4.3.6 Social acceptance of EcoSan toilets

The social acceptance of EcoSan toilet has been shown (Figure 4.20) on the basis of field survey conducted in this study. Lowest value of accepted level of these attributes was considered to measure the social acceptance of the toilets. Among those attributes, maximum and minimum level of acceptance was perception of using urine in agriculture, positive attitudes of using EcoSan toilets in religious point of view and perception of using feces in agriculture, respectively. Considering the basic of those results, social acceptance of EcoSan toilets was found 31.25% among the EcoSan families, marked by circular shape with dark color shown in the Figure 4.20. The minimum acceptance limit of 31.25% users was common in all attributes which indicates a common level of perception of the toilets in the study area.

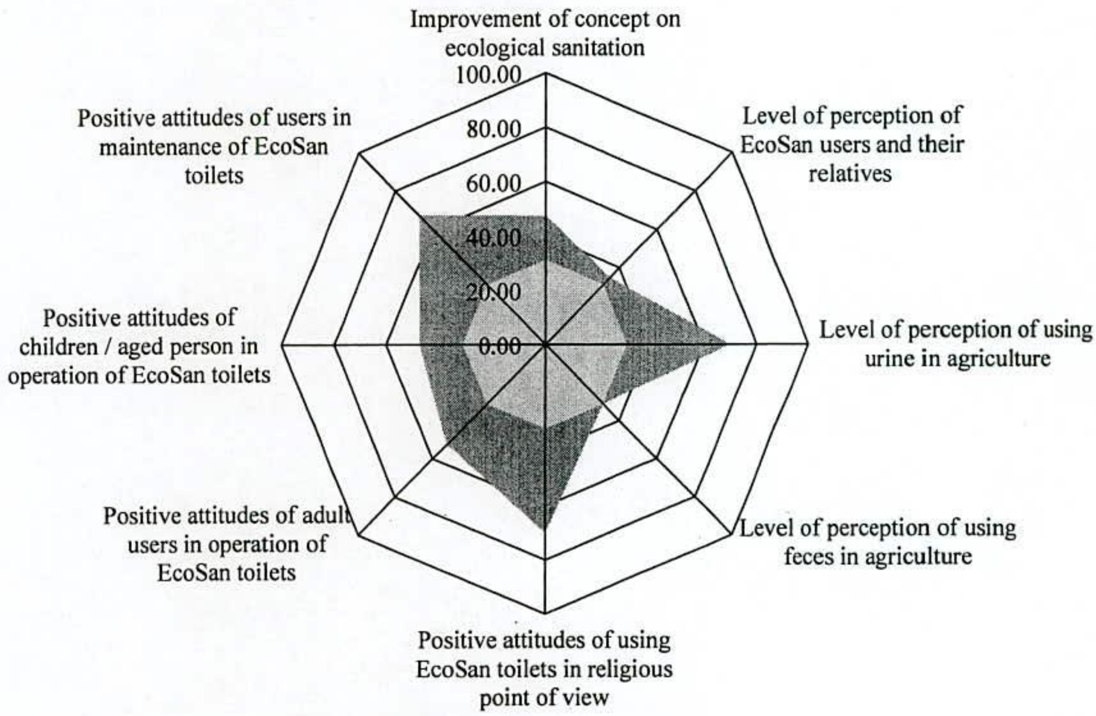


Figure 4.20 Social acceptances of EcoSan toilets in the study area

Nonetheless, the users had satisfaction for other benefits of EcoSan toilets as outlined below:

- Required land area for the toilet construction with management of human excreta is 70 sq. ft (6.50 sq. m) which is not more than required area of pit toilet, toilet with septic tank etc.
- They did not dig an alternate hole in case of pit toilet when one pit got filled. However, EcoSan toilet had already been made of twin vaults that would be used in cyclic order for longtime.
- Stability, stiffness and longevity of the structure were very high in comparison to other types of toilets.
- In case of EcoSan toilets, health risks had been significantly reduced than pit toilets.
- Defecation place was raised 2 ft from the existing ground level which deemed suitable in waterlogged condition in wet season.

- Feces unit was made of brick masonry wall and had limited chance to contaminate the surrounding water sources.
- The toilet was comfortable to use in both sunny and rainy weather.
- The toilet was free from bad odor.
- Organic fertilizer was obtained from EcoSan toilets which reduced the cost of chemical fertilizers.
- It also minimized the medical expenses.
- Operation and maintenance cost was cheaper than other types of toilets.
- Surrounding environment of home looks good for its isometric view.

4.4 Conclusions

The major findings from the field survey are outlined as below:

- Public awareness on ecological sanitation is being increased along with using EcoSan toilets which produces organic fertilizers from human excreta. These fertilizers are being used in the farmland as a replacement (partial) of chemical fertilizers.

- EcoSan toilets are not only a good source for organic fertilizers but also profitable in terms of financial savings. It was found that users can earn BDT 286.28 per person per year from the toilets. It has been shown that EcoSan toilets are able to decrease the medical expenses, income loss due to illness along with increasing the income of EcoSan families. In these circumstances, they are well practiced with hygiene behaviors. Furthermore, this study reveals that sanitation could be treated as a business through community based organization (CBO).
- This study observed that the performance of EcoSan toilets in water logged areas was good because of its raised platform around 2ft high from the existing ground level. Moreover, there was limited chance to enter the surrounding water into the feces vaults due to higher level than flood water as well as water-sealed structure.

- Social barrier such as hesitation to using EcoSan toilet with regards to religious aspect was found to be a problem in the adaptation of this sanitation strategy. According to users' comments, relatives and/or friends were not willing to use the EcoSan toilets.

- Some problems were identified in the operating systems of the EcoSan toilets especially for children and elderly people. Children usually had problems such as pouring water into feces hole, falling leg into feces hole, forgetting to remove cover, mistakes of adding ash over the feces into the vault. On the other hand, it was difficult for the elderly people to follow all the sequential steps of using the EcoSan toilets.

- This study demonstrates that O&M technique plays an important role for the long-term sustainability of EcoSan toilets. In this context, a well managed sanitation system, involving CBOs, could be achieved by service providers to collect and transport the urine and feces to a centralized shed for further treatment into compost/fertilizer.

- The social and economic aspects of EcoSan toilets would be optimized through modified design and good management system.

CHAPTER 5

WATER QUALITY AROUND ECOSAN TOILETS

CHAPTER 5

WATER QUALITY AROUND ECOSAN TOILETS

5.1 Background

Most of the rural population of Bangladesh does not have access to safe and reliable toilets. A good toilet, together with a safe reliable and protective water supply from contamination and the practice of good personal hygiene can do much to improve personal and family health and wellbeing. There is an imperative need for the construction of simple, low cost, affordable toilets that are easy to build and maintain, are relatively free of odors and flies and protect the surrounding water sources. Third objective of the research work was to investigate any possible contamination of groundwater / surface water resources around the existing EcoSan toilets in the rural area of Bangladesh. This chapter presents the test results of water quality of groundwater and surface water sources nearby EcoSan toilets. In previous chapter, socioeconomic acceptance with hygiene practice that was interlinked to water quality was described. For this reason, it was very urgent to be confirmed about the possibility of water pollution throughout EcoSan toilets. Rural sanitation systems are very poor in the context of Bangladesh. Both groundwater and surface water sources are being polluted due to lack of proper management of sanitation system. Like the conventional sanitation systems such as open defecation, hanging toilets, pit toilets and open discharge from septic tank, EcoSan toilets may and/or may not pollute the water bodies that will be elucidated in this chapter. Parameters were introduced for laboratory experiments through which contamination or its probability might be found comparing with Bangladesh standard. In this study, it has been focused at being environment friendly of EcoSan toilets in rural Bangladesh in view of protecting neighboring water sources and improving sanitation on ecological sanitation concept which was assessed through water quality survey, improved by rural population.

5.2 Experimental approach in this study

5.2.1 Collection of field water samples

For the experimental work, water samples were collected from both pond and shallow tube-wells as sources of groundwater and surface water, respectively. No. of ponds and shallow tube-wells was 10 and 20, respectively. Water sources which were found within 10 m distance from EcoSan toilets were selected. Samples were collected in both dry and rainy season of the year 2012. Every sample was collected from same sources for two types of parameters; physicochemical and microbiological tests were conducted for the laboratory experiment. However, sampling bottles and thio-bags were used during sampling of water for physicochemical and microbiological parameters, respectively.

5.2.2 Laboratory analysis of collected water samples

Samples of water were collected for laboratory test of physicochemical parameters (pH, SO_4^{2-}, PO_4^{3-}, NO_3^-, BOD_5, COD, DO) and microbiological parameters (fecal coliform, E. coli and total coliform). Laboratory analysis was conducted in Environmental Engineering Laboratory, KUET, Khulna. The analyses methods are summarized in Table 4.1.

Table 5.1 Standard methods for laboratory determination of selected water quality parameters

Water quality parameters		Standard Methods Followed
Physicochemical parameters	pH	Electrometric Method
	SO_4^{2-}	UV Spectrophotometric Method
	PO_4^{3-}	UV Spectrophotometric Method
	NO_3^-	UV Spectrophotometric Method
	DO	Membrane Electrode Method
	BOD_5	BOD Bottles & Incubator
	COD	Closed Reflux, Titrimetric method
Microbiological parameters	Fecal coliform	Membrane filter procedure
	E. coli	
	Total coliform	

5.3 Results and discussion

5.3.1 Physicochemical water quality

5.3.1.1 Surface water

For analyzing the quality of surface water surrounding EcoSan toilets, ponds were considered as the major source of surface water. Collected water samples were analyzed in the laboratory for selected water quality parameters (Table 5.2). Water samples were collected from nearby ponds within the distance of 10 m from EcoSan toilets.

Table 5.2 Test results of physicochemical parameters of surface water

Parameters		Season	Min	Max	Mean	Median	Std. Dev
pH		Dry	6.58	7.92	7.23	7.23	0.41
		Wet	6.33	6.91	6.66	6.62	0.22
SO_4^{2-}	mg/l	Dry	0.00	26.00	11.50	10.00	8.38
	mg/l	Wet	0.00	53.00	30.60	28.00	14.78
PO_4^{3-}	mg/l	Dry	0.47	2.11	1.10	1.01	0.53
	mg/l	Wet	0.14	1.12	0.58	0.60	0.34
NO_3^-	mg/l	Dry	0.00	0.90	0.36	0.35	0.27
	mg/l	Wet	0.94	3.16	1.71	1.70	0.63
DO	mg/l	Dry	5.35	6.93	6.52	6.68	0.45
	mg/l	Wet	5.34	7.05	6.56	6.85	0.61
BOD_5	mg/l	Dry	0.62	3.20	1.83	1.80	0.78
	mg/l	Wet	0.52	2.00	1.37	1.75	0.67
COD	mg/l	Dry	16.00	48.00	27.20	24.00	13.17
	mg/l	Wet	16.00	64.00	44.80	48.00	16.52

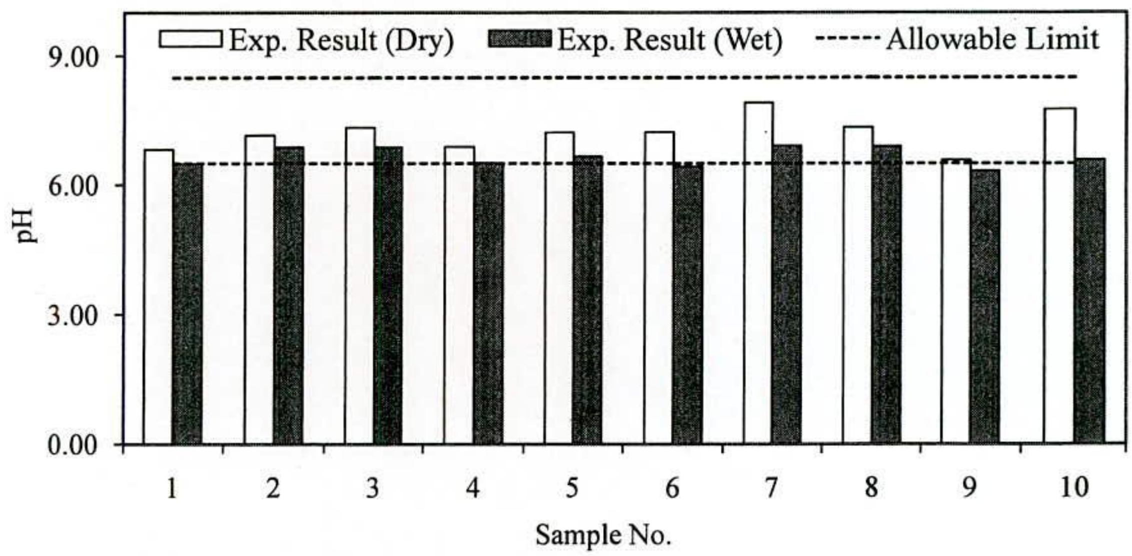


Figure 5.1 pH in surface water during dry and wet season, 2012

Figure 5.1 shows the result of pH in pond water around EcoSan toilets during dry and wet season in last year, 2012. It was observed that Figure showed two types of comparative result; one was between dry and wet season and another was between experimental result and allowable limit of safe drinking water. According to Bangladesh standard, pH value in drinking water is 6.50 to 8.50. In the study area, the range of pH value was found within the range 6.58 to 7.92 and 6.33 to 6.91 during dry and wet season, respectively. Little change of nature of water quality in pond water was occurred in form of acidic to alkaline from dry to wet period. But it was found that both results in dry and wet season were laid within the allowable limit except the three sources in wet season. However, pH value of those sources was nearly equal to allowable limit. So, it is concluded that pH value was suiTable for aquatic life, drinking and cooking.

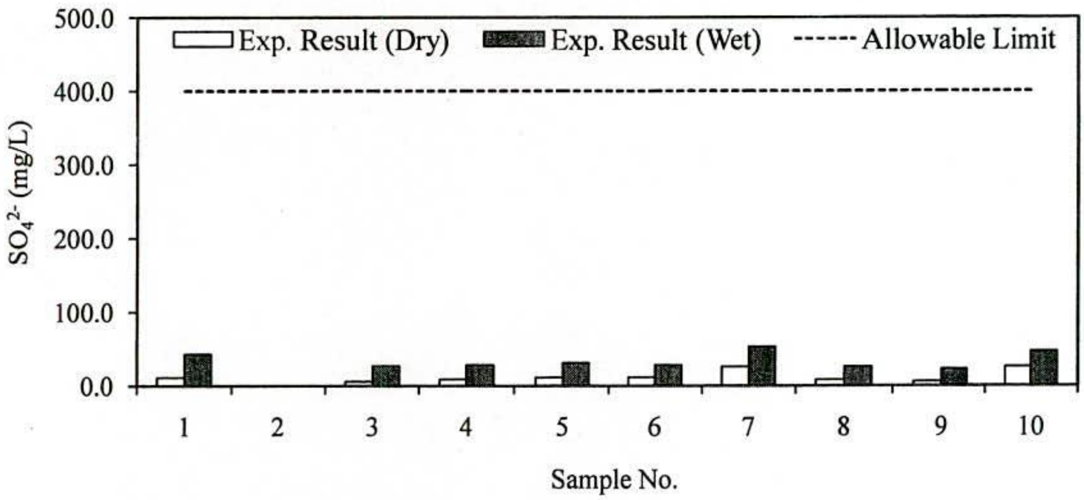


Figure 5.2 Concentration of sulfate in surface water during dry and wet season, 2012

Sulfate may be leached from the soil and is commonly found in most water supplies. Magnesium, potassium and sodium sulfate salts are all soluble in water. Calcium and barium sulfates are not very easily dissolved in water. Decaying plant and animal matter may release sulfate into water. Numerous chemical products including ammonium sulfate fertilizers contain sulfate in a variety of forms. The treatment of water with aluminum sulfate (alum) or copper sulfate also introduces sulfate into a water supply. Human activities such as the combustion of fossil fuels and sour gas processing release sulfur oxides to the atmosphere, some of which is converted to sulfate. In Figure 5.2, the level of sulfate varied from 0 mg/l to 26 mg/l and 0 to 53.00 mg/l in pond water during dry and wet season, respectively. The experimental results in both seasons were below Bangladesh standard limit of SO_4^{2-} that equals to 400 mg/l for drinking purpose. But it was observed that level of sulfate in dry season was greater than the level in wet season. As a reason, surface runoffs get increased naturally in monsoon period and chemical fertilizer that was used in agriculture was washed out and mixed with water in pond. However, EcoSan toilets from where leachate did not come out were found because the toilets were built based on closed and dry sanitation. It can be understood that level of sulfate in surface water remains within safe limit and EcoSan toilet does not affect water quality in ponds.

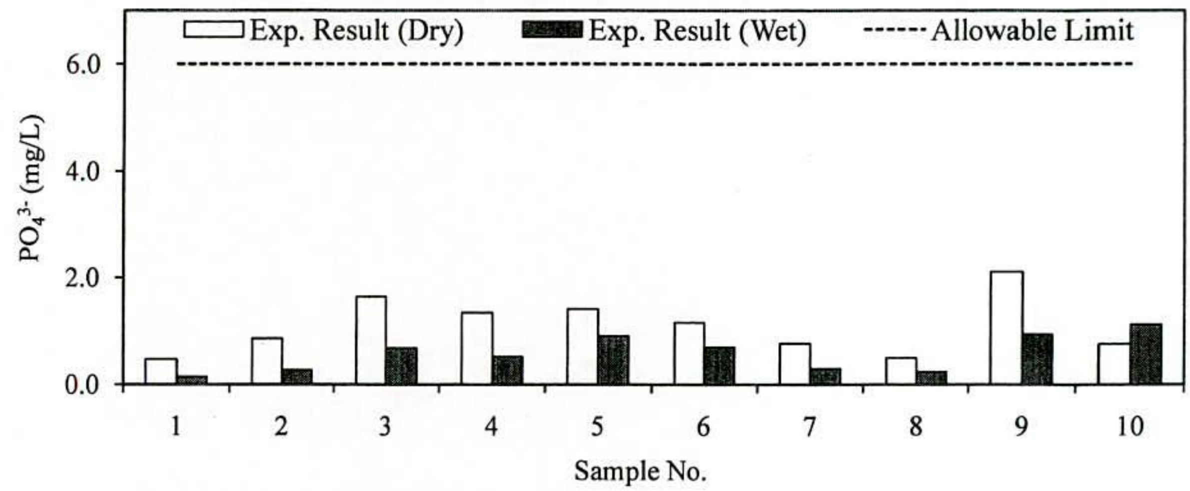


Figure 5.3 Concentration of phosphate in pond water during dry and wet season, 2012

Phosphates enter waterways from human and animal waste, phosphorus rich bedrock, laundry, cleaning, industrial effluents, and fertilizer runoff. So measuring phosphate in aquatic environments can be a very important tool in understanding the health of a system or its "water quality". Natural events such as heavy rainfall will wash agricultural fields of their topsoil and introduce phosphate salts into ponds which will increase phosphate concentration causing algal blooms that could lead to fish kills or impacts on other organisms. Wastewater released into the environment, that has not been properly treated, can potentially contain phosphates from detergents can cause similar effects. Figure 5.3 indicates the range of phosphate present in surface water sources nearest to EcoSan toilet. In the Figure, it was shown that the level of phosphate was 0.47 – 2.11 mg/l and 0.14 – 1.12 mg/l in dry and wet season, respectively. The test results were below Bangladesh standard limit of phosphate that equals to 6 mg/l for drinking and cooking purpose. Comparing the seasonal results, it was found that level of phosphate was decreased in wet period. It can be decided that flow of phosphate into water source from surrounding agricultural field was very little. No fault of EcoSan toilet was found in increasing phosphate content in surface water. But monitoring of phosphate levels in water can help identify possible sources for phosphate introduction to aquatic systems. Precautions can be taken to minimize these inputs and can prevent any harmful effects that can occur as a result eutrophication.

Nitrates form when microorganisms break down fertilizers, decaying plants, manures or other organic residues. Usually plants take up these nitrates, but sometimes rain or irrigation water can leach them into water body. Although nitrate occurs naturally in water body, in most cases higher levels are thought to result from human activities. Normally only small amounts are found naturally, but an increase in nitrate levels can come from many man-made sources such as septic systems, fertilizer runoff and improperly treated wastewater. Of these, nitrate is usually the most important to consider when determining water quality. As nitrates increase, they act as a plant nutrient and cause an increase in plant growth. As the plant material dies and decomposes, dissolved oxygen levels decrease. In the Figure 5.4, the level of nitrate in the pond water varied from 0 to 0.9 mg/l and 0.94 to 3.16 mg/l in dry and wet season, respectively which was below 10 mg/l, Bangladesh standard limit for drinking. It can be understood that water is safe from contamination through EcoSan toilet.

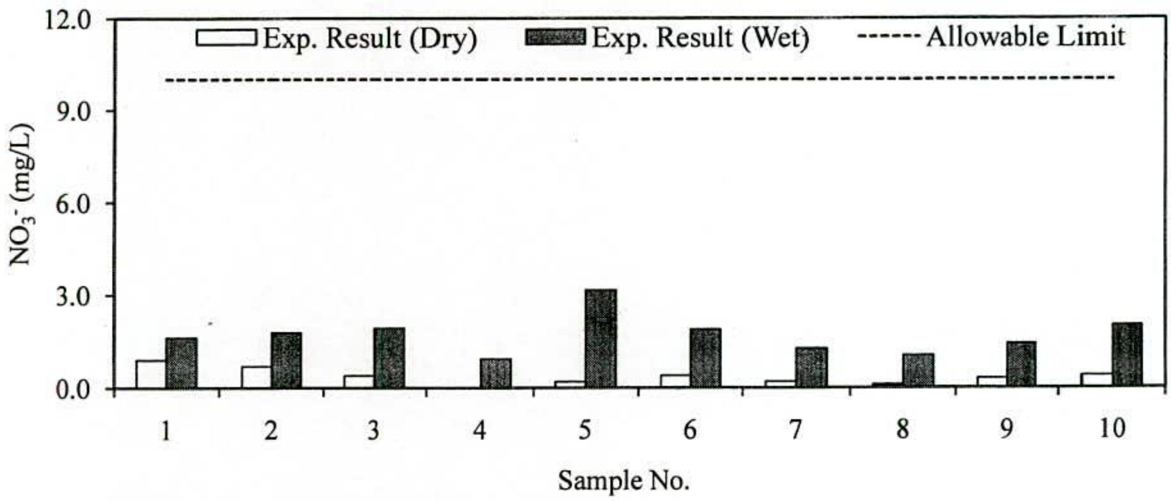


Figure 5.4 Concentration of nitrate in pond water during dry and wet season, 2012

In the Figure 5.5, it was shown that concentration of DO varied from 5.35 mg/l to 6.93 mg/l and 5.34 mg/l to 7.05 mg/l in dry and wet season, respectively. In case of seasonal results of water quality, DO level of 80% ponds was higher in wet season comparative with dry season. On the other hand, DO concentration of all sources in both dry and wet season was nearly equal to Bangladesh standard limit. From the result, it was found that leachate was not mixed with pond water. However, feces vaults were sealed with cement grouting both inside and outside. It was also found that some users made pit toilets as an alternative usage for their relatives and the pit toilets were placed beside the ponds.

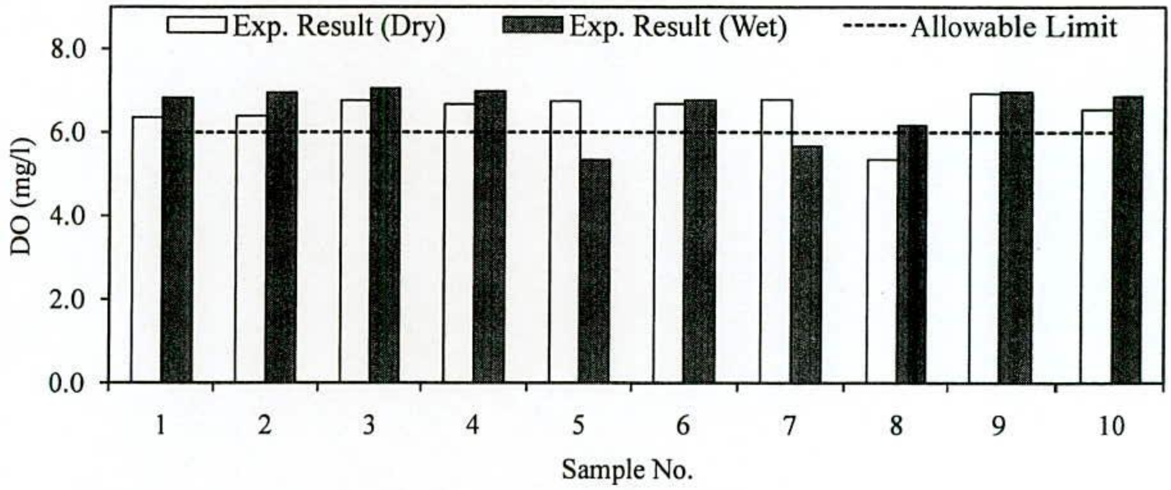


Figure 5.5 Concentration of dissolved oxygen in pond water during dry and wet season, 2012

It was found that BOD_5 in all of sources of surface water during both dry and wet season was higher compared to Bangladesh standard limit of drinking water showing in Figure 5.6. In the Figure, it was shown that value of BOD_5 varied from 0.62 mg/l to 3.20 mg/l and 0.52 mg/l to 2.00 mg/l in dry and wet season, respectively. For drinking purpose, value of BOD_5 is 0.2 mg/l according to Bangladesh standard limit. The Figure indicated the large amount of oxygen was needed to decompose organic matter, presented in pond water. During the survey period, it was found that both EcoSan toilets and pit toilets were present nearby the ponds. Most of the ponds were not protected from the inflow of wastewater. It was understood that EcoSan toilet had no chance to pollute the surrounding water bodies because the toilet carried a closed system. But pit toilets had so many chances to get mixed with pond water for which pond water was polluted and content of organic matter was increased. And the organic matter was decomposed at presence of oxygen. It was concluded that BOD value will be increased with increasing the decomposing organic matter.

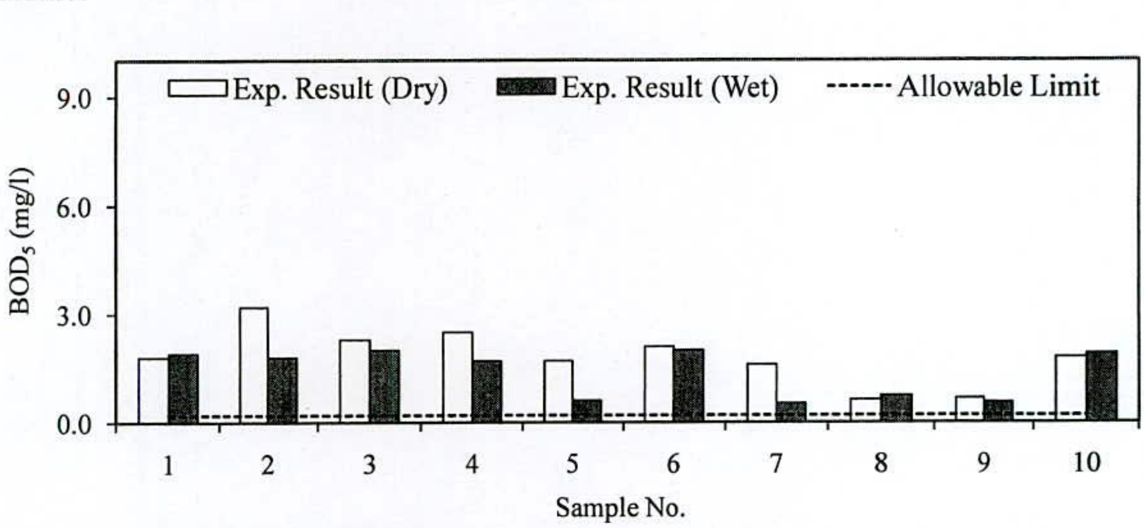


Figure 5.6 Concentration of BOD_5 in pond water during dry and wet season, 2012

In Figure 5.7, it was shown that COD concentration in surface water sources varied from 16 mg/l to 48 mg/l and 16 mg/l to 64 mg/l in dry and wet season, respectively which was higher than 4 mg/l, Bangladesh standard limit for drinking purpose. Form the result, it was understood that large amount of oxygen was demanded for oxidizing the organic compounds. High concentration of COD indicates that large amount of oxygen was consumed in those ponds. However, there were no EcoSan toilets through which human excreta; feces and urine was not mixed with surrounding water bodies in the study area. But some pit toilets were installed nearby the existing ponds. The ponds might be polluted caused by these pit toilets because the excreta had a great chance to be mixed with surface water sources through percolation from the pits. For this reason, COD concentration in those ponds water raised.

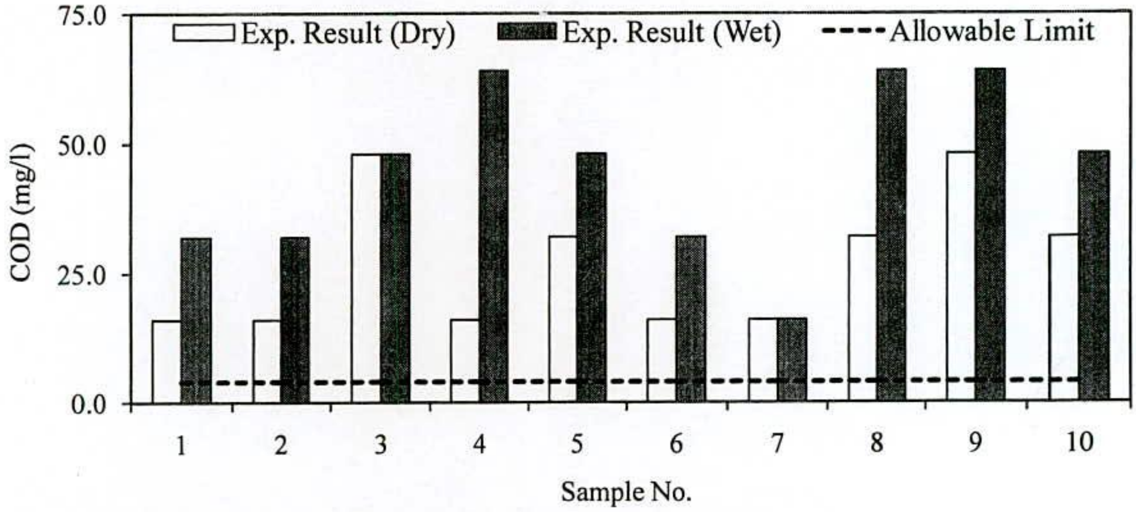


Figure 5.7 Concentration of COD in pond water during dry and wet season, 2012

5.3.1.2 Groundwater

Table 5.3 Test results of physicochemical parameters of groundwater

Parameters		Season	Min	Max	Mean	Median	Std. Dev
pH		Dry	7.12	7.50	7.28	7.27	0.11
		Wet	6.33	6.94	6.67	6.66	0.22
SO_4^{2-}	mg/l	Dry	0.00	8.00	1.15	1.00	1.84
	mg/l	Wet	0.00	76.00	27.00	27.00	18.52
PO_4^{3-}	mg/l	Dry	0.54	5.10	1.51	1.16	1.01
	mg/l	Wet	0.23	1.59	0.76	0.79	0.35
NO_3^-	mg/l	Dry	0.10	6.00	0.70	0.40	1.26
	mg/l	Wet	0.75	3.18	1.86	1.64	0.70
DO	mg/l	Dry	5.02	5.89	5.50	5.47	0.23
	mg/l	Wet	4.93	6.03	5.62	5.73	0.35
BOD_5	mg/l	Dry	0.45	1.77	0.97	0.92	0.32
	mg/l	Wet	0.39	1.23	0.87	0.90	0.25
COD	mg/l	Dry	32.00	128.00	78.40	80.00	25.90
	mg/l	Wet	32.00	128.00	81.60	88.00	27.91

For analyzing the feature of groundwater surrounding EcoSan toilets, tube-wells were introduced as source of groundwater. Collected water samples were conducted to laboratory experiment of which results was shown in Table 5.3. To indentify the contamination of tube-well water through EcoSan toilet was the main purpose of the laboratory test. Water samples were collected from the tube-wells which were very close to the toilets. However, tube-wells were laid within the distance of 10 m from EcoSan toilets were selected. Table 5.3 presents the result of physiochemical parameters in both dry and wet seasons such as pH, SO_4^{2-}, PO_4^{3-}, NO_3^-, DO, BOD_5 and COD of tube-well water.

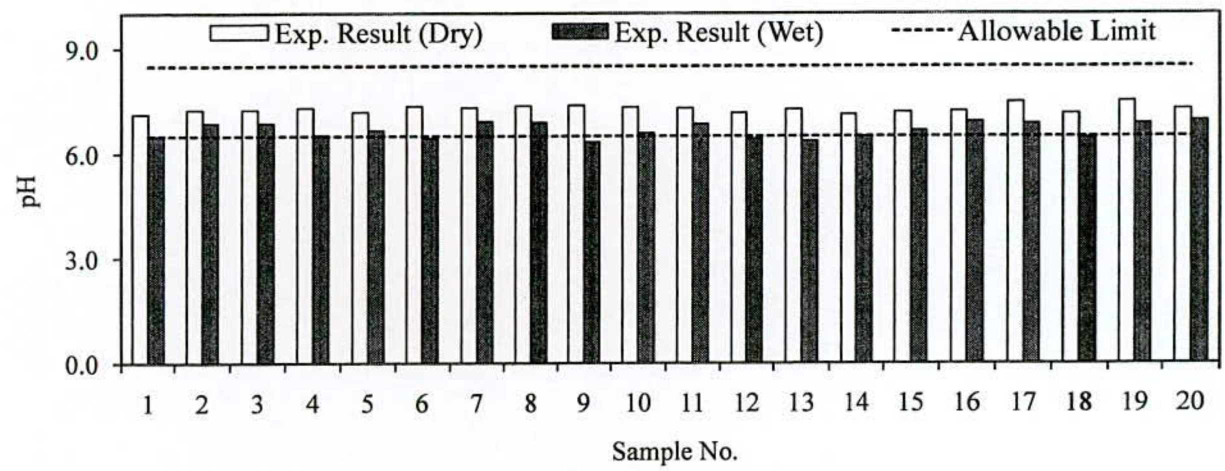


Figure 5.8 pH in groundwater during dry and wet season, 2012

In Figure 5.8, it was shown the result of pH in tube well water at shallow depth around EcoSan toilets during dry and wet season in last year, 2012. The Figure presents two types of comparative result; one was between dry and wet season and another was between experimental result and allowable limit of safe drinking water. According to Bangladesh standard, pH value in drinking water is 6.50 to 8.50. In the study area, the range of pH value was found within the range 7.12 to 7.50 and 6.33 to 6.94 during dry and wet season, respectively. It was observed that water quality was alkaline and acidic in dry and wet season, respectively. But it was found that both results in dry and wet season were laid within the allowable limit. However, pH of 35% tube well water was below allowable range in wet season. An observation was that pH value was higher in dry season than wet season like pond water quality. So, it is concluded that people were using this water for drinking and cooking purpose without health hazards.

In Figure 5.9, the level of sulfate varied from 0 mg/l to 8 mg/l and 0 to 76.00 mg/l in tube well water during dry and wet season, respectively which remains within Bangladesh standard limit of SO_4^{2-} that equals to 400 mg/l for drinking purpose. But it was observed that level of sulfate in dry season was greater than the level in wet season. Water mixed with chemical fertilizer might be leached through soil in rainy season for which level of sulfate was increased in ground water sources. However, EcoSan toilets that did not allow the seepage were found. It can be said that level of sulfate in groundwater is below the safe limit and EcoSan toilet does not occur water pollution.

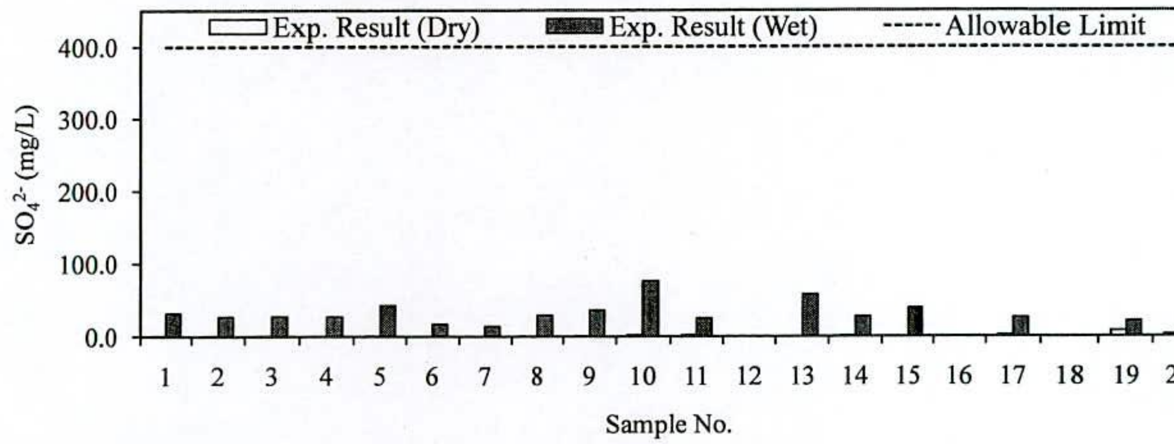


Figure 5.9 Concentration of sulfate in groundwater during dry and wet season, 2012

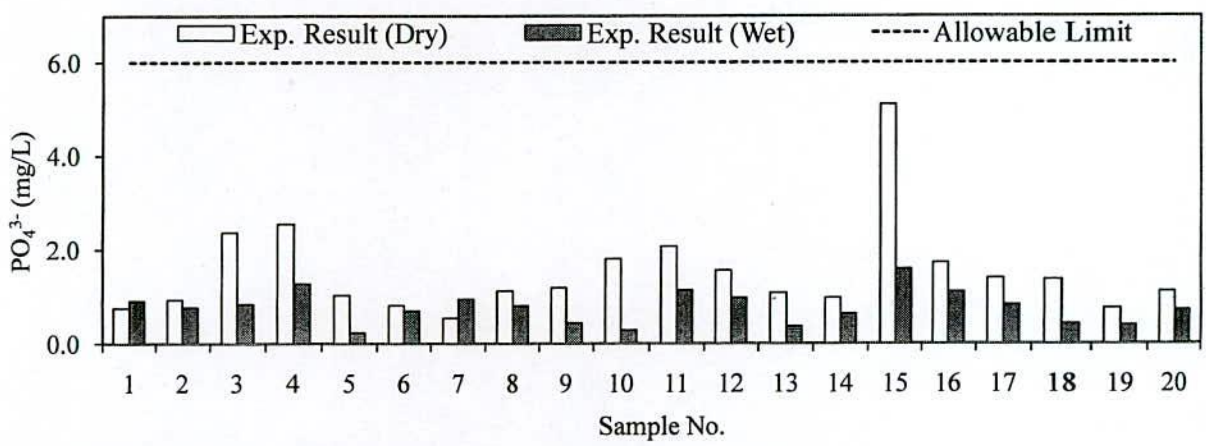


Figure 5.10 Concentration of phosphate in groundwater during dry and wet season, 2012

Figure 5.10 indicates the level of phosphate present in groundwater sources nearest to EcoSan toilet. The Figure showed that level of phosphate was 0.54 – 5.10 mg/l and 0.23 –

1.59 mg/l in dry and wet season, respectively which was below Bangladesh standard limit of phosphate which equals to 6 mg/l for drinking and cooking purpose. Comparing the seasonal results, it was found that level of phosphate was decreased in wet period. It can be decided that flow of phosphate into water source from surrounding agricultural field was very little. No fault of EcoSan toilet was found in increasing phosphate content in groundwater. But monitoring of phosphate levels in water can help identify possible sources for phosphate introduction to aquatic systems. Precautions can be taken to minimize these inputs and can prevent any harmful effects that can occur as a result eutrophication.

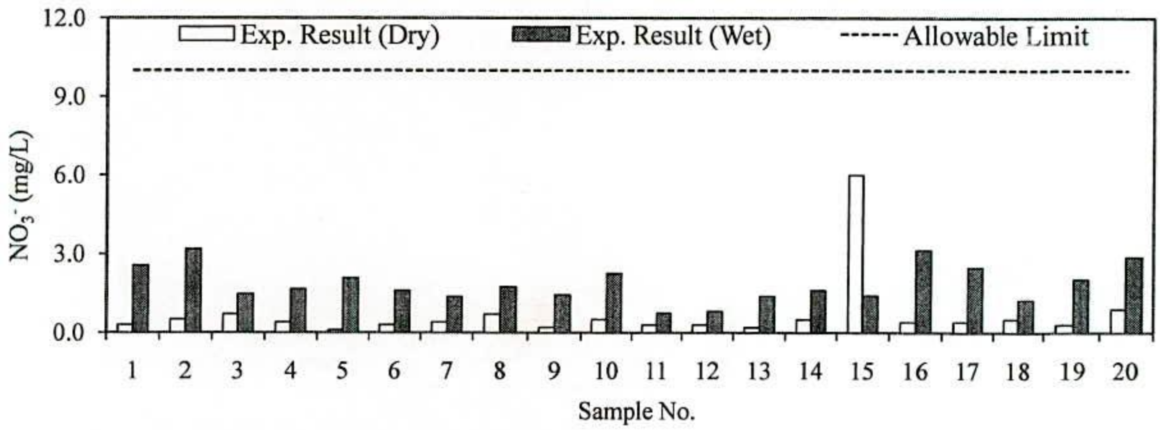


Figure 5.11 Concentration of nitrate in groundwater during dry and wet season, 2012

Figure 5.11 focused the level of nitrate in groundwater varied from 0.10 to 6.00 mg/l and 0.75 to 3.18 mg/l in dry and wet season, respectively which was below 10 mg/l, Bangladesh standard limit for drinking. Form the test results, it was found that concentration of nitrate was increased in rainy season due to surface runoff through which washed out water of agriculture field might be leached into ground. On the other hand, there was no chance of leaching from EcoSan toilets. It can be understood that water is safe from contamination through EcoSan toilet.

Dissolve Oxygen of the groundwater in both dry and wet season in the study area was nearly equal to Bangladesh standard limit for drinking purpose showing in Figure 5.12. The tube-wells were found nearby EcoSan toilets. The concentration of DO was found 5.02 - 5.89 mg/l and 4.93 - 6.03 mg/l in dry and wet season, respectively. In case of seasonal variation of water quality, DO level of 70% tube-wells was higher in wet season comparative with dry season. On the other hand, DO concentration of all sources was near about Bangladesh standard limit. In this circumstance, EcoSan toilets were safe to affect the DO level in groundwater.

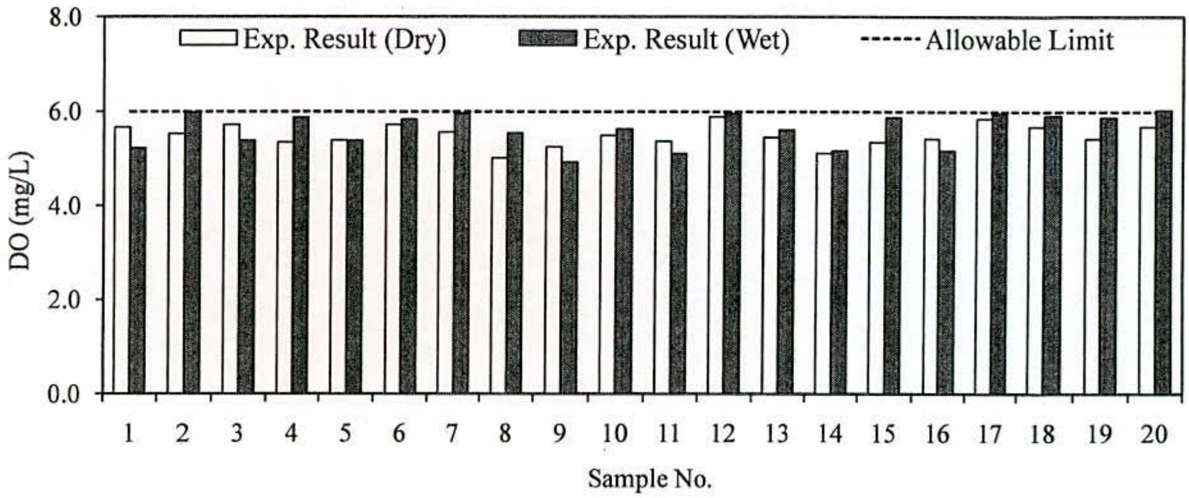


Figure 5.12 Concentration of dissolved oxygen in groundwater during dry and wet season, 2012

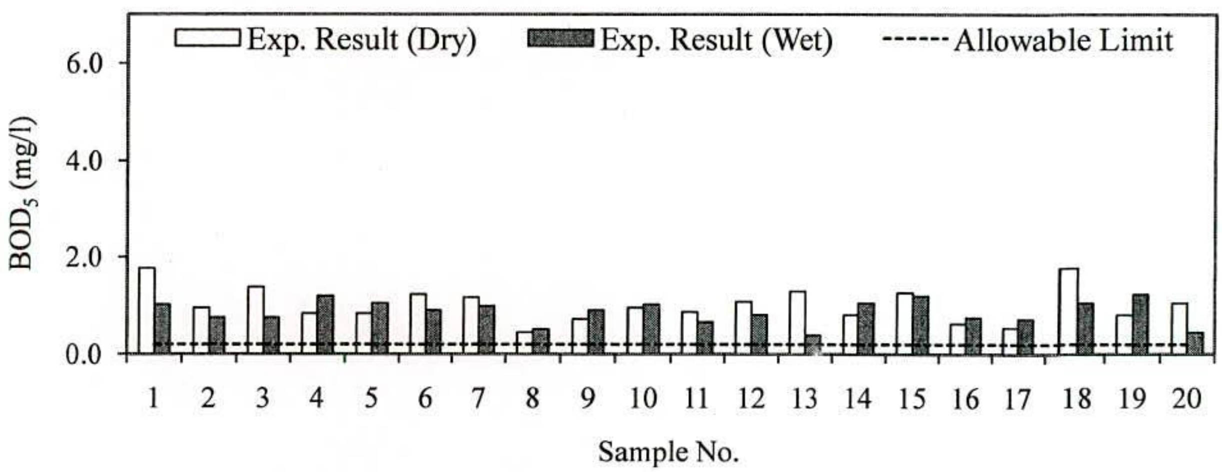


Figure 5.13 Concentration of BOD_5 in groundwater during dry and wet season, 2012

It was found that BOD_5 in all of sources of groundwater during both dry and wet season was higher compared to Bangladesh standard limit of drinking water showing in Figure 5.13. In the Figure, it was shown that value of BOD_5 varied from 0.45 mg/l to 1.77 mg/l and 0.39 mg/l to 1.23 mg/l in dry and wet season, respectively. For drinking purpose, value of BOD_5 is 0.2 mg/l according to Bangladesh standard limit.

In Figure 5.14, it was shown that COD concentration in groundwater sources varied from 32 mg/l to 128 mg/l in both dry and wet season, respectively which was higher than 4 mg/l, Bangladesh standard limit for drinking purpose.

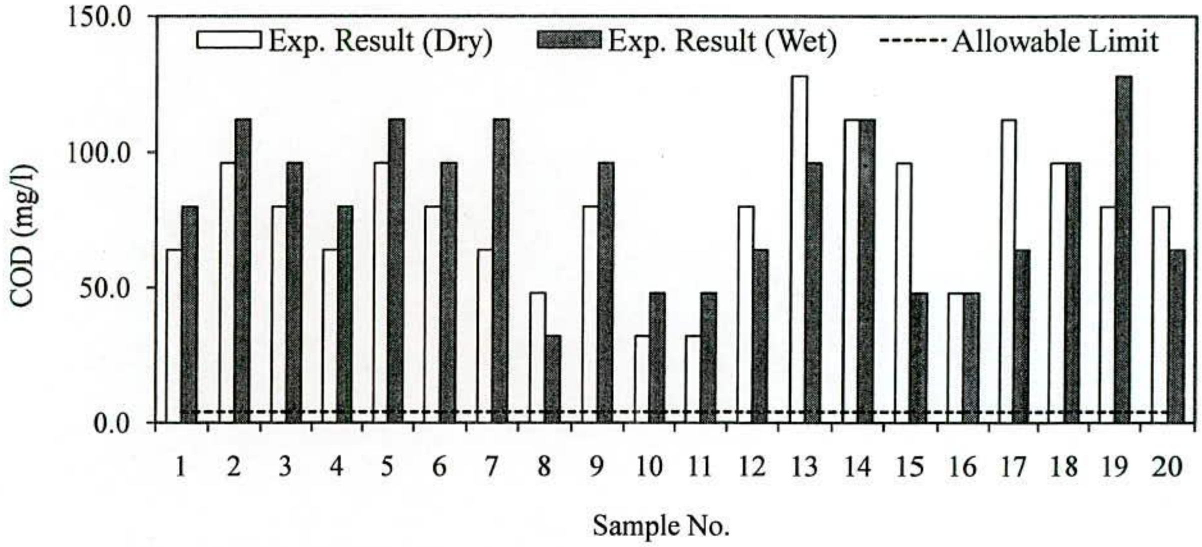


Figure 5.14 Concentration of COD in groundwater during dry and wet season, 2012

5.3.2 Microbiological water quality

5.3.2.1 Surface water

Ponds as source of surface water surrounding EcoSan toilets were introduced for analyzing the quality of water. After collecting the water samples, laboratory experiment was conducted and results were shown in Table 5.4. To indentify the microbiological contamination of pond water through EcoSan toilet was the main reason of the laboratory test. Water samples were collected from the ponds which were within the distance of 10 m from EcoSan toilets. Table 5.4 presents the amount of microbiological parameters such as fecal coliform (FC), E. Coli (EC) and total coliform (TC) in pond water. The results of two seasons; dry and wet were presented in the Table.

Table 5.4 Microbiological water quality of pond waters in dry and wet season

Statistic	FC		EC		TC	
Result	N/100 ml		N/100 ml		N/100 ml	
Season	Dry	Wet	Dry	Wet	Dry	Wet
Min	50.00	50.00	60.00	115.00	190.00	315.00
Max	190.00	300.00	180.00	225.00	390.00	575.00
Mean	112.50	168.00	125.50	173.50	307.50	428.00
Median	102.50	147.50	130.00	172.50	310.00	405.00
Std. Dev	52.88	76.75	42.72	35.59	61.07	100.81

Table 5.5 Distance of EcoSan toilets and pit toilets nearest to pond

ID No.	Distance between pond & EcoSan Toilet (ft)	Distance between pond & Pit Toilet (ft)
PW-01	25	-
PW-02	33	20
PW-03	27	17
PW-04	45	22
PW-05	35	15
PW-06	27	15
PW-07	40	-
PW-08	40	35
PW-09	32	-
PW-10	47	27

The microbiological feature in pond water was shown in Figure 5.15, 5.16 and 5.17 that carried the presence of FC, EC and TC, respectively at large scale. Fecal coliform was found varying from 50 to 190 no/100ml and 50 to 300 no/100ml in dry and wet season, respectively showing in Figure 5.15. E. coli varied from 60 to 180 no/100ml and 115 to 225 no/100ml in dry and wet season, respectively showing in Figure 5.16. Total coliform was found varying from 190 to 390 no/100ml and 315 to 575 no/100ml in dry and wet season, respectively showing in Figure 5.17. It was observed that bacteriological contamination was increased in wet season showing in both Figures 5.15 to 5.17.

According to Bangladesh standard, value of FC, EC and TC is 0 no/100ml. However, TC was sum of all types of bacteria including FC and EC. The ponds were found using in many purposes. For instance, bathing of people and washing clothes and utensils; swimming of ducks; falling leaves from surrounding trees, flowing of animal excreta, chemical fertilizer and refuges through surface runoff during rain and washing animal in pond which were responsible for microbiological contamination in pond water which was a limitation in microbiological point of view in the study. However, pit toilets were found nearest to ponds surrounding EcoSan toilets shown in Table 5.5. On other hand, EcoSan toilet protected the contamination because the toilet was a closed system in human excreta management. So it understood that EcoSan toilet was not responsible for this type of contamination.

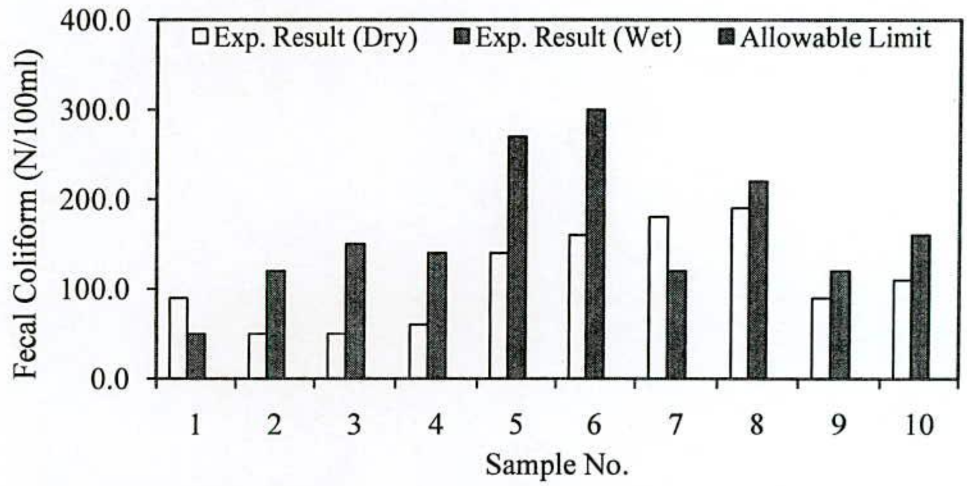


Figure 5.15 Fecal coliform in pond water during dry and wet season, 2012

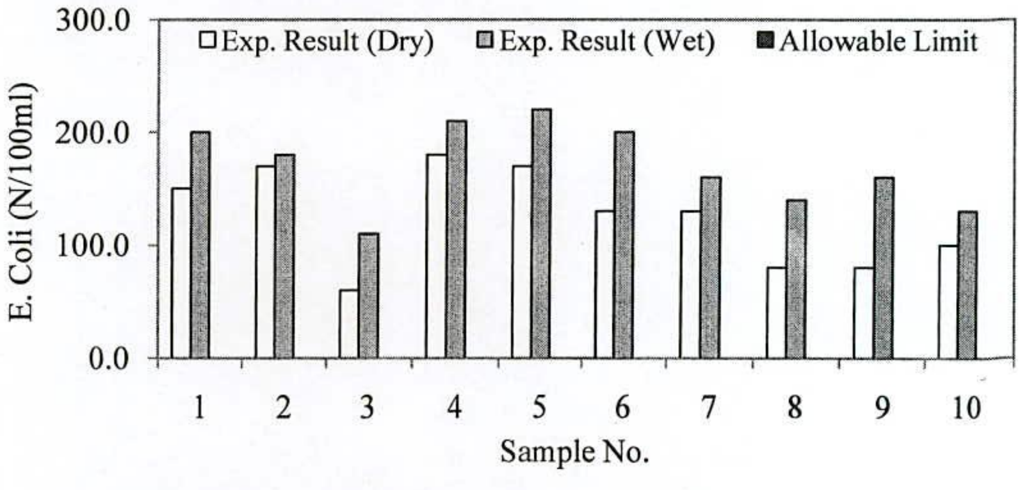


Figure 5.16 E. Coli in pond water during dry and wet season, 2012

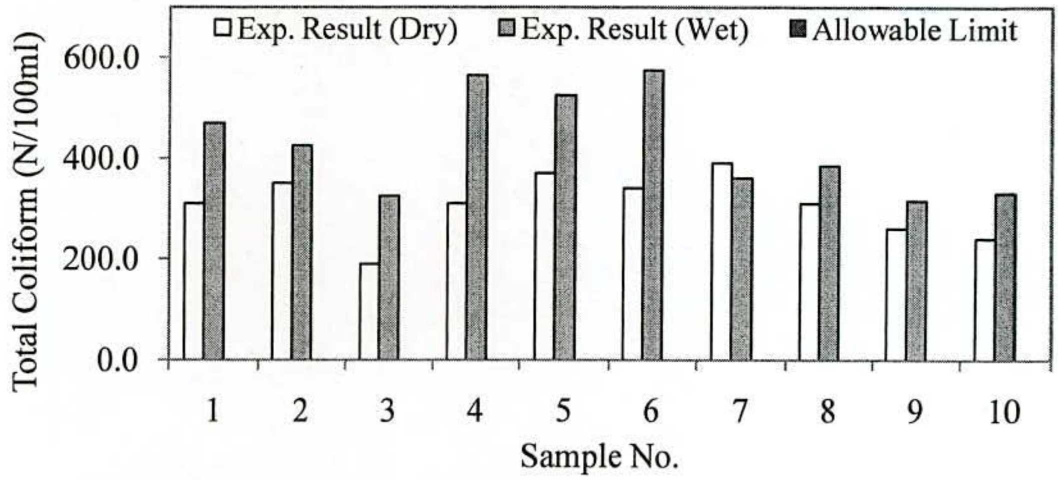


Figure 5.17 Total coliform in pond water during dry and wet season, 2012

5.3.2.2 Groundwater

Tube-wells were considered as source of groundwater surrounding EcoSan toilets were introduced for analyzing the quality of water. After collecting the water samples, laboratory experiment was conducted and results were shown in Table 5.6. To indentify the microbiological contamination of Tube-well water through EcoSan toilet was the main reason of the laboratory test. Water samples were collected from the tube-wells which were within the distance of 10 m from EcoSan toilets. Table 5.6 presents the amount of microbiological parameters such as fecal coliform (FC), E. Coli (EC) and total coliform (TC) in pond water. The results of two seasons; dry and wet were presented in the following Table.

Table 5.6 Test result of microbiological parameters of groundwater in dry and wet season

Statistic	FC		EC		TC	
Result	N/100 ml		N/100 ml		N/100 ml	
Season	Dry	Wet	Dry	Wet	Dry	Wet
Min	0.00	0.00	0.00	0.00	0.00	0.00
Max	8.00	4.00	4.00	8.00	40.00	18.00
Mean	0.70	0.20	0.50	2.60	6.50	5.40
Median	0.00	0.00	0.00	0.00	0.00	3.00
Std. Dev	2.18	0.89	1.10	3.38	10.80	6.19

Table 5.7 Distance of EcoSan toilets and pit toilets nearest to tubewell

ID No.	Distance between tubewell & EcoSan Toilet (ft)	Distance between tubewell & Pit Toilet (ft)
TW-01	15	21
TW-02	27	-
TW-03	8	-
TW-04	25	17
TW-05	33	13
TW-06	12	-
TW-07	17	15
TW-08	15	-
TW-09	15	-
TW-10	45	-
TW-11	7	-
TW-12	24	-
TW-13	26	24
TW-14	20	-
TW-15	20	-
TW-16	30	22
TW-17	13	-
TW-18	13	-
TW-19	21	11
TW-20	24	-

The microbiological effect in groundwater was shown in Figure 5.18, 5.19 and 5.20 that carried the presence of FC, EC and TC, respectively. Fecal coliform was found varying from 0 to 8 no/100ml and 0 to 4 no/100ml in dry and wet season, respectively showing in Figure 5.18. E. coli varied from 0 to 4 no/100ml and 0 to 8 no/100ml in dry and wet season, respectively showing in Figure 5.16. Total coliform was found varying from 0 to 40 no/100ml and 0 to 18 no/100ml in dry and wet season, respectively showing in Figure 5.17. It was observed that bacteriological contamination was increased in wet season except Figure 5.18. According to Bangladesh standard, value of FC, EC and TC is 0 no/100ml. It was found that presence of coliforms was higher in surface water than groundwater although pit toilets were found nearby groundwater shown in Table 5.7. In case of groundwater, coliforms were very few at presence of pit toilets. So, it is concluded that it was not possible making contaminated water through EcoSan toilets.

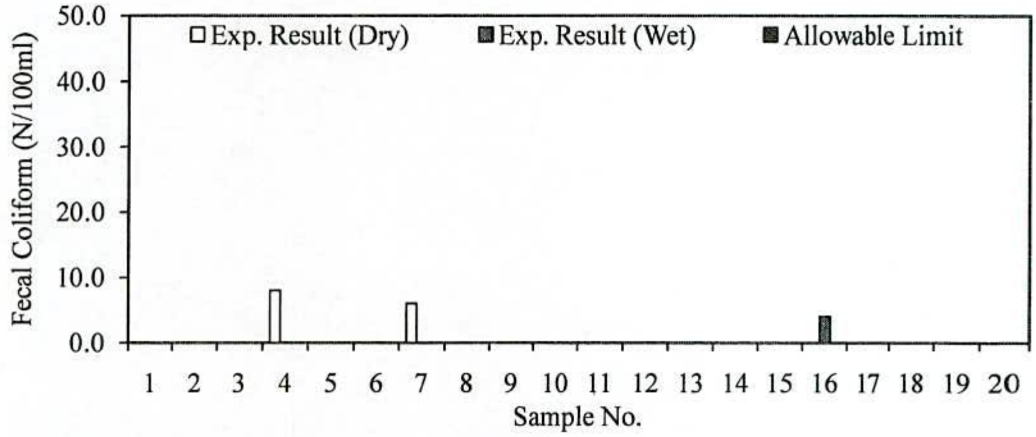


Figure 5.18 Fecal coliform in tubewell water during dry and wet season, 2012

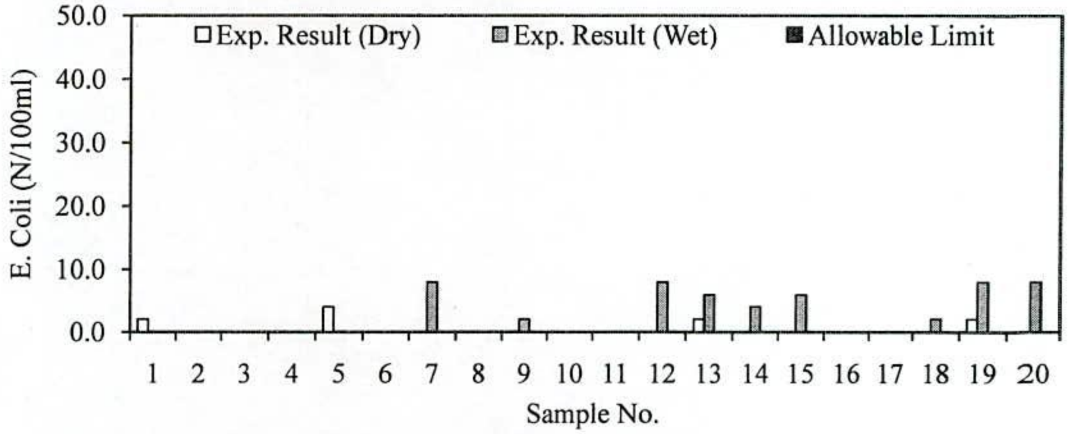


Figure 5.19 E. Coli in tubewell water during dry and wet season, 2012

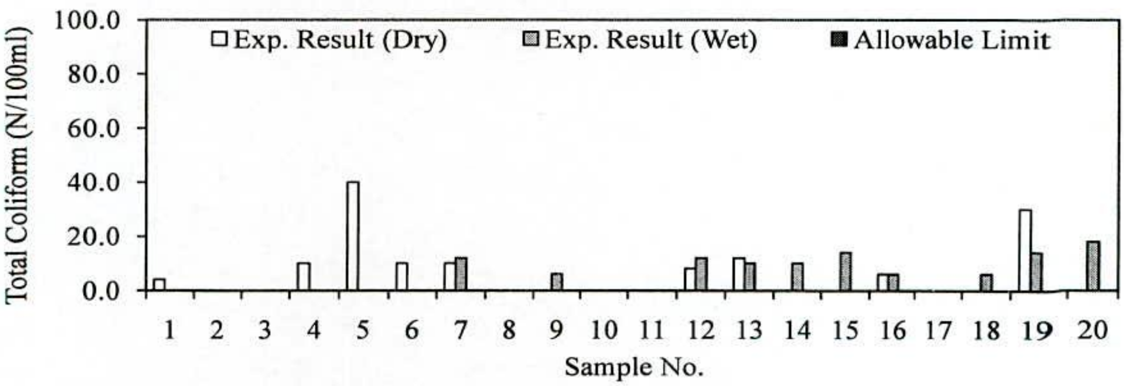


Figure 5.20 Total coliform in tubewell water during dry and wet season, 2012

5.4 Conclusions

- In case of microbiological parameters, experimental results of surface water in dry and wet season were much higher than Bangladesh standard limit. As a reason, it was found that the pit toilets nearby those ponds were used in various purposes. On the other hand, experimental results on microbiological studies in groundwater were found to be less contaminated in comparison to surface water quality though pit toilets were located surrounding the tubewells. Thus, it is concluded that surrounding water sources of EcoSan toilets were not polluted through the toilets. Because the structure of feces vaults were made of bricks and plastered with cement grouting both inside and outside.

- Based on the experimental results, it was found that EcoSan toilets are safe and reliable technology.

CHAPTER 6

PROPOSALS FOR DESIGN MODIFICATION OF EXISTING ECOSAN TOILETS

CHAPTER 6

PROPOSALS FOR DESIGN MODIFICATION OF EXISTING ECOSAN TOILETS

6.1 Background

The fourth and final objective of the research work was to modify the design of existing EcoSan toilets. This chapter presents the modified design as a replacement for existing design of squat plate, used in EcoSan toilets. The existing design has been modified to ensure easy and comfortable operation of the toilet. Modified design is a solution of problems in operating system of existing design. Existing EcoSan toilets were being used by rural beneficiaries with good operation and maintenance but most of them felt disturbed due to some difficulties, described in chapter 4. The purpose of the design is to accumulate the activities at once sitting on a pedestal during and after defecation such as to be careful for diverting urine and feces, removing lid to open defecation hole, movement to another place for anal washing, placement a lid over the hole. In brief, the design is proposed for sustainable development of rural sanitation in the context of Bangladesh.

6.2 Design of existing EcoSan toilets

Figure 6.1 represents a layout of an existing EcoSan toilet. Area of the toilet is measured about 114 sq. ft. Different parts of the toilet; two feces chambers, an evaporation bed, staircase are also located in this Figure. The structure of toilet was built with brick column of 10 x 10 inch at four corners. Line along first periphery indicates earthwork that is necessary to level the ground by cutting soil up to 6 inch and filling the deep with local sand. The second periphery marks the margin of base slab, made of cement concrete and flat brick soling upon which brick wall stands. The third periphery is boundary of brick column and wall. Staircase with four treads and five risers has been shown in the Figure. There is no handrail along the staircase. A partition wall of which thickness is 5 inch lies between two chambers of feces shown in the Figure.

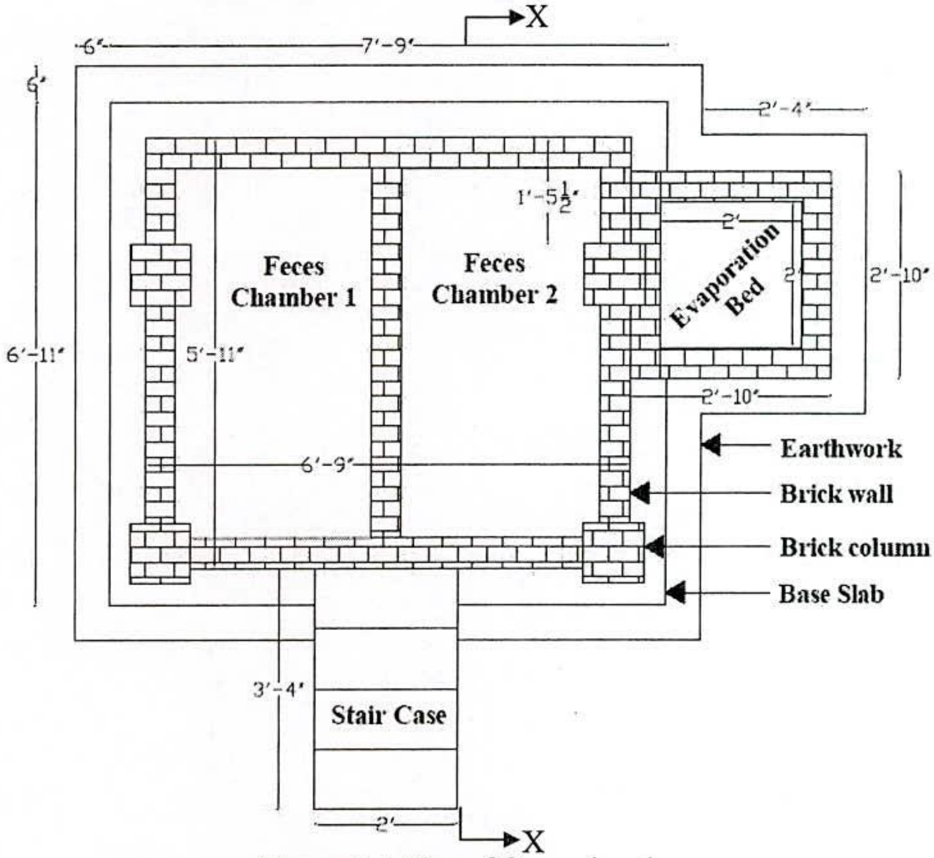


Figure 6.1 Plan of feces chamber

Figure 6.2 illustrates the top view of floor upon the feces chambers. The floor indicates roof of these chambers although it does not cover full area of chambers. Rest of the area is covered by galvanized iron sheet called heat panel because the sheet gets heat from solar radiation for which inside of the chamber is heated. For this reason, temperature inside the chamber rises and pathogenic organisms are inactive at higher temperature. However, the chamber remains air tight because defecation hole and backside are covered by lid and heat panel, respectively and surrounding walls and bottom of it are made of bricks and cement concrete, respectively. Backside of the chambers is inclined at top on which the heat panel is set up because rain water cannot stand on it. After setting heat panel, surrounding gap is filled by cement mortar so that it can be easily removed when the chamber will be emptied. Pipes of 1.5 inch diameter through which urine and anal washing water pass, position and diameter of defecation hole, place of urination and anal washing, pedestals on which man sits during defecation and/or urination, set up of door, position of air vent pipe of 2 inch diameter, plan of evaporation bed and measurement of all dimensions are shown in the Figure 6.2.

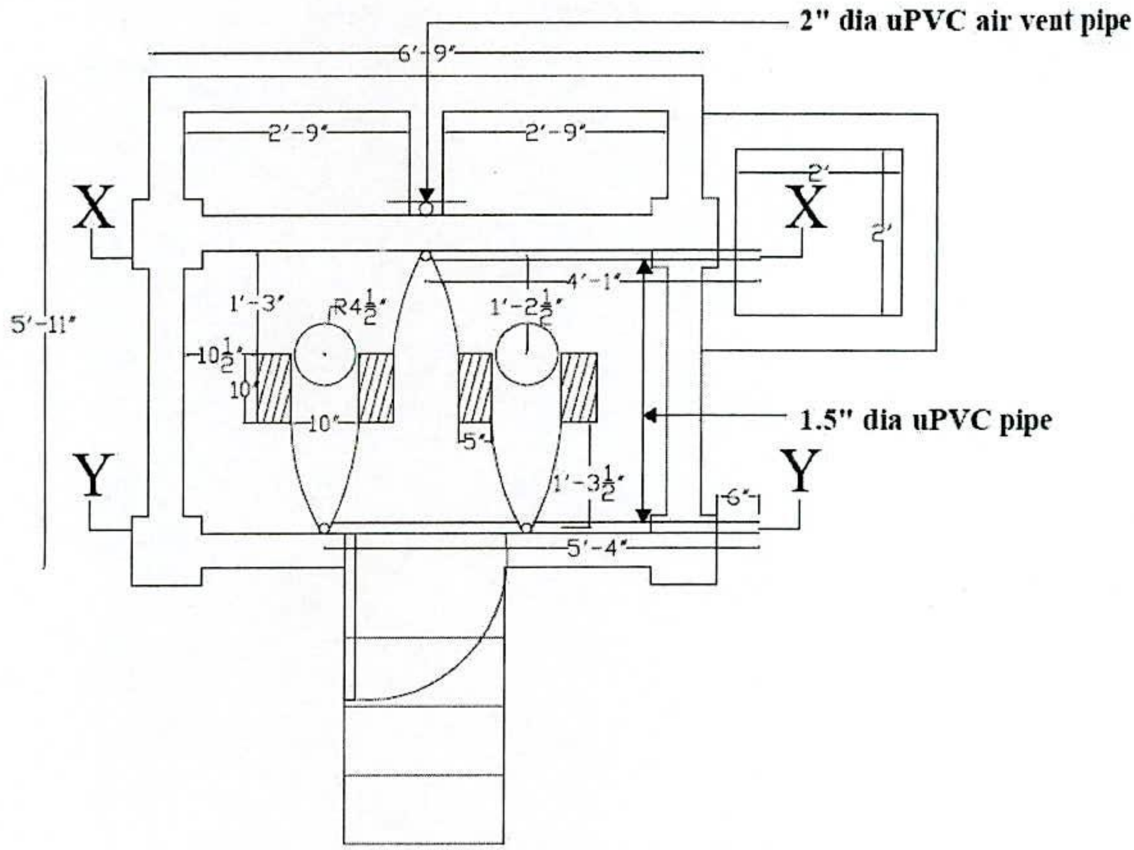


Figure 6.2 Plan of Floor of existing EcoSan toilet

A cross section of floor along the longitudinal direction marked by X-X is illustrated in Figure 6.3. Slope of anal washing water passing pipe, cross section of evaporation bed, aggregates in the evaporation bed are shown in the Figure. It is clearly understood that anal washing water passes through the pipe and falls on the evaporation bed through which liquid part infiltrates into soil and solid part (little amount of feces) remains on brick chips and gets dried at sun light. Vertical distance between inner and outer ends is 7 inch showing in Figure. The three dimensional measurement of floor slab, made of reinforced cement concrete is 81 inch long, 51 inch wide and 4 inch thick.

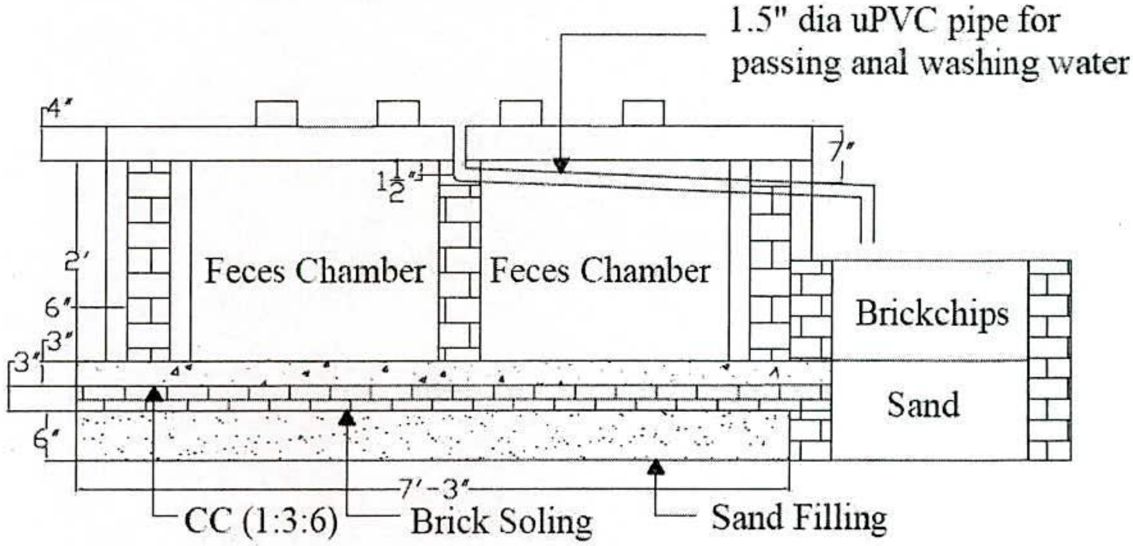


Figure 6.3 X-X cross section of feces chamber

Another cross section of floor along the longitudinal direction marked by Y-Y is shown in Figure 6.4. The Figure presents collection of urine into urine container. Urine passes through the pipe of1.50 inch in diameter at slope. Vertical distance of outer part with respect to inner part is also 7 inch. Urine container is placed on ground.

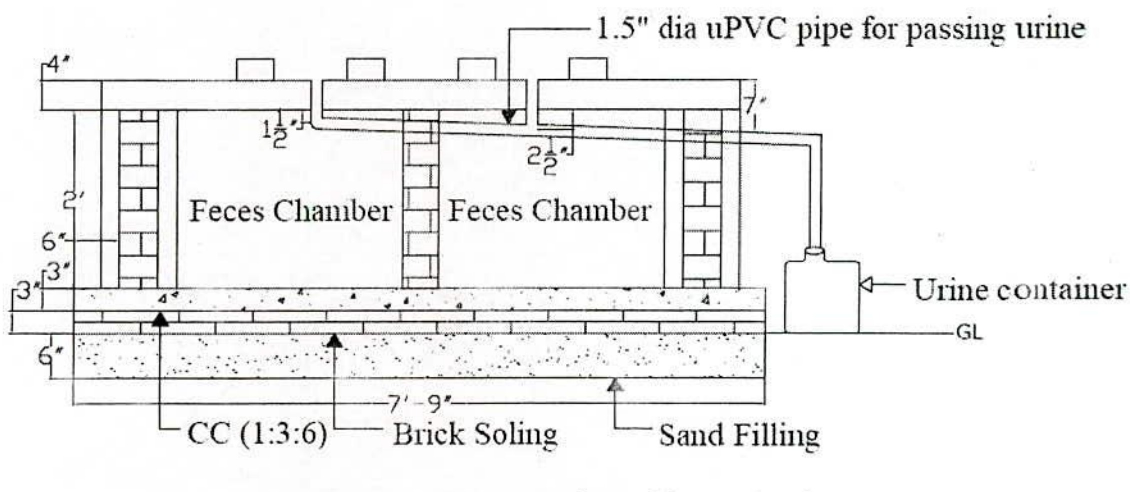


Figure 6.4 Y-Y cross section of feces chamber

A side elevation of existing EcoSan toilet is shown in Figure 6.5. The Figure presents a cross section of complete EcoSan toilet. Rain water passing system from the roof, roof made of reinforced cement concrete, ventilation of toilet and all dimensions are arranged in the Figure.

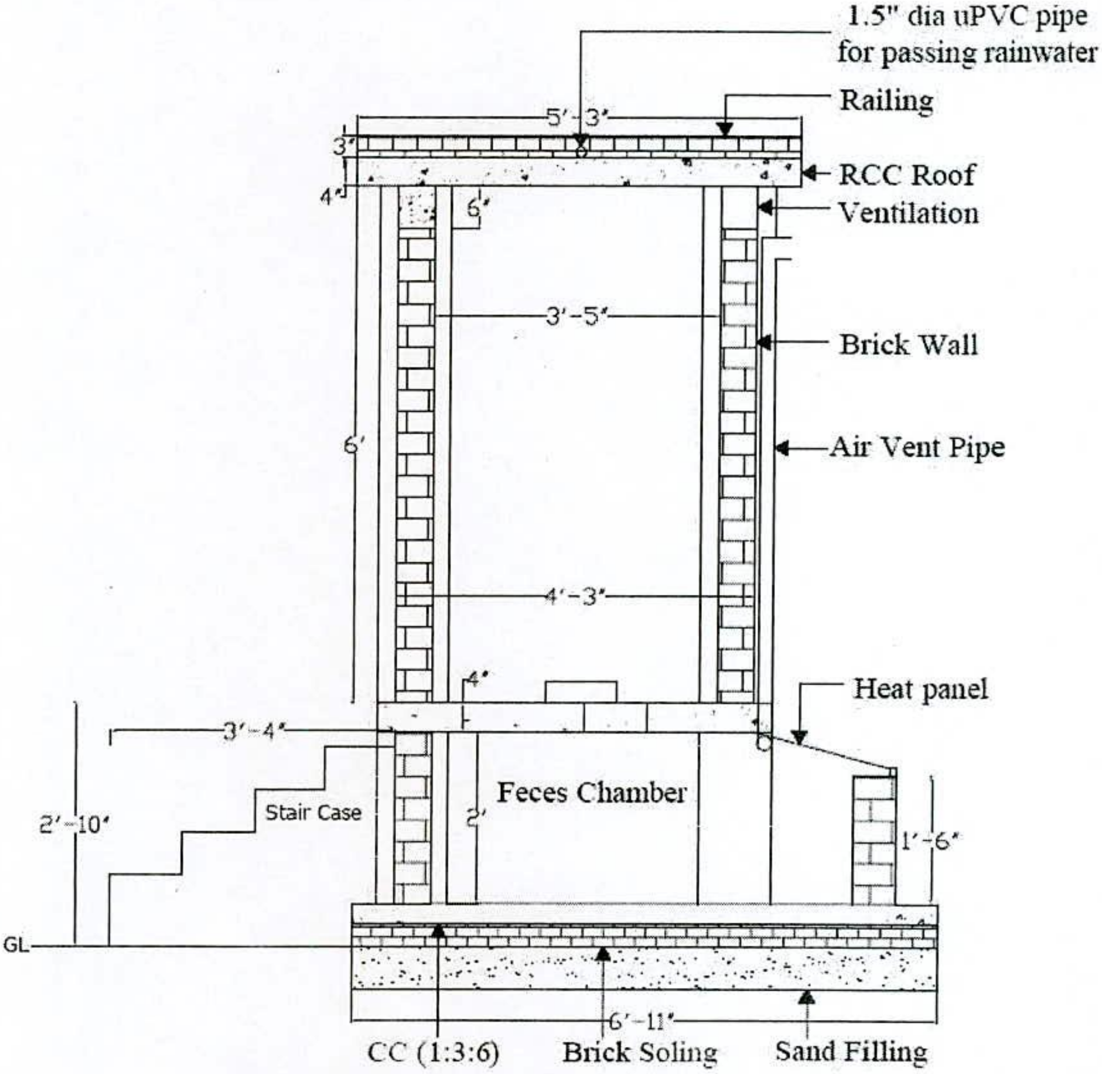


Figure 6.5 Side elevation of existing EcoSan toilet

6.3 Problems in the existing design

EcoSan families are well known and trained to use the toilets and its benefits. They are also sound practiced to keep the toilet neat and clean and proficient to prompt non-EcoSan users about the concept of ecological sanitation. But their relatives are unknown to use the toilet having different mechanisms in operating system for which the toilet is completely new technology to non-EcoSan users and absent at their home. Practically, it is true when the EcoSan toilet was installed in Banshbaria in 2009, people of this area were not practiced at first but they were being experienced in using the toilet day by day. It is difficult to use the EcoSan toilet having some differences in its mechanism from other types of toilet such as pit toilet, double pit toilet, direct pour flashing toilet, community latrine, septic tank system toilet etc. Removing cover, keeping ash into hole, covering hole and changing position for anal washing for which EcoSan is complicated than those types of toilet in Bangladesh because those systems are completely absent in these types of toilet. In the study area, the existing EcoSan toilets run well and users are satisfied but some users both men and women are disturbed in its operating system that is marked as problem. In previous chapters, many types of problems such as social and technical in O&M are described.

The problems based on design of EcoSan toilets are out lined below:

- Opening the defecation hole before defecation
- Adding ash to spread over the feces into the chamber
- Closing the hole after defecation
- Movement from defecation place to anal washing place
- In religious point of view, the toilet is not perfect to use.
- It is difficult to use the toilet for children/aged person
- To clean the evaporation bed
- To replace the corroded heat panel
- To remove the ash in the pipes when it gets blocked by pieces of paper or ash
- Removing the feces from the vault
- Operation of urine container

Alternatively, the toilet has some following advantages:

- EcoSan toilet does not need water for flashing
- It protects the environment
- It allows the nutrients in human feces and urine to be returned to the soil as fertilizer
- It does not need extra place for septic tank
- It doesn't create bad smell
- It may be constructed along with bed room for ease of access at night and/or in rain and
- Cost effective

If the existing design is modified as a good solution of these problems along with above advantages, all of EcoSan users will use the toilet comfortably and its social acceptance will be increased.

6.4 Design modification for sustainable development

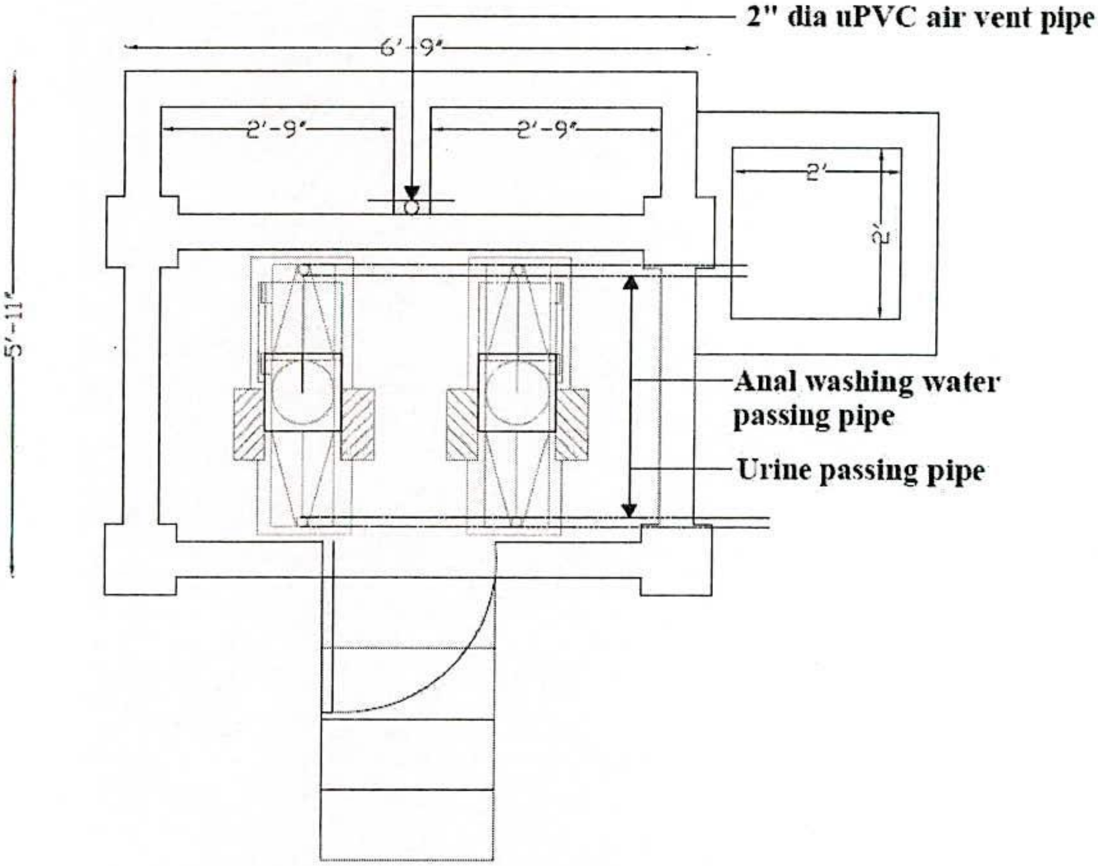


Figure 6.6 Plan of floor with modified squat plate

The EcoSan toilet was negatively impacted with the operating system. The specific problems, related to this issue, were identified and their solutions were proposed in Figure 6.6. According to the research objective, design of the existing EcoSan toilets had been modified, especially squat plat where urine and feces will be diverted, urine will be passed through pipe smoothly so that it cannot come back to human body; lid will be easily operated before and after defecation and users will use water for washing their anal simultaneously. Plan of floor where a couple of squat plate has been attached is illustrated. The squat plate was designed without changing the total area of floor and position of pipes in the toilet. Two types of plate; left and right were designed considering alternate usage of feces chambers on which they are set. Plan of both existing and modified design of toilet is same but differs in arrangement of squat plates. In the existing design, manually operation of lid and different place of defecation and anal washing which completely absent in the modified design. The design arranged a combination of mechanically operated lid and using it for anal washing over the defecation hole that make the EcoSan toilet more comforTable than previous mechanism. The plate is a frame that will be set on the floor during its construction period. After finishing shuttering work, the plates will be placed according to its position. Then the pipes will be connected at below the floor slab same as existing design showing in Figure 6.7.

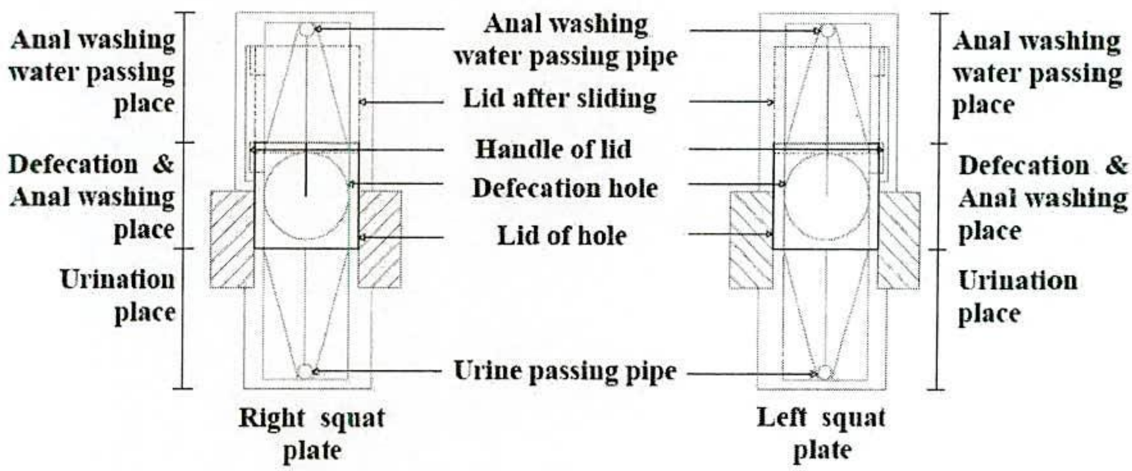


Figure 6.7 Components of combined squat plate

A couple of squat plate was designed accumulating its functioning place; anal washing water passing place, place of defecation and anal washing, place of urination and operating components; anal washing water passing pipe, defecation hole, lid of defecation hole attached with a handle, sliding nature of lid to removed and placed upon the hole and urine passing pipe shown in Figure 6.7. Right and left squat plates were justified based on user's sitting on it. User will sit on the right and left plate looking front of the toilet where handle of lid are positioned at his/her right and left hand side, respectively. Operating systems of the squat plate are given below:

- At first, user will sit on the pedestal.

- Defecation hole will be opened by sliding the lid backward so that feces fall directly downward and diverting urine drop at sloped plane to be collected into urine container.
- After defecating, ash will be added into the feces chamber spreading over the feces.
- Then lid will be slid forward to cover the hole so that anal cleaning water drops on it.
- Anal cleaning water will fall on the evaporation bed along flowing over the lid at slop.
- Then user will come out the toilet and wash their hands with soap.

Figure 6.8 and Figure 6.9 are showing the plan and side elevation of right and left squat plate, respectively.

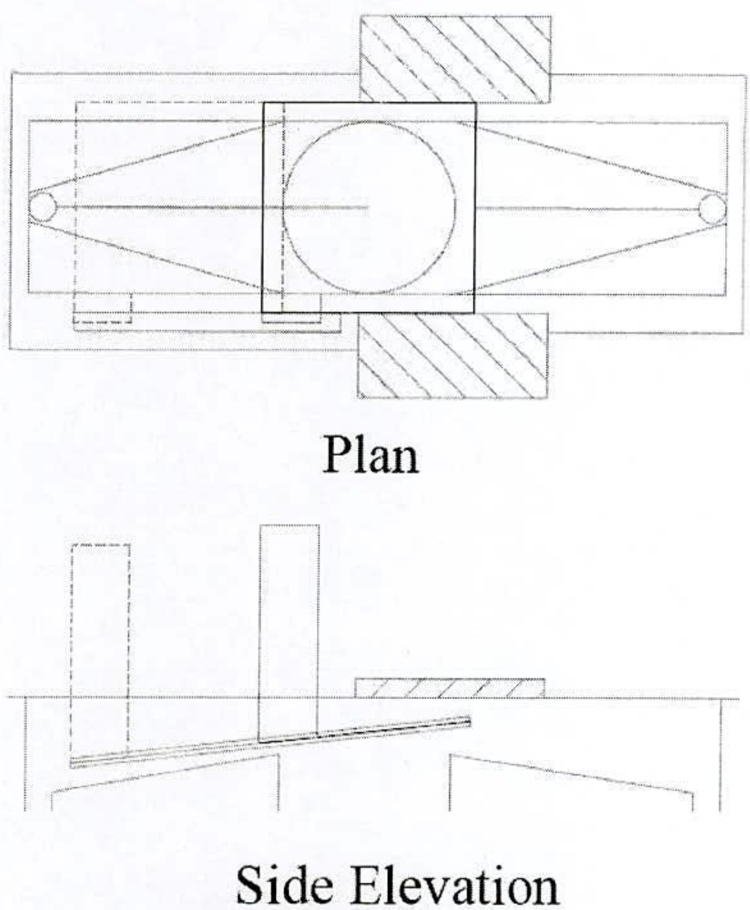
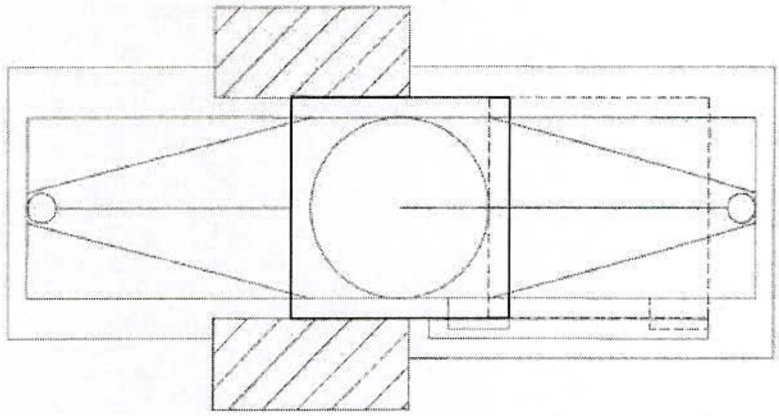
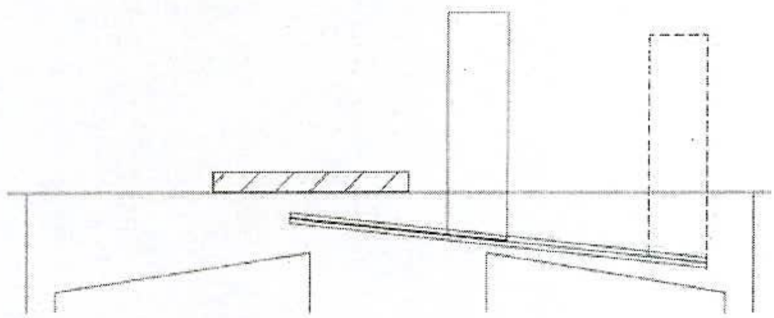


Figure 6.8 Design of right squat plate



Plan



Side Elevation

Figure 6.9 Design of Left squat plate

Figure 6.10 is showing all dimensions of the squat plate.

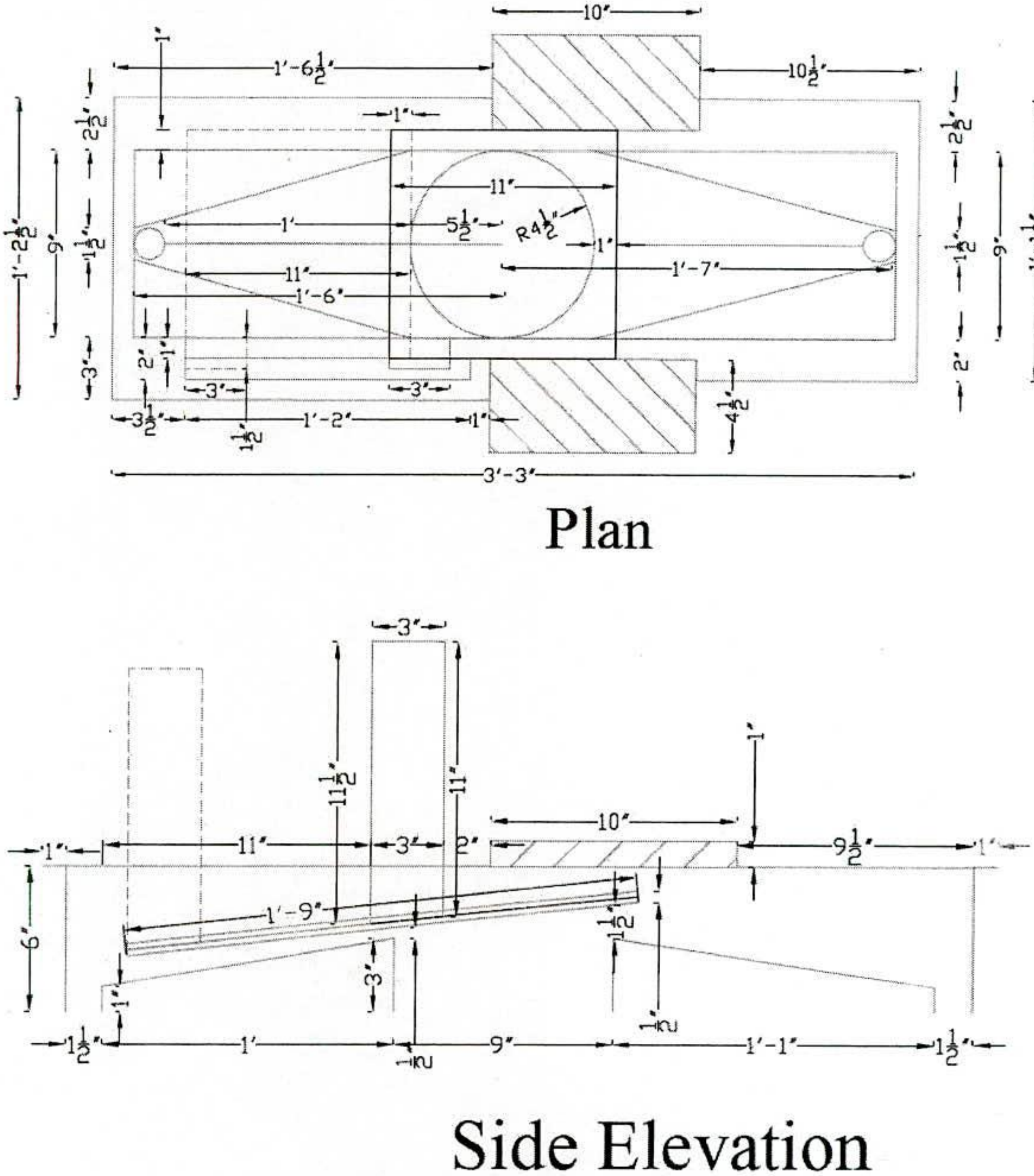


Figure 6.10 Measurement of squat plat

6.5 Operational guidelines for safe sanitation

EcoSan toilet was treated as a good management of human excreta that are very much harmful in unacceptable management. Nutrients of urine and feces are returned to the soil recycling through EcoSan toilet. Users were benefited applying the nutrients in the agricultural field. Practically, most of the users were well known in field application of urine and feces which was possible for good operation and management. For sustainability of EcoSan toilet, operational guidelines are outlined below:

- Ash should be kept in a pot that remains in the toilet.
- Ash that is free from charcoal will be added in the feces vault after every visit the toilet because ash make feces dry that is easy to handle or transfer.
- After using tissue, it is to be deposited in a basket that is kept in the toilet. Nonetheless, tissue is not allowed to throw into feces vault and pipes.
- It is mentioned that pipe may be blocked by solid part in ash; charcoal and tissue.
- Pipes should be checked by GI wire on regular basis due to possibility of blockage.
- User should be careful during urination so that urine cannot go into the vault.
- They should be aware for the period of cleaning the toilet in order that water may not go through the feces vault.
- It is conceptual that water does not go into the vault during anal cleaning. If water enters or insects are found into the feces chamber, ash will be added instantly in sufficient quantity.
- Grease will be added in the channel through which lid slides for easy movement.
- Rearrangement of coarse aggregates in the evaporation bed is an important task.
- Urine container should be removed before flowing over.
- Urine should be applied to the plants getting mixed with water at proper ratio. Nevertheless, raw urine is not allowed to apply directly to the plants.
- When one feces chamber is fulfilled, it is closed so that no air passes into it. It will be emptied when another one will get fulfilled. However, removing and applying the feces will not be done simultaneously.

6.6 Conclusions

- To overcome some problems, design of EcoSan toilet was modified that was proposed in the study. Comparing design of existing and modified EcoSan toilet, it is confirmed that modified design will be easier than previous. It is a better solution of those problems, observed in existing EcoSan toilet.

- In the existing design, removed lid was placed beside the hole that was not easy because most of the lid had no proper handle and user was replaced for anal cleaning that was very unusual.

- On the other hand, lid will be moved mechanically at an ease operation and used as a plate on which anal cleaning water drops but does not go through the vault and user does not need to transfer another place. For these reason, modified design will formulate the toilet for easy operation and good management.

- Finally, it is concluded that modified design accumulated the solutions of two major problems such as replacement of lid and changing place for anal cleaning which will be operated at once.

CHAPTER 7

CONCLUSIONS AND RECOMMENDATIONS

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7.1 Background

The research explored the modified design of existing EcoSan toilet, concept of ecological sanitation in the context of rural Bangladesh. The study had four major objectives: (1) to study the field performance of existing EcoSan toilets regarding its socio-economic acceptance by rural population in Bangladesh; (2) to identify the technical problems in the operation and maintenance of EcoSan toilets; (3) to investigate any possible contamination of groundwater/surface water resources around the EcoSan toilets; and (4) design modification of EcoSan toilets for its sustainable development in rural Bangladesh. Conclusions with regard to each objective are stated in section 7.2 and recommendations are listed in section 7.3.

7.2 Conclusions

Concerning the first objective of this study, the field performance of existing EcoSan toilets regarding its socio-economic acceptance by rural population in Bangladesh was highly appreciated in response to rural people who were using the toilet. 94 nos. families using EcoSan toilets were found in the study area. It was found that rate of literacy was 38.97% among the agriculture based families of which 82% were directly involved in agriculture. On the other hand, organic fertilizer, recycling urine and feces produced from EcoSan toilet were being used in field of different types of crops, vegetables and fruits. So, it can be said that EcoSan toilet and agriculture are directly correlated with each other. The life style of those users was very poor due to lower rate of literacy with low income which roughly affects the self interest on sanitation and hygiene practice. Social acceptance of EcoSan toilet was dependent on users' performance that is interlinked with concept of sanitation based on literacy, occupation and income. Both urine and feces carry the valuable nutrients; nitrogen, phosphorus and potassium which are richer in urine than feces. The value of equivalent profit of these nutrients was developed analyzing the chemical properties and market price. According to economic point of view, EcoSan toilet was impended as a source of income. It was found that one person can produce fertilizer in organic form instead of chemical fertilizer, equivalent to BDT 286.28 through EcoSan toilet. Not only that but also the toilet was treated as sanitation business for which community based organization (CBO) was mainly responsible. A community may be developed in economic through the sanitation business. EcoSan toilet was profitable through reduction of medical cost and loss of income due to illness which is another positive attitude of this technology. EcoSan toilets made the users hygiene practiced through ensuring the suitability in using during waterlogged condition. The toilets were satisfied up to water depth of 60 cm during flood period. During the last flood, it was observe that inside of the feces vault was dry.

With reference to second objective of the study, some social, operational and maintenance problems of EcoSan toilets were identified. Performance of EcoSan toilets was found good although the toilets had some problems. In religious point of view, some users recommended that the toilet was not perfect to use. This was marked as a social problem that was found in field investigation. One technical issue was related with the problem. The issue was improper slope at place of urination that was fault of construction. If the slope was made properly, the problem was solved. In technical point of view, proper slope was considered in modified design of squat plates in EcoSan toilet. Finally, it is concluded that above 70% users expressed the positive attitudes on EcoSan toilets. Relatives of those users were disturbed that was found in baseline survey. Among the problems, to remove and place the lid over defecation hole, to add ash and/or sawdust into feces vault to over the feces, transferring from defecation place to anal washing place were main operational problems. Other problems were removing the urine container when it was fulfilled, emptying feces vault, pipe blockage, disturbance of children and aged person to use the toilet etc. These problems were minor that might be solved by regular observation because urine container was removed per week, feces vault was emptied per year, pipe blockage could be removed by GI wire on regular basis, children and aged person should be checked when they entered into the toilet. But major problems did not need any regular observation or maintenance. Those problems need permanent solution. As a solution, design of squat plates in existing EcoSan toilet had been modified. In the modified design, user will operate the toilet sitting at once i.e. movement of lid and anal cleaning will be possible at same place but ash will be added as previous design. So, monitoring is a most essential duty of toilet owner and private organizations that are related with its activity. In this case, toilet owners have more responsibilities to check the important points of toilets that may be disturbed. After all, in socio-economic point of view, EcoSan toilet was an appropriate technology in rural Bangladesh.

Third objective was addressed to investigate the possible contamination of groundwater and surface water around the EcoSan toilets. To identify the contamination, samples were collected from both ground water and surface water resources for both physiochemical and microbiological test. No. sampling points were 30 in two times per year; dry and wet season. For the experimental results of physicochemical parameters, it was found that experimental values in both dry and wet season were with Bangladesh standard limit for which the toilets did not affect the surrounding water sources. On the other hand, results of all microbiological parameters of surface water were above the Bangladesh standard limit in both seasons. But bacteriological contamination in groundwater was found little more in both seasons compared to surface water. EcoSan toilets were closed system of dry sanitation. So, it has no opportunity to get mixed with surrounding water bodies. However, there were some pit toilets nearby the ponds and tube-wells in the study area, found in baseline survey. This was limitation of the study.

Regarding the fourth objective of this study, the existing design of squat plates in EcoSan toilet was modified for sustainable development. Modified design of the plates is frame in which two tasks such defecation and anal cleaning will be finished at same place; no transferring is required. Figures of the plates with dimension, position on the floor, operational mechanism were described in the respective chapter. In the baseline survey, it was found that users were greatly demanded for accumulation of these tasks at once sitting in the toilet. To be transferred from defecation place to anal washing place is much polluted task for human being. In context of Bangladesh, people are culturally habituated in using water for anal cleaning at place of defecation. However, this technology (existing deign of EcoSan toilet) was completely astounded to the users in the study area. So they needed a modification in the design of EcoSan toilet. And according to this requirement, a modified design was proposed in the research work.

One important finding of this study is that, perception of a new idea among the inhabitants was so much high in the village of Banshbaria under Keshabpur Upazila in Jessore district where the many piloting projects on establishment of EcoSan toilets were carried out from

2008 to 2011. However, trend of perception was being gone through upward during the project period. It is mentioned that they were very week in sanitation point of view for which a good technology for safe defecation and its good management was required. In brief, they were greatly thanked for accepting the EcoSan toilet in concept of ecological sanitation

The users not only had used the toilet but also used the organic fertilizer that was produced from EcoSan toilet. Most of them used urine getting mixed with water and the recycled feces in fields of rice, jute, potatoes, onions etc. They were very pleased because production rate of crops was good. They were satisfied for another reason that cost of chemical fertilizer was reduced after getting organic fertilizer from the toilet. They were benefited using the fertilizer in the quality and quantity of crops. So EcoSan toilet can be sustainable technology for saving the living environment pollution of water and soil, increasing fertility of land, reducing the necessity of water for flushing in toilet, possible reduction of medical expense and suitability in waterlogged areas with good management of human excreta.

7.3 Recommendations

Within the scope of this research, it was aimed to modified design of existing EcoSan toilet in rural areas of Bangladesh. Nevertheless, the defecation facilities in real field situation includes open defecation in small bushes, jute field in the day time and beside roads, in the open field far from home in the night, pit toilets without water seal, hanging toilets. All of these facilities of defecation are defectively influencing the management of human excreta in rural Bangladesh. To recover this problem, EcoSan toilet was introduced in the study area. In the previous chapters of the study, socio-economic acceptance, operation and maintenance, possibility of water pollution, problems of existing design and its modification of EcoSan toilets are described in detail. In the modification, squat plat are designed including operation of lid and anal cleaning without transferring place but it needs to modify more as follows as:

- The design should be modified including such activity; adding ash into feces vault after defecation in the toilet.
- To ensure safe application of recycled urine and feces in agricultural land.

Thus, another modified design approach in which all activities of EcoSan toilet will be operated automatically is recommended for the practical field of rural sanitation in context of Bangladesh.

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ANNEX

Table - A Monitoring records of EcoSan toilets

Name of Toilet Owner		**Date of Monitoring**		**Toilet ID**
	Subject	**Good**	**Bad**	**Remarks (if bad)**
1	Broken part of staircase			
2	Set up of the door			
3	Plaster inside & outside of brick wall			
4	Pedestal of the toilet			
5	Clealiness of defecation hole			
6	Lid of defecation hole			
7	Cleanliness and slope of urinal			
8	Blockage of urine drain pipe			
9	Outer part of urine drain pipe			
10	Set up of urine container			
11	Cleanliness and slope of anal washing place			
12	Blockage of anal washing drain pipe			
13	Outer part of anal washing drain pipe			
14	Wall and aggregates of evaporation bed			
15	Presence of cracks in roof			
16	Set up of air vent pipe with cap at top			
17	Presence of any leakage in feces vault			
18	Presence of flies/insects in feces vault			
19	Set up of heat panel and it surrounding mortar			
20	Availability of ash in the toilet and its usage			
21	Application of urine and feces in farmland			
22	Presence of bad smell surrounding the toilet			
23	How do you feel to use the toilet?			
24	Can children/aged person use easily?			

Table - B List of points of EcoSan toilet have to be checked

Sl No.	Points have to be checked	Remark
1	Blockage inside the pipe through which urine and anal washing water pass	
2	Possibility of breaking the outer part of pipe through which urine and anal washing water pass	
3	Percolation of anal washing water through the evaporation bed	
4	Collapse of brick wall surrounding evaporation bed	
5	Deposition of clay on brick chips in evaporation bed	
6	To observe the fulfillment of urine container	
7	Soil erosion surrounding the toilet	
8	Corrosion of heat panel and steel door	
9	Existence of air vent pipe with its cap	
10	Presence of flies/insects/water in the chamber	
11	Observation on crack between wall and stair case	
12	Plaster of whole structure	
13	Soaking of water through defecation hole	