Ecological Sanitation: A Reality of 21st Century in Developing Countries

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Abstract
About 40% of the World's population is deprived of the drinking water facility whereas the urban populace uses excessive quantity of fresh water to flush the excreta. Recent data shows that more than 2.6 billion people need to gain access to effective and sustainable sanitation and out of this about 2 billion people live in rural areas. Close to 6000 children die each day from diseases related to inadequate sanitation and hygiene, and a lack of access to safe drinking water. In Nepal 73 percent of the people have access to piped water supply whereas only 41 percent have access to improved sanitation. Nepal, one of the poorest countries of the world can not afford centrally controlled conventional waste water treatment plants due to their high operation and maintenance cost. More than 80% of the people are farmers in Nepal. Human excreta reuse had been practiced in agricultural purposes since ancient times but the personal and community hygiene was not taken into account in this process. In this indigenous technology, a long pit like surface drain of about to 40-60 cm deep and 30 cm wide was used for defecation purposes for 10 to 15 people at a time, separately for male and female. Similarly "Naugal" a pit situated below the staircase of almost every house was used to collect the night time urine along with the ash.
Ecological Sanitation is the principle concerned with composting human waste into a nutrient-rich soil amendment. It is based on a number of sustainability criteria like recycling and it provides alternative solutions with or without water, while providing containment, treatment, and recycling of excreta. Such kind of toilet can be designed with or without urine diversion. This work has used appropriate technology and studied their performances in the context of Nepal with full involvement of local people. Two Lab scale reactors, one exposed to sunrays and the other without sunrays were constructed to replicate the vault to collect the faeces. In sunrays model, it was found that in 48 days of observation the faecal coliform presence depleted to 610 cells per gm from the initial value of $7x10^{10}$ and the volatile organic matter came down to 70 % from 98.09 %.
Thus this paper deals with the dry ecological toilet practices in Nepal. Ninety-six dry ecological toilets have been studied and found that these toilets can stand as a successful alternative over other established option of sanitation and also suggests modification for the implementation of dry ecological toilets in Nepal. In respect to social acceptance this study shows that Dry Ecological toilet was found superior to the traditional one in the agro based and low land settlements. Dry Ecological toilets will facilitate for the implementation of model Eco-village and sustainable healthy city, similarly will fulfil the demand of total sanitation concept in emerging towns in developing countries Nepal certainly and this is a reality of twenty first century for the advanced sanitation sector.

Keywords
Dry EcoSan Toilet, Nutrient recovery, Sustainable sanitation

INTRODUCTION

Justifiable and reasonable use of water resources is the call of the day. While many countries in the world are facing chronic shortage of water, waterborne sanitation has become an unrealistic option. Use of water for flushing excreta is not only a senseless matter but also a crime, because 40% of the World's population are deprived of the drinking water facility whereas the urban populace use excessive quantity of water to flush the excreta. This has in turn become a cause for the water

pollution in rivers and streams and ultimately degradation of the environment as a whole. Domestic wastewater, which is disposed off through drains, contributes significantly to the water pollution. About 50 to 60% of the human wastes from toilet are discharged into the river in Kathmandu, which is the major concern for the environmental condition of the city.

Demand of water in Kathmandu valley is 180 million litres per day (MLD), whereas the supply is about 120 MLD and 15% of supplied water is used to flush the excreta. In Kathmandu valley all the rivers including the sacred Bagmati River has been now looking s like an open drain due to the direct disposal of untreated sewage. To reduce the environmental degradation dry EcoSan toilet is the only realistic option in the context of Nepal. This research work was conducted to study the viability of dry EcoSan toilet in Nepal.

Dry EcoSan toilet is defined in this report as the on-site disposal of human urine and faeces without the use of water as a carrier. This definition includes many of the most popular options for low-cost sanitation including pit latrines, Ventilated Improved Pits etc. The dry EcoSan toilet not only lessens the pollution in the water course but also enable the reuse of the urine & faeces as nutrient & conditioner to increase the fertility of soil. This could eventually reduce the haphazard use of chemical fertilisers.

The objectives the study carried out over a period of over two and a half years are:

- To determine the faecal coliform concentration of dehydrated faeces at different time.
- To examine the cost effectiveness of dry EcoSan toilet.
- To compare the performance of dry sanitation system with and without the solar radiation in terms of rate of decomposition of faeces.
- To evaluate acceptability, operation and maintenance of dry sanitation system in the local context.

METHODOLOGY

The entire process of the study of the dry EcoSan toilets was carried out in a set of theoretical and experimental research works. The work was completed in following stages:

Design and implementation of the system

Detailed design of different types of dry EcoSan toilets were made which consisted the design of urine chamber, faeces containing vault, anal cleansing water collection chamber, floor slab, and other components of dry EcoSan toilet. The design was implemented at the community level in the pilot project in Lalitpur district with the leadership of ex-vice chairman of the Village Development Committee. The site was selected such that there was tradition of excreta reuse. Construction of eight toilets was completed.

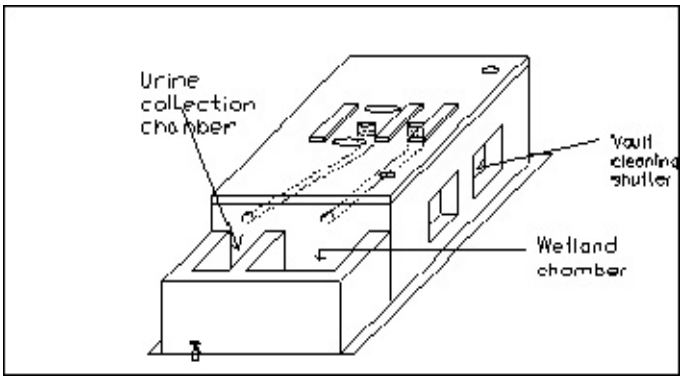
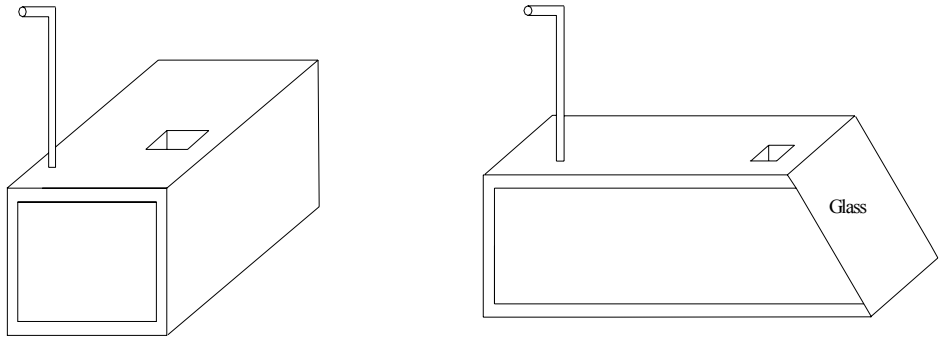


Figure 1: Pilot project Isometric View of dry EcoSan toilet

A base line survey on 60 households of the pilot area was conducted. The survey provided a good overview of the community as well as individual characteristics of local people.

Construction of Lab Scale Reactor

When the researcher has started the study, pilot project was in design phase. So far the pilot project is in construction, in order to monitor the ambient air temperature and the variation of temperature within the reactor another Lab scale reactor was required The model was constructed at the Researcher's house to take the sample of faeces for laboratory analysis in order to find out the decomposition rate and to monitor the temperature in the reactor and the ambient air. The figures of the reactor are presented below in the Figure 2:



Without Sunrays (Reactor 2) Sunrays model (Reactor 1)

Figure 2: Model of EcoSan reactor

Laboratory analysis

In the laboratory analysis methodologies adopted for the study are as follows:

- Faecal coliform of urine and faeces analysis was carried out using the multiple tube fermentation technique.
- The analysis of pH of urine and faeces sample, Electric Conductivity and total dissolved Solid of urine sample was conducted. Similarly the biodegradation of faeces was examined by ignition using Muffle oven at 550^0C.
- Total Nitrogen, Phosphorus and Potassium, TOC were also measured.

Biodegradability of Organic Waste Components

During the study period biodegradability analysis of faeces pile was done. The results of the analysis were used to characterize the chemical composition of the organic matter. Volatile solids (VS) content, determined by ignition at 550^0C, was used as a measure of the biodegradability of the organic fraction of faeces. During the study period total dissolved solids (TDS) analysis of urine was done. Similarly, temperature variations of ambient air and faeces pile were also observed for a period of three months.

Performance evaluation

In order to evaluate the function of constructed dry EcoSan toilets, questionnaires were prepared and distributed to the concerned household and analysed. The responses obtained from the survey were later used to rectify the shortcomings in the design.

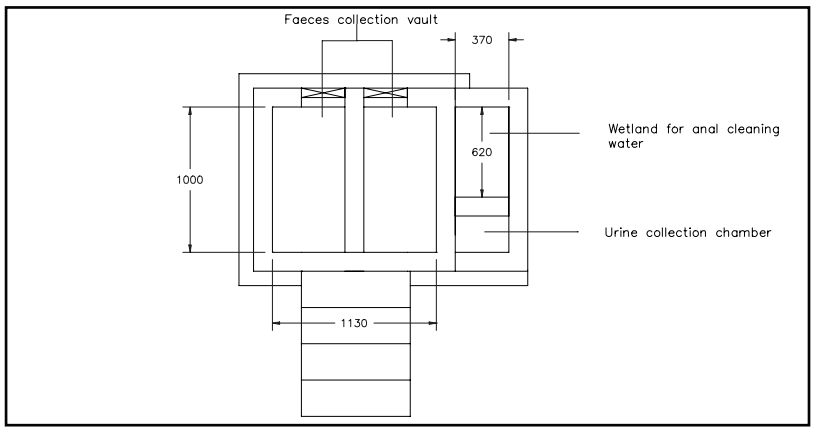


Figure 3: Plan of implemented dry EcoSan toilet

RESULTS AND DISCUSSIONS

Urine Analysis: The analysis of Nutrients (NPK) showed that total Nitrogen, Phosphorous and Potassium was found up to 14.21 g/L, 0.713 g/L and 2.51 g/L, respectively. The results indicate that the sufficient concentrations of major plant nutrients (NPK) are present in urine. In case of flushing toilets these nutrients are wasted and become of a cause of contamination. So, the above result proves the dry EcoSan toilet to be an ecologically better option.

Faeces Analysis: Biodegradability of faeces was carried out taking the sample from the small-scale reactor. During the lab test sample was weighed and taken to the muffle oven at 550 ^{0}C for two hours. Faeces of 25 days storage contain organic matter 93.74 %, after 47 days the percentage of Volatile organic matter was found 70.18 %. Similarly in reactor-2 36 days storage faeces contains 93% volatile organic matter. Whenever after 75 days storage contains 70.56% volatile organic matter. Total organic carbon content of the first day faeces Experimental results shows 56.89% and 48 days faeces 40.71%. Obtained results of reactor one is presented below in the table 4 and reactor two in table 5:

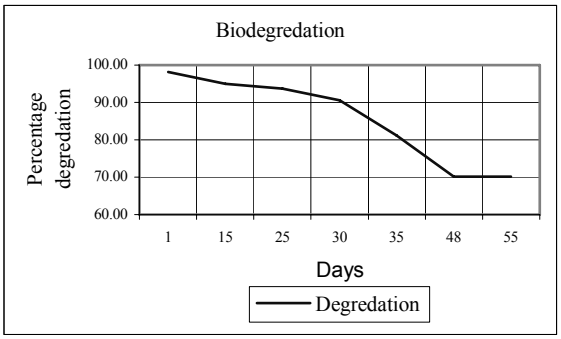


Figure 4: Biodegradation of volatile organic matter reacter-1

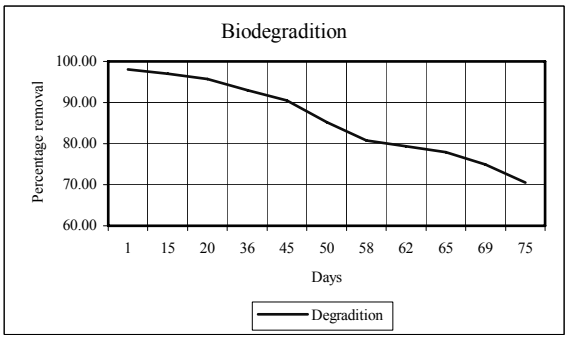


Figure 5: Biodegradation of volatile organic matter reactor-2

Faecal Coliform Analysis

In reactor one, to analyse the pathogen destruction, sample of urine-separated faeces was taken from the reactor with sunlight and laboratory test was conducted by multiple tube fermentation technique. The result of the faecal coliform concentration on first day was 7.0 * 10^{10} cells/gm, after 35 days the

concentration was found to be $1.7*10^7$ cells/gm and $6.1*10^2$ cells/gm after 48 days. Similarly in reactor two, the result of the faecal coliform concentration on First day was $3.5*10^{13}$ cells/gm, after 35 days storage the concentration was found to be $1.7*10^{12}$ cells/gm and $3.6*10^2$ cells/gm after 70 days. The detail is presented in the figure 6 and 7.

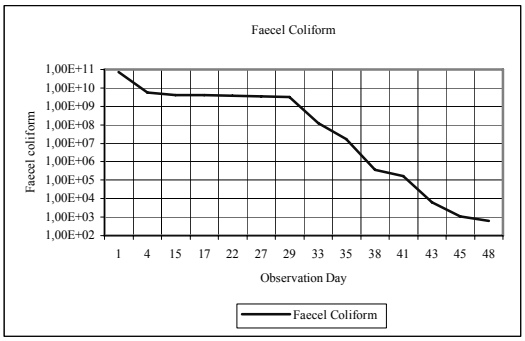


Figure 6: Pathogen destruction in urine-separated faeces with sunrays

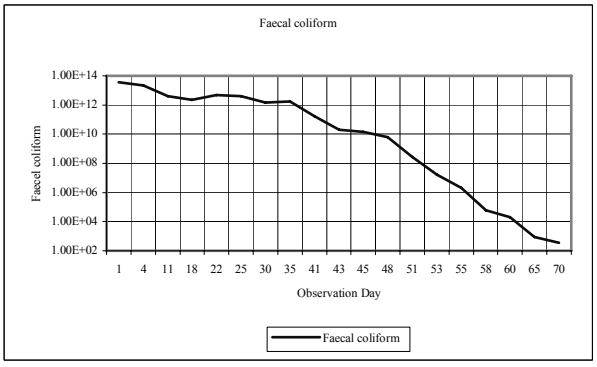


Figure 7: faecal Coliform reductions in urine-separated faeces without sunrays

Total Organic Carbon Analysis

Total Organic Carbon (TOC) of faeces was analysed and found that the organic carbon of initial day was 56.8% and after 63 days the TOC was found 41%. The result remained unaltered there after.

Total Dissolved Solids

The result showed that TDS concentration in urine is 22.78 g/L, which is high. The salt concentration affects the plants to obtain needed water from the soil. It is recommended dilution of urine with water in ratio 1:8 is the best option.

Temperature Variation Analysis

To analyse the temperature variation of faeces, monitoring of temperature of urine-separated faeces was conducted on both the reactor constructed with and without sunrays. The results of the temperature suggest that when the ambient temperature is 22^0C the inside temperature of the reactor rose up to 40^0C. This fact reinforced the concept of dry EcoSan toilets creating a speedy decomposition.

Feasibility of the dry Ecosan toilets

The users' perception regarding its easiness in uses and their acceptance in comparison to traditional type of pit system toilet clearly revealed the feasibility of the Dry EcoSan toilet Concept. Since this type of system has been introduced for the first time in Nepal, it was necessary to get the peoples response regarding its easiness in construction and uses, odour and foul problem and the potential of recovery of the nutrient value from faeces and urine and use it in agricultural crop farming. The result of the base line survey has been used to arrive at the feasibility of the Dry EcoSan toilets.

Public Response to the dry sanitation toilets

Public response study was carried out by sample household survey of the users of dry EcoSan toilet in the pilot area. The questionnaire particularly focussed on the acceptance of the toilet by the users. 65% of the respondents were in the view that the dry EcoSan toilet is better than the traditional type. However, 25% suggested design modification. The modifications suggested by the respondent were regarding the size of toilet and shape of the pan hole.

Based on the public response following design modification was made:

- Size of the toilet is modified as per the drawing shown below
- The hole of squat is done rectangular instead of circular.

Potentials of Resource Recovery

The objective of this research work was to develop a mechanism so that the nutrient value of the urine and faeces is recovered so as to use it in place of chemical fertiliser. There are 60 households having 313 people and 8.4 hectares of land basically that are used to grow paddy, maize and wheat. The average landholding per family is 0.15 hectares of cultivable land. The household survey conducted in the study area shows that the people have been using excreta, compost and chemical fertiliser on their farmland. Since the people in the study area were already using excreta as fertiliser, majority of the people (90%) were ready to use the urine and dehydrated and stabilised sludge in the field.

On average an adult produces about 500 litres of urine in a year. On the basis of the lab test 500 litres of urine contains 5.0 Kg of Nitrogen, 0.4 kg of phosphorous and 1.1 Kg of potassium. Total population according to survey of the cluster area is 313. This means 1565 kg of Nitrogen is produced annually. Similarly Phosphorus and Potassium production annually amounts to 125 kg of 344 kg, respectively. This can be expected to suffice the local fertilizer needs. The above discussion clearly shows that the Dry EcoSan toilet system can have high potential of Nutrient recovery and can at least to some extent reduce the use of chemical fertiliser.

Cost Effectiveness

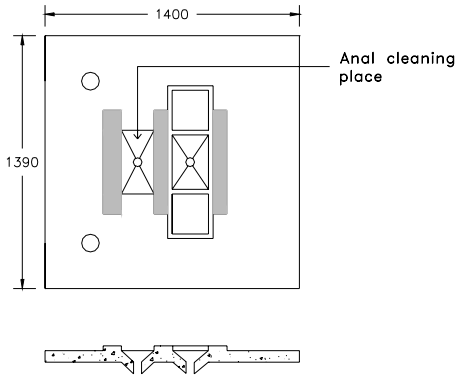
The comparative cost analysis of different toilets was carried out. The result of the analysis shows that the dry EcoSan toilet is cheaper compared to all the other types of toilet except offset type VIP pit latrine. The comparison is such that the next cheaper option, latrine with septic tank (Euro 112), is 35.5% costlier than the dry EcoSan toilet (Euro 83).

CONCLUSIONS

The conclusions drawn from the study is as follows:

- The decomposition process start very rapidly at the temperature above 22 ^{0}C.
- The decomposition rate was 1.5 times faster in the vault with sunrays toilet than without sunrays one. To arrive at 80% reduction of organic matter in faeces it took 48 days in reactor 1 compared to 70 days in reactor 2.
- The destruction of 99% faecal coliform was achieved within 48 days in the reactor 1 and 70 days in reactor 2. This indicates that reactor 1 is more efficient. A retention time of two months seemed short for total pathogen destruction in without sunrays toilet
- The experiment was extended to the winter season and it was seen that in winter the decomposition of faeces could be obtained after two months.
- About 20% of water consumption can be reduced in the Dry EcoSan toilet in comparison to other toilets. This can tremendously benefit the areas with water scarcity.
- The vault of a dry EcoSan toilet can accommodate the faeces of 10 persons for 6 months.
- Since all the structures in the Dry EcoSan toilet are above ground there is no chance of effluent seepage into under ground water. The Dry EcoSan toilet is therefore suitable in the areas with high Ground Water level. Especially in Terai of Nepal dry EcoSan toilets are highly suitable where Ground water table is close to the ground.

Modified design of dry EcoSan toilet for Nepal.



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