Improved design of ecosan toilets and their impact on the economy and environment in Kenya

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Abstract

Development of Ecological Sanitation (EcoSan) technology has greatly improved the problems and costs related to water consumption, management of water resources, environmental and pollution, outbreaks and control of waterborne diseases, conversion of human waste into humanure. However, the economic and environmental importance of Urine Diversion Toilet (UDT) which is an Ecosan has not been well understood by the rural communities in Kenya. The improved design of current EcoSan toilet is aimed at making it acceptable among the kenyan communities. An ash dispensing unit that is operated as a water cistern has been designed to eliminate direct handling of ash in ECOSAN toilets. Also an opening and closing mechanism of toilet defesification opening attached to the pan has been designed to eliminate exposer of human feaces. These designs makes it easy to use Ecosan system and is more hygienic. This makes it acceptable to most Kenyan communities that have negative cultural believes and is expected to improve the uptake of these toilets.. It is recommended that the communities adopt the modified system and the government and non-governmental institutions take their role in sensitizing the communities of the technology.

Keywords— Keywords: Ecosan, Environment, Water resource, Humanure

I. INTRODUCTION

Depletion of soil nutrients and water scarcity are major factors that affect productivity. Human and animals being the sole consumers of the produce must find a way to return the nutrients back to soil after energy utilization in the form of the waste, thus closing the nutrient loop. Also fresh water is increasingly becoming scarce, conventional flush toilets consume five to six times more water for sanitary purposes [6][18]. Ecological sanitation is a typical approach to improve human health and economy and allows for the safe recycling of nutrients to crop production [5][12].

Ecosan toilets are designed specifically to separate urine and faeces and stored dried for about three or four months and processed into humanure. By not mixing urine (the natural fertilizer) with the fecal waste, which contains most of the pathogens, the bad smell from the latrines is greatly reduced. The solid wastes, collected in a separate chamber (vault), are mixed with ashes, soil, leaves, grass, sawdust or any other available material substance processing to produce humanure [8]. The ash is sprinkled over faeces to kill pathogens, cover the human solid waste to eliminate flies and smell and also reduce the rate of germ contamination. The use of humanure is green organic fertilizer which minimizes farming practices whereby excess chemical fertilizer and pesticides are used. In this regard, eco-san facilitates sustainable agriculture and increased food grain output. Fresh Water availability has also been on the decline owing to groundwater depletion and pollution of surface water. Ecosan cuts down on water usage which is a basic commodity especially for those communities in the semi-arid areas.

The manual operation of the Ecosan toilet cover for the UDTs designs causes irritation and is cumbersome to most people. However, a simple mechanized cover and ash cistern could make the Ecosan toilets hygienic and decent to use.

The main aim of this study is to improve ecological sanitation and promote its uptake which in turn reduce water wastage, prevent water pollution and promote reuse nutrients contained within wastes. This paper shares finding of a research undertaken to meet this object.

Problem statement

Despite the contributions and commitment of the government and other non-governmental organizations in implementing the use of the Ecosan toilets in Kenya, many people still do not recognize their importance. The low implementation of the Ecosan systems in most parts of Kenya is mainly due to lack of proper information about the Ecosan systems, cultural believes and the perceived high costs to construct the Ecosan system.

II.LITERATURE REVIEW

Ecosan systems and their application

Ecological sanitation system (Ecosan) is system which allow for the safe recycling of nutrients to crop production [2]. The commonly used types of Ecosan toilets are urine diversion toilet (UDT), *Skyloo*, Fossa Alterna and, the arborloo toilets. The UDT has been implemented extensively all over the world including Kenya [2][4][17]. They are broadly classified into two major groups: the dry Ecosan and the wet Ecosan. Our study was on the dry Ecosan with ash dispensation. The principle of dry EcoSan is mainly to collect feaces in dry state using dry materials such as ash, husk and saw dust to cover the feaces instead of using water to flush it, which is the traditional practice. The urine is diverted and collected separately. As the dry system saves water, this type of toilet can be most useful in

regions where water is scarce. The only water consumption and wastewater produced in this type of toilet is during the process of hands and occasionally anal cleaning, which requires about one liter of water per use. The wastewater from anal cleaning is collected separately in a soak pit or a small constructed wetland just outside of toilet. This prevents underground water contamination.

When properly designed and operated, Ecosan systems can strive to provide a hygienically safe, economical, and closed-loop system to convert human excreta into nutrients to be returned to the soil, and water to be returned to the land [1][13][15].

The Ecosan Toilet consists of the following components: Substructure and superstructure Plate 1 shows the inside with the ash container and squatting pan. The side section view Ecosan toilet for Double Vault toilet is presented in Figure 1.

Plate 1: Ecosan toilet with ash container and squatting pan

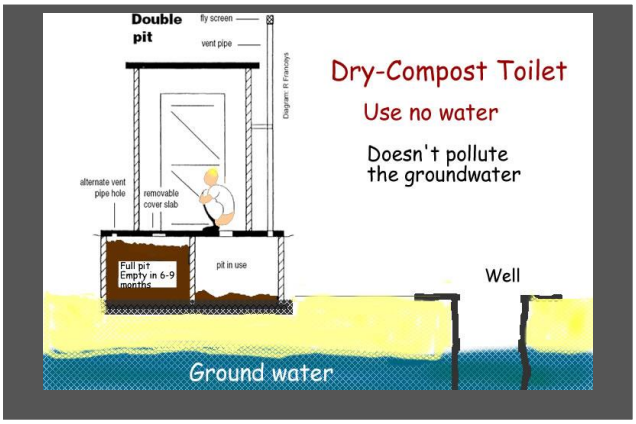

Fig.1. Ecosan toilet side section view for Double Vault toilet

The ECOSAN toilets are considered to provide Waterless Toilet Solution. They have the following advantages:

- The capacity to save space/land,
- Plumbing-free solution, no sewage pipe network and sewage treatment plants required,
- Completely closed system, no effluent seepage into underground water resources,
- Indoor or outdoor installation,
- Saving money, minimum monthly operating costs, water free toilet system
- Generating income through sales of humanure,
- Durability and safety,
- Status symbol and prestige as have no obnoxious odours.
- Does not attract flies which can spread diseases
- No conflict with neighbors since there is no pollution of underground water resources and environment

Since 2006 to date in Kenya, a number of organizations and government departments that include the Water Services Trust Fund (WSTF), German Financial Cooperation (KfW) and the German Development Cooperation (GIZ) in partnership with the Bill and Melinda Gates Foundation (BMGF), AfDB, the Ministry of Public Health & Sanitation (MoPHS) and, the Ssecretariat of the Sustainable Sanitation Alliance (SuSanA) located at GIZ among others have been involved in the establishment and use of Ecosan toilets [10].

However, there have been some problems in the uptake of this technology associated with beliefs of some communities and general design of the toilets in Kenya. The existing Ecosan toilet usually has open pans and given the shallow depths one can see the faeces which, for many Kenyan communities is not acceptable (taken as a Taboo). Currently, sprinkling of ash is done manually using cup and scoping cover materials for a packet placed in the toilet which is not hygienic.

III.RESEARCH METHODOLOGY

The study involved literature review, field study and designing and fabrication of an ECOSAN toilet with ash dispensing and toilet hole opening and closing mechanisms. The field work involved physical observations, interviews and data collection using a questionnaires involving the Econsan designers, users and managers. A total number of five schools and thirty (30) homesteads in Nakuru County and Kajiado North Counties of Rift Valley in Kenya where studied.

IV.FIELD WORK FINDINGS

Poor attitude among users especially pupils who could experiment with wrong usage of the toilets leading to misuse – sometimes mix both calls blocking the system.

There is poor attitude towards use of Ecosan. Handling of human waste in polythene bags were inserted into the containers for easy removal. People believe that use of buckets for human waste was done during the colonial rule thus most had a negative attitude and did not welcome the idea.

Ash was poured by hand on the feces after each use to cover the feces and stop flies from visiting the feces. Sharing of ash cup with contaminated hands is unhygienic and can lead to spread of diseases. Also it is not easy to control of amount dispensed per usage. Sometimes the pupils bring wet ash which

cannot be used effectively. Alternatives cover materials proposed to ash include sawdust, alum, charcoal and sand.

To deal with the psychological dilemma of seeing the human waste, a design for incorporation has been designed which opens when the user steps on the floor of the toilet. There was need to think of a hygienic ways of dispensing and controlling the quantity of the ash used.

A complete single Urine Diversion Toilet (UDT) unit in Kenya will cost Kshs. 280,000 (2,800 US Dollars) with a life spun of 50 years. The high cost is due to the concrete superstructures and substructures and the mechanized Ecosan system. However, this cost can be reduced by almost 50% in some parts of the country where bricks can be used as construction materials. This cost is also justified with saving of reduction in water usage, conversion of waste into humanure, elimination of water contamination and the long life of the toilets.

All interviewed accepted that the Ecosan toilets had the following benefits: unlike the pit latrines, they do not smell and there were no flies, there was reduced water use (water was used to clean hands and floor only), humanure could be generated for farming, they are economical – toilets don't fill up, thus no rebuilding, reduced cost of water and no emptying of septic tanks, and there is no contamination of water sources and soil thus lead to environmental hygiene.

V.DESIGN OF ECOSAN (UDT) TOILET

Introduction

The problems of the uptake of the ECOSAN Toilet are majorly related to their design. Special attention has been given to the design of the toilet opening shutter/cover mechanism attached to the pan and ash/dust dispenser mechanisms. These are presented and which have not been incorporated in the existing ECOSAN toilets.

Our design is based on a single vault which requires use of containers positioned in the chambers in the substructure and is frequently removed once filled to three quarter. This takes at least one week of usage. It is modeled for Musa primary school located in Isinya area of Kajiado County, Kenya.

In designing the components of the ECOSAN toilet the following factors were considered:

- Social/cultural: the customs, beliefs, values and practices that influence the design of the social components of a sanitation system and its acceptability by a community
- Current and projected students population: which currently stands at 248
- Availability of construction materials/resources,
- Structural reliability and decency,
- Robustness, simplicity and ease to use,
- Technical capacity: the level of technology that can be supported and maintained by local skills and tools.
- Economic: cheap with low operating costs the financial resources of both individuals and the community as a whole to support a sanitation system, and Clean and environmentally acceptable.

Design and Construction of the ECOSAN Toilet structure

The site of the ECOSAN toilet was selected where there was no swamp. The structure consists of the superstructure and substructure. The emptying hole is located at the backside of entrance with adequate space for emptying. The designed ECOSAN toilet structure is shown in Figure 2. Plumbing for water supply and drainage for urine include vent pipe, waste pipe and plastic fitting works among others. Waste pipe to convey urine and hand wash water is passed under the slab whereas the vent pipe is fitted just under the slab. Pipe fitting are such that they do not allow leakage neither into the chamber or the surrounding. Urine and hand wash water are directed to a soak pit.

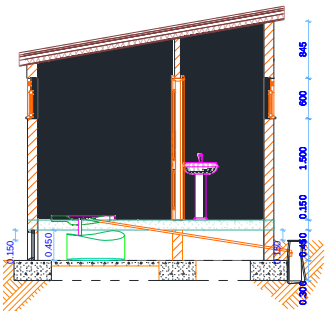

Figure 2: Structure of ECOSAN toilet

Design of Ecosan UDT Pans

In the school that was being piloted there were 248 pupils with almost 50% boys and 50% girls. Eight ECOSAN squat toilet holes were preferred for construction, four being for girls and four for boys. . Each gender side has urinals. This means on average thirty one (31) students could use one toilet. In one day they could deposit 4.34 litres of faeces and 21.7 litres in one week. The height of the container (h_c) of the solid waste chamber was determined to be 80 cm and hence chamber height adopted (H_{ca}) was 100 cm. A cylindrical plastic container with top opening of 40 cm is recommended for use. The collection compartments are covered by a roof for hygiene purposes and to prevent rainwater and insects from entering.

Currently there are various types of pans already in use. Below Plate 2(a) and 2(b) are some of the existing pans most of which are produced in Kenya and India respectively [18].

An opening and closing mechanism of toilet opening cover attached to the pan has been developed and implemented to

eliminate exposer of human feaces. The mechanism is operated by foot. The cover opens outwards when someone steps on the pan peddles and closes after use and moving away (Plate 3 and 4).

The improved mechanized design of Ash Dispenser Mechanism (ADM) has a cistern similar to that one of the conventional flush toilet which is used to dispenser 250 cm3 amount of ash per usage which is sufficient to cover the feaces. This dispenser releases the required amount of ash by pushing a button just like the one used in a water cistern (Plate 5). It has capacity of 12,500cm3 of ash enough to serve 31 to a maximum of 50 persons a day.

a)

b)

Plate 2: Types of existing ECOSAN pans: a) Ndarugu Primary School, Nakuru, Kenya b) Mythri Sarva Seva Samithi, New Thippasandra, Bangalore, India

Plate 3: Mechanized Pan: Top view

Plate 4: Mechanized Pan: Side View

Plate 5: Ash Dispenser: Side View

VI.ECONOMIC AND ENVIRONMENTAL IMPACT ANALYSIS

Humanure production

Humanure produced from productive sanitation could be used to promote food production thus improving food security especially among farming communities. Humanure may be deemed safe for humans to use on crops if handled in accordance with approved health regulations, and composted properly.

Each person's urine and humanure contain approximately enough nutrients to produce enough food to feed that person. Human fecal matter and urine have high percentages of

nitrogen, phosphorus, potassium, carbon, and calcium. It is equal to many fertilizers and manures purchased [5][16]

Middle and developing economies like China, India, Haiti and Mauritius have adopted the use of humanure in place of chemical fertilizers. This has seen exponential growth in food production, improved sanitation and resulting health. This has also reduced wastage of scarce water resources since ecological sanitation toilets utilize minimal amounts of water [14][15][16].

Currently Kenya food production caters for 30 million which leaves a gap of about 10 million facing hunger and starvation. Kenya open data puts fertilizers consumption in Kenya is approximately 15.6 kg per acre. The government spends up to Kshs. 3 billion (30 Million US Dollars) annually to provide farmers with low cost imported fertilizers [7].

One of the measures of reducing these high costs is the government support of a Japanese Company to construct fertilizer factory locally in Eldoret Kenya at a total cost of Kshs. 123 billion (approximately 1.23 Billion US Dollars). The factory is also expected to serve Uganda, Rwanda, Tanzania and Democratic Republic of Congo. However, the best alternative is the use of green technology which includes humanure.

Each person produces 50 kg wet mass of faeces (20 kg after drying) and 550 litres of urine annually. This means that in the sanitation sector in Kenya of about 700,000 tonnes of wet mass faeces (or 280,000 tonnes after drying) requires to be disposed. This has not been achieved by the use of conventional waste treatment methods which is covers only 19.5% of the total urban population. Each person produces fertilizer with nutrients (N, P, K) enough to fertilize 250 kg of cereal annually.

Currently 50kg bag DAP and NPK fertilizers cost on average Kshs 3,200 (32 US Dollars) while CAN costs Kshs. 2,500 (25 US Dollars). However, with the government subsidizing the cost goes down by almost 50% to Kshs 1,500 (15 US Dollars) and Kshs 1,300 (13 US Dollars) respectively [7].

A 50kg bag of *humanure* after processing can be sold for up to Kshs. 800 (8 USD) which is much cheaper than the conventional fertilizer compared to common DAP, NPK and CAN fertilizers. Most people would use four bags in one farming season (one year), for one acre of land. This means there is a saving of Kshs 14,000.00 per acre farmed.

Efficient use of water

In Kenya, per capita water availability is about 500 m^3 and most of health and poverty problems are related to water. The current population of Kenya is estimated to be about 45 million of which about 14 million people are living in urban areas require seven trillion litres of water [7]. There is a big problem of water in Kenya which can be minimized by reducing the volume of water required and its related cost by using Ecoasn systems..

For conventional toilets each person use on average 16 litres of water per day to flush the toilet which gives 187 million litres. Assuming the average cost of water of Kshs. 125 per cubic metre, then the monthly expense for an average Kenyan family of six persons, will be Kshs 350 and 702 million Kenyan shillings (7.02 million US dollars) per month for the whole country. This is almost 50% of total expense for water required per a family. The use of an Ecosan system reduces this cost by almost 100%. This will also mean the scarce water resource will be available for other essential usage such as drinking and human general hygiene.

Environmental Impact

Almost 50% of Kenyans have no access to a toilet with acceptable standards, only 19% are connected to a sewer system and 12% are forced to open defecation. Most Kenyans use onsite sanitation facilities, most of which are pit latrines or septic tanks. There is no proper system in place to handle the sludge coming from these facilities. Human waste is often being emptied into open water bodies like streams and rivers resulting to water resources pollution and outbreaks of waterborne diseases. This also happens when there is frequent relocation of pit latrines once they are filled up.

Estimates on access to private, improved sanitation in Kenya, including sewerage, indicate that only 30 per cent (31 per cent of urban and 30 per cent of rural), which is over 21 million people in Kenya, still use unsanitary or shared latrines [19].

From the global facts presented above, it is clear that many people get sick due to poor sanitation or lack of proper sanitation facilities and contamination of water resources and there is a lot of man-hour loses both to self and to employers. Water as an environmental medium could be free from *Escherichia coli*, if human faeces reach soil as organic fertilizer, instead of water [3].

Poor sanitation costs the country, Kshs 27 billion annually, equivalent to US$324 million. This sum is the equivalent of US$8 per person in Kenya per year or 0.9 per cent of the national Gross Domestic Product (GDP). Diarrhea caused by poor sanitation and unsafe water kills over 1.5 million children worldwide each year [19]. It is further indicated that disease transmission at work caused by poor sanitation and hygiene practices, causes 17 % of all workplace deaths [11]. Loss of productivity due to illnesses caused by lack of sanitation and poor hygiene practices is estimated to cost many countries up to 5% of GDP [9]

The lack of proper sanitary facilities at the workplace and at homes has a negative impact on the economy. They cause diseases leading to reduced concentration, absenteeism, exhaustion decreased productivity and generally poor health.

During the field study the communities interviewed on easy usage, safety, decomposition and oduor of the Ecosan system as compared to a pit latrine indicated as follows: about 82% of the respondents accepted that Ecosan were more friendly to use as compared to 44% for pit latrine; 84% of the respondents said Ecosan were safe to use as compared to 24% who were satisfied with safey of pit latrine; 100% of the respondents said Ecosan were ease to decompose as compared to 40% who considered pit latrine offers ease decomposition; while 24% of the respondents said Ecosan were oduorless as compared to

20% for pit latrine. This findings shows that the communities that are using the Ecosan system appreciate their importance.

VII.CONCLUSION AND RECOMENDATIONS

Conclusion

The world is progressively advocating for the green economy. This envisages sustainability and equity. The basic methodology to achieve this is Reduce, Reuse and Recycle of all natural resources so as to avoid degradation and depletion.

The use of Ecosan systems has several advantages and has great direct economic and environmental impact to the communities especially to the communities living in arid and semi-arid areas. They lead to a reduction in underground water pollution, efficient use of water and can generate some income by conversion of feaces into fertilizer. In Kenya like other countries in the world the government and non-governmental organizations have funded and encouraged the use of ecosan systems. A number of people and organizations especially schools in Kenya have embraced this technology.

The improved design has made the Ecosan toilet descent to use and the use of locally available have greatly impacted the uptake of this technology. The amount of water requirements, cases of diseases and related respective costs are expected to go down. Excreta do not need to be seen as a "waste" but as a resource offering a safe fertilizer to thousands of Kenyans suffering from hunger and lack of food every year. There is need for Kenya to adopt Ecosan systems in order to solve problems of food insecurity, water scarcity, poor health and sanitation.

Recommendations

Social acceptance is a major pre-requisite for promoting EcoSan which represents a very different way of managing excreta for many people. In many societies, handling human excreta is considered to be a cultural taboo and this can be a major barrier for promoting EcoSan. It is recommended that in order for the African communities to appreciate the importance and economic and environmental impact of Ecosan systems, policy makers and other stakeholders in ecological sanitation development create forums to sensitize the communities Ecosan systems especially after the improved design that marches the modern lifestyle.

Further research on the quality and use of humanure is requiredThis should be followed with field demonstrations through some pilot projects on its effects when applied on plants in order to improve the perspective of the people towards Ecosan. Communities needs to be sensitized on the economic and environmental importance of Ecosan systems.

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