ECOLOGICAL ALTERNATIVES IN SANITATION

Systems for Enhancing Ventilation for Improved Control of Odour and Fly Nuisance in Dry urine Diverting Ecological Sanitation Toilets

Submitted

by

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1 Background

Ecological Sanitation (Ecosan) is a holistic sanitation system which enables complete recovery of nutrients from faeces, urine and grey water to the benefit of agriculture (sanitise and recycle). Ecosan systems minimise water pollution, while at the same time ensuring that water is used economically and is reused to the greatest possible extent, particularly for irrigation purposes (Esrey et al, 2001).

In Uganda, Ecological sanitation (ecosan) was introduced in 1997 as an alternative sanitation system to solve problems of traditional means of human excreta management namely; difficult soils (rocky as well areas with high water table), need for digging new pits which is expensive and sometimes there may not be land for digging new pits in the case of pit latrines; high initial cost as well as high operation and maintenance costs in the case of water borne systems; and potential for contamination of ground water by both systems (Niwagaba, 2005).

The introduction of ecosan in Uganda started in the south western districts of Kisoro and Kabale mainly because the areas were characterised by porous but rocky formations and pit latrines were a risk to ground water pollution. In some areas in these and neighbouring districts, there was another problem of collapsing formations. There was a search for an alternative sanitation system that could solve these problems. The Uganda Government, the South Western Towns Water and Sanitation project, co-funded by GoU and government of Austria initiated the concept of ecosan. At the beginning, attempts to introduce ecosan toilets were met with resistance as people felt it was unheard of to re-use human excreta (Niwagaba, 2005). The very first ecosan toilets were of the composting type. These were inappropriately operated since they resembled ordinary pit latrines and people did not follow the correct procedures of adding carbon-bulking materials (Niwagaba, 2005). Consequently, the toilets were associated with flies and odours and were abandoned in favour of urine diverting dehydration ecosan toilets. Use of dehydrating ecosan toilets is on the increase and there are about 6,000 toilets in Uganda (Personal observation, 2005).

In dry urine diverting toilets, the urine and faeces are collected separately, and no water is used. To keep away the flies, odours and to sanitise the faeces as well, often materials known as additives are used. Lime, wood ash, dry soil and sawdust are among the additives that can be used but mostly wood ash and dry soil have been applied as they are the possible materials that can be got relatively easily. Additives alone cannot keep the toilet free from odours and flies. There is a combination of factors that have to be controlled (Del Porto, 1998). The factors include airflow
(provided by good ventilation), optimum sizes of vent pipes as well as correct placement, good choice of materials for pipes and vault access doors, material and chamber placement in relation to incident light, location and placement of toilet in relation to the direction of wind flow etc. All these factors should be optimized in a toilet, coupled with proper operation and maintenance.

When ventilation is improper, the faeces do not dry fast enough and to the moisture levels expected. The low rate at which faeces in the processing chambers dry up and the resulting odour in the system is a serious impediment to the development of ecosan toilets and this affects their popularity. Accelerating the rate of drying in a dry toilet can be of great significance. Increasing the rate of drying potentially increases the rate at which pathogens are destroyed. Thus the required retention period will be reduced since with an increased rate of drying, the faecal matter will be sanitised (free from pathogens-safe for handling) at a faster rate. With a decreased retention period, the sizes of vaults can be reasonably reduced hence lower cost of construction. This may be more relevant in peri-urban dense settlements where ecosan systems may be very useful in the future. With the relatively high number of anticipated users in such areas and the limited space available for use, this may imply a faster rate at which the processing chambers fill up. This too necessitates accelerated drying to shorten the required retention period, without rendering the faecal matter unsafe for handling and subsequent use. Therefore, improved ventilation systems are a necessity to accelerate drying of faecal matter in the chambers and reduce the sanitisation period hence size of chambers.

Previous research (Ntabadde, 2004) dealt with design of ventilation systems for accelerated drying. In this research, basing on theoretical calculations it was recommended that the minimum vent pipe size should be 150mm. For further accelerating drying, it was recommended that the design should be equipped with one way glass for the behind access vault doors, with the glass allowing in sunlight into the vaults and limited quantities in the reverse direction and a rotary turbine (located 265mm above roof, maximum diameter 340mm, throat diameter 155mm and 16 blades rotating on two vertically aligned ball bearings on a stainless steel rod) vent that could be locally manufactured from aluminium. This kind of ingenious thinking has not been tested. It is also hypothesised that improving airflow in vaults using glass that allows incident light to pass without reflection thereby hitting the faecal matter placed on some kind of false floor inside the chamber may improve ventilation (Pers. Comm. with Vinnerås, 2005).

2 Problem statement
Ecosan systems have enormous benefits. However, the systems face some constraints, which may restrict optimum performance and hence rate of adoption by the people. In addition, poorly
operating ecosan systems may be a source of water and excreta related diseases. The basic factor that may easily determine whether or not people use a given sanitation facility is odour and fly nuisance. These often go hand in hand as an odoriferous toilet always has flies. Odour may not necessarily cause a health threat but the accompanying flies are leading carriers and transmitters of water and excreta related diseases. Smells in toilets are often because the faeces are not dry, either because of moisture from water or urine intrusion and poor ventilation. As moisture intrusion can be monitored and controlled, the ventilation is a design issue which needs to be done properly during the design and construction stages.

3 Justification
Recent research carried out by Drangert (2003) found out that people like to use clean toilets. Cleanliness of a toilet is a function of a number of factors, one of them being non-smelly. Thus toilets that are odorous are often thought to be dirty and hence people may not want to use them. It is therefore necessary to come up with designs of ecosan toilets that are non-odoriferous, and easy to use. Good ventilation is thought to be a good starting point in control of odours and fly nuisance in dry urine diverting ecosan toilets. This research therefore is aimed at designing and installing an improved ventilation system on an existing toilet and then monitoring it to study the effect on odour and fly occurrence/disappearance; studying the effect on faecal drying within the chamber and hence pathogen die-off.

4 Objectives
The main objective of this research is to generate information that can be used in the technology development for improved ventilation, fly and odour control as well as impact of improved ventilation on drying within faecal chambers and pathogen die-off.

- Smells/Odours and flies (subjective evaluation),
- Moisture reduction with time in the chambers,
- Pathogen die-off (bacteria, protozoa and helminths) are being investigated.
- To study the ecosan ventilation systems available and their operation,
- To identify loopholes in the design and operation of the current systems,
- To produce adequate modifications to accelerate drying, depending on the findings and describe how the modified ventilation system is expected to perform,
- To come up with a prototype of the modified system
- To produce design drawings of the modified system with the aid of a software
- Estimate the cost of construction of the Ecosan with the modified ventilation system.
Methodology

5.1 Literature review

Introduction

Ecological Sanitation is a cycle or closed loop system which treats human excreta as a resource (Esrey et al., 1998). In this system, excreta are processed on site until they are free of pathogenic organisms. Thereafter, the sanitized excreta are recycled by using them for agricultural purposes. Ecosan systems enable the complete recovery of nutrients from faeces, urine and grey water to the benefit of agriculture. The systems also minimise water pollution, while at the same time ensuring that water is used economically and is reused to the greatest possible extent.

Principles of Ecological Sanitation

An ecological Sanitation system is based on the following principles (UNDP, 2003).

1. Prevent Disease - must be capable of destroying or isolating faecal pathogens;
2. Protect the environment - must prevent pollution and conserve valuable water resources;
3. Return nutrients - must return plant nutrients to the soil;
4. Culturally acceptable - must be aesthetically inoffensive and consistent with cultural and social values;
5. Reliable - must be easy to construct and robust enough to be easily maintained in a local context;
6. Convenient - must meet the needs of all household members considering gender, age and social status;
7. Affordable - must be accessible to all households in the community.

Processes by which Pathogens are destroyed

Ecological sanitation systems employ two main processes to achieve pathogen destruction; dehydration or decomposition/composting

i. Composting

Composting is a biological process in which, under controlled conditions, bacteria, worms and other types of organisms break down organic substances to make humus, an excellent soil conditioner in which roots thrive. In a composting ecosan toilet, human excreta along with additional bulking agents such as vegetable scraps, straw, wood shavings, are deposited into a processing chamber where soil based micro-organisms decompose the solids. Temperature, airflow and other factors are controlled to varying degrees to promote optimal conditions for composting. The humus produced is free from pathogens if the right conditions are achieved and if adequate retention time is achieved.

ii. Dehydration

In a dehydrating toilet, the contents of the processing vault are dried with the help of heat, ventilation and addition of dry material. The moisture content is brought down as quickly as possible to below 25% (Esrey et al., 1998). At this level, there is rapid pathogen destruction, no smell and no fly breeding. The use of specialised collection devices (squatting pans or seat risers) which divert urine for storage in a separate container allows the faeces to be dehydrated fairly easily. Since urine contains most of the nutrients but generally no pathogens, it may be used directly as a fertiliser, after dilution, without the need for further processing.
**Ventilation**

Ventilation is the process by which fresh air is introduced and ventilated air is removed from an occupied space. Ventilation serves several purposes; preserve the qualities of air, it removes odours, it dries out the contents and in composting toilets, provides oxygen for the decomposition. ventilation may also be used to lower the temperature inside an occupied area

A vent pipe should have a diameter of 10-15cm (Esrey et al, 1998) In humid climates with large amount of liquid to be evaporated, the diameter could be larger, up to 25cm. The pipe should be as straight as possible and reach 30-90cm above the roof.

**Types of ventilation**

*Natural ventilation:* the process of supplying and removing air by means of purpose-provided aperture (such as windows, louvers, ventilators and vent pipes) and the natural forces of wind and temperature-difference pressures.

*Mechanical ventilation:* the process of supplying and removing air by means of mechanical devices, such as fans. It may be arranged to provide supply, extract or balanced ventilation for an occupied space. Extract ventilation aims at extracting bad air from a given space.

**Principles of Natural Ventilation (in a vent pipe)**

For air to move into and out of a building, a pressure difference between the inside and outside of the building is required. Natural Ventilation conditions, through combined stack effect and wind, and through wind only at air speed in excess of 3m/sec.

**Stack Effect**

Warm air is lighter than cool air and it rises being replaced by cooler air. In an ecosan toilet, when the solar radiation heats the black vent pipe, the pipe heats the air inside it and its density lowers and it rises upwards out of the vent. A downward draught of cooler air of higher density then flows in through the squat plate hole replacing the vacuum space created after warm air rising. The flow is along the path of least resistance. The rate of ventilation is directly proportional to the size of the openings and the height difference between inlet and outlet.

**Wind Ventilation**

When wind rushes past the air vent, due to the speed at which the wind is moving in addition to the air passing out of the pipe relative to the air in the vent, a negative pressure is created and thus establishing a suction phenomenon. Thus the air in the pipe is drawn out and is replaced by fresh air.

In most cases, natural ventilation depends on a combined force of wind and stack effects

**Principle of mechanical ventilation**

The air pressure difference created by fans and other mechanical ventilators, between the inside and the outside of a structure the reason why air is exchanged in mechanically ventilated facilities. For example exhaust fans create a slight negative pressure or vacuum in a structure which causes air to enter the structure through designed inlets for example louvers and the squat hole in a latrine.
6.0 sampling and data collection

Preliminary field Visits were made to Kabale and Soroti and Data collected with the aid of observation and Check lists, to identify one toilet to be modified as an experimental toilet and the 2nd one as a control in each Town. The following considerations were made for the selected samples;

In both the experimental and the control toilets there was one conservative design for the ventilation system employing natural ventilation. The vent pipes were all made of PVC, about 120mm diameter and were raised between 0.4 and 1m above the roof.

Both toilets were averagely smelly (you could feel it just as you enter the toilet), and were household toilets used by an average 10 people in the family. These considerations were made in the two Towns.

The only difference is that the two towns are taken from two different regions with different weather conditions, Kabale being a cold region, while Soroti is hotter. This is an attempt to find out if weather has effect on the ventilation process. This is also as some kind of standard in order to compare with the modified toilet to study the extent to which the improvements have impacted upon the ventilation.

The checklist were used for more technical information and these included:

1. The height of the pipe above the roof.
2. Location of the vent pipe.
3. Diameter of the vent pipe.
5. Obstruction to wind directions.
7. Orientations of the behind access door and whether this door is painted black or not.
8. Moisture in the faecal matter.
9. Anal cleansing materials used.

Measuring and observation took these. In order to assure quality of results, the measurement of the diameter was repeated three times at different locations and the average of these values were taken. Since the height of the pipe above the roof could not be accessed, for direct measurements, the value was taken from the average of three close values, independently estimated by other people and myself.

Data analysis methods

The data obtained from the field visit was summarised in a table bellow:

Table 1 showing summery of all field results from 10 toilets visited, five in Soroti, and another five in Kabale.
<table>
<thead>
<tr>
<th>Height of pipe above roof(m)</th>
<th>&lt;0.5</th>
<th>&gt;=0.5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>Parentage</td>
<td>40</td>
<td>60</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>orientation of vault doors</th>
<th>vertical</th>
<th>slanting</th>
</tr>
</thead>
<tbody>
<tr>
<td>number</td>
<td>1</td>
<td>9</td>
</tr>
<tr>
<td>percentage</td>
<td>10</td>
<td>90</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Vent cups</th>
<th>available</th>
<th>Not available</th>
</tr>
</thead>
<tbody>
<tr>
<td>number</td>
<td>8</td>
<td>2</td>
</tr>
<tr>
<td>percentage</td>
<td>80</td>
<td>20</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Odour problems</th>
<th>smells</th>
<th>Does not smell</th>
</tr>
</thead>
<tbody>
<tr>
<td>number</td>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td>percentage</td>
<td>60</td>
<td>40</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Location of the vent pipe per stance</th>
<th>Centre of 2 vaults</th>
<th>2 sides of each vaults</th>
<th>Centre of each vault</th>
</tr>
</thead>
<tbody>
<tr>
<td>number</td>
<td>3</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>percentage</td>
<td>30</td>
<td>50</td>
<td>20</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Diameter of the vent pipe</th>
<th>&lt;=100mm</th>
<th>&gt;100mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>number</td>
<td>9</td>
<td>1</td>
</tr>
<tr>
<td>percentage</td>
<td>90</td>
<td>10</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Availability of a Siphon in the Urine diversion pipes</th>
<th>available</th>
<th>Not available</th>
</tr>
</thead>
<tbody>
<tr>
<td>number</td>
<td>1</td>
<td>9</td>
</tr>
<tr>
<td>percentage</td>
<td>10</td>
<td>90</td>
</tr>
<tr>
<td>Additives used</td>
<td>ash</td>
<td>others</td>
</tr>
<tr>
<td>-------------------</td>
<td>-----</td>
<td>--------</td>
</tr>
<tr>
<td>number</td>
<td>10</td>
<td>0</td>
</tr>
<tr>
<td>percentage</td>
<td>100</td>
<td>0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Anal cleaning materials used</th>
<th>Dry papers</th>
<th>Others including fresh leaves</th>
</tr>
</thead>
<tbody>
<tr>
<td>numbers</td>
<td>8</td>
<td>2</td>
</tr>
<tr>
<td>percentage</td>
<td>80</td>
<td>20</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Availability of moisture in the faecal matter</th>
<th>Wet faecal matter in the chambers</th>
<th>Completely dry faecal matter</th>
</tr>
</thead>
<tbody>
<tr>
<td>number</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>percentage</td>
<td>40</td>
<td>60</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Obstruction of wind movements around vent pipes</th>
<th>obstructed</th>
<th>Free wind movement</th>
</tr>
</thead>
<tbody>
<tr>
<td>number</td>
<td>3</td>
<td>7</td>
</tr>
<tr>
<td>percentage</td>
<td>30</td>
<td>70</td>
</tr>
</tbody>
</table>

All the toilets visited had vent pipes made of polyvinyl Chloride (PVC). These are the most common ones, and cheap that most people can afford. However, they are weak and easily broken plastics. The other is that they act as insulators and do not allow as much heat to penetrate through them to heat the air inside the vent pipe, as metallic ones would. Thus the ventilation rate due to stack effect is retarded, especially during the day.

Basing on the above field results, 4 toilets were selected, with similar features, two from each region (2 in Soroti, and 2 in Kabale). Two toilets were modified one from each region as experimental, while the other two were left as they were to be used for control. Thus I had project A in Soroti, and project B in Kabale.

The modifications were done in the following ways:

### 6.1 Modification of the toilet

A competent mason was selected from those who were trained in ecosan to install/incorporate the design proposals into the existing toilet.

### 6.2 selection of pipe diameter

A 150mm diameter pipe was found to meet the recommended ventilation rate of 20m3/hr (Ntabadde, 2004). For ventilation due to both thermal and wind effect, and were installed in the experimental project A and B
6.3 **Sizing of vaults** were based on the formulae \( V = N \frac{(F+A+U)}{1000} \) where:

- \( V \) = volume of vaults in m\(^3\)
- \( N \) = number of users
- \( F \) = volume of faeses in litters produced per person per year considered to be 50 litters
- \( A \) = volume of ash in litters added per person per year considered to be 50 litters
- \( U \) = volume of urine in litters per person per year considered to be 500 litters but in UD toilets it will be 0 because no urine is added in the chambers. The vault volume of the experimental toilets was modified for 15 people.

6.4 **Selection of a solar powered DC / AC fan** was based on the type available in the market. A portable exhaust and centrifugal fan was placed on the vent pipe to assist in enhancing ventilation.

6.5 **A vent cup** made from light material of a conical shape was installed on top of the vent pipes to cover against rainwater and fly breeding.

6.6 **A modification was done on the urine diversion pipe** where the diameter of the siphon is the same as that of the urine diversion pipe.

The diameter of the vent pipe on the urine diversion coincided with the diameter of the urine diversion pipe.

6.7 **Training of users on the operation and maintenance of UD toilets** was conducted to both the control and experimental toilets such that O&M problems do not interfere with the results of the research.

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**Monitoring**

The toilet is being monitored once every two weeks. During the monitoring period:

1. Samples are taken once a month for laboratory tests to determine the pathogen die off rates in both control and experimental toilets. The results will then be analysed and compared if proper ventilation enhances pathogen die off in the UD toilets. Sample is also tested to determine moisture contents in the faecal matter.

2. Subjective evaluation of odour/smells and flies (where possible, count flies that can be seen), or subjectively evaluate if they are too many in some of the toilets,
PRELIMINARY RESULTS:
The lab results have yet to take a lot more time because we so far only taken one month of data
For test so we don’t have a comparative result.

The table bellow shows the evaluation of odour, flies availability and moisture contents in the
faecal matter for 4 monitoring visits after modification, and O&M training to the users

**Experimental project A**

<table>
<thead>
<tr>
<th>SMELL</th>
<th>FLY PRESENCE</th>
<th>MOISTURE CONTENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

**Experimental project B**

<table>
<thead>
<tr>
<th>SMELL</th>
<th>FLY PRESENCE</th>
<th>MOISTURE CONTENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
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<td>1</td>
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<td>1</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

**Control project A**

<table>
<thead>
<tr>
<th>SMELL</th>
<th>FLY PRESENCE</th>
<th>MOISTURE CONTENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>2</td>
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<td>2</td>
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<td>2</td>
<td>2</td>
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</tbody>
</table>

**Control project B**

<table>
<thead>
<tr>
<th>SMELL</th>
<th>FLY PRESENCE</th>
<th>MOISTURE CONTENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

**NOTE:** During the 2nd visit there was a blockage in the urine pipe.

**KEY**

a) Every raw represents one visit.

b) Odour is expressed at three levels here:

- Very smelly = 3
- Relatively = 2
- No smell = 1
c) Fly presence is expressed according to their numbers in the toilet:

- More than 5 = 3
- Less than 5 = 2
- No fly seen in the toilet = 1

d) Moisture content in the vaults is represented by:

- Wet = 3
- Relatively dry = 2
- Dry = 1

Discussions and conclusions:

- The experimental toilets are performing very well generally compared to the control toilets, showing that improved ventilation system is required for the UD toilets to work perfectly.

- While using the toilet one has to be very careful not to pure any additives into the urine pipe as it caused the blockage of the urine pipe in the control project A, making the toilet to smell, and flies to breed in the toilet.

- There has been a remarkable improvement in the control project B from worse to better. This could have been due to improper use of the toilet by the users who used to wash in the faecal vaults. But after the O&M training the mistake was corrected, and the toilet improved. Probably this is proving that even with the traditional ventilation system, the toilet can still work properly if users are well trained on proper usage.

- The improved system has cost implication, which may be difficult to the poor to afford. However, if the system is carefully selected to achieve odour control

- The cost of the modified toilet with a siphon on the urine pipe, and a fan on the vault vent Pipe is 800,000/= (eight hundred thousand shillings only) per stance.

It is important to note that I am still doing this project because I started late due to funds delay, and also the lab results will need time (almost a year) to analyse the data after a full 6 months of pathogen die off period.
7.0 Expected Benefits

The following are the expected benefits of the study:

- Improved ventilation system designs of ecosan toilets for control of smells/odour and flies,
- An understanding of the ventilation, and its importance in temperature elevation and moisture reduction within chambers as well as on pathogen die-off,
- Publication of research findings,
- Active participation in the global ecosan networks through contribution to knowledge generation.
- Results are expected to be ready by the end of March 2006 due to the lab analysis required for this research.

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