Ecological Sanitation Approaches in Kenya

A PAPER PRESENTED AT THE ANNUAL INTERNATIONAL CONFERENCE ON THE ENGINEER AND VISION 2030

J.O. Odhiambo 1, Hagen von Bloh 1

1 EU-GTZ EcoSan Promotion Project P.O. Box 19512-00200 Nairobi

2 Department of Environmental and Biosystems Engineering University of Nairobi Box 30197-00100 Nairobi

orodijo@uonbi.ac.ke

Abstract

Kenya has a large rural and rapidly growing peri-urban population that lacks sustainable solutions to safe and adequate water supply, energy and sanitation. Access to safe water and sanitation was 57% and 84% respectively by 2006 with 80% of the rural population and 44.6% of the urban population relying on firewood and kerosene respectively as the major source of energy. Kenya is also regarded as a water scarce country with a per capita supply of renewable water of 647 m$^3$/year. The challenges posed by lack of access to safe water and sanitation and reliable and efficient energy supplies erodes the country’s capacity to embrace economic gains necessary to usher in vision 2030 while undermining its capacity to attain the millennium development goals.

Ecological Sanitation Approach is being muted as a sustainable way of recycling, reusing and reclaiming natural resources through a concept that turns waste into utility resources and consequently taking advantage of what is currently considered as problem sources and converting them into useful inputs. The EU-GTZ funded EcoSan Promotion Project in Kenya is piloting initiatives in six pilot sites to showcase the potential of using human and kitchen waste in addressing the challenges of environmental degradation witnessed across the country marked with incidences of ground and surface water pollution with attendant seasonal outbreaks of water related diseases and diminishing access to safe water supplies. The initiative targets public, institutional, individual and agro-based establishments provides an intervention whose philosophy revolves around protection of the environment, restoration of the food chain and ensures that the law of conservation of matter and energy is promulgated to turn engineering solutions from the conventional linear systems to cyclic systems that run tandem to nature for sustainability. The philosophy utilizes such age old techniques like the bio-latirines, dehydrated toilets and constructed wetlands to reclaim recycle and reuse waste water and human excreta through a bio-process that provides energy for cooking and soil enrichment and water for irrigation and other non potable uses.

Simple systems that provide 2-3 hours of cooking gas in quantities of 300-liters per day to complex systems that can provide up to 45,000 litres of methane gas per day are under test in Kenya and are proving to be reliable sources of energy, non-potable water and bio-fertilizer for rural and peri-urban households, public places and agro based industries. The initiative aims to reach 50,000 beneficiaries in the next 20 months and gears at laying the foundation for a paradigm shift from the conventional unsustainable linear systems to modular cyclic systems required to attain the millennium development goals jumpstart the economic and social reorientation towards fulfilment of Vision 2030

Keywords: Water, Sanitation, Integrated, Waste, Energy, Biogas
Introduction

The Kenyan country has one of the world’s poorest and densest populations [1] living in the backdrop of the second largest freshwater lake on the earth [2]. The large rural and rapidly growing peri-urban population lacks sustainable solutions to safe and adequate water supply, energy and sanitation with access to safe water and sanitation assessed 57% and 84% respectively by 2006 [3] [4]. The populace depends heavily on biomass resource to supply energy [5] [6] with the dense population overstretching the land resource base. 80% of the rural population and 44.6% of the urban population rely on firewood and kerosene respectively as the major source of energy. This has led to massive degradation of the environment through deforestation, erosion and soil nutrient depletion [7]. The cumulative effects are heralded by the high eutrophication and sedimentation (Figure 1) of the surface water resources [8]. These provide a suitable habitat for the invasive water hyacinth (Figure 1) and the hippo grass.

In the peri-urban settlements, the high dependence on conventional pit latrines and the unplanned disposal of grey water from houses has led to pollution of groundwater resources and overflow of unsafe effluent to the living neighbourhoods [9]. The net effect is a cyclic pollution and contamination of the water systems leading to the proliferation of water borne and water related diseases. The prevalence of water borne diseases continues to compromise the health of the people of this region with morbidity and mortality rates standing at highs of 30% and 60% respectively [10].

Poor access to water, sanitation and energy supplies limits the participation of women in core socio-economic activities and interferes with the learning of the girl child as they allocate their precious time and energy to collect water and firewood for household use. Reliance on firewood and paraffin stoves has their negative effects of polluting the indoor air with a marked negative impact of increased incidences of respiratory diseases like pneumonia [11]. The poor living conditions that militate against the health of the populace, is compounded by the high rate of poverty indexed at 63% of the populace living on less than one dollar per day and 70% regarded as chronically hungry [12]. A multi faceted intervention is therefore required to stem these worrying statistics [13].

![Figure 1: Highly turbid water and invasion by the water hyacinth in Lake Victoria basin](image)

To meet the UN millennium development goals on poverty reduction [14] and battle the overall environmental degradation by 2015 in this region, Ecological Sanitation (EcoSan) is being muted as an entry package [15]. This system aims to improve access to water and sanitation, provide biogas
and biomass for energy and construction purposes and release the requisite manure back to the depleted soils as a step to improving agricultural production [16] (Figure 2).

The goal is to develop a more sustainable way of utilising the natural resources through a concept that turns waste into a resource and thereby take advantage of what are currently considered as problem sources and converting them into useful inputs. The system proposes a paradigm shift from the conventional waste water systems that works on the principle of Mix First Separate then Dispose (MFSD, Figure 3) to one that aims to Keep Separate Treat and Use (KSTU) waste through an innovative multifaceted technological approach operating on the principle of a closed loop system (Figure 4).

In the conventional waste management system, black water which represents a small part of the total waste water, is mixed with the less polluted grey water and then conveyed to the treatment facility for purification. The purification process results in purified water with a quality that is the same as that of the grey water before the mixing process [16]. This linear process [17] is wasteful and unsustainable as it consumes a lot of energy and denies the soils access to the nutrient rich sludge [18].

The EcoSan concept proposes a closed loop system [19] that brings agriculture into the waste management process and thereby reconnects the nutrient chain into the system. This is done by separation of waste products and passing them through an appropriate treatment and reuse cycle that ensures sustenance of a balanced and closed energy and matter chain (Figure 4).

The EcoSan system is being tested through a piloting initiative in six sites in Kenya through an initiative that targets individual households, public places like bus stops, institutions like schools and prisons, agro based industries like sisal farms and slaughter houses and informal settlements.

Figure 2: Paradigm shift on the waste management chain
Methodology

Six pilot sites are being developed across the country of Kenya by the EU-GTZ-Sida funded EcoSan Promotion Project. The systems have been set up to showcase the use of EcoSan principles in improving community and institutional access to water, energy and sanitation.

The sites employ a combination of a constructed wetland-bio-latrine- system and urine diverting dehydrated toilet systems (UDDT) (Figure 5). The main philosophy muted by this principle is one
that “turns waste into resource” while making sanitation rewarding in a way that is appreciated by the system users. Grey water is made available for re-use by purifying it through constructed wetland (Figure 6) and sand filters (Figure 7). The sand filtration uses the *Moringa Oleifera* tree seeds with known flocculating qualities as an organic alternative to aluminium sulphate to purify water to potable levels. A biogas module (Figure 8) is on the other hand used to turn organic waste, faeces and urine into non hazardous plant nutrients while providing alternative clean energy for cooking, heating and lighting. The UDDT supplies the nutrient reach urine and dehydrated faeces to enrich agricultural soils.

![Figure 5: Constructed wetland biogas system and UDDT](image)

Further, other sub-systems are being promoted. For example, the fast growing bamboo is being used in the wetlands not only to purify the waste water but also to serve as an alternative timber material for the construction, furniture and hand crafts industries. Bamboo woodlots would also regulate the environment and act as carbon sinks to counteract the negative effects of global warming.

![Figure 6: Illustration of the constructed wetland](image)
A 42 m² wetland system was designed and constructed to treat grey water from an institutional kitchen in Kendu Bay with a discharge of 2.3 m³ of effluent per day. An inlet tank to the wetland serves as a combined settling tank (Figure 6) for primary treatment of the waste water and grease trap for the separation of grease for use in the biogas system. The effluent from the wetland is collected in an outlet tank from where it is abstracted for non potable uses like gardening or washing or passed through a sand filtration system for further purification. A combination of locally available murram (lateritic) and limestone (calcium carbonate) that contain large concentrations of both iron and calcium serve as an excellent treatment media. Aeration tubes are also integrated into the system to supply oxygen into the gravel bed and reduce leakage of ammonia. Due to the porous nature of the soil at some sites, infiltration rates are reduced by using PVC-membranes or clay as a lining material. The constructed wetland systems are divided into two cells, planted either with a reed (*Phragmites Australis*) or Bamboo plants(*B. Siamensis*) (Figure 5). The purpose of this is to promote the use of the bamboo due to its known purification qualities of the bamboo. The bamboo was chosen due to its structural strength and its multifaceted uses as firewood, timber for building and furniture. In one case, a plug flow biogas system (Figure 8) consisting of a digester lying parallel to the ground with two inlets, for the latrine and the kitchen waste respectively formed the
energy arm of the system. The outlet for the gas was connected to a storage unit made of a PVC-bladder. The digester is designed to be fed continuously with waste every day, maintaining a plug flow movement and ensuring a stable retention time for a complete digestion. A 1m³ digester is fed daily with 30 litres of waste mixed with water. A good mixture between the wastes is guaranteed by the mixing chamber using rotating blades. The digester design has several advantages compared to other types. In most digesters, the slurry is mixed horizontally, with the consequence that some of the slurry is exited after a short period of time. In this design the slurry forms a plug slowly moving forward guaranteeing a retention time of 25 days producing a hygienic and pathogen-free effluent. The effluent is used as a fertilizer in fields irrigated with water from the wetland system. In large institutional settings 50 to 150 m³ dome shaped bio-digesters are being promoted (Figure 9 and Figure 10).

![Figure 9: Dome Shaped Bio-Digester under construction](image)

To reach drinking water quality from surface water resources or from the wetland effluent an additional water purification unit was added (Figure 7) Conventional sand filters do not have the capability to purify raw water of high turbidity unless an additional pre-treatment step is added to the purification process. The system developed is designed to meet at least the domestic and drinking water demand of single household dwellings of up to six people (250 litres per day). The flocculation tank is placed on top of the sand filter to minimize space requirements and allow for gravity flow through the filter module. The flocculation can be done by using either Moringa seeds or aluminium sulphate. The use of aluminium sulphate is however not environmentally friendly and is therefore not a sustainable long term solution. This makes the option of using Moringa seeds that is totally organic and biodegradable a preferable alternative. Where the filter system is used in combination with the biogas unit, the Moringa flocculation product can be passed through the digester to aid in biogas and manure production. The complete water purification system is designed to be easy to use and requires minimal maintenance availed at a pocket friendly price for economic and technical sustainability.

**Results**

Initial results indicate a continual supply of 300 litres per day of gas with 60 percent methane at a pressure of 30 cm water column for the plug systems. This is sufficient to cover the daily cooking needs for a household of six to seven people while improving crop yields by 5 to 20 percent with the 20-30 litres of slurry produced per day. The fields could further be irrigated using 200-500 litres of non potable water available per day from the constructed wetland while the sand filtration system can supply some 100 to 250 litres of water per day with NTU values of less than 5 (Figure 11) purified from the highly turbid water sources (with NTU values of 60 and above) found in the area.
(Figure 1). In large institutions, 15000 to 45000 litres of gas is produced at pressures of 70 to 90 cm of water. This provides about 1/3 of the daily energy needs of schools leading to savings of on firewood equivalent to 20000 shillings per term or a saving on destruction of biomass equated to one hectare of mature wood per year.
Figure 10: Design of a dome shaped Bio-digester
The physiochemical analyses [20] of the effluent from the different sources at one pilot site in Kendu Bay are given in Table 1. The results give an indicative performance of the constructed wetland proving that the system improved the quality of grey water to levels that are acceptable for non potable uses like washing and gardening [21].

<table>
<thead>
<tr>
<th>Physicochemical Parameter</th>
<th>Source of Effluent</th>
<th>Laundry</th>
<th>Kitchen</th>
<th>Wards</th>
<th>Pond</th>
<th>From ponds</th>
<th>Before CW</th>
<th>After CW</th>
</tr>
</thead>
<tbody>
<tr>
<td>PH</td>
<td></td>
<td>9.7</td>
<td>5.7</td>
<td>7.8</td>
<td>6.7</td>
<td>7.2</td>
<td>8.8</td>
<td>7.3</td>
</tr>
<tr>
<td>Dissolved Solids mg/l</td>
<td></td>
<td>2.63</td>
<td>5.24</td>
<td>0.08</td>
<td>0.56</td>
<td>0.57</td>
<td>4.8</td>
<td>1.02</td>
</tr>
<tr>
<td>BOD mg/l</td>
<td></td>
<td>-190</td>
<td>670</td>
<td>750</td>
<td>770</td>
<td>160</td>
<td>700</td>
<td>30</td>
</tr>
<tr>
<td>COD mg/l</td>
<td></td>
<td>912</td>
<td>5120</td>
<td>64</td>
<td>656</td>
<td>416</td>
<td>4800</td>
<td>120</td>
</tr>
</tbody>
</table>

Increased supply of biomass is envisaged together with some cooling effects on the environment due to the modifying effects of the bamboo timber lots growing in the wetland. Further studies are going on to improve on the designs with replications and up scaling sites targeted for peri-urban settlements and institutions that currently do not have access to centralised energy, water and sanitation systems.

**Conclusions**

Tests from the Pilot and replication sites developed show that grey and black water, kitchen and solid human waste can be used as separate inputs into an integrated waste management technological chain system that incorporates a constructed wetland-biogas-sand filter system to purify water and biodegrade solid waste in a manner that provides water for non potable uses, biomass and biogas for energy and timber supply and manure for soil nutrient enrichment.

This holistic approach that ensures that waste is kept separate in the state in which it is generated, treated and used provides a viable solution to increasing rural and peri-urban access to safe water and sanitation and energy for domestic and agricultural use. The system when applied at macro scales will stem the increasing trends of environmental degradation while providing a lifeline to the disenfranchised rural communities who do not have access to safe and adequate water, sanitation and energy supplies. It is the kingpin that will stimulate the social and economic fabrics of the
country’s vision 2030 when engineered into the water, energy and sanitation solutions of the country.

Acknowledgments

The author(s) would like to extend their gratitude to Katwekra and Kendu community for providing sites for the initial pilot work and Sida Stockholm, EU and GTZ for the funds used to set up the pilot sites.

References


[16] Jönsson H. *The role of EcoSan in achieving sustainable nutrient cycles*, 2nd international symposium on ecological sanitation, 2003; 35-41


