37th WEDC International Conference, Hanoi, Vietnam, 2014

SUSTAINABLE WATER AND SANITATION SERVICES
FOR ALL IN A FAST CHANGING WORLD

Is manure from ecological sanitation latrines safe for use to fertilize crops? A review of evidence from literature

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REFEREED PAPER 1853

Studies have shown that manure harvested in ecological sanitation (ecosan) latrines has more thermo tolerant bacteria and helminthic eggs than the World Health Organisation (WHO) recommendation. The review was aimed at assessing adequacy of available guidelines on use of ecosan to produce safe manure. Relevant literature was searched and critically reviewed. Literature on effect on pathogen die off was not consistent from one study to the next and in some situations conflicting results have been found. Guidelines on waiting period after pit is sealed differed from one country to the next and there is an agreement that six months waiting period is not enough to produce safe manure. There is need for further research in real latrine situation to investigate all potential factors that affect pathogen die off. These may assist to explain inconsistencies in literature on pathogen die off and assist to develop specific guidelines for different locations.

Introduction

In low income countries, diarrhoea was the third cause of death leading to 6.9% of all deaths and most of the deaths were in the under-five children, while globally, diarrhoea was ranked fifth accounting for 3.7% of total deaths (WHO, 2008). The main factors that lead to diarrhoea include lack of sanitation and hygiene, consumption of unsafe water and other diseases including helminthic infection. It is estimated that 2.6 billion people lack adequate sanitation as compared to 1.1 billion who lack improved water supply (Moe and Rheingans, 2006). To improve access to basic sanitation in order to meet the Millennium Development Goal (MGD) number seven by 2015, will require implementation of sustainable technological solutions (Moe and Rheingans, 2006). The world spends the required amount of money on sanitation but inappropriately, there is need for appropriate technologies to achieve universal access (Mara et al., 2010). The effective sanitation technology should both provide access and reduce public health risks.

It is known that parasitic diseases caused by helminthes and protozoa are major causes of human disease and misery in most countries of the tropics. The WHO estimates that one person in every four harbours parasitic worms ("WHO | Parasitic diseases," n.d.). A study done in Malawi indicates a prevalence of Schistosoma haematobium at 10.4% in children in Blantyre (Kapito-Tembo et al., 2009). One of the strategies to reduce diarrhoea and parasitic infections is to have and properly use improved sanitation. There are several types of latrines used for disposal of human excreta and these include traditional pit latrines, improved traditional pit latrines, ecological sanitation (ecosan) latrines, ventilated improved pit latrines, pour flush latrines and water closet latrines. While the other types of latrines have been in existence for many years in Malawi, ecosan was first officially practiced in the country in year 2001 and was introduced by Water Aid in Salima and by the Church of Central African Presbyterian (CCAP) in Embangweni (Morgan, 2010).

Ecosan is the type of sanitation option where the contents of latrine (manure) or urine diverted or both are used as fertilizers for agricultural use. This is called closing the loop (Figure 2). Closing the loop means making available the nutrients that may have been lost if urine and faecal matter is buried and never reused (Esrey, 2001). Ecosan, is an approach used towards the provision of basic sanitation. It is an environmentally friendly sanitation technology that allows economic use of human excreta after decomposition (Ministry of Irrigation and Water Development., 2011). Ecosan promotes recycling of nutrients contained in excreta to grow crops and fruits; thus enhancing food security and reducing the need to rely on artificial fertilizers (Schuen, R. and Parkinson, J, 2009). Human excreta contain nutrients suitable for agriculture such as nitrogen, urea, potassium and phosphorous (Ministry of Irrigation and Water Development., 2011; Schuen, R. and Parkinson, J, 2009). History traces reuse of faecal matter in China, Greece, Rome and Britain in the ancient times. For example, in Britain, Henry Moule persuaded farmers to fertilize their crops with earth from his latrine in the 1840's (Smet and Sudgen, 2006). In China, the use of human manure is predicted to have started more than three thousand years ago (Shiming, 2002). Shiming noted phrases like "use of excreta in the fields" in literature dating back to 475-221 BC and 221-207 BC. Ancient writers indicated that human excreta improve soil fertility and were used to fertilize crops directly and were also used for fish ponds as food for fish (Shiming, 2002). Swedish International Development Coorporation Agency (SIDA) started researching on sustainable ecological sanitation in 1993 while in Ethiopia, ecological sanitation started in 1994 as Economy, Ecology and Sanitation (ECOSAN) (Terrefe and Edstrom, 2005; Winblad et al., 2004).

In Malawi, three types of ecosan are available. Their shape and size are mostly determined by that of the san plat used. The types include Fossa Alterna which means alternating pits, the Skyloo which is built above the ground with double vault for collection of human excreta once decomposed within 6 to 12 months, and is also called urine diverting dry toilet (UDDT) if urine is separated from faeces and the arborloo which is a simple, composting toilet with a portable slab, pedestal and superstructure (Fig. 1). The arborloo pit is dug up to one metre in depth (Ministry of Irrigation and Water Development., 2011).

Arborloo **Skyloo (UDDT)** **Inside Forsa antenna**

Figure 1. Types of ecosan latrines

The ecosan technology just like the water closet toilet invented by John Harrington in 1596 and further improved in the subsequent years to the present time, needs research to improve to acceptable and convenient levels (Figure 2). The water closet latrine had several challenges including failure to flush, smell, noise and frequent breakdowns but these have been improved overtime and nowadays it is an important technology that helps prevents disease and pollution in most of the cities in the world (Pathak, 1995). Similarly, Ecosan latrines may seem to pose health risks and involve strict operations but with time, these may be modified and it can be the next sanitation option for all in the years to come. The technology does not rely on water which is becoming a problem and threatens use of water closet latrines (Winblad et al., 2004). The framework for improvement of ecosan latrines is outlined in Table 2 below.

Since some literature is available on safety of ecosan latrines, it was important to review it and determine if the manure from ecosan latrines is safe and decide if there is need for further research. This article therefore presents a review of literature on the adequacy and consistency of information on pathogen die off in ecosan latrines. The review will assist in determining whether manure from ecosan latrines is safe to handle and use in agriculture.

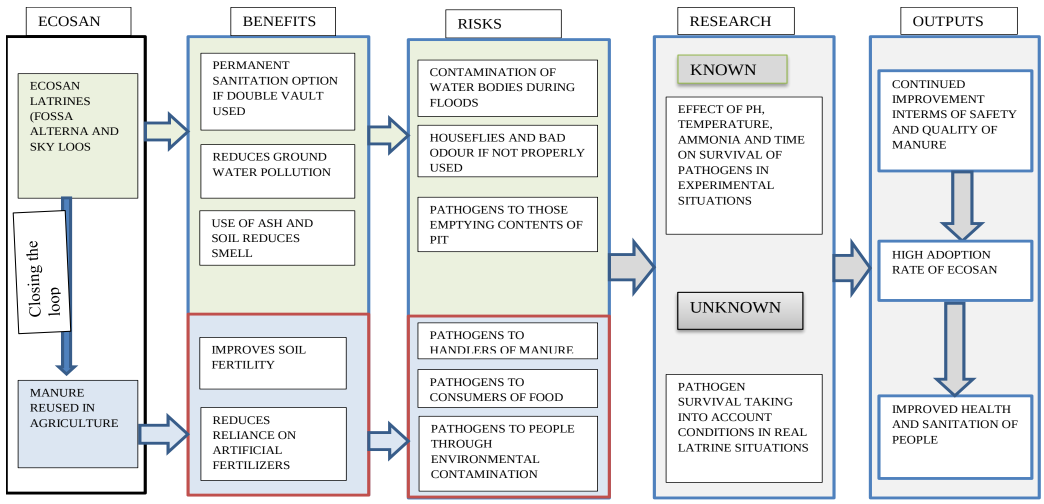

Figure 2. Summary of concepts of ecosan latrines

Methods

Relevant literature was searched from PubMed, The Lancet, BioMed Central, African Journals Online (AJOL), EcoSanRes website, Share research website, websites for Non-Governmental Organizations with ecological sanitation projects and from unpublished literature from Organisations. Information was also gathered through consultations with experts in the field and general internet search using keywords. References from key articles retrieved were also searched and analyzed. The search was repeated every month for a period of six months (July 2013 to December 2013) when saturation was reached. Retrieved literature was grouped according to the specific objectives and critically analyzed. Included in the analysis were journal articles, conference reports, books and reports on ecological sanitation latrines. The articles were included regardless of their design, year of publication and ecosan latrine type. Literatures for other types of latrines which are not ecological sanitation and reports in non-English language were excluded.

Results

Factors affecting pathogens die off in ecosan latrines

On factors that lead to pathogen die off, eight articles and documents were revised as summarized in the Table 1 below.

There are various studies done to determine the factors leading to pathogen die off in ecosan manure but still more research need to be done to understand the complex environmental interactions. The obvious factors include temperature above 36 degrees, moisture content below 25%, pH greater than 10 and storage time (Scott, n.d.). From Table 1 above, it has been found that different levels of lime added to faeces were not associated with pathogen die-off while hot conditions in summer, ammonia, storage for 3 months or more and regular stirring of faecal matter were associated with pathogen die-off (Jensen et al., 2009). This partly agrees with results from a study done in rural Panama where high pH treatment did not achieve total inactivation of helminthes (Mehl, 2008). However, the effect of pH by addition of lime, ash or oyster in combination with ammonia from urea or urine contributed significantly to pathogen die off (Magri et al., 2013; McKinley et al., 2012). While other studies find that temperature contributes to pathogen reduction (Nordin, 2010; Nordin et al., 2009), the other study found that temperature was not related to survival of microorganisms in faecal matter. The study recommended further studies on impact of humidity because it was hypothesized that high humidity might be the cause of inactivation despite the high temperatures observed. This could also be the case in rural Panama (Mehl, 2008).

Table 1. Effects of different factors on pathogen die off in ecosan manure

	Author (s) and year	Study design, place and type of ecosan latrine used	Factors investigated	Effect on pathogen die off
1.	Jensen et al., 2009	Experimental using heaps of faecal matter collected from non-urine diverting double vault composting latrines in Vietnam	pH, ammonia, temperature and moisture content	More than 99% die-off of eggs after 105 to 117 days of storage for all lime concentrations and 97% of eggs were non-viable after 88 days. Ammonia (urine) was critical in pathogen die off while pH did not matter
2.	Magri et al., 2013	Experimental using layers of faeces from urine diverting dry latrines	Desiccation, pH (oyster, Ash) and ammonia (urea)	Different combinations of oyster, ash and urea produced 7 log10 units of all bacteria and bacteriophages reduction within 2.8, 4.2 and 6.1 months respectively
3.	McKinley et al., 2012	Experimental study in urine diverting dry latrine in Bolivia	Ammonia, pH on Ascaris suum ova die off	Compost mixed with urine and ash was most effect at 99% inactivation in 2 months (8 weeks)
4.	Nordin, 2010	Experimental study using faecal matter from men in military service and faecal bins of those using urine diverting latrines and also urine from various sources in Uganda	Ammonia and temperature	Temperature proved to be key for NH_3 (aq) toxicity on the viral models and *Ascaris* eggs. At NH_3 concentrations in the interval 20-60 mM, a sharp decrease in inactivation was observed at 24 ºC and below. Ascaris persisted at 14 ºC
5.	Nordin et al., 2009	Experimental study of faeces and urine collected for a month from a source separated toilet for a single household in Uppsala, Sweden	Ammonia and temperature	At 34°C eggs were inactivated in less than 10 days. Treating faeces at 34°C can give a 6-log10 egg inactivation within 1 month, whereas at 24°C, 6 months of treatment is necessary for same level of egg inactivation. At temperatures of 14°C and below, inactivation rates were low
6.	Mehl, 2008	Cross sectional survey of double vault urine diverting composting latrines for households in rural Panama	Temperature, high pH, desiccation and decomposition	Various pathogens mainly helminthes were still present in faecal samples even after 6 months of decomposition
7.	Itchon et al., 2009	Observational study of urine diverting dehydrating latrines' excreta in Philippines	Time	Parasitic eggs still persist after six months of treatment. Temperature was not related to survival of microorganisms.
8.	Höglund et al., 2002	Observational laboratory study of urine from urine diverting latrines	Time and pH	90% of Gram -ve bacteria was inactivated in less than 5 days at pH 9 in urine. Clostridia spores were not reduced at all after 80 days

In terms of pathogen die-off, the arbour loo does not present any risk as the contents are not harvested for use as manure. The non-urine diverting latrines (sky loos and fossa antenna) have been suggested to produce safe manure within three months because of the effect of ammonia which is produced from urine (Jensen et al. 2009). The period of die off is reduced with other conditions like addition of ash and increase in temperature (McKinley, Parzen, and Mercado Guzman 2012; Nordin 2010). Ammonia was found to be the critical parameter in determining die off of pathogens in latrines where urine is not diverted (Jensen et al. 2009). A recent study found that ammonia or urea are not the important parameters instead pH and dessication were the most important factors in pathogen die off and hence suggesting that urine diverting dry latrines are effective in pathogen die off (Magri, Philippi, and Vinnerås 2013). Standardized research on all the possible factors across the globe where ecosan is practiced may help to come up with the real differences in pathogen die off.

The study results by Nalivata and Kadewa compiled into a report (Morgan and Mekonnen, 2013) puts it clear that humanure from eocsan latrines in Malawi is not safe and recommends further investigation. The microbiological analysis results showed a high level of faecal coliforms and Ascaris eggs contrary to the World Health Organization's guidelines for sludge use in agriculture (World Health Organization, 2006). The authors argue that the varying levels of pathogens in humanure is due to various factors including altitude, humidity, density of location and prevalence of diseases in these areas which have not been researched and hence not taken on board during designing and implementation of ecosan latrines in Malawi. They also argue that the high pathogen survival may be due to design and lack of seriousness in operating the latrines. They observed that less ash and soil were added and that most organizations in Malawi were advocating for a waiting period of 6 months after sealing which according to them was less than the recommended period of 12 months (Morgan and Mekonnen, 2013).

Period of storage after sealing the ecosan latrine

Period of storage after sealing the pit is known to be an important factor leading to pathogen die-off. The period of storage is supposed to vary depending on environmental conditions (i.e. temperature, humidity and seasonality) and household conditions (i.e. health status of members and materials for anal cleaning), but literature search has shown that these variations are not taken into account as the maximum limits are used. Few studies looked at the waiting time and in this review, the mentioned periods in various literatures were used (Table 2).

Table 2. Recommended periods of treatment after the ecosan pit is sealed

	Reference	Recommended storage period after sealing	Type of ecosan latrine	Country
1.	Biplob et al., 2011	Six months	Urine diverting dry toilet (UDDT)	Bangladesh
2.	Jensen et al., 2009	Six months	Ecosan latrines	Vietnam
3.	Mehl, 2008	Six months	Ecosan latrines	Panama
4.	Itchon et al., 2009	Six months	Ecosan latrines	Philippines
5.	Morgan and SEI, 2004	Twelve months	All ecosan latrines	Malawi and Mozambique
6.	CCODE, 2011	Six months	All ecosan latrines	Malawi
7.	WaterAid, 2011	Six to twelve months	All ecosan latrines	General handbook by WaterAid in Nepal
8.	Winblad et al., 2004	Six to twelve months	Ecosan latrines	Book on ecosan
9.	Morgan and Mekonnen, 2013	Twelve months	All ecosan latrines	General recommendation

Centre for Community Development (CCODE), one of the NGOs promoting ecological sanitation in Malawi shows that they are not certain of the actual period of storage after the pit is sealed but they recognize that the period may vary. In their field note report posted on their website, they wrote: "…*Decomposition periods may vary depending on environmental conditions; however, a period of six months is often regarded enough for optimum decomposing of the faecal matter…"* (CCODE, 2011). Morgan and Mekonnen in their report published in 2013 have also indicated that most NGOs in Malawi do not advocate to 12 months storage period. The NGOs encourage people to store the pit contents for 6 months after it is sealed. The statement by Morgan and Mekonnen is not easy to interpret making people to conclude that 12 months is for both usage and storage. The statement reads "…The two alternating pits were designed with an optimum period needed for a complete composting and service time of 12 months" (Morgan and Mekonnen, 2013). Morgan in 2004 report clearly indicated that storage time should be 12 months (Morgan, 2010). The other literature from other countries is clear on the storage period after sealing the ecosan pit. A study by Jensen and others in Vietnam indicated that the official guideline for storage after sealing the pit was 6 months but households were waiting for three to four months contrary to the guideline (Jensen et al., 2009). The guideline of 6 months was similar to that in Panama where the pits are designed to fill in about 6 months depending on family size and are supposed to be stored for another 6 months (Mehl, 2008). In Philippines, Itchon and others found that the 6 months period was not enough to kill helminthic ova (Itchon et al., 2009), this may be the reason why others recommend a period of between 6 to 12 months (WaterAid, 2011; Winblad et al., 2004). However, the period of 6 to12 months in rural areas where educational levels are low and poverty is high, the people may not wait for 12 months to get the much needed humanure to fertilize their gardens.

Conclusion

Manure from ecosan latrines may not be safe for handling and use in agriculture. Waiting period of six months is not enough in most intances to sanitize human faecal matter for use in agriculture and need more studies on various factors that lead to pathogen die off. It is hypothesized that designing and managing ecosan latrines depending on prevailing environmental conditions at a household level will make the inactivation of pathogens successful and complete. The conditions that successfully lead to pathogen die-off are different in different areas depending on environmental conditions and these should assist in determining waiting period after sealing the pit. It has also been found that most studies on effectiveness of different factors on pathogen die off were experimental hence results from these studies may not be directly applicable to real situations in latrines due to non-controlled environments hence the need for a comprehensive observational follow up study.

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Acknowledgements

This paper has been compiled from the literature review of my PhD proposal which I am currently pursuing with support from Consortium for Advanced Research Training in Africa (CARTA), Scotland Chikhwawa Health Initiative (SCHI) and The Polytechnic.

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