HOUSEHOLD ADOPTION OF ECOLOGICAL SANITATION: An Assessment of Agricultural Value and User Perspectives in Nyanza Province, Kenya

by

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Abstract

Ecological sanitation, or ecosan, refers to a range of sanitation technologies in which human excreta is recovered and retained on-site, and eventually reused. However, when a culture does not have a tradition of reusing or handling human waste, what would motivate a household within that culture to recycle and reuse their waste? More specifically, how do the agricultural value of the material from an ecosan toilet and user perspectives on ecosan systems influence households' adoption of ecosan toilets?

On average, households in the study area produce 4 kilograms of nitrogen and 0.6 kilograms of phosphorous per year from urine collected in the skyloo toilet, the type of urine-diverting ecosan toilet available in the study area in the Nyanza Province, Kenya. These nutrients are the equivalent of a cost savings of about US $12 per year (the GDP per capita in Kenya in 2004 was US $1100). About two-thirds of the households reuse the processed feces and urine in household gardens. Users reported additional major benefits such as the absence of foul odors, inexpensive construction costs (partly due to a materials subsidy by the promoting NGO), and the aesthetic value/social status that the facility brings to the owners' homes. The major negative factors included problems with construction and design of the facility, training new users—especially children—how to use the toilet, and handling human excrement.

The findings suggest that ecosan is a viable sanitation option that fills a niche within this region of Kenya. Ecosan's comparative advantages seem to be significant enough to outweigh negative cultural sentiments regarding the handling of human excrement to some user groups. Such user groups include the very poor who practice household agriculture (those who have trouble affording commercial fertilizer and also have reason to want it), those who live in areas with high nutrient loads to natural waters, households with an exceptional environmental conscious, and households in which adverse hydrogeologic conditions (such as a high water table or loose soils) make pit latrines an environmental and human health hazard. In addition to household-level advantages, the niche that ecosan fills has the potential to make headway towards the Millennium Development Goals' provision of sanitation, and to be a valuable contribution to integrated water resource management strategies.

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1 Introduction

1.1 The Challenge

It took two hours to find the Chief's house as we rode down narrow single-track paths, which were actually intended for foot travel, on our motorcycle. We stopped at multiple houses, each time told to keep heading further down the unpaved trails into the African bush. We were on our way to visit a household that reportedly had an ecological sanitation toilet, the fifth house of the day.

Upon arrival at the household (with a group of children and on-lookers in tow), it became clear that they did not actually have an ecosan-style toilet, but what appeared to be a regular pit latrine. Closer inspection revealed that the man had retro-fitted his pit latrine with a urine-separating device, which diverted urine to the ground next to the toilet. We asked this man, who was a Chief of his village and a respected community leader, why he opted *not* to build a complete ecosan toilet (which he had the opportunity to do), but only a hybrid combination of ecosan and a traditional pit latrine. The man responded in well-spoken English, "people around here don't like those kind of toilets. Handling their own feces is not something they are used to, and even if they were personally not opposed to it, the community would shun them. Even if a house had that kind of toilet, no one would use the manure from it."

The Chief's statement is a clear reflection of the way we might expect most families to respond to the idea of reusing their feces and urine in their home's family garden, i.e. for food that will eventually end up on their table. This is especially true when we consider some of the normal cultural attitudes toward human excrement in this area. Local Luo custom dictates that feces is "bad" and has the potential for negative consequences to family members. In this part of Kenya, feces have a history of being used in witchcraft and are reported to cause eye disease if it is looked at for too long.

Most people would likely identify with these feelings toward human excreta. Even if the reasons for cultural aversion are different, many (if not most) cultures across the world would consider themselves opposed to handling human feces and urine. How would most people in Europe or the United States respond to the opportunity to recycle their excrement for a backyard vegetable garden? Would they do it? What incentives would someone need to even *try* using it?

This thesis investigates what motivates households to adopt an ecological sanitation toilet. In a community that mostly uses pit latrines or openly defecates in "the bush," and reuse of human excrement has no cultural context, why would someone choose to use a technology and practice that is clearly incongruous with the general community's attitudes and sentiments?

1.2 Goals and Objectives

Ecological sanitation refers to technologies and practices in which human excreta is collected and processed in a manner such that: 1) it does not pollute water systems; 2) human excreta is processed to a point that it is safe for human handling; and 3) the material can be utilized in ways that take advantage of its nutrient properties (Esrey, 1998; Esrey, 2001; GTZ, 2003). Ecosan is not a singular technology, but "an approach which takes economic, ecologic, and social parameters into account... by promoting... new sanitation principles and concepts" (Müllegger, 2004: 3).

This thesis broadly aims to explore why households would choose to adopt ecological sanitation and choose to use a toilet that recycles their excrement for reuse. The research seeks to address three aspects of this topic in greater depth:

1) What is the agricultural value of reusing urine?;
2) How is excreta managed after it has been recycled?; and
3) What are the important factors of the ecosan toilet (aspects they like and dislike) to the ecosan owners?

The first question seeks to characterize the nutrient value, specifically the nitrogen and phosphorous content, of the urine. These values can be quantified into the amount of nutrients that urine could contribute to agricultural productivity, and it can then be seen if the agricultural applicability of the urine might be able to convince households to adopt an ecosan toilet.

Answering the second question regarding how excrement is managed after it has been recycled (when it leaves the toilet) will provide a means to characterize whether or not households reuse the processed fertilizer material, and what reuse methods households are employing. An understanding of this aspect of households' use of the ecosan toilet will demonstrate the value that households give to the processed excreta.

Finally, by asking users about their likes and dislikes of their ecosan toilet, we can gauge what benefits the ecosan toilet brings to the users and what costs or negative impacts it might impose. Characterizing these positive and negative aspects of the toilet will make it possible to comment on other reasons, besides the agricultural products, that households might be attracted to the ecosan toilet.

Gathering information on these three topics, I draw conclusions regarding why people would adopt this type of toilet. It is hoped that this information will be valuable to international development organizations, local non-governmental organizations, and governments that promote ecosan. This information will allow these institutions to (a) better promote ecosan toilets to potential owners and communities; and (b) allow ecosan systems to be designed to more specifically meet user's needs, and (c) help inform policy decisions and discussions regarding options of sanitation technologies and integrated water resource management strategies.

1.3 Relevance and Importance

In more developed countries, the major reported benefits of ecosan usually focus on achieving goals related to environmental sustainable development and the prevention of pollution to receiving water bodies. In developing countries, these benefits also include access to safe and improved sanitation. This thesis will focus on ecosan's application in developing countries, specifically in western Kenya. While much ecosan research to date has concentrated on the health and agricultural reuse aspects of these systems in developing countries, little rigorous work is available on the actual field use of these systems at the household level, and why users would choose to adopt toilets that produce human fertilizer. Many practitioners have reported that most ecosan systems are not used in ways that fulfill the real potential of these systems, that is, complete reuse of human excreta (Knapp, 2004a). This research will help identify some of the reasons for this in one region of Kenya.

This thesis draws on field data regarding the agricultural potential of urine from urine-separating ecosan toilets and contributes to the understanding of the impact of an ecosan project that has actually been implemented. Many research projects have conducted agricultural experiments with the material from ecosan toilets (see GZT, 2003); however, they do not examine the value of the nutrients gained from urine as compared to other locally available nutrient sources such as commercial fertilizers. The data collected and presented here will contribute to the growing body of literature available, as well as the debate on the economic efficiency of ecosan technology (see McCann, 2005).

1.4 Major Findings

On average, households in the study area produce 4 kilograms of nitrogen and 0.6 kilograms of phosphorous per year from urine collected in the skyloo toilet, the type of urine-diverting ecosan toilet available in the study area in the Nyanza Province, Kenya. These nutrients are the equivalent of a cost savings of about US $12 per year (the GDP per capita in Kenya in 2004 was US $1100). About two-thirds of the households reuse the processed feces and urine in household gardens. Users reported additional major benefits such as the absence of foul odors, inexpensive construction costs (partly due to a materials subsidy by the promoting NGO), and the aesthetic value/social status that the facility brings to the owners' homes. The major negative factors included problems with construction and design of the facility, training new users—especially children—how to use the toilet, and handling human excrement.

The findings suggest that ecosan is a viable sanitation option that fills a niche within this region of Kenya. Ecosan's comparative advantages seem to be significant enough to outweigh negative cultural sentiments regarding the handling of human excrement to some user groups. Such user groups include the very poor who practice household agriculture (those who have trouble affording commercial fertilizer and also have reason to want it), those who live in areas with high nutrient loads to natural waters, households with an exceptional environmental conscious, and households in which adverse hydrogeologic conditions (such as a high water table or loose soils) make pit latrines an environmental and human health hazard. In addition to household-level advantages, the niche that ecosan fills has the potential to make headway towards the Millennium Development Goals' provision of sanitation, and to be a valuable contribution to integrated water resource management strategies.

1.5 Organization of this Thesis

This chapter presents an introduction to the thesis and the motivation for the research. Chapter 2 gives an introduction to ecological sanitation, its global applications, and how the technology and practice works. Ecological sanitation in Kenya, and more specifically the area where the research took place, is described in greater detail in Chapter 3, as is the ecosan program of the Kenya Water for Health Organization (KWAHO), the NGO whose toilets were studied. Chapter 4 describes the methods that were used to investigate the research questions. Chapters 5, 6, and 7 examine each of the three research questions noted above, respectively. Finally, Chapter 8 synthesizes the research and provides conclusions and recommendations.

2 Ecological Sanitation

2.1 Introduction

The past decade has seen rapid development and diffusion of ecological sanitation around the world. Ecological sanitation, or ecosan, refers to a variety of technologies that recover and recycle human waste for uses that take advantage its nutrient properties. Early contributions by the World Bank (1980-1982; Feachem et. al. 1983) and the Swedish International Development Cooperation Agency (Sida) laid the foundation for international development projects which began to flourish in the late 1990's. By 2001 an annual international ecosan-dedicated conference started with the first session in Nanning, China. Presently, the international development community is producing a vast amount of research and publications dedicated to ecological sanitation. While the theoretical value of the technology is clear, it remains to be seen if it has the potential to make large-scale impacts on excreta management and control in developing countries around the world.

Ecological sanitation has received much attention because of its ability to provide adequate sanitation to households, provide a nutrient-rich product, and protect water resources. Goal 7 of the United Nations' Millennium Project is to "ensure environmental sustainability" (United Nations, 2005). Target 10 of the Millennium Development Goals is to halve the proportion of the world's population without access to safe water and improved sanitation, and Target 9 aims to "reverse the loss of environmental resources." Ecological sanitation works toward achieving both of these targets and consequently could be an ideal component of integrated water resource management initiatives.

Communities, however, often have negative associations with human excrement. Feces have an offensive smell, contain a variety of pathogens that are harmful to human health, and often provoke visceral disgust and aversion. Over time this dislike and disgust can be incorporated into culture. Feces can be viewed as not only repulsive, but also dangerous: "human faeces are disgusting enough to exemplify the saying that 'evil should be fought with evil' " (Drangert, 2004: 24). What, then, would motivate a household to violate these general human sentiments, especially in a society that does not have a history or reuse of human excrement, and choose to adopt an ecosan toilet?

This chapter describes the basic components of ecological sanitation and shows that, when managed properly, the reuse of human feces and urine can be both hygienic and valuable with respect to the agricultural application of its nutrients.

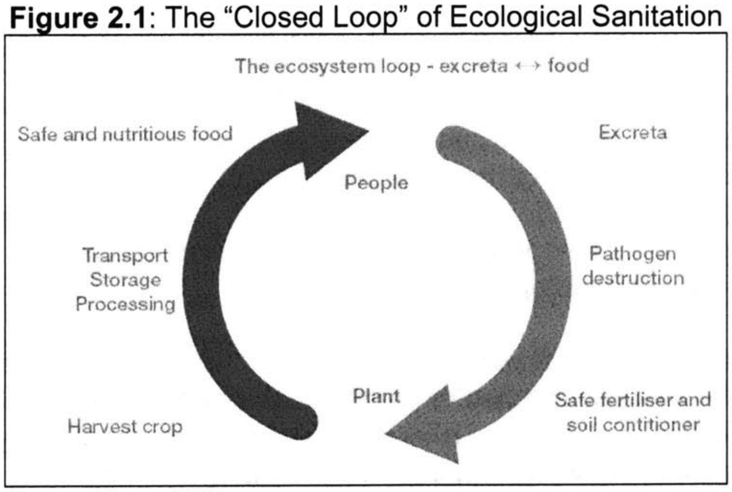
2.2 What is Ecological Sanitation?

Over human history, human excreta has returned to the land through agriculture or dispersed defecation on the open land (Rockefeller, 1996). As Uno Winblad (1997: 4) notes, "The human body does not produce 'sewage'. Sewage is the product of a particular technology." The technology to which he refers is the piped infrastructure needed for centralized sewerage collection and wastewater treatment facilities.

Ecological sanitation, or ecosan, refers to decentralized sanitation technologies in which excreta is recovered and retained on-site, and eventually reused. Ecosan differs from other decentralized sanitation systems (such as a pit latrine) in that there is a deliberate focus on the reuse of excreted material as opposed to treating it as waste. In ecosan systems, excreta is collected and processed in a manner such that: 1) it does not pollute water systems; 2) human excreta is processed to a point that it is safe for human handling; and 3) the material can be utilized in ways that take advantage of its nutrient properties (Esrey, 1998; Esrey, 2001; GTZ, 2003). It is important to note that ecosan is not a single new technology, but "an approach which takes economic, ecologic, and social parameters into account... by promoting... new sanitation principles and concepts" (Müllegger, 2004: 3).

The ecosan process can be thought of as a "closed loop" cycle of nutrient flows. The cycle starts with human consumption of food, which then leads to defecation and urination, the excretion of bodily "wastes," which ecosan technologies regards as "resources." The feces then lay fallow in a vault for a processing time (usually 6-12 months is needed for proper pathogen die-off under anaerobic conditions). Later it is brought to its reuse destination, where it is distributed to the soil to be absorbed by plants over time. In the case where these plants are crops, nutrients from the human fertilizer are consumed again by humans. Figure 2.1 depicts this cycle. Industrialized sanitation systems break this loop and effectively create a linear system of flows. Excrement is flushed through sewerage systems, possibly treated at a wastewater treatment plant, and then discharged into a receiving water body.

Figure 2.1: The "Closed Loop" of Ecological Sanitation



Source: Esrey, 2001

While the value of using human excreta as a fertilizer has been recognized in some communities, such as China, for at least the past few thousand years (Winblad et. al., 2004), ecosan has only recently begun to gain recognition as a technical option that could be institutionally promoted and implemented on a wide scale. Stenström (1997: 23) notes that "with our rapidly growing knowledge we can, in theory, make more sound risk assessments while at the same time taking advantage of the nutrient potential of the material." In the past few years, there has been an explosion of published material in the field of ecosan,[1] and many international development organizations around the world are now studying and building various types and designs.

2.3 The Dominant Sanitation Paradigm

Industrialized sanitation systems typically use water-based flush toilets to dispose of human waste through a sewerage collection system. Excreta (urine and feces) are transported through sewerage pipes to centralized wastewater treatment facilities. After the wastewater undergoes treatment, it is then discharged into a river, lake or ocean.

It has long been recognized that people in developing countries do not have comparable forms of hygienic sanitation (Kalbermatten, 1980). In the international development field, the dominant paradigm in addressing sanitation has been to try to provide select communities with industrialized sewage systems. However, these types of systems are often a poor technological fit for many of these lesser economically developed places (Kalbermatten, 1980). The initial capital cost of installing piped sewerage networks often makes them too expensive to be an affordable or viable option (Esrey, 2001). Even when a community builds a piped network, it is not always accompanied by a wastewater treatment system; 90 percent of the wastewater in developing countries discharges into receiving water bodies untreated (Esrey, 2001; Schlick, 2001). An economically and technically appropriate first step in wastewater treatment in many developing countries that has been proposed for wider use is chemically enhanced primary treatment (Harleman and Murcott, 2001; Parker et. al., 2001). However, conventional forms of centralized sanitation still include large operation and maintenance costs, high rates of water consumption, frequent service to the wealthy and neglect of the poor (GTZ, 2004).

Decentralized, on-site sanitation is an alterative to the centralized wastewater treatment paradigm. Excrement is processed and disposed of locally with a type of facility and technology that is appropriate for the given setting (Kalbermatten, 1980). In developing countries, decentralized sanitation can offer a viable alternative to conventional systems for dispersed rural populations and informal urban/periurban settlements due to its low cost and limited use of technology.

There are many types of decentralized sanitation, each with varying costs and benefits.[2] In rural Kenya, the dominant method of excrement disposal is a pit latrine. The Demographic and Health Survey for 2003 reports that 44 percent of Kenyans use a pit latrine while 39 percent have flush toilets. When looking at a more rural region like Nyanza Province (where this research was conducted) the usage of pit latrines is even more widespread—66 percent of the population uses a pit latrine. The majority of the remaining population in Nyanza, 26 percent of the total, has no sanitation facility at all and use "the bush" (Central Bureau of Statistics, 2004). When introducing a new sanitation technology, like ecosan, communities are bound to compare and contrast it

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[1] Seminal works in the mid 1990's include Winblad, 1985, Winblad, 1997 and Esrey 1998. These were all published by the Swedish International Development Cooperation Agency (Sida).
[2] See Vol. 1, 4-8, and 10-11 of the World Bank Series: "Appropriate Technology for Water Supply and Sanitation," 1980-1982.

with the more familiar pit latrine. This thesis focuses on ecological sanitation as an alternative to the dominant sanitation paradigm in Nyanza Province.

2.4 Nutrient Composition of Excreta

The main limiting nutrient elements for the growth of plants are nitrogen, phosphorus, and potassium. The plant nutrients that humans consume in the form of food are excreted in urine and feces. In an adult, nearly 100 percent of the consumed plant nutrients are excreted because there is no longer net accumulation of nitrogen, phosphorus, or potassium in the body (Jönsson et. al. 2004). Therefore, the foods that one eats should be directly related to the amount of plant nutrients that one excretes.

Table 2.1. Excreted Nutrients Per Capita in Various Countries[3] (compiled from Jönsson & Vinnerås, 2004 and SEPA, 1995)

Country		Nitrogen kg/cap/yr	Phosphorus kg/cap/yr	Potassium kg/cap/yr
China, total		4.0	0.6	1.8
	Urine	3.5	0.4	1.3
	Feces	0.5	0.2	0.5
Haiti, total		2.1	0.3	1.2
	Urine	1.9	0.2	0.9
	Feces	0.3	0.1	0.3
India, total		2.7	0.4	1.5
	Urine	2.3	0.3	1.1
	Feces	0.3	0.1	0.4
South Africa, total		3.4	0.5	1.6
	Urine	3.0	0.3	1.2
	Feces	0.4	0.2	0.4
Sweden, total		4.6	0.5	1.3
	Urine	4.0	0.4	0.9
	Feces	0.5	0.2	0.4
Uganda, total		2.5	0.4	1.4
	Urine	2.2	0.3	1.0
	Feces	0.3	0.1	0.4

Jönsson and Vinnerås (2004) estimated average nitrogen, phosphorus, and potassium contents from country-specific nutritional data for five countries: China, Haiti, India, South Africa and Uganda (Table 2.1). Table 2.1 does not represent actual data collected in urine and feces samples in these countries, but rather estimates of average nutrient concentrations in these countries based on diet as reported by the Food and Agriculture Organization (2005). This table is presented here to show the range of compositions that are possible due to differences in diet. The nutrient compositions between the different countries are diverse, yet there is a consistent proportional difference in the distribution of nutrients in urine versus that in feces.

(3) In some cases, combining 'urine' and 'feces' do not equal the 'total' due to round-off errors and computational variability in the conversion from nutrient data to excreta content.

Nitrogen and phosphorous are the major limiting nutrients in plant growth and are, therefore, the major constituents of interest in excrement. Table 2.2 shows that about 90 percent of the nitrogen in excreta is found in the urine, as is about 70 percent of the phosphorous and potassium.

Table 2.2: Average distribution of Plant Nutrients in Human Excreta (compiled from Jönsson & Vinnerås, 2004 and SEPA, 1995)

	Urine Average	%	Feces Average	%
Nitrogen (kg/cap/yr)	2.82	87.8%	0.36	12.2%
Phosphorus (kg/cap/yr)	0.31	67.9%	0.14	32.1%
Potassium (kg/cap/yr)	1.07	73.1%	0.40	26.9%

2.5 Pathogens in of Excreta

A central concern with reuse of human excrement is the associated health risks. It is natural, perhaps even evolutionarily instinctual, to be adverse to human excrement because of its ability to cause sickness. It is no surprise then, that people are initially skeptical about this method of dealing with human waste. The pathogenic characteristics of urine and feces are briefly described below.

2.5.1 Pathogens in Urine

There are several bacteria that are known to be excreted with urine: *Leptospira, interrogans*, *Salmonella typhi*, *Salmonella paratyphi*, and *Shistosoma haematobium* (Shönning and Stenström, 2004; Feachem et. al., 1983). None of these, however, usually pose major health risks to humans. *Leptopira* is usually associated with urine from infected animals. The *Salmonella* species, while transmitted from persons with typhoid and paratyphoid, generally have higher risks from fecal-oral transmission than from urine-oral transmission. The *Shistosoma* eggs which are excreted through the urine need a freshwater snail host within a few days of excretion or the cycle is broken (Shönning and Stenström, 2004; Feachem et. al., 1983). Table 2.3 shows pathogens associated with urine, their transmission route and importance as disease causing to humans.

There is also concern over viruses, mycobacteria, microsporidia, venereal diseases, and bacteria from urinary tract infections. However, the associated risks with all these factors are all low (Shönning and Stenström, 2004). Shönning and Stenström (2004: 4) conclude that the "main risks of disease transmission from handling and using urine are related to faecal cross-contamination of urine and not from the urine itself."

Table 2.3: Urine-Excreted Pathogens and The Importance of Urine as a Transmission Route (adapted from Shönning and Stenström, 2004).

Pathogen	Urine as a transmission route	Importance
Leptospira interrogans	Usually through animal urine	Probably low
Salmonella typhi and *Salmonella paratyphi*	Probably unusual, excreted in urine in systemic infection	Low compared to other transmission routes
Schistosoma haematobium (eggs excreted)	Not directly but indirectly, larvae infect humans via freshwater	Need to be considered in endemic areas where freshwater is available

Mycobacteria	Unusual, usually airborne	Low
Viruses: CMV, JCV, BKV, adeno, hepatitis and others	Not normally recognized other than single cases of hepatitis A and suggested for hepatitis B. More information needed	Probably low
Microsporidia	Suggested, but not recognized	Low
Venereal disease causing	No, do not survive for significant periods outside the body	--
Urinary tract infections	No, no direct environmental Transmission	Low

2.5.2 Pathogens in Feces

The disease burden produced from feces is far greater than that of urine. Pathogens in feces come in four major forms: viruses, bacteria, protozoa and helminths (Feachem et. al., 1983). Bacteria are traditionally thought of as the largest contributor to gastrointestinal illnesses, but there are also 120 different kinds of viruses found in feces (Shönning and Stenström, 2004) and the Ascaris egg (a helminth) is the most resistant to natural environmental degradation (Feachem et. al., 1983). Feachem et. al. (1983) gives a very complete report of the disease-causing organisms found in excreta and Shönning and Stenström (2004) provide a good overview of major pathogenic concerns. Table 2.4 shows some of the major fecal pathogens that can be transmitted though water or improper sanitation and hygiene.

Table 2.4: Examples of Fecally Excreted Pathogens, Related Diseases and Symptoms (adapted from Shönning and Stenström, 2004)

Group	Pathogen	Disease – Symptoms
Bacteria	*Aeromonas* spp.	Enteritis
	Campylobacter jejuni/coli	Campylobacteriosis - diarrhea, cramping, abdominal pain, fever, nausea; arthritis; Guillain-Barré syndrome
	Escherichia coli (EIEC, EPEC, ETEC, EHEC)	Enteritis
	Pleisiomonas shigelloides	Enteritis
	Pseudomonas aeruginosa	Various; bacteraemia, skin infections, ear infections, meningitis, pneumonia
	Salmonella typhi/paratyphi	Typhoid/paratyphoid fever - headache, fever, malaise, anorexia, bradycardia, splenomegaly, cough
	Salmonella spp.	Salmonellosis - diarrhea, fever, abdominal cramps
	Shigella spp.	Shigellosis - dysentery (bloody diarrhea), vomiting, cramps, fever; Reiter's syndrome
	Vibrio cholerae	Cholera - watery diarrhea, lethal if severe and untreated
	Yersinia spp.	Yersinioses - fever, abdominal pain, diarrhea, joint pains, rash
Virus	Adenovirus	Various; respiratory illness. Added here due to the enteric types (see below)
	Enteric adenovirus 40 and 41	Enteritis
	Astrovirus	Enteritis
	Calicivirus (incl. Noroviruses)	Enteritis
	Coxsackievirus	Various; respiratory illness; enteritis;

		viral meningitis
	Echovirus	Aseptic meningitis; encephalitis; often Asymptomatic
	Enterovirus types 68-71	Meningitis; encephalitis; paralysis
	Hepatitis A	Hepatitis - fever, malaise, anorexia, nausea, abdominal discomfort, jaundice
	Hepatitis E	Hepatitis
	Poliovirus	Poliomyelitis - often asymptomatic, fever, nausea, vomiting, headache, paralysis
	Rotavirus	Enteritis
Parasitic protozoa	Cryptosporidium parvum	Cryptosporidiosis - watery diarrhea, abdominal cramps and pain
	Cyclospora cayetanensis	Often asymptomatic; diarrhea; abdominal pain
	Entamoeba histolytica	Amoebiasis - Often asymptomatic, dysentery, abdominal discomfort, fever, chills
	Giardia intestinalis	Giardiasis - diarrhea, abdominal cramps, malaise, weight loss
Helminths	*Ascaris lumbricoides*	Generally no or few symptoms; wheezing; coughing; fever; enteritis; pulmonary eosinophilia
	Trichuris trichiura	Unapparent through vague digestive tract distress to emaciation with dry skin and diarrhea
	Hookworm	Itch; rash; cough; anemia; protein Deficiency
	Shistosomiasis spp.	

2.6 Pathogen Die-Off

Temperature, pH, ammonia content, moisture, ultraviolet radiation, other microorganisms, nutrients and a few other factors are the main parameters that influence the survival of microorganisms in the environment (Shönning and Stenström, 2004). Table 2.5 shows these factors as they relate to the breakdown of pathogens in human excrement.

Table 2.5: Factors that Affect the Survival of Microorganisms (adapted from Shönning and Stenström, 2004 and Esrey, 1998.)

Temperature	Most microorganisms survive well at low temperatures (<5°C) and rapidly die off at high temperatures (>40-50°C). This is the case in water, soil, sewage and on crops. To ensure inactivation (e.g. in composting processes), temperatures around 55-65°C are needed to inactivate all types of pathogens (except bacterial spores) within hours (Haug, 1993).
pH	Many microorganisms are adapted to a neutral pH (7). Highly acidic or alkaline conditions will have an inactivating effect. Addition of lime to excreta in dry latrines and to sewage sludge can increase pH and will inactivate microorganisms. The speed of inactivation depends on the pH value, e.g. it is much more rapid at pH 12 than at pH 9.
Ammonia	In natural environments, ammonia (NH_3) chemically hydrolyzed or produced by bacteria can be deleterious to other organisms. Added ammonia-generating chemical will also facilitate the inactivation of pathogens (e.g. in excreta or sewage sludge) (Ghigletti *et al.*, 1997; Vinnerås *et al.*, 2003).
Moisture	Moisture is related to organism survival in soil and in faeces. A moist soil favors the survival of microorganisms and a drying process will decrease the number of pathogens (e.g. in latrines).
Solar radiation/ UV-light	UV-irradiation will reduce the number of pathogens. It is used as a process for the treatment of both drinking water and wastewater. In the field, the survival

	time will be shorter on the soil and crop surface where sunlight can affect the organisms.
Presence of other microorganisms	The survival of microorganisms is generally longer in material that has been sterilized than in an environmental sample containing other organisms. Organisms may affect each other by predation, release of antagonistic substances or competition (see Nutrients below).
Nutrients	If nutrients are available and other conditions are favorable, bacteria may grow in the environment. Enteric bacteria adapted to the gastrointestinal tract are not always capable of competing with indigenous organisms for the scarce nutrients, limiting their ability to reproduce and survive in the environment.
Other factors	Microbial activity is dependent on **oxygen availability**. The **soil's particle size and permeability** will affect the microbial survival. In soil as well as in sewage and water environments, various **organic and inorganic chemical compounds** may affect the survival of microorganisms.

There are two main ways that ecosan systems deal with pathogens in human excreta and attempt to control the above factors: aerobic or anaerobic digestion. Aerobic digestion, or composting, uses exothermic reactions of microorganisms to produce heat which inactivates pathogens. Anaerobic digestion breaks down pathogens by non-oxygen consuming means, that is, by desiccation (dehydration) or by the creation of an unfit living environment.

2.6.1 Aerobic Decomposition

In aerobic systems, an appropriate carbon to nitrogen ratio of between 15:1 and 30:1, moisture content of about 50 to 60 percent and adequate oxygen availability create the proper conditions for benign microbes to thrive (Esrey, 1998). Because feces contains virtually no carbon and a small amount of nitrogen, a carbon source such as leaves, grass, sawdust or the organic components of garbage must be added (Feachem et. al., 1983). Additionally, proper moisture content must be maintained and regulated. In order to maintain oxygen supply to the middle of a compost pile, 'turning' of the pile or some other method of bringing oxygen to the center of a pile is often required.

With these appropriate environmental conditions, the activity of these microbes raises the temperature of the compost pile to 50 to 60°C. This temperature is high enough to destroy all but the most resilient pathogens, which are usually helminths, within a few hours (Feachem et. al., 1983).

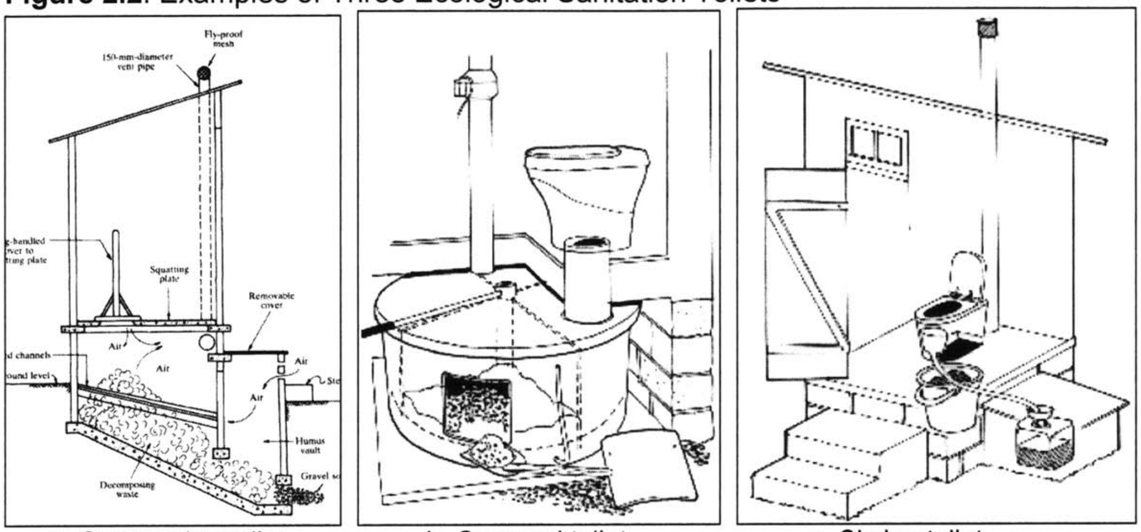
2.6.2 Anaerobic Decomposition

The ecological toilets that are the subject of this research (see Section *3.5.4: The Skyloo*) break down pathogens in excreta by anaerobic means. Anaerobic digestion either dehydrates the excreta in which organisms live, or creates conditions that are unfit for the organisms to live. Dehydration is primarily promoted by separation of the urine and feces, and can be further aided with addition of ash, lime or soil to the feces. The addition of these materials to the feces increases pH and decreases moisture (see Table 2.5). It also decreases odors by covering the feces with ash, soil, or lime which additionally discourages the reproduction of flies.

2.7 Built Unit Options

"Ecological sanitation" refers to the technology of recycling of human waste for purposes of reuse. The 2004 edition of *Ecological Sanitation* (Winblad), the 1980's World Bank Publications titled "Appropriate Technology for Water Supply and Sanitation", and Peasey (2000) provide a more comprehensive review of different types of ecosan toilets. Figure 2.2 shows a few examples of ecosan toilets. Figure 1.2a shows a side view of a composting toilet, common in more developed-world settings; figure 1.2b is a carousel toilet which has gained popularity in Norway; and figure 1.2c is the design of the toilet that was studied in this investigation, the skyloo toilet.

Figure 2.2: Examples of Three Ecological Sanitation Toilets



a. Composting toilet
Feachem (1983)

b. Carousel toilet
Winblad (2004)

c. Skyloo toilet
Winblad (2004)

2.8 Ecological Sanitation and Agriculture

When collected separately, urine and feces can be optimally utilized by playing different roles in agricultural production due to the difference in their composition (see Section *2.4*). Because the toilets that are the subject of this study separate urine and feces at the toilet (Figure 2.2, also see Section *3.5.4: The Skyloo* for details about the toilet), the roles of urine and feces in agriculture will be compared. The properties of urine are then described in more depth due to the large nutrient concentrations in urine and, therefore, its potential to increase agricultural productivity.

2.8.1 Role of Urine Versus Feces

<u>Urine</u>

As noted in Table 2.2, urine contains the majority of plant nutrients in excreta. Urine, therefore, is valuable as a direct plant fertilizer. While the nutrients found in urine are not in the same proportions as those in commercial fertilizers (phosphorus is typically the largest proportion of commercial fertilizers), they still provide nutrients in forms that are readily available for uptake by plants (Winblad et. al., 2004).

Drangert (1997) also notes that there are at least two other good reasons to reuse urine in agriculture beside the fact that it is more nutritive than feces. Urine is more dense than feces and, thus, more expensive to transport away from the household. Reusing it onsite omits these costs. Second, people are more ready to accept the idea of urine reuse and handling as opposed to the reuse and handling of feces.

Feces

Feces, on the other hand, are valuable as a soil conditioner. Esrey noted in *Closing the Loop: Ecological Sanitation for Food Security* (2001) that processed human manure provides benefits to the soil by:

◊ improving soil structure,
◊ increasing the water-holding capacity of soil,
◊ moderating soil temperatures,
◊ breaking up organic matter into the basic elements that plants need,
◊ returning to soil what agriculture takes out of it,
◊ releasing nutrients at the rate plants need them,
◊ neutralizing soil toxins and heavy metals, and
◊ reducing pests and disease.

Additionally, even though faeces contain fewer nutrients than urine, the humus produced from faeces actually contains higher concentrations of phosphorus and potassium (Winblad et. al., 2004). These much-needed plant nutrients make the processed feces a great soil supplement when urine is used as the primary fertilizer.

2.8.2 Urine Kinetics

Nitrogen Reactions

When urine is excreted from the body, nitrogen is present in the form of urea ($CO(NO_2)_2$. In the presence of water and the enzyme urease, urea undergoes a process referred to as urea hydrolysis, or ureolysis. Urea breaks down into ammonia, carbon dioxide and hydroxyl via the following equation (Jönsson et. al. 2004):

$$\underset{\text{urea}}{CO(NH_2)_2} + \underset{\text{water}}{3\,H_2O} \xrightarrow{\text{urease}} \underset{\text{ammonium}}{2\,NH_4^+} + \underset{\text{hydroxyl}}{OH^-} + \underset{\text{carbonate}}{HCO_3^-}$$

Urease-positive bacteria are almost always found in urine receptors (toilets, urinals and urine collection devices alike), so this reaction is ubiquitous in ecological sanitation toilets (Udert, 2003a). Moreover, this reaction is relatively quick; complete ureolysis of urine outside the body is usually achieved within a few days (Udert, 2003b). The ammonia produced is directly available to plants, and in arable soil containing nitrifying bacteria, it is further transformed within a few days to nitrate (NO_3^-), which is even more preferred by plants (Jönsson et. al. 2004).

Fresh urine has, on average, about 0.27 moles of urea ($CO(NH_2)_2$)and 0.034 moles of ammonia (NH_3) (Ciba-Geigy, 1977). The nitrogen (N) portions of these concentrations translate into an average total nitrogen concentration of 8.04 grams per liter in urine. In theory, after the ureolysis described above is complete, all of this nitrogen should be in solution in the form of ammonia. However, the relatively high pH (usually 8.5-9.5) of undiluted urine coupled with the high ammonium concentrations produces aqueous ammonia, which is readily volatile in solution.

$$NH_4^+ + OH^- \rightarrow NH_3\,(aq) + H_2O$$
$$NH_3\,(aq) \rightarrow NH_3\,(g)$$

(Jönsson et. al. 2004)

The natural volatilization of ammonia is immense. Udert (2003c: 78) calculates that the equilibrium concentration of a half-full container of undiluted urine "...is 2300 mgN/m^3, which is far above the toxic level of 210 - 280 mgN/m^3!" However, these concentrations are hardly reached because the exchange of gas-phase and aqueous-phase ammonia is slow (Udert, 2003b). Udert (2003b) describes the overall reaction as

$$NH_2(CO)NH_2 + 2\,H_2O \rightarrow NH_3 + NH_4^+ + HCO_3^-.$$

Phosphorus

Phosphorus is one of the limiting nutrients in plant growth, and is excreted in the form of inorganic phosphate ions and are directly plant available (Jönsson et. al. 2004). However, as ureolysis reactions proceed and the pH of the solution increases to 9 – 9.3, portions of phosphate, magnesium and calcium minerals are no longer soluble. These minerals precipitate out to form struvite ($MgNH_3PO_4$) and apatite ($Ca_{10}(PO_4)_6(OH)_2$) (Jönsson et. al., 2004). As much as 30 percent of the phosphorous present in fresh urine can further be taken up in these forms (Udert et. al., 2003b; Jönsson et. al., 2000).

Potassium

Potassium is excreted, similarly to phosphorus, in the ion form. These are also directly plant available and should have similar uptake rates to that of commercial fertilizers (Jönsson et. al., 2004).

pH

The pH of average fresh urine is about 6.2. This level increases as urine undergoes ureolysis, usually stabilizing around 9 – 9.3 (Udert, 2003b).

2.8.3 Application of Urine

Jönsson et. al. (2004) provides the most complete description of application techniques for human urine to date. The following section is a short summary of some of the main points from this document.

Determining the Amount

To determine the agricultural application rate of urine, first determine the amount of nitrogen, phosphorous and potassium that are needed by the specific crop in question. Nutrient application rates can be ascertained by determining the locally recommended fertilizer application rates and the fertilizer's concentration of nutrients. If the local recommended rate is not known, Jönsson et. al. (2004) provides a table of nutrient needs of some common crops from which estimated values may be calculated.

Next, multiply the nutrient needs of the crop by the total estimated amount of the crop that will be harvested to determine the total nutrients removed. This will be the minimum amount of nutrients that should be returned to the soil via urine or by other means. In practice, it is recommended that 1.5-2 times this amount be applied in order to compensate for nutrient leaching, volatilization, sorption to the soil and in application of nitrogen-fixing crops such as beans and legumes.

Application

Dilution is usually convenient in order to avoid over-application of nutrients and to avoid a heavy ammonia stench. Common dilution ratios range from 5 to 2 parts water to 1 part urine. The amount of urine to apply should be determined through the method described above. If the urine is diluted, this should be taken into account. The amount of urine applied should be determined based on the plant's nutrient needs while the plant's water needs should be considered separately, irrespective of whether or not these two are applied together or separately.

It is recommended that the user apply the urine solution close to the ground so as to avoid volatilization of ammonia or application to the leaves of plants (the formation of salts on the leaves after the urine dries may cause burning).

Fertilization of the crops, "as a rule of thumb, should stop after between 2/3 to 3/4 of the time between sowing and harvest" (Jönsson et. al., 2004: 18). When the crop enters its reproductive stage, nutrient uptake from the soil declines drastically.

While the high nitrogen levels make urine especially suitable for application crops such as spinach, cauliflower and maize, ecosan has shown positive results with a variety of crops all over the world.

2.8.4 Safety of Urine Reuse

As noted above in Section *1.5.1 Pathogens in Urine*, fecal cross-contamination poses the largest possible health risks from the reuse of urine. However, the high pH of urine promotes die-off of pathogens (Shönning and Stenström, 2004; Drangert 1998).

For diluted urine pathogen die-off rates decrease (Peasey, 2000). Ambient temperatures of 20°C promote die-off (Peasey, 2000; Drangert, 1998), which is generally the situation in the Nyanza Province of Kenya, where the research was conducted. Drangert (1998) also suggests that individuals on antibiotics not reuse their urine for plant growth.

The recommended storage times from the literature for the safe handling and reuse of urine are mixed. Drangert 1998 recommends a (self-admitted) conservative storage of 6 months to ensure pathogen die-off. Shönning and Stenström (2004) however, claim that as long as the urine is collected and used on the household level for household agriculture, and it is not being applied to crops that are not going to be eaten raw, immediate (no storage) application of urine is acceptable. For large-scale systems, they only recommend 1 month of storage time. In any case, urine is recognized as a relatively safe material compared to the safety of feces and the largest risk from the handling of urine is from fecal cross-contamination (Shönning and Stenström, 2004).

2.9 Community Adoption of Ecosan

Community adoption of ecosan technology has been mixed. Some researchers suggest that uptake is slow because a paradigm shift in the management of excreta is necessary (Feachem, 1983; Peasey, 2000). Peasey (2000) proposes that the benefits are not seen as quickly as the costs because individuals' behaviors must change to adapt to the new technology and practice, which takes time, and the benefits of excreta reuse only become visibly obvious after adoption of an ecosan latrine for a few growing seasons. In addition to general widespread cultural aversions to handling excreta (Drangert, 2004), Feachem (1983) reports that the taboo sometimes associated with those who handle feces in a community will cause others to be less inclined to be associated with that stigma. Douglass (1966) theorized that "uncleanliness" arises from "matter out of place… which must not be included if a pattern is to be maintained." Applying this to the case of ecosan, feces should be excluded from normal daily patterns of life. Drangert (2004) suggests designing toilets to keep feces out of normal sight, as a general rule.

Windblad (2004) describes communities on a "faecophilic—faecophobic" continuum. A "faecophilic" community (literally, a feces-loving community) is one that has tradition of reusing and recycling excrement, and has no problem talking about it, handling it, and smelling it. Some East Asian communities are examples of fecophilic cultures—Winblad notes China as one such community, and many of the earliest ecosan toilets were based on a design that originated in Vietnam.

A "faecophobic" community is a community that has no tradition of reusing or dealing with human excrement. Winblad (2004: 100) describes faecophobia in the context of sub-Saharan Africa, the area in which this research took place:

> Faecophobic attitudes are also common in Africa south of the Sahara. Here many farmers have until recently been practising shifting agriculture. There was no need for them to recycle human excreta and as shifting agriculture often meant a semi-nomadic life there was no tradition of building permanent wells and toilets.

In dealing with a faecophobic culture, an "attempt to fundamentally change residents' views of fresh feces seems futile… however, we could also think of transforming the faeces to another product that has no connection to fresh feces" (Drangert, 2004: 24). Therefore ecosan programs in many places in the world use systems that try to "transform" the feces before anyone has to handle or move it.

2.10 Household Adoption of Ecosan

The individual household adoption of ecosan is related to many factors, and only sometimes reflective of the community's sentiment regarding handling human excrement. Several documents provide more detail regarding why a household would or would not want to adopt an ecosan toilet.

In Nalubega's (2004) report "What Drives Choice of Sanitation Technologies: A Case Study from Uganda" seven major demand drivers for choice of general sanitation technology are laid out: hygiene considerations, cost/affordability and service life, predisposition (what has been used in the past), convenience and ease of cleaning, aesthetics/modernity, promoters (enforcement and subsidies), and colonial legacy. For ecosan, he reports that users were most concerned with the hygienic aspects of the toilet, its affordability, easy operation and maintenance (no water is needed), and that it is convenient to the house.

Drangert (2004) reports that households are concerned about the smell associated with feces, in particular and, as noted above, with handling the fresh feces and urine. However, he also says that "most people agree to the rationale of nutrient reuse and of savings on chemical fertilizers" (Drangert, 2004: 23), implying economic cost savings from the toilet from its reuse value in agriculture.

The World Bank Water and Sanitation Program (WSP) in Nairobi developed a list of factors that drive demand for sanitation, in similar fashion to Nalubega's study in Uganda. The demand drivers they recognized for sanitation in general are: health and hygiene awareness and education; land sub-division, densification and need for privacy; prevention of diseases; and project assistance from organizations. They also recognized seven major factors that hinder sanitation coverage, which include: households' limited financial ability, lack of sanitation and hygiene awareness, adverse hydro-geological conditions, flooding, nomadic pastoralism, cultural issues.

Table 2.6 presents, in no particular order, these noted factors which might influence household adoption of sanitation. This list is relevant to sanitation in general, and draws mostly on literature from east Africa. Although these issues are related to sanitation in general, they can serve as a starting point for thinking about factors that influence household adoption of ecological sanitation. With the local context and on the ground research of this thesis, we can then develop a list of relevant factors that are specific to ecosan in the area. The three issues in italics are specific to ecological sanitation, not sanitation generally.

Table 2.6 Factors that Affect Household Adoption of Sanitation

- Cost of the facility/ finances of household
- Service life of the facility
- Sanitation & hygiene awareness
- Predisposition towards specific technology
- Convenience & ease of cleaning
- Aesthetics/Modernity
- Promoters (enforcement and subsidies)

- Colonial Legacy
- Hydro-geologic conditions
- Flooding
- Cultural issues, including nomadic pastoralism
- *Handling feces and/or urine*
- *Savings on chemical fertilizer*
- *Production of agricultural product*

2.11 Summary

This chapter shows that feces and urine can be reused safely, as long as the material is "processed" correctly. However, for household ecosan systems, users must take on a great deal of the responsibility for using facilities properly and, in particular, properly recycling the feces from the toilet. Moreover, ecosan toilets will be contending with the dominant sanitation paradigm in this area of Kenya—pit latrines and open defecation in the "bush." The negative aspects of the toilet are likely to be negative in relation to the pit latrine, just as the positive aspects are likely to be positive in comparison to the pit latrine.

The literature shows that feces and urine have agricultural value, and urine contains the majority of nutrients in the excrement. However, the amount of nutrients depends on the diet of any one individual, and will therefore vary with a culture or region's diet. Also, we need to know "where" the nutrients are—i.e. in what chemical form—in order to measure the nutrients available in the urine, which will depend on the degree of urea hydrolysis that the urine has undergone.

Social factors might also play a large role in household's adoption of ecological sanitation. In many cultures, the reuse of human excreta is not an accepted practice. However, households can also behave inconsistent relative to the surrounding culture. One of the largest challenges to the adoption of the technology is to understand what aspects of ecosan toilet have both positive and negative importance to users. Some of the factors that may have positive or negative consequences are identified in Table 2.6. The field research should provide insight into the factors that are important to users of ecological sanitation in the area studied in Kenya. It may then be possible to hypothesize about what factors might be able to overcome the cultural aversion to the handling and reuse of excrement.

From this chapter we see that ecosan can be a viable, safe technology that has potential to provide a valuable nutrient addition to farming communities. Yet the method by which ecosan owners reuse and handle the feces and urine might have a great impact on how well they adopt these toilets. Cultural concerns specific to the local community have the potential to outweigh the value that the material has for owners, and must be considered heavily.

3 Ecosan in Kenya and the Local Community

3.1 Kenya Background

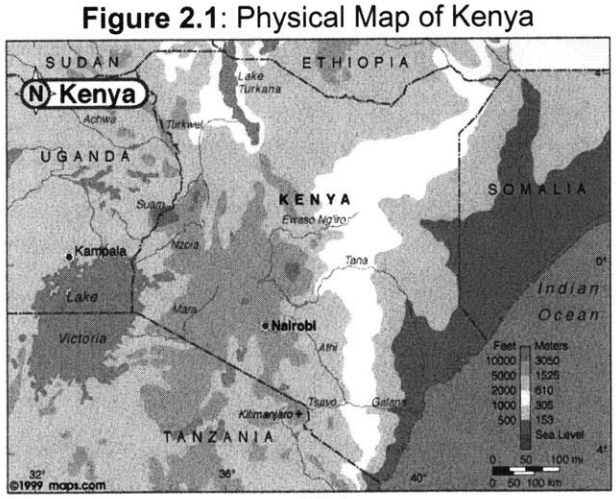
3.1.1 Geography

Kenya, on the Earth's equator, varies climactically from tropical in the coastal areas to arid in the west. It is bordered by Somalia to the east, Ethiopia to the north, Sudan to the northwest, Uganda to the west, and Tanzania to the south. Two major water bodies, the Indian Ocean to the east and Lake Victoria to the west, also help define Kenya's borders. The research for this thesis took place in and around the small districts of Maseno and Kombewa the western part of Kenya in Nyanza Province, just northwest of Kisumu near the northern shores of Lake Victoria.

Kenya experiences two rainy seasons—one from October to December and another from April to June. Two thirds of Kenya is arid or semi-arid; therefore access to water in many parts of the country is scarce. With only 647 cubic meters of water per capita per year, Kenya is classified as a "water scarce" country[(4)] using the Falkenmark index for water availability (Falkenmark et. al., 1989). However, different regions of the country receive drastically different amounts of rainfall. In the northeast, rainfall can average only 30 cm/year (13 in/year). Yet in the Lake Victoria basin, where the research was conducted, rainfall ranges from 175-200 cm/year (70-80 in/year). In January, the month in which the research took place, the average high and low temperatures for western Kenya are 34°C (93°F) and 14°C (57°F), respectively (Southtravels.com, 2004).

The climate of Kenya is, in some ways, ideal for anaerobic degradation of feces. Year-round temperatures above 20ºC ensures that the material will be exposed to conditions that promote evaporation of moisture from the feces and conditions which are favorable for pathogen destruction in urine (Peasey, 2000).

Figure 2.1: Physical Map of Kenya



Source: www.maps.com, 2004

(4) Typically, countries with less than 1000 m^3 per capita per year are classified as "water scarce."

Kenya is also a noted tourist destination, in part, due to its varied landscape. To the east are lowland coastal plains that are relatively fertile. To the west are the Kenyan highlands, defined by land over 900 meters in elevation (Figure 1). The Rift Valley, which runs from Syria south to Mozambique, is seen in Kenya running from the north at Lake Turkana almost directly south, just east of Lake Victoria. Kenya is also home to vast land reserves that are home to many of the famous large land mammals for which Africa is famous, which are exploited by many tourist outfits taking travelers on safari. Preserving this landscape's environmental quality is essential to sustain the county's economy.

3.1.2 Life and Livelihood

Kenya's economy is based mostly on the service (62 percent), industrial (19 percent), and agricultural (19 percent) sectors (CIA, 2005). The 2004 estimate of Kenyan's purchasing power parity is US $1,100 (CIA, 2005) while the gross domestic product per capita is a little more than US $500 (International Monetary Fund, 2005).

The education level of the community in which the research was conducted is generally low. Only 45 percent of both men and women continued schooling after primary school in Nyanza Province (CBS, 2004). This is among the lowest in Kenya, second only to the Western Province.

Infrastructure in this area is also lacking. Only 5 percent of the population in Nyanza Province reported having electricity, which is similar to the average for all rural communities in Kenya. In urban areas, about half of the households reported having electricity. (CBS, 2004).

The majority of the floors of the houses in Nyanza are dirt (74 percent), whereas in urban areas more than 70 percent of the homes have cement floors. About 30 percent of the households in Nyanza use grass or thatch as a roofing material with the remainder of the population (68 percent) using corrugated iron. In all rural areas of Kenya, the statistics are similar to those in Nyanza. In urban areas, however, virtually no one uses grass or thatch and corrugated iron and cement dominate. (CBS, 2004).

Nyanza has one of the highest proportions of women working in agriculture in Kenya. Almost 60 percent of the women who work participate in agriculture in Nyanza, while throughout Kenya the average figure is less than 50 percent. The percentage of men in agriculture in Nyanza, however, is only slightly higher than the national average at 47 percent, compared to 42 percent nationally. (CBS, 2004).

The life and livelihood of the population of the community where the research took place is based mainly on agriculture. The statistics for Nyanza given above include some sizable urban centers such as Kisumu (population 400,000), Kisi (70,000), and Homa Bay (50,000 people). The study area communities of Kombewa and Maseno (discussed further in Section *3.5*) are not urban centers and, at best, could be considered small townships. The statistics presented above, therefore, represent communities that have a higher level of urban development than the communities that were the subject of the research.

3.1.3 Water and Sanitation in Kenya

Access to Safe Water

Out of a total population of 32 million people, about 31% of Kenyans receive their drinking water from a pipe (household or communal tap), while 37% obtain water from an open spring, stream, or river. The rest get water from wells, water vendors or other sources (Central Bureau of Statistics, 2004). WHO estimates that in 2002, 38% of Kenyans lacked access to safe drinking water. However, when looking only at rural areas, this number increases to 54% (WHO, 2004).

In the Nyanza Province, where this research was conducted, only 14% of people receive their drinking water from a pipe. The percentage of people using open water sources such as springs, streams, and rivers amounts to nearly 58% (Central Bureau of Statistics, 2004). In such open water systems, the likelihood of contamination is significantly higher than for piped and treated water systems. The time estimated median time that households spend accessing a water source in Nyanza province is about 20 minutes (Central Bureau of Statistics, 2004).

Access to Improved Sanitation

WHO estimates that in 2002 52% of Kenyans did not have access to improved sanitation. In rural areas, 57% of people lacked proper sanitation coverage (2004). About 11% of all Kenyans use flush toilets, which often discharge to sewerage systems that may or may not have treatment facilities. The most common form of sanitation facility is a pit latrine, which is used by nearly 64% of the population, while more than 16% have no facility and defecate in the brush, a field or in the open. Of those that do use a latrine or toilets, 49% share their facility with other households (Central Bureau of Statistics, 2004).

In Nyanza Province 66% of the people use a traditional, unimproved pit latrine, only 2% have a flush toilet and over 26% have no facilities at all. Over half of the people that have access to a toilet in Nyanza share this latrine with other households (Central Bureau of Statistics, 2004).

Diarrheal Prevalence and Treatment

An indicator of health as it relates to sanitation practices is diarrheal prevalence and hygiene practices. In Nyanza, only 5.5 percent of children always use a toilet or latrine. More than 17 percent of children in Nyanza had diarrhea in the two weeks preceding a survey in 2003 (Central Bureau of Statistics, 2004).

Oral rehydration salts are an effective way to replenish the liquids and nutrients that diarrhea take away from one's body. In Nyanza, over 78 percent of mothers were at least aware of oral rehydration therapy. However, only 36 percent actively practiced oral rehydration therapy or increased a child's intake of fluids during a diarrheal incident (Central Bureau of Statistics, 2004), showing little motivation or financial capacity to address the symptoms of diarrhea. This argues that prevention of diarrheal diseases (i.e. with adequate sanitation), as opposed to treatment, might be a more effective way to reduce diarrheal incidence in this area.

3.2 Ecosan Promotion in Kenya

The primary push for ecological sanitation in Kenya comes from international organizations and international development donors. The on-the-ground implementation of ecological sanitation is mainly due to the work from local, national, and international non-governmental organizations (NGOs). The Kenyan National government, while aware of some of the ecosan activities in the country, has not taken an active stance to support, promote, or reject ecological sanitation as a viable sanitation option.[5]

3.2.1 Non-Governmental Organizations

Ecosan technology, first recognized as a viable modern technology in Sweden in the 1970s, seems to have come to Kenya in the late 1990s. The World Bank Water and Sanitation Program (WSP) has been an active promoter of the technology and produced numerous publications on the subject in East Africa. The WSP tried to initiate an Ecosan Promotion Group—a gathering of organizations that are practicing promoters or organizations that are interested in promoting of ecosan. They appear to have held a few workshops in Nairobi beginning around 2003, in which many organizations were involved. Both the Peace Corps attendee and the World Bank[6] indicated that the group is currently not very active.

There are several organizations that currently promote ecosan in Kenya. Some of the most active promoters have been the Regional Land Management Unit (RELMA), Osienala (Friends of Lake Victoria), CARE International, Merlin, the Intermediate Technology Development Group (IDTG) and the Kenya Water for Health Organization (KWAHO—the partner organization in this project). Many of these organizations lie in the western part of Kenya, near Lake Victoria. In spite of this network supporting the introduction of this new technology in Kenya, the extent of implementation is still quite limited. Table 3.1 shows the sites and number of ecosan toilets implemented in Kenya as of 2002 (Knapp, 2004) was less than 200 units for the whole country.

Table 3.1: Extent of Ecosan Implemented in Kenya as of 2002

Region/City in Kenya	No. of Toilets	Type of Toilet (see Section 3.3)	Implementing Organization	Funders	Date Started
Kusa,Nyando,Nyaza	112	Arboloo/Fossa Alterna/Skyloo	Kusa Community	RELMA/SIDA	2000
Mbooni/Makueni, Nyanza	100	Arboloo/Fossa Alterna/Skyloo	Mbooni and Makueni Community	RELMA/SIDA	2001

(5) The Deputy Director of Water Quality in the Water Resources Authority took a full day to visit ecosan sites and observe this field research in an effort to expose the Ministry to ecosan practices.
(6) Representatives from the Peace Corps and the World Bank were interviewed during the field visit in January 2005.

Homa Bay	8	Urine diversion/Dehydration	CARE		
Kisumu	15	Urine diversion/Dehydration	Osienala	SIDA	1998
Mombasa		Arboloo/Fossa Alterna/Skyloo	Coast Development Authority		
Wajir	0	Urine diversion/Dehydration	Wajir - Merlin		
Nairobi	1	Biogas	IDTG		2002
Kisumu	37	Urine diversion/Dehydration	KWAHO	Austrian Development Agency	2003

Source: Partially adapted from Knapp, 2004[7]

3.2.2 International Funding Organizations

Many of the NGOs mentioned above are funded, at least in part, by international donor organizations that have an interest in the dissemination of ecosan technologies. For example, KWAHO's ecosan program is funded by the Austrian Development Agency and Osienala's projects were funded by the Swedish International Development Cooperation Agency (SIDA). Other international agencies involved in the promotion of ecosan include the World Bank's Water and Sanitation Program (WSP), the United Nations International Children's Education Fund (UNICEF) and the Consultative Group on International Agriculture Research (CGIAR).

3.2.3 Kenyan Government

In Kenya, general sanitation issues fall under the purview of the Ministry of Health and, tangentially, with the Ministry of Water. Sanitation has not been firmly addressed in Kenya's body of laws to date, although a National Environmental Sanitation and Hygiene Policy is currently under development (WSP, 2005). While no law addresses sanitation directly, there are some statues that deal with sanitation in some capacity, mostly to give relevant Ministries authority over sanitation issues (BG Associates, 2003).

The Ministry of Health had a National Health Sector Strategic Plan from 1999-2004, which dealt with sanitation in more detail. The WSP (2005) reports that in the early phases of this plan, the Government of Kenya focused on building latrines with the idea that as long as the infrastructure was there, people would use it. They learned that the infrastructure had to be accompanied by hygiene education and a basic understanding of why toilets are important in order for people to use of the infrastructure. In the upcoming National Environmental Sanitation and Hygiene Policy (likely to be put into law by the Government of Kenya in 2005) sanitation education, increased investment, and regulation by decentralized health boards will be implemented. The WSP (2005) also stated that the new comprehensive policy will also leave sanitation regulations flexible enough to encompass alternative technologies like ecosan.

[7] All information was from Knapp (2004) except for the statistics for IDTG and KWAHO, which were collected during the field research.

3.3 Types of Ecosan in Kenya

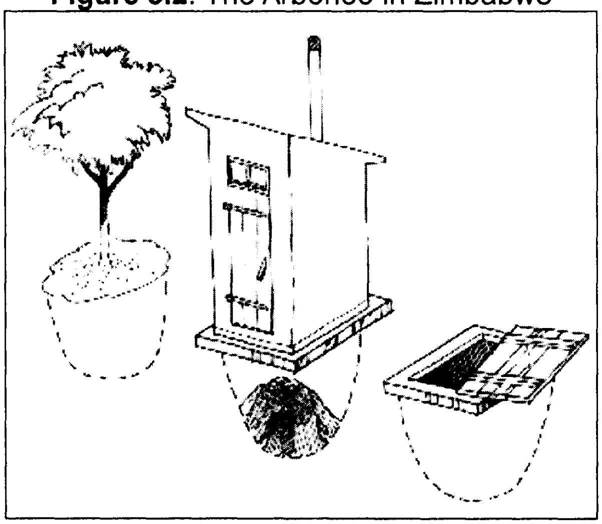
During the late 1990s there were three types of ecosan toilets introduced in Kenya: the arborloo, the fossa alterna, and the skyloo (World Bank WSP-AF, 2004; KWAHO, 2005). These are certainly not the only types of ecosan that exist, but they seem to be the most popular forms of ecosan in Sub-Saharan Africa.

3.3.1 The Arborloo

The arborloo is an ecosan latrine in which a simple pit is dug in the ground and a toilet superstructure (the above-ground built structure) is placed on top of it. After defecating, users add a few cups of soil, ash, or dried leaves to the excrement. When the pit fills up, the superstructure is taken off the pit and it is topped off with dirt. In this dirt, the seed of a tree is planted. As the roots form in the topsoil, the excrement decomposes in the ground (Winblad, 2004). Over time, the excrement from the toilet supplies the nutrients for the tree's growth.

The advantages to the arborloo are that it is simple to use, there is no handling of the excrement, and it is inexpensive. Some families using this sanitation method over the years have created an orchard that is essentially fed by their past excrement. However, this style of ecosan needs a great deal of space to continually fill shallow pits and plant trees, and it also can be problematic in areas with high water tables.

Figure 3.2: The Arborloo in Zimbabwe



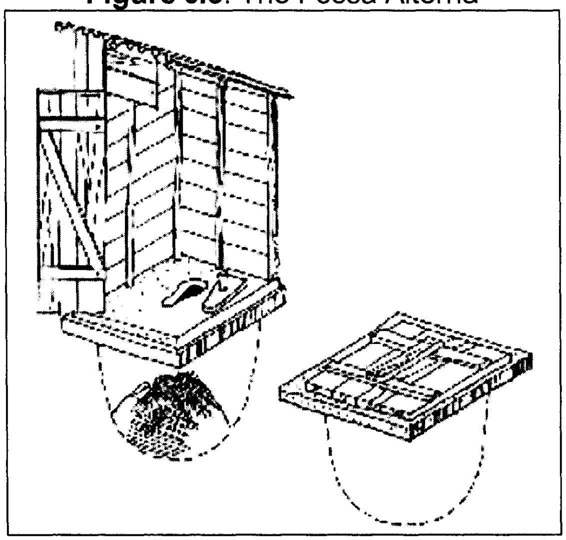
Source: Winblad, 2004

3.3.2 The Fossa Alterna

The fossa alterna type of toilet consists of two permanent pits placed side-by-side. Only one side is used at a time. Similar to the arborloo, ash, soil, or dry leaves are added to the excrement just after it is deposited. After the active pit is three-fourths full, the superstructure is removed and the pit is topped off with soil. The household members begin to use the other pit. While the full side is lying fallow, the added soil and ash aids the processing of the material by furthering dehydration and increasing the pH of the system, and thereby increasing the die-off of pathogens (Peasey, 2000). As long as the time that it takes to fill one pit is approximately six months to one year, the fallow time for the other pit will be sufficient to allow the excrement to become safe. The processed material can then be dug up from the pit and reused elsewhere, just before the pit becomes reactivated for household use again.

With both the arborloo and the fossa alterna, just as with a pit latrine, it is important that the groundwater is sufficiently deep so that no leachate from the pit can contaminate the groundwater and so that flooding does not interfere with the decomposition process. The advantages of the fossa alterna are that one does not handle unprocessed excrement and that the pits are reusable, so no extra land, beyond the original two pits, is needed for continual use.

Figure 3.3: The Fossa Alterna



Source: Winblad, 2004

3.3.3 The Skyloo

The skyloo, the third type of ecosan technology common in Kenya, separates the urine from feces at the toilet. For the Skyloo, there is no pit that needs to be dug into the ground. The whole structure, including the storage vault for the urine and the feces, are constructed above ground. Steps lead up to the toilet and feces are stored in the vault at ground level. Because the skyloo is the subject of investigation, it is described in greater depth than the arborloo and fossa alterna below (section *3.5.4: The Skyloo*).

Figure 3.3: The Skyloo in Kenya

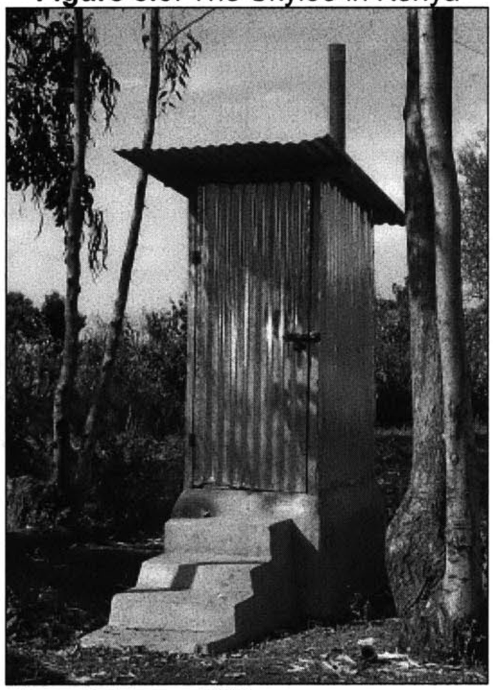


Photo: Robinson, 2005

3.4 Ecosan in Western Kenya

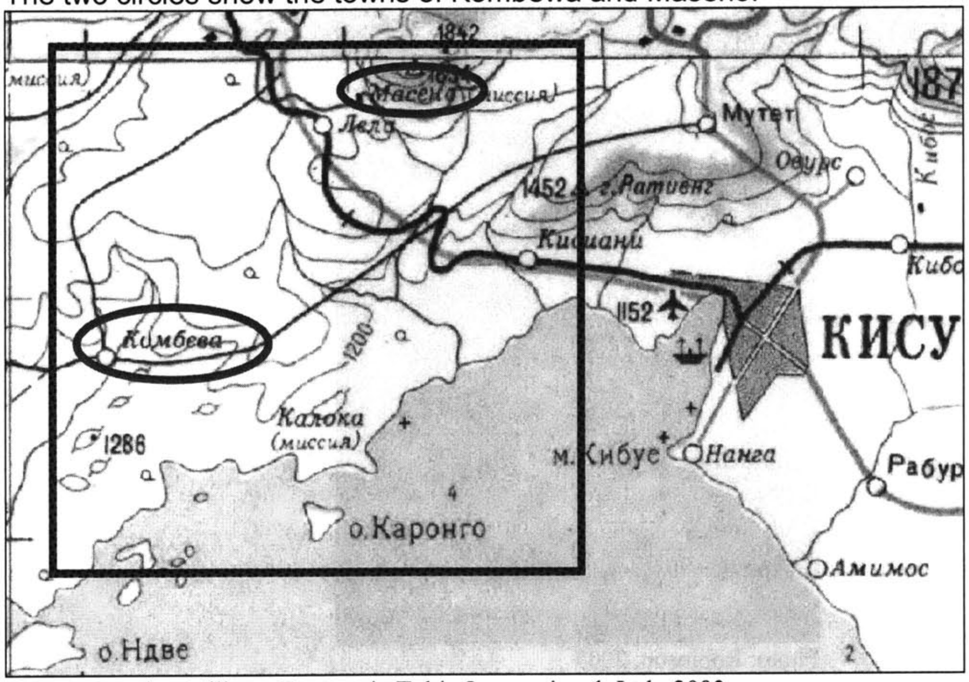
Lake Victoria has been the subject of much attention in the past few years due to the rapid growth of water hyacinth that is choking the lake. The growth of this exotic species has been fueled by high nutrient loads to the lake from the compound impact of population growth (and untreated sewage discharge) and increased fertilizer use in the area (Mailu, 2001). Residents of the Lake Victoria region are highly dependent on the lake for the local economy and, for this reason, ecological sanitation has been promoted more heavily here than Kenya's middle or western ends. "Promotion of ecosan" is even sited as a development strategy of the Kisumu City government as a way to reduce pollution of Lake Victoria (UN-Habitat, 2003). RELMA, Osienala and KWAHO are the ecosan promoters that have been identified in the Lake Victoria basin.

3.5 The Kenya Water for Health Organization's Ecosan Program

3.5.1 KWAHO

The Kenya Water for Health Organization (KWAHO) is a national water and sanitation organization which "offer[s] partnership to disadvantaged communities to improve their social and economic standards by facilitating the provision of safe water, hygienic sanitation, management of sustainable environment and promotion of income generating initiatives" (KWAHO, 2005). KWAHO is headquartered in Nairobi, and has field offices in the Lower Tana River area of eastern coastal Kenya and in Maseno near the shores of Lake Victoria. All research in this report was conducted with the help and collaboration of the KWAHO office in Maseno.

Figure 3.4: Geographic Extent of KWAHO's Ecosan Program, denoted by the square. The two circles show the towns of Kombewa and Maseno.



Source: Russian Military Forces via Tobin International, Ltd., 2003

KWAHO works with many aspects of water and sanitation issues. In particular, the organization has a growing and active ecosan program. Currently, KWAHO promotes ecosan in the Maseno and Kombewa districts, although there are plans to expand the program to the Lower Tana River area (on the eastern coast of Kenya), where they also have a field office.

3.5.2 The Process of Receiving an Ecosan Toilet

KWAHO has a detailed and formal process by which they distribute resources (materials and manpower) for the ecosan toilets. The process begins during community "sensitizing" meetings in which KWAHO talks about sanitation and the importance of having a toilet in general. KWAHO then introduces the two types of toilets that they promote and help build: the ventilated improved pit (VIP) latrine and the skyloo ecosan-type latrine. Regarding the skyloo, they introduce the concept of ecosan, how ecosan toilets function, and the technology's benefits, particularly in comparison with the VIP latrine.

Those interested in obtaining a VIP or skyloo toilet for their homestead are invited to write a letter of application to KWAHO which includes their name, address and why they would like the toilet. KWAHO then reviews the letter of applications and notifies those who they select (see Section *3.5.3: Eligibility to Receive an Ecosan* for selection criteria).

When those selected to receive an ecosan toilet are notified, they are given a list of materials that they must gather to personally contribute to the construction of the toilet.

Table 3.1 shows the materials that households must provide and the materials that KWAHO provides to the construction of the toilets.

Table 3.2: Materials Supplied by Households vs. Those Supplied by KWAHO

Households	KWAHO
6-9 posts	Corrugated iron sheets
90-120 bricks	Timber
Door shutters	Nails
Ballast	Hosepipe for the urine
Sand	Cement
Containers (for feces and urine)	Skilled labor

KWAHO provides the materials that are most expensive in order to give residents incentive to try an ecosan style toilet, and to target those who could benefit from the reuse of human excrement the most. The materials that the households are required to provide have either no monetary cost (e.g. sand), can be bought cheaply (e.g. containers, bricks), or can be made by hand (e.g. posts). When the households have collected all the materials necessary, they notify the KWAHO office, and the KWAHO office sends a representative to the house verify the materials.

When it has been confirmed that the household has all the necessary materials, KWAHO will then notify that household when the KWAHO-provided materials are ready for pick-up at the KWAHO office. It is the responsibility of the beneficiary to pick up the materials from the KWAHO office and transport them back to their home. While KWAHO wants to give households incentive to try ecological sanitation, they also try to ensure that the household is committed to the process. Having them pick up their materials at the KWAHO office is one way they try to do this. When all the materials are at the home of the recipient, KWAHO sends a trained mason to the house to construct the toilet.

The whole process from application to receipt of the toilet usually takes 2 to 3 months. The construction of the toilet takes approximately 1 week. After the construction is complete, KWAHO then returns to the house to conduct more detailed training regarding use and maintenance of the toilet.

3.5.3 Eligibility to Receive an Ecosan Toilet from KWAHO

Because the ecosan program is relatively new, KWAHO wants to target those in the community that might be in a position to spread word of the technology to others in the area. For this reason, many of the recipients of ecosan are area Chiefs[(8)] of a sub-district.

The other possible recipients of an ecosan toilet are participants of local women's groups, which are usually organized around management of local water sources. KWAHO opens ecosan application to this group in furthering their other organizational goal of gender

[(8)] The position of "Chief" as used here is an appointed governmental office with governance of the smallest geographic jurisdiction.

equity and empowerment. Women's groups are often made up of women of varying economic status, which allows KWAHO to reach poor households in addition to the influential (Chief's) households as noted above. KWAHO reports that they also generally want to encourage the organization of community members, and supporting women's groups is a way to do that.

3.5.4 The Skyloo

Thus far, KWAHO has only built and promoted the skyloo type of ecosan toilet. The skyloo does not deposit the feces and urine into the ground, but collects them separately in a chamber above ground. Therefore, the structure of the skyloo is raised, and feces and urine can be removed from the toilet's lower vault through a door in the rear (see Figure 3.4a, b, and c).

There are two ways to collect and use the feces in the skyloo. One option is to collect the feces directly on the floor of the vault and, when the vault is full, to let it lie fallow for 6 months to 1 year. Two adjacent toilets can sit side by side and be alternatively used similar to the fossa alterna. Another option, which is the method that KWAHO promotes, is to build a toilet with only one vault and collect the feces in a plastic bag-lined container. When the container is full, the feces can then be deposited elsewhere for decomposition and reused after 6 months to 1 year. This is the type of toilet that KWAHO promotes and is the subject of this research.

Figure 3.4a: Front View of the Skyloo

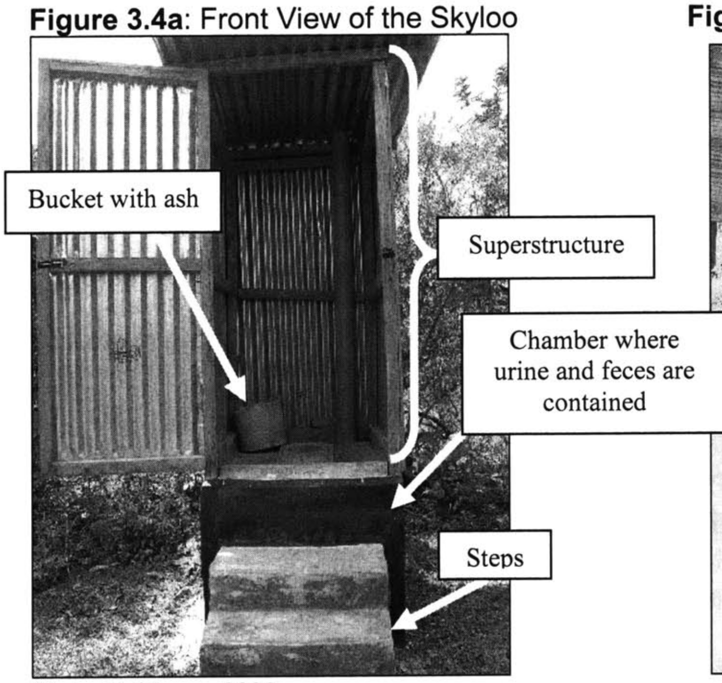


Photo: Robinson, 2005

Figure 3.4b: Back View of the Skyloo

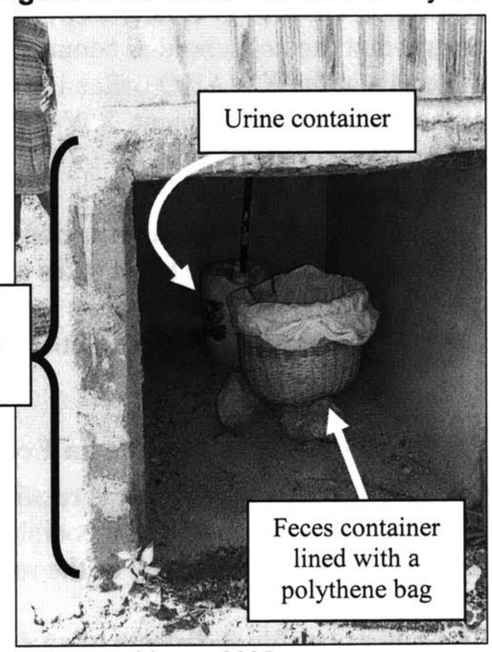


Photo: Robinson, 2005

Figure 3.4c: Urine Separating Squatter Plate

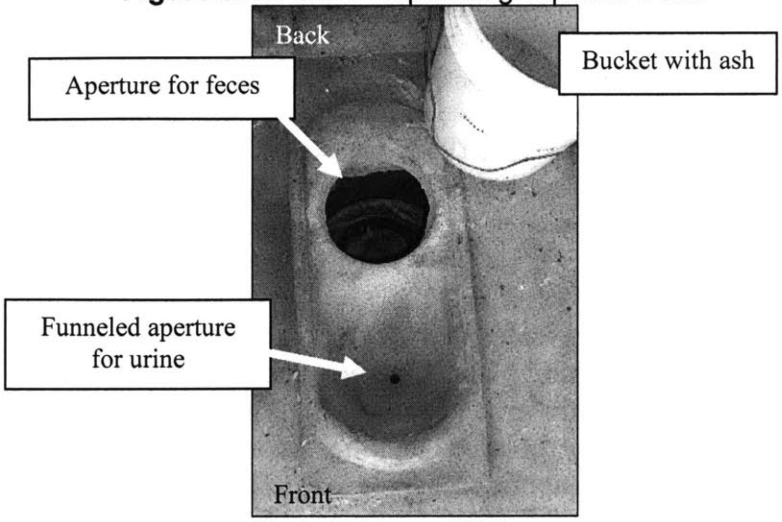


Photo: Robinson, 2005

Some of the reasons KWAHO chooses to promote the skyloo are that:

- Urine separation provides easy dehydration of the feces;
- Urine separation provides urine as a valuable resource (see Table 2.2);
- It is a permanent structure and no new pits need to be dug in the future;
- It is completely above ground and provides a latrine solution for some of the communities that have shallow water tables or loose, sandy soils; and
- The one vault makes construction and materials cheaper.

3.6 Recipients' Background

There are some characteristics that are common to all the households that took part in KWAHO's ecosan program. The demographic background of the households in the region is similar, therefore, those participating in KWAHO's ecosan program are similar. All households were rural and, on average, about 30 kilometers away from the nearest large town, Kisumu. As noted above (see Section *3.5.3*), only village chiefs and participants of women's groups are targeted for KWAHO's promotion of the skyloo toilets.

3.6.1 Agricultural Practices

From the user interviews, all (100 percent) of the households that were surveyed practiced some form of household agriculture, and all of the individuals that were spoken to from these households participated in these agricultural activities. This suggests that at a household level, there is a great amount of participation amongst the members of the homestead in farming and particularly subsistence farming, although sometimes they sell extra produce at the market or on the roadside.

Because all households are involved in agriculture for their survival, the recycled feces and urine from an ecosan type toilet have tangible personal value. For households that do not practice farming, a successful ecosan program would require an alluring incentive for recycling feces and urine other than personal use in agriculture. Such households might require an individual "collector" whose job is to collect the material from households, and who is responsible for transportation, marketing, and distribution of the manure (Salifu, 2001). While the literature suggests uses such as aquaculture, poultry feed, or fuel resources, (Feachem et. al., 1983; Jönssen et. al. 2004) none of these households were aware of using feces or urine for such purposes.

3.6.2 Household Fertilizer Use

Interviews with the households revealed that all (100 percent) of the households use animal fertilizer on their agricultural plots. Of these, about half (11 out of 23) use, or have tried using, commercial fertilizer (see Table 3.2). Thirty percent, though, use commercial fertilizer consistently, in large quantities (more than 10 kg in a year), and set aside a substantial amount of economic resources to it. These 7 households report spending an average of about 4000 Kenyan Shillings (KSH) ($52.60 USD[(9)]) on commercial fertilizers, and used an average of about 100 kilograms each last year.

Table 3.3: Household Fertilizer Use

	Yes (or tried)		No	
	Count	%	Count	%
Commercial	11	47.8%	12	52.2%
Animal	23	100.0%		

(n = 23)

These usage rates of fertilizer show that households are aware of the relationship between manure and agricultural productivity and that there is a general demand for both animal and commercial fertilizer. The commercial fertilizer is not more widely used due to its cost (Ksh 40/kg, US $0.53/kg), whereas animal manure is almost always free.

One interviewee reported that in January of 2005, a Kenyan government official announced that the price of fertilizers would double over the next year. There seemed to be much public dissent for such a high increase in cost, especially among the farmers who would not be able to afford the fertilizer anymore, and it remains to be seen if the announcement will become a reality. If it does, it should make ecosan an even more attractive option to many of these poorer households in the coming years.

3.7 Summary

Ecosan is still in a nascent stage of development in Kenya. NGOs are the on-the-ground implementers of ecosan, while international donor organizations fund, direct, and actually control the drive for ecosan in Kenya. The Government of Kenya is mostly passive in the ecosan movement, likely waiting to see if the technology catches on in larger scale with the Kenyan populace.

[(9)] In January 2005, US $1 = Ksh 76

The three forms of ecosan currently practiced fill different niches of characteristics that households want in a sanitation facility. The skyloo, which was the toilet studied, is above ground and urine separating, therefore good for adverse hydrogeologic conditions. It additionally generates concentrated nutrients in the form of urine that are valuable for agriculture. The arborloo does not require handling or processing of human excrement, and has the byproduct of creating fertile soils for growing plants and crops. The fossa alterna also requires little manual processing of the excreta, but still provides a manure product that can be mobile and applied in various places.

Households in the region in which the research was conducted have a predisposition to valuing free manure and fertilizer. The fact that all these households practice some form of subsistence farming, and that there is an active demand for fertilizer and manure, makes them more apt to personally value the material from a skyloo than urban households that do not practice any form of agricultural activity.

4 Research Design and Methodology

4.1 Introduction

In order to understand why households would want to adopt a skyloo toilet, I used two methods of data collection. A structured interview composed of close-ended questions was used to collect household information on methods of excreta reuse. To gather information about users' preferences regarding the skyloo[10] I also asked open-ended questions which made it possible for people to express their own likes and dislikes about the system without prompting from an enumerator.

To investigate the agricultural value of the skyloo for this area required taking urine samples from the jerry cans beneath the skyloo toilets. I analyzed the samples for their nutrient content, pH and level of fecal contamination. Urine contains the majority of the nutrients in human excreta and has can be applied as an agricultural fertilizer (Winblad, 1997). This quantitative data enabled me to calculate the amount of nutrients that the skyloo can capture, and what value these nutrients would have to the average farmer in the region.

4.2 Household Interviews

4.2.1 Interview Design

The interview instrument was designed to gather descriptive statistics on households' reuse practices and to get information on why people do and do not like their skyloo toilet (see Appendix A for a copy of the interview instrument). The interviews consisted of both close-ended and open-ended questions. The interview instrument had five main sections: respondent information, household agriculture, fecal reuse, urine reuse, and perceived value.

4.2.2 Household Selection

KWAHO began building toilets in the spring of 2003. The organization's records indicate that they have built 37 skyloo toilets in Maseno and Kombewa (combine population of approximately 50,000 people) since the inception of their skyloo promotion program. KWAHO is the only known NGO that promotes ecosan in this region of Kenya. Of the 37 toilets that they have helped build, 35 are household toilets, and 2 are at institutional compounds (one at the KWAHO office and one at a chief's camp).

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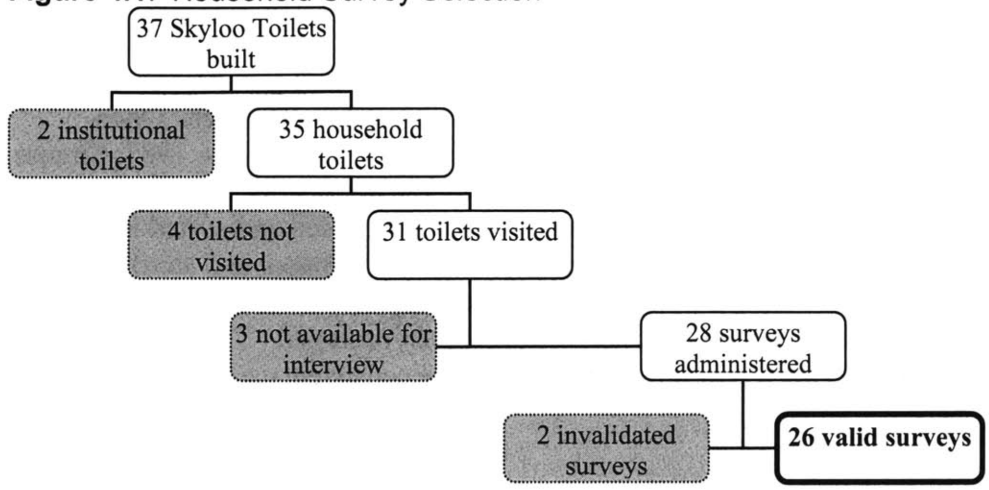
[10] All the toilet visited were skyloo toilets. See Section *3.5.4: The Skyloo*.

Figure 4.1: Household Survey Selection



I visited 33 of the 37 skyloo toilets, 31 of them at households and 2 at institutions (1 at a Chief's camp, and 1 at a school). The remaining 4 household toilets that exist in this area were not visited due to time restrictions (2 cases) or the inability of KWAHO's staff to locate their address (2 cases). At 3 houses no one was home, and time did not permit a return visit. In total, 28 surveys were administered, two of which were invalidated due to an inconsistency between answers given in the survey and observed realities of the toilet's use. Specifically these two households gave interviews as if they were actively using the toilet, but upon visiting the facility, it was clear that it had not been in use for some time.

4.2.3 Survey procedure

Each household was visited in the period between 8 January and 17 January 2005. KWAHO assigned one of their staff members to aid my visits to all of the households. Each interview took between 30 and 60 minutes, depending on the interviewee's interest in the topic. While most of the rural residents spoke English with great proficiency, it was a great advantage to have a local partner join me on the household visits. The KWAHO partner greatly facilitated locating rural household villages, maintaining cultural sensitivity during household visits, and handling situations in which complex language issues arose. He also had an established relationship and good rapport with some of the households. This was an advantage in that it helped some households feel more comfortable in communicating with me, but also a disadvantage in that he was a recognized member of KWHAO and probably biased some of the answers that households gave.

Upon arriving at each household, I requested to meet with the head of household and asked his/her permission to participate in the survey. After administering the survey, we visited the household's toilet to verify current use and take a sample of urine from the jerry can collection vessel. All households signed a Participation Consent Form in accordance with regulations set forth by MIT's Committee on the Use of Humans as Experimental Subjects.

4.2.4 Data Analysis

Data from closed-ended questions were analyzed using descriptive statistics. Open-ended questions were analyzed using grounded theory method (see Strauss, 1987; Strauss and Corbin, 1990; Strauss and Corbin 1997). The interview transcripts were first analyzed for discrete statements. These statements were then coded and sorted into categories by placing discrete statements on individual pieces of paper and shuffling them into observable patterns and similar categories. These categories were compared and relationships were evaluated, condensed, and hierarchically arranged. The process was repeated over a period of two weeks until satisfactory and consistent categories were found.

4.2.5 Limitations to the Qualitative Research

There are several limitations to the data collection in this research. First, as noted above, a KWAHO staff member was present with me on all household visits. While this was necessary and extremely helpful, it likely limited the range of responses given by the households. Households could have reported a positive bias for the toilets in the presence of their donor or, for example, could have limited any criticism of KWAHO's administration of the program.

Another challenge was trying to understand the social norms surrounding household dynamics in this area of Kenya. A mother and father traditionally have a house that faces the "gate" of the home (the forward facing orientation) and sons build their houses lining the walkway from the gate to the head (parental) home, but often have second homes away from their parents' house. This can result in large homesteads, or compounds, for which complete sanitation coverage can be challenging, and whose population can be fluctuating or transient. While interviewing respondents, it was difficult to firmly say how many people lived in the home, and often there were multiple sanitation facilities that served the compound.

It is also noted that we usually interviewed one or two people from each household. While these people were usually the elders of the household, it is still difficult to say whether or not they gave a complete or representative picture of all the household users' views on the skyloo toilet.

Finally, the focus of this research is on those who use the skyloo toilets. However, it might have been helpful to talk to others members of the community that were not already using ecosan toilets. A documented view of the dominant cultural perception of the handling of human excreta has great potential to help inform well-designed, user-friendly ecosan toilets. There was simply not enough time to do it all.

4.3 Urine Sample Analysis

4.3.1 Laboratory Research Design

Because KWAHO promotes the skyloo, which is a urine-separating toilet, it was determined that urine was the most reasonable and a readily available material to test for this research. Moreover, because a large focus of this research is on agricultural application, the limited field time was best spent investigating urine because it contains more nutrients than feces.

The quantitative data gathered from urine samples was designed to provide information by which to gauge the agricultural potential of urine for the people who currently use the toilet. As has been discussed earlier (Section *2.8.2: Urine Kinetics*), the major limiting nutrients in agriculture are predominately nitrogen, potassium, and phosphorus (which are the common main nutrients in commercial fertilizer). It was feasible to test for two nutrients, nitrogen and phosphorus, given the time available, the equipment that needed (which had to be transported via air to Kenya), and the relative importance of nitrogen and phosphorus. Additionally, the urine was tested for fecal coliform to investigate the safety of handling it.

4.3.2 Sampling procedure

Urine samples were taken from the urine-collecting jerry can stored in the toilet's chamber beneath the superstructure (Figure 3.2a). The samples were extracted from the container with a 60 milliliter syringe which had two feet of ¼-inch polyethylene tube attached to its end. The urine was then expunged from the syringe into a 100 ml Whirl-Pack® bag (Figure 3.2b). A total of 100 milliliters of urine was extracted from each toilet that had urine available.[11] After extracting and expunging two 50 milliliter syringe volumes of urine into the bag, it was labeled (consistent with the numerical ID for the survey) and dated.[12]

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[11] A few household were not using the toilet or had just emptied the urine container and there was too little to take a good sample.
[12] Each household had a numerical ID that was identical for the household survey and the urine sample.

Figure 4.2a: Vault of the skyloo. Foreground—the feces bucket. Background—urine-collecting jerry can.
Figure 4.2b: Collecting sample with syringe and placing it in a Whirl-Pack® bag.

a.

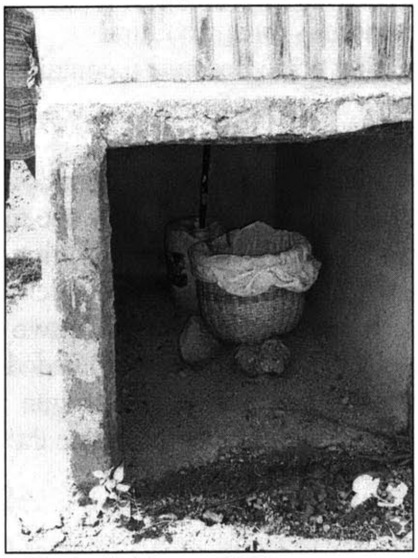

Photo: Robinson, 2005

b.

Photo: Robinson, 2005

4.3.3 Nitrogen

Ammonia-Nitrogen Methods

Nitrogen is present in fresh urine in three major forms: as urea ($CO(NH_2)_2$), ammonium (NH_4^+), or creatinine ($C_4H_7N_3O$) (Lentner et. al., 1981). After a few hours outside the body, urease bacteria convert urea to ammonia (NH_3), ammonium (NH_4^+) and carbonate (HCO_3^-) through a process known as urea hydrolysis, or ureolysis (Vinnnerås et. al., 1999; Jönsson et. al., 2000) (see Section *2.8.2: Urine Kinetics*). Given that most of the nitrogen is bound up in the ammonia[13] (Jönsson et. al., 2004), the ammonia (NH_3)-nitrogen content of the urine.

The Hach spectrophotometric test-in-tube method for NH_3-N (Hach Company, 1997)[(14)] was used. The range of this test is 0 to 50.0 mg/L of NH_3-N. First, a range of dilutions (1:10, 1:100, 1:1000, 1:100000) were tested to determine which was most appropriate for the range of the method used. A dilution of 1:100 was determined appropriate, and this was used for all subsequent NH_3-N tests. In a test tube vial, 0.1 milliliter of the dilution was pipetted and into another, 0.1 milliliter of deionized water (as a blank). An Ammonia Salicylate Powder Pillow was then added, followed by an Ammonia Cyanurate Reagent Powder Pillow to each of the vials. The test tubes were capped and shook until the powder was thoroughly mixed and mostly dissolved. A green color develops if ammonia is present in the sample, otherwise, the vial contents will remain clear. The blank test tube was zeroed in the spectrophotometer set to 655 nanometers, and a reaction period of

(13) In a high pH solution, ammonium is readily converted to ammonia: $NH_4 (aq) + OH^- \rightarrow NH_3 (aq) + H_20$

(14) Hach® method number 10031 for the DR/2010 spectrophotometer

20 minutes was allowed. The sample vial was again tested, and both the NH_3-N and the NH_3 values were recorded.

Urease Methods[15]

As noted above, urine that has been in storage for longer than a few hours in the presence of urease bacteria has usually undergone complete ureolysis. If, however, there is nitrogen that is still bound up in urea as $CO(NH_2)_2$, we would not be able to detect it using the ammonia-nitrogen test as described above. This was done to ensure there was no urea left in the urine samples and, thus, validate that the NH_3-N tests that were performed represented the total nitrogen in the urine.

Adding artificially manufactured active urease bacteria[16] will catalyze the ureolysis reaction and convert any remaining urea-nitrogen to ammonia-nitrogen. One can then run the ammonia-nitrogen test as described above to determine the total nitrogen in the urine solution. Subtracting the first ammonia-nitrogen value from the ammonia-nitrogen value that we get after adding the urease solution will give us the amount of nitrogen originally in the urea.

Addition of the urease solution begins by making dilutions of the sample that are consistent with the range of ammonia-nitrogen that we expect from the sample *after* urea degradation. Because the total nitrogen expected in urine is around 7.5 g/L, and our test range is 0-50.0 mg/L of NH_3-N, the urease test samples were diluted to 1:1000. A 10-ml test tube was filled with the sample and 0.1 ml of the urease solution was pipetted into the 10 ml sample. At this point it is best to keep as little headspace as possible in the test tube vial to prevent volatilization of aqueous NH_3 after the urea conversion. After mixing it well, the sample stood for at least one hour. After this time period, all urea should be degraded to ammonia. The the NH_3-N can then be measured per the Hach® method described in the Ammonia-Nitrogen section above.

Due to time constraints not all of the urine samples were able to be tested with the urease method. Subsequently a range representative samples were chosen based on the nitrogen levels from the initial NH_3-N tests.

4.3.4 Phosphorus

Phosphorus is a major limiting plant nutrient and available in large concentrations in urine. Recognizing this, the urine samples were analyzed for their dissolved phosphorous content. Dissolved phosphorous is present in urine as orthophosphate PO_4^{3-} and precipitates out of solution in urine mainly in the form of struvite ($MgNH_4PO_4$) and hydroxylapatite ($Ca_{10}(PO_4)_6(OH)_2$) (Udert et. al., 2003). Although these solid forms of phosphorous can break down over time and become bio-available, the form most directly available to plants is the phosphate ion in solution. For this reason, the dissolved orthophosphate (PO_4^{3-}) content of the urine was measured.

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(15) Laboratory methodology adapted from Küffer, 1983 with consultation from Dr. Kai Udert, MIT.

(16) Sigma-Aldrich Inc., Urease Canavalia ensiformis [Jack bean] in glycerol solution, product #U1875

The Hach® spectrophotometric method[17] was used to measure the PO_4^{3-}-P (Hach Company, 1997). This test measures values in the range of 0 to 2.50 mg/L of PO_4^{3-}-P. I first tested a range of dilutions (1:10, 1:100, 1:1000, 1:100000) to determine which best fell into the range. At first, I determined 1:2000 dilutions of the urine sample were appropriate. After six tests this returned consistently low values and I halved the dilutions to 1:1000. This dilution was used for the subsequent PO_4^{3-} tests.

A 10 milliliter glass vial (a matched pair with this vial was used for the zeroed sample) was filled with the sample. Next a PhosVer 3 (ascorbic acid) Powder Pillow was added and stirred until the powder was thoroughly mixed and mostly dissolved. A reaction period of 2 minutes was allowed, and the vial was placed in the spectrophotometer set to 890 nanometers. For the phosphorus readings, I zeroed the spectrophotometer with a blank vial of deionized water before each reading. Both the PO_4^{3-} and the PO_4^{3-}-P values were recorded.

Additionally, there may be small background amounts of PO_4^{3-} present in the deionized water. To account for this, I followed the same procedure of adding the PhosVer 3 Powder Pillow to a blank sample of deionized water and testing it for a PO_4^{3-} value. This background amount was subtracted from the final results.

4.3.5 Fecal Contamination

Fecal contamination was measured using the membrane filtration method (Standard Methods, 2004; Hach®, 2004). The membrane filtration method uses a vacuum pump to suction water through a 0.45 μm filter. Water will pass through these pores, but anything larger than 0.45 μm (such as fecal indicator bacteria) will remain trapped on the filter. The bacteria are then placed in optimal growing conditions to allow individual bacterium to colonize into sizes that are visible to the human eye or low-powered microscopes.

Membrane filtration can be used to test for a variety if organisms; the organisms of interest are selected for based on the culture media and incubation temperature one uses. In this case, I was interested in looking for bacteria that indicated fecal contamination in the urine, specifically the fecal coliform *Escherichia coli* (*E. coli*).

[17] Hach® method number 8048 for the DR/2010 spectrophotometer

Figure 3.3: Portable Millipore Membrane Filtration Unit

Photo: Robinson, 2005

Dilutions of the urine samples were made for the membrane filtration tests. Testing various dilutions, it was determined that the limiting factor was the amount of pure urine one could pass through the filter before the filter clogged. Some urine samples clogged easily, while some passed through the filter smoothly, indicating the presence of precipitates and solids in the solution. A dilution of 1:100 worked sufficiently even for the samples with highest amounts of precipitate.

The membrane filtration stainless steel field unit (Figure 3.3) is first sterilized using methanol before each sample, and a sterile 0.45 μm membrane filter is placed on the screen of the unit using sterile procedures. After the dilution is vacuum-sucked through the filter, the filter is removed from the filtration apparatus. The filter was placed in a petri dish soaked in M-coli Blue broth,[18] and incubated for 24 hours at a 37 °C (the temperature that is optimal for the colonization of these bacteria).

Some membrane filter tests were prepared with only deionized, sterilized water that was used for the dilutions as "blanks" to ensure that the water had not become contaminated during transport or storage. All blanks conducted during the time of the experiments returned zero total and zero fecal coliforms.

4.3.6 pH

Finally, the pH of the urine samples was recorded to compare with reported literature values of urine that has undergone ureolysis. The Thermo Orion pH meter was calibrated with 4.01, 7.00 and 10.01 pH buffer solutions and, after calibration, the pH electrode was stored in an electrode storage solution. The pH meter was recalibrated every 3-4 days.

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[18] The m-coli blue broth is a culture media specific to the growth of coliform indicator bacteria, total coliforms will grow with a red-ish tint while *E. coli* (a fecal coliform) will appear blue. This particular product is manufactured by Millipore, Inc.

To measure the pH, I placed the electrode directly in each urine sample and recorded the reading after the pH meter reading stabilized. I rinsed the electrode thoroughly with deionized water after each use.

4.3.7 Special Travel Considerations

All of the laboratory tests were conducted on the urine in-country, which made it necessary to bring all laboratory equipment with me to Kenya. All of the laboratory experiments were planned in December, in preparation for the January trip. All materials and equipment were packed in a suitcase and carried to Kenya as checked baggage. The transport of the lab equipment imposed special restrictions on the types of experiments that could be performed due to the types of materials that are allowed in air travel. For all procedures, the chemical's Materials Safety Data Sheets (MSDS) were checked to make sure there were not any relevant air travel restrictions, and all MSDS were present on the flight to Kenya. Additionally an official MIT letter from the project supervisor stating the nature of the project and use of the materials was carried on the flight. Appendix B provides a complete list of the lab equipment and supplies that I took to Kenya.

4.3.8 Limitations to the Quantitative Research

One limitation to the quantitative research is that it began by assuming ureolysis, the natural degradation of urea to ammonia in excreted urine, was mostly complete in the urine that was sampled. As described in Chapter V, it is not certain that this is true, and other experiments could have been employed to research this phenomenon more clearly.

The size and regulatory restrictions due to air travel to Kenya limited the types of tests that could be performed and the kinds of equipment that could be brought. More complex or detailed methodologies might have been feasible if these restrictions were not in place.

The largest limitation to the quality of the laboratory data resulted from the laboratory conditions in which I worked. KWHAO generously gave me a whole room with which to set up a laboratory. However, due to the nature of the room, it was impossible to sterilize most spaces and it was difficult to keep equipment clean and free from dust. I worked in the conditions the best I could, but it is possible that some inaccuracies resulted from these conditions. That said, data checks (such as blanks) proved alright, duplicates were consistent, and meaningful data was obtained.

Finally, the number of urine samples that I obtained is relatively small (sixteen). Due to the small sample size, statistical processing of the data is limited.

5 Agricultural Value of Urine

5.1 Liquid Gold?

One of the foundations of ecosan is that excrement is a good fertilizer for garden crops. The urine should be especially valuable to farmers due to its high nutrient concentrations and the relatively small amount of storage time that it needs to be ready for use. But how good is it? Could one person's urine, or even the urine from an entire household, really make a substantial impact on the growth of a household's crops? This chapter explores the nutrient loads available from the urine in the skyloo toilets that were visited, and the potential impact of those loads to households' farms.

In order to know the amount of nutrients in solution, we have to know where to look for the nutrients. That is, is the nitrogen in the form of urea or in the form of ammonia? Is the phosphate in solution or has it precipitated out in the form of struvite?

To estimate where the nutrients are, we need to know where the urine samples are in the natural cycle of urea hydrolysis, or ureolysis. Urine undergoes ureolysis when it has left the body and is in the presence of urease-positive bacteria (which all toilets generally contain [Udert, 2003b]). In the following analysis, we explore the nutrient content of the urine from visited skyloo toilets, calculate the total amount of nutrients available to agriculture, and evaluate the impact this might have on an average household.

5.2 Nutrient Content in the Urine

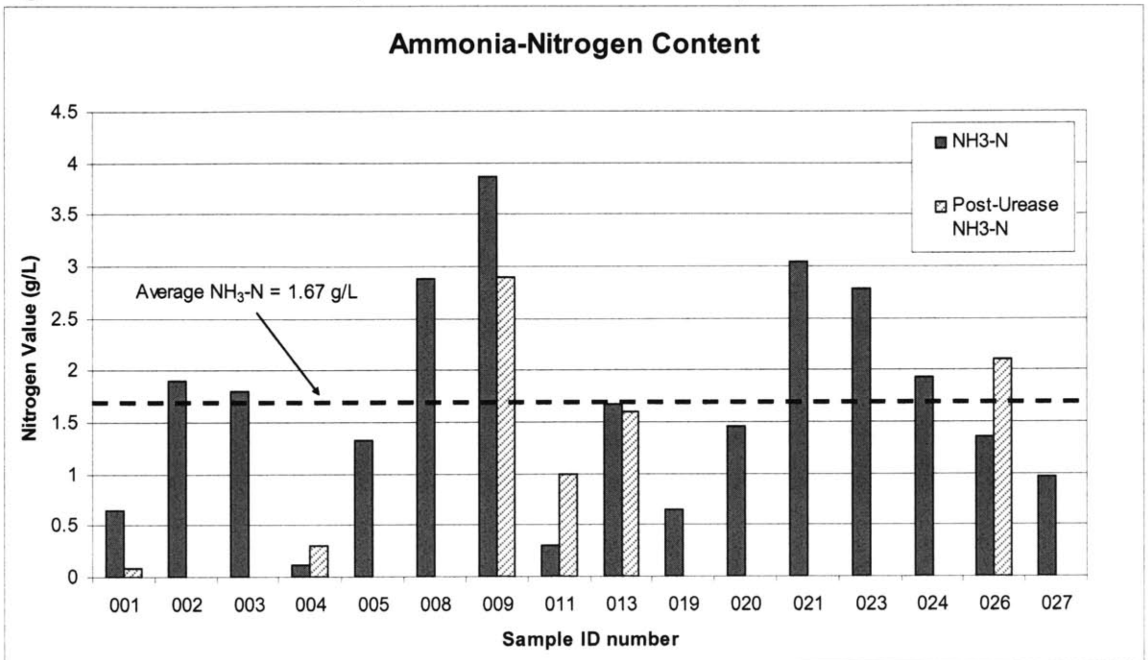
5.2.1 Nitrogen

Fresh urine has, on average, about 8.04 grams of nitrogen per liter (g-N/L) (see Section *2.8.2 Urine Kinetics* on nitrogen in urine) with about 6 percent of the nitrogen bound up in ammonia (NH_3), and about 94 percent of it in urea[(19)]. After a period of time outside the body, and when urea hydrolysis (ureolysis) is complete, all of the nitrogen will be degraded to NH_3. However, if ureolysis is incomplete, some of the nitrogen would still be bound up in the urea in the urine. Ammonia nitrogen (NH_3-N) in the samples ranged from 0.12 to 3.86 grams per liter (g/L), with an average of 1.67 g/L. Figure 6.1 shows the levels of NH_3-N in the urine from the skyloo toilets.

In samples 001, 004, 009, 011, 013 and 026, urease-positive bacteria were added to the urine to drive ureolysis to completion. This addition would break down any remaining urea to NH_3. Then I could perform the NH_3-N test again to see if the levels of nitrogen changed. Figure 6.1 shows the NH_3-N levels after the urease bacteria were added. These levels vary widely from 0.3 to 2.9 g-NH_3-N/L, roughly corresponding to the NH_3-N levels before the addition of the urease solution. While some of the samples return higher values after the addition of urease, an equal number return lower values.

(19) Based on the composition of urine given by Ciba-Geigy, 1977.

Figure 5.1: Ammonia-Nitrogen Content of the Urine Samples from the Skyloo



These results suggest two competing possibilities. One possibility is that the urine has undergone complete ureolysis, and all the nitrogen is in the form of ammonia, as would be the case if the urease addition had little effect on the urine samples. If this is correct, then the nitrogen levels from the urine containers are much lower than expected. Based on the Ciba-Geigy (1977) values for total nitrogen in fresh urine, these levels are expected to be ~ 7.5 to 8 g/L. This data was based on European urine, however. As shown in Table 2.1, diet plays a large role in determining the amount of theoretical nutrients found in excreta (Jönsson & Vinnerås, 2004). The composition of nutrients in the Ugandan and Kenyan diet are comparable (FAO, 2005), so from the Ugandan values given in Table 2.1 we could expect the nitrogen content in the Kenyan urine to be around 4.4 g/L[(20)]. This is much more agreeable with some of the data samples (i.e. Sample 009), although still greater than the nitrogen content from many of the urine samples from the skyloo toilets.

The second competing possibility is that the urease solution was inadvertently inactived (which is possible without proper refrigeration), and further ureolysis in the samples was not possible due to the lack of a catalyst. If this possibility is correct, there could still be much nitrogen bound up in urea that has yet to hydrolyze and is unaccounted for in the results presented above. This would imply that the urine was relatively fresh to have so much urea still present, though. As long as the toilets are in constant use, patrons would continually add fresh, un-ureolyzed urine to the container. This could, theoretically, lower the amount of NH_3-N concentration in solution and account for at least a part of the lower concentrations. However, for these NH_3-N levels to be lowered to these levels, the samples would need to be at least half fresh urine and half hydrolyzed urine, even for the

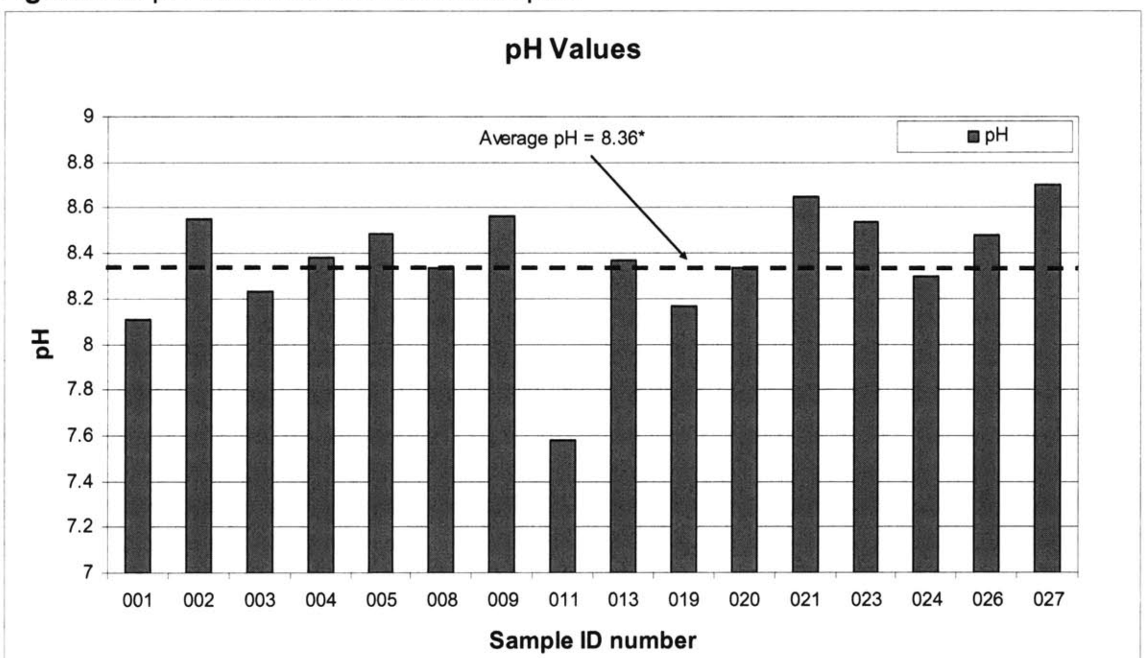
[(20)]Assuming that a person, on average, excretes 500 liters of urine per year (Average of data from Larsen et. al., 1996 and Fittschen et. al, 1998).

concentrations with the highest NH_3-N values. To account for the lower NH_3-N values the ratio would have to be even more in favor of the fresh urine, which is not possible except for the first few days' use of the toilet.

5.2.2 pH of the Urine

The pH values of the urine were also taken. We can see that all the pH values fall in a fairly close range, with one anomaly. Excluding sample 011, the average value of the pH levels is 8.41 ($\sigma^2 = 0.17$). As Udert (2003b) reports, urine that has undergone complete ureolysis has a pH greater than 9, which suggests that the samples have not yet completed ureolysis (the second competing hypothesis is supported by this evidence).

Figure 5.2: pH Values for the Urine Samples



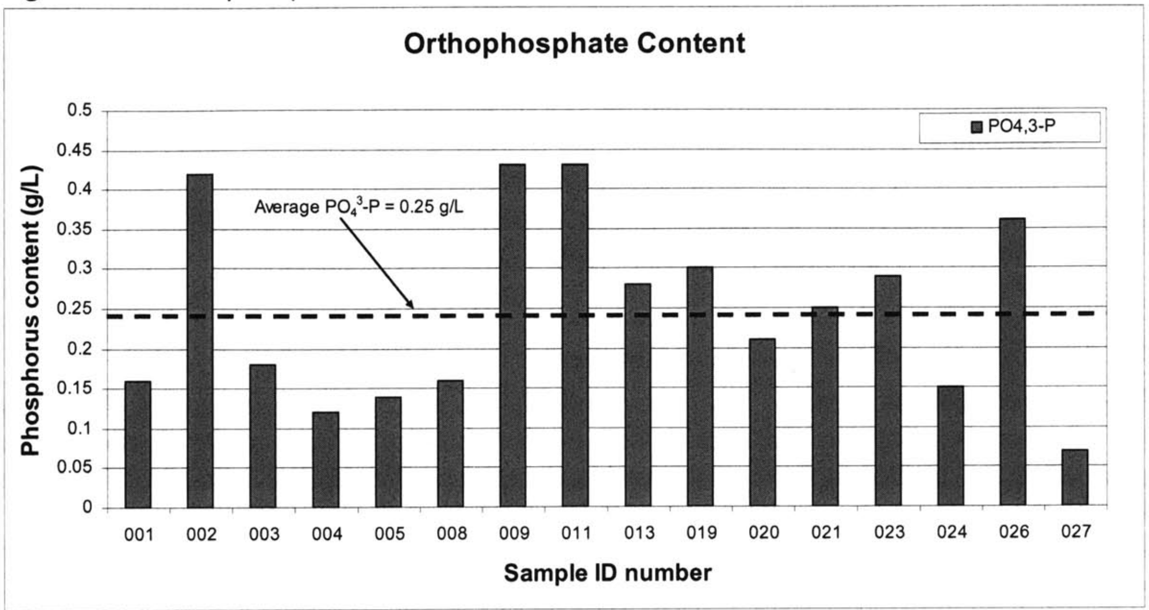
*excluding sample 011

5.2.3 Phosphorous Content in the Urine

As suggested by Jönsson & Vinnerås (2004) the average phosphorous (P) concentration in fresh urine in Uganda is 0.6 g/L(21). Outside the body, however, the pH of urine increases, which causes some minerals in solution to precipitate out. From Udert (2002a), after ureolysis is complete, we expect about 20% of the phosphorous to precipitate out of solution as struvite—leaving about 0.48 g/L in solution. Therefore, the amount of P in the urine can also provide insight into the urine's degree of ureolysis. We see in Figure 6.3 that the P concentrations range from 0.07 g/L to 0.43 g/L, with an average concentration of 0.25 g/L, also suggesting that ureolysis is, generally, incomplete.

(21) Assuming that a person, on average, excretes 500 liters of urine per year (average of data from Larsen et. al., 1996 and Fittschen et. al, 1998).

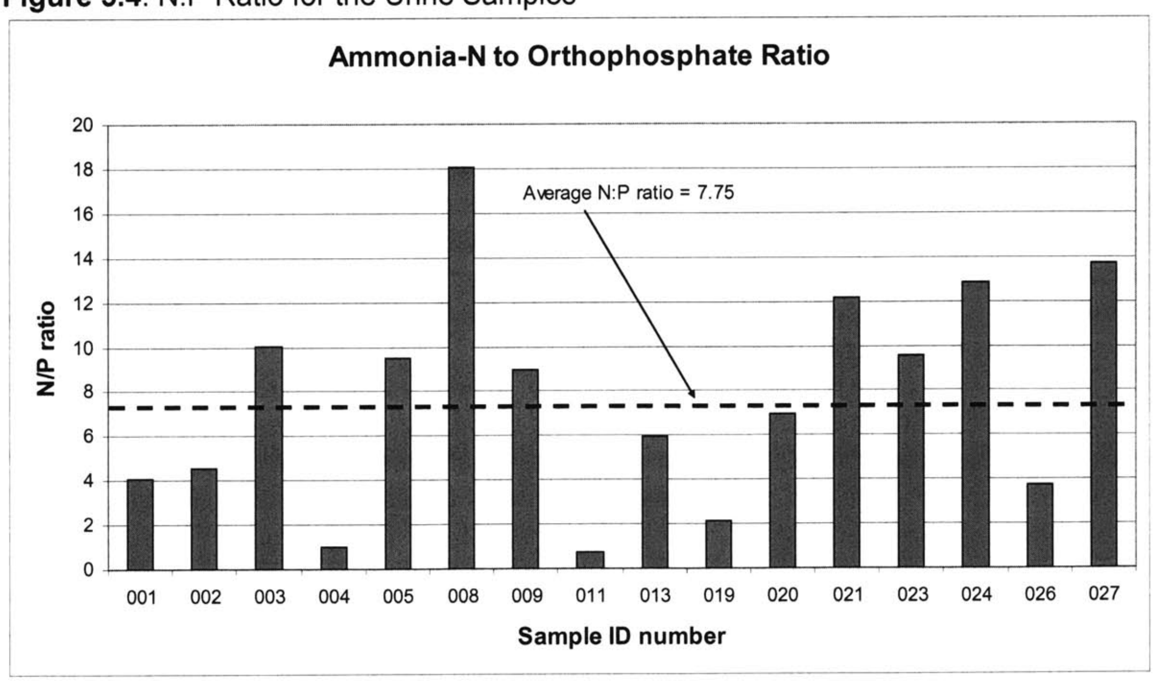
Figure 5.3: Orthophosphate Concentrations in the Urine Samples



5.2.4 Kinetic Implications

"Normal" urine has a nitrogen to phosphorous ratio of about 10-11 (Udert, pers. comm., 2005). The N:P ratio was calculated for the urine samples and produced a range of values with an average of 7.75. In Figures 6.2 and 6.3 above, we see that the individual nitrogen and phosphorous concentrations in the urine are lower that what we expect in urine that has undergone complete ureolysis. The ratio here, however, suggests that P concentration relative to the N concentration is high, or that the N concentration is low.

Figure 5.4: N:P Ratio for the Urine Samples



There are three factors that suggest that ureolysis is incomplete in these samples:

1. Low NH_3-N levels. Although this is not supported by tests with the urease solution, it is recommended that the test be performed with a new batch of solution to ensure that these results are not due to the inactivity of the solution.
2. The pH of the urine samples are significantly less than 9.
3. The N:P ratio is low, suggesting that not all struvite has precipitated out of solution as suggested by Udert (2003b).

5.2.5 Discussion of Nutrients and Kinetics

Incomplete ureolysis seems to be a strange conclusion given the consistency of pH across the samples. It is possible that diet may have other chemical effects on the kinetics of the urine samples. For example, a person with a low-protein diet (as in Kenya) will have lower urea concentrations in their urine. A lesser amount of urea will produce a lesser amount of hydroxyl ions and, therefore, a lower pH (see Section *2.8.2*). A lower pH would produce less precipitation of phosphorous, and could help explain the low N:P ratios as well. While decreasing the original urea concentration in fresh urine from 0.27 moles to 0.18 moles (a decrease of one-third) will only result in a decrease in pH of 0.18 (i.e. a pH of 9 would lower to a pH of 8.82), this still could explain part of the low values seen here.

Another consideration could be the effect of continual addition of urine into the containers from which I drew my samples. Could incomplete ureoloysis be the steady state condition for continuous input of fresh urine into the system? This is a possibility, but the ratio of hydrolyzed urea to unhyrolized would, in theory, be proportional to the amount of urine that has undergone ureolysis in the container. We would therefore, expect the extent of ureolysis to be related to the amount of urine in a container. In containers with even a few liters of urine, we would not expect this to be a large factor.

Finally, (Kreig and Gunβer, 1986) calculated the constituents of fresh urine throughout the day versus the morning. Their research showed that the first urination of the day, which they refer to as "morning urine," contained about 1.3 times more nitrogen and 1.5 times more phosphorous than the average concentrations in the urine collected over a whole day. If people do not use the skyloo for the first urination of the day, the concentration of the urine could be quite a bit less than we expect. This might be possible due if people use an in-door container for the first urination of the day, or simply do not use the toilet for the first urination.

The topics addressed in this section are areas for further study and research. However, even given these constraints in understanding the kinetics of urine in these toilets, we still see the average nitrogen and phosphorous contents of the samples are substantial.

5.3 Urine Color

5.3.1 The Dark Color of the Urine

Dark color was an unexpected feature of many of the urine samples (see Figure 6.5). The bottom row contains the samples that were included in the analysis above. In the top row on the left is a sample of the author's urine that had been sitting for a few days, solely included to provide a comparison. The two samples on the top right were taken from skyloo toilets, but had been diluted with flushing water and, therefore, were not included as test samples.

Because such variation and anomalous dark colors in the urine were not expected, the equipment, procedures, and materials needed to test for possible causes were not brought. However, blood in the urine (hematuria) and pigment in the urine (bilirubinuria) can cause dark colors such as these (Health Central, 2005; University of Leeds, 2005).

Figure 5.5: Color Spectrum of Urine Samples

Photo: Robinson, 2005

5.3.2 Possible Causes

There are two likely causes of blood in the urine in this area of Kenya. First, malaria is endemic to the northern shores of Lake Victoria. Blackwater fever, caused by *P. falciparum* malaria, is a condition in which hemoglobin from burst red blood cells can pass in the urine, producing a dark color (National Disease Surveillance Center, 2004). The Centers for Disease Control established a research station in western Kenya in part because "*P. falciparum* malaria [is a] major public health problem" in this area, and it "has intense malaria transmission; on average, each inhabitant receives 150-300 infective mosquito bites per year" (CDC, 2004:1).

Second, *Schistosoma haematobium*, the helminth species which causes one form of schistosomiasis, is also common in Kenya. This particular species of *Shistosoma* lays and excretes its eggs via the host's bladder, and intense infections can cause blood in the urine. A World Health Organization bulletin even reviews the possibility of using urinary blood as a rapid indicator of infection of *Schistosoma haematobium* (Lengeler et. al., 2002). Although data is not available on the prevalence of infection in the

Kombewa/Maseno area, one study indicated a 53 percent prevalence of this species in a highly endemic area of eastern Kenya (Clennon et. al., 2004). Schistosoma infection is ubiquitous throughout Kenya, and it is likely that this species is found in the western part of the country where the samples were taken. Extremely high prevalence is not needed to support this hypothesis, though. Even one person in a household with the disease could alter the color of the urine in the container. If this is the case, safety should not be affected. As long as the urine is stored for the recommended one-month recommended time period, death of the helminth eggs should be complete (Schönning and Stenström, 2004).

Finally, hepatitis A causes the body to release the pigment bilirubin, which causes conditions of jaundice. In addition to the commonly-known yellowing of the skin and eyes, jaundicing can cause excretion of this pigment in the urine producing a dark color (Medic8, 2004), rather than blood in the urine, as in malaria and shistosomiasis. Urine colored by bilirubin tends to be "frothy" and microscopy can reveal if the color is due to pigment or due to hemoglobin (University of Leeds, 2005). Hepatitis A is moderate to highly endemic in Kenya (WHO, 2002), and is of special concern in areas with low levels of sanitation.

Any of these three diseases or, more likely, a combination of all of them are probable causes of the color found in the urine.

5.4 Agricultural Application

Using the average nitrogen and phosphorous concentrations from the urine samples, we can theorize about the agricultural applicability of the urine. The average N concentration is 1.67 grams per liter. If we assume that one adult, on average, excretes approximately 500 liters of urine per year,[22] then one adult will produce about 835 grams of nitrogen in one year. From the visits with skyloo owners, 4.8 people per household, on average, used the homestead's skyloo. In one year, nitrogen production would average more than 4 kilograms per household.

The average P concentration from the urine samples is 0.25 g/L. Using the same assumptions as for the N concentrations (one person excretes 500 liters of urine per year, and each household collects the urine from 4.8 people), an average household would produce about 0.6 kilograms of phosphorous in one year.

Table 5.5: Average Nitrogen and Phosphorous Values from Urine Samples

	Average Concentration	**Yearly Production (per person)**	**Yearly Production (per avg. household)**
Nitrogen	1.67 g/L	835 g/person /yr	4000 g/yr
Phosphorus	0.25 g/L	125 g/person /yr	600 g/yr

These production rates can now be compared with the amount of nutrients that are contained in crops of interest. Jönsson & Vinnerås (2004) provide a table of the nutrient

(22) Using the average of data from Larsen et. al., 1996 and Fittschen et. al, 1998.

components of common crops. The nutrients produced by one family are equivalent to the amount of nutrients in a hectare of spinach. Or, looked at slightly differently, these nutrients could supply a hectare of equivalent amounts of fresh corn, spinach, and watermelon.

Often, twice the application rate is needed in order to simultaneously increase soil fertility and provide nutrients for crop uptake (Jönsson & Vinnerås, 2004). So, in reality, it would only be possible to fertilize about half of the crops suggested with the given urine. Even so, these calculations show a clear nutrient value from the urine in agriculture, even with the somewhat low levels of nitrogen and phosphorous reported from the laboratory analysis.

5.5 Potential Cost Savings

About half of the households reported commonly using diammonium phosphate (DAP) fertilizer, at a cost of about Ksh 40 per kilogram (US $0.53/kg[(23)]). The nitrogen and phosphorous content of DAP is between 16 to 18 percent and 42 to 48 percent by weight, respectively (Africa Union Holdings, 2005). The 4 kg of nitrogen and 0.6 kg of phosphorous from an average household's the skyloo toilet, therefore, would be purchased in about 22 kg of DAP at a cost of Ksh 890 (US $11.70) per year. For less than US $1 per month, a family could supply itself with the same amount from commercial fertilizer as from the urine's nutrients in the skyloo.

Revisiting household's expenditure on commercial fertilizers (see Section *3.6.2*) helps to put this economic savings into perspective. Even for the skyloo owner that reported spending the most on fertilizer—Ksh 9000 (US $118) on 200 kg of fertilizer products per year—the nutrients from the skyloo would represent about a 10 percent savings in fertilizer expenditures. Of the fertilizer-using households that were visited, the average amount that was spent on commercial fertilizers was about Ksh 4000 (US $53). In this case, the nitrogen and phosphorous from the urine collected in the skyloo would replace about 22 percent of an average fertilizer-using household's expenditures on commercial fertilizer.

About 60 percent of the households that own a skyloo, however, did not report purchasing any commercial fertilizer. In this case, the nutrient production could be considered a material profit of Ksh 890 (US $11.70), which will also result in better crops. Not only does this benefit the farmer in added value to agriculture, but it also helps stabilize the household economic flows (by not having to spend as much cash on fertilizer) and produces a more reliable crop. Regardless, considering the materials subsidy provided by KWAHO, any household using a skyloo and the agricultural product from it would likely recover the value of their investment within a few years of owning it.

[(23)] US $1 = Ksh 76 in January 2005

5.6 Discussion

While the nitrogen and phosphorous concentrations in the urine are lower than expected, they still show potential to contribute to agricultural practices. The average household size of the families visited was about eight people. If the whole family were to use the skyloo the toilet's productivity would almost double.

The urine can have a relatively large impact on agriculture. The economic value of the nutrients also has the potential to have a positive impact on the household's economics. In this case, the skyloo provides a basic sanitation facility *and* agricultural input products. However, it is still not clear how the time spent maintaining the toilet or handling the excrement affect people's views on using the skyloo. Agricultural reuse methods are explored in Chapter 6, and how households feel about the toilet in general and reusing excrement will discussed further in Chapter 7.

6 Reuse of Urine and Feces

6.1 Household Reuse

Arguably the most novel aspect of ecological sanitation is that the excrement from the toilet is intended to be recycled and reused. In household systems such as the ones in Kombewa and Maseno, the households themselves are intended to recycle and reuse their own excrement. If reuse is not happening but communities are still applying for and receiving the skyloo, then we could conclude that there are other reasons the community wants and uses the toilet. If reuse is happening, then we can conclude that at least for some segment of the population finds the reuse aspects of excrement from the skyloo acceptable. Fundamentally, this chapter explores what people do with the urine and feces after they remove it from the toilet's chamber. What methods of reuse do users employ, if any?

6.2 Common Household Characteristics

Before looking more closely at methods of reuse, it is important to note some of the common characteristics among households in this area of Kenya, as presented more fully in Section *3.6*. First, all of the households practiced household agriculture, for which at least a portion of these crops were used for family subsistence. This is likely related to the fact that households must apply for a skyloo toilet from KWAHO, and these people are most likely to already have the intention or desire to reuse the excrement for its fertilizer value. Still, it is important to note that the population that participated in this study was not a random sample, but all have personal incentive and are predisposed to reuse.

Second, all of the households use animal manure to fertilize their agricultural plots and a bit less than half use commercial fertilizer (see Section *3.6.2 Household Fertilizer Use*). This shows that households use and value manure and fertilizer. At least some of the demand for these items has the potential to be met by the manure and urine from the skyloo.

Finally, the demographic background of the households was similar. All households were rural and of similar socioeconomic levels. There are only two groups of people that are targeted for KWAHO's promotion of the skyloo toilets: village chiefs and participants of women's groups. Therefore, this research does not comment on the reuse value to a variety of community members, even though the two groups are composed of diverse members in general.

6.3 Reuse of Urine and Feces

The second research question asks how (and if) people are reusing the material from their ecosan toilet. There is no existing documentation on how households commonly deal with the excrement after it leaves the ecosan toilets in practice. Is reuse actually practiced by the majority of people? What will people do with the excrement when they don't reuse it?

In the case of the skyloo, users reuse the processed feces and the processed urine separately. First, issues related to recycling and reusing the urine are examined; the same categories of information are then covered regarding feces.

6.3.1 Urine

Reuse

Out of the 26 households surveyed, 18 had completed at least one collection-storage-use cycle with reusing the collected urine. Table 6.1 shows what these households reported doing with the urine after collection and storage (if anything). The most common use of urine was as fertilizer for agricultural applications: 67% had experience using it in household gardens and 11% had experience using it in commercial gardens.(24)

It was also common for a household to not reuse the urine at all. In this case, the household would collect the urine and then immediately dumped it out to the ground when the container was full. One user reported that the urine stench was so bad, that she just wanted to get rid of it as quickly as possible. Later, she claimed to recognize that the plants near where she dumped the urine were "doing very well." She finished the anecdote by saying she will dilute and use the urine as instructed from now on (for the purposes of this report, however, she was counted as dumping it to the ground).

Table 6.1: Urine Reuse Options

	Yes		No		Don't Know	
	Count	%	Count	%	Count	%
Use it in your household garden	12	66.7%	6	33.3%		
Let it soak into the ground/ dump it	6	33.3%	12	66.7%		
Use in a commercial garden	2	11.1%	16	88.9%		
Give it away	1	5.6%	17	94.4%		
Do nothing with it	1	5.6%	16	88.9%	1	5.6%
Other uses	2	11.1%	13	72.2%	3	16.7%

(n = 18)

Skyloo owners were also asked if they used urine in community gardens, in aquaculture, or if they had sold any of it. No one reported a positive response to any of these questions.

Interestingly, one user reported giving some of her urine to a neighbor who asked her for some to use on his crops. A different skyloo owner reported that her neighbors inquired about getting some of her urine. She told them that they could have some, but only if they started contributing to the collection!

(24) The products of some household gardens were also sold. Therefore, there is some overlap in the "household garden" and "commercial garden" categories.

Of the households that collected the urine, 59% of them report to use all of the urine for agricultural applications. Of the remaining households, 29% dump the urine out to the ground, and 12% had used or experimented with about half of the recycled urine at the time of interview.

Perceived Value

While not a rigorous method of judging the *actual* impact of the reuse of urine, questions about how users *perceive* the impact of human manure on their gardens does give an indication of how much people value the urine. Of the 14 households that reuse urine, 13 believed that they had benefited from the urine because it lead to better crops. The one remaining respondent reported that he was not sure because "it takes time for the urine to work."

Over 40 percent of households thought that the amount of urine was more than they would like to deal with, showing that the perceived value of the urine is not very high among a great deal of the households surveyed.

Bad smells can discourage users from wanting to reuse the urine and have an impact on what they perceive the value of the urine to be. However, only one household reported being bothered by the smell of the urine.

Quantity of Urine

The amount of urine that is available through the skyloo will depend on how many people use the toilet. The amount of land to which a household can apply the urine will determine if all this urine can be used. I asked users if the amount of urine that came from their toilet was too much, too little, or just right. Out of the 21 people who were actively using their skyloo, 9 of them thought that the quantity of urine is "too much." Of the remaining 12, 9 households thought they could use more urine, on average they suggested 100 liters more per year ($n = 4$, $\sigma = 49$ liters).

6.3.2 Feces

Reuse

Out of the 26 households surveyed, 17 stored their feces and owned the toilet long enough that they had experience with at least one collection-storage-use cycle. Table 6.2 shows how the households from the survey are reusing their feces. The most practiced method of reuse is in household gardens (65%), the next most widely practiced activity undertaken after the feces has matured is burial in the ground (29%).

The skyloo owners were also asked about other reuse options such as use in a community garden, use in aquaculture, trade for other goods, sold for money, or given it away. No one reported an affirmative answer to any of these options.

Even when reuse was practiced, sometimes all of the processed feces was not used: 33% said they had used less than one hundred percent of it. These households reported that they simply had not used the total amount of the manure to date and that they buried some of the feces that they did not need at the time (3 households), or the feces was still in storage (2 households).

Table 6.2: Feces Reuse Options

	Yes		No		Don't know	
	Count	%	Count	%	Count	%
Use in household garden	11	64.7%	6	35.3%		
Bury in the ground	5	29.4%	12	70.6%		
Use in a commercial farm	1	5.9%	16	94.1%		
Do nothing with it	2	11.8%	14	82.4%	1	5.9%
Other uses	1	5.9%	16	94.1%		

(n = 17)

Perceived Value

Of those that were reusing the feces for agricultural purposes (a household or a commercial garden), 82% reported that it had a positive effect on their crops. The other 18% reported that they do not know if it has had a positive effect or not because there had not been enough time to gauge its impact on their crops' growth. No one reported that they thought that the feces had no impact, or that the impact was negative.

Out of 21 households using the toilets, only 4 said they sometimes have smell problems with their toilet. Even those people usually predicated that statement with "if you don't add the ash." Indeed, one of the most cited benefits of the skyloo toilet is that it does not smell (see Section *7.9* on the top six reasons people like their skyloo).

Quantity of Feces

Only 14 percent (3 out of 21) of households said the amount of manure they get is more than they would like to handle. The other 18 households, however, said they would use more if they had access to it, on average 205 kilograms more per year ($n=10$, $\sigma = 124$). This indicates a relatively high demand for the manure, at least from users who are culturally sensitized to the system.

6.3.3 Household Comments about Reuse

It seems that users like the reuse aspects of the skyloo as well. While talking to households, the production of "manure" was the most frequently cited single issue that they said they liked about the system: 14 out of 26 households spontaneously commented on the production of manure as a positive aspect of the skyloo.

6.4 Community Perception

Given the generally innate human repulsion to feces, it is logical that people would be adverse to the idea of an ecosan toilet. It follows that those who handle and reuse feces might receive negative cultural pressure from their surrounding community. Of the 26 households surveyed, 29% reported issues with the greater community's or neighbor's perception of them. This has potential to play a role in a user's use or disuse of a system.

One respondent reported that he received community "pressure that [the skyloo] is dangerous and primitive, they even tell children!" At least two respondents mentioned during the survey that the community suspected the toilet is causing health issues, including cholera and diarrheal disease. Another user claims that her neighbors "can't imagine that someone would want to store feces, [even] my sister won't weed the trees for a week after application [of feces or urine]." Even though the majority of the survey's respondents did not identify community pressure as a problem, this issue was acknowledged by the KWAHO staff as one of the major limitations to the spread of the technology.

6.5 Health Risks

A central concern with reuse of human excrement is the associated health risks. As noted in Section *2.6*, the die-off of pathogens in urine and feces is well documented, and guidelines regarding the storage time needed for safe handling have been established. Below, we examine the level of fecal contamination of the urine samples and the storage time for urine and feces.

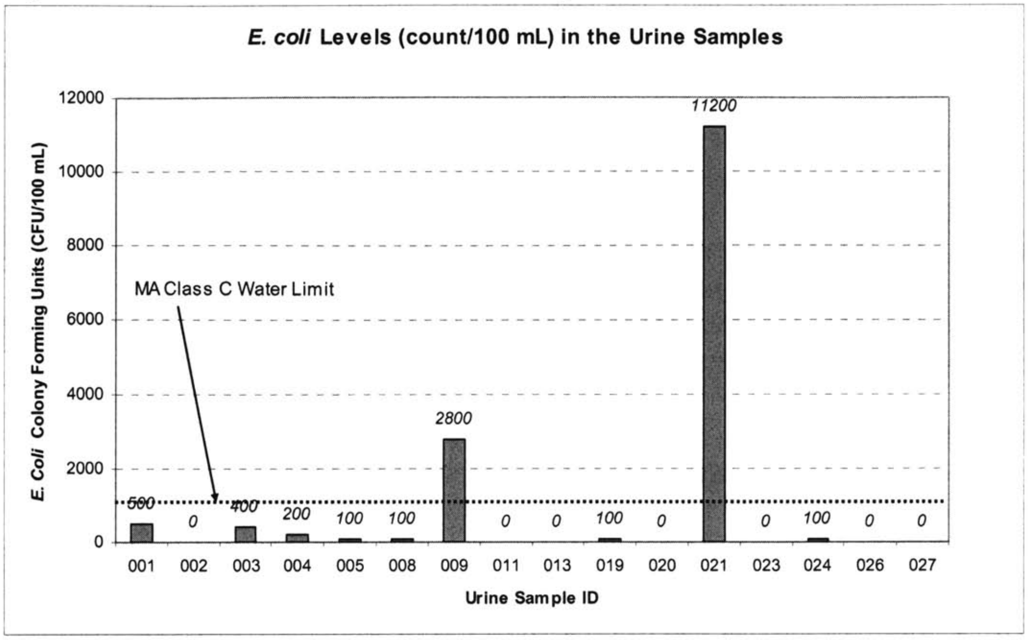
6.5.1 Urine

Fecal Contamination

The health risks associated with the handling of urine were quantified by looking for fecal indicator bacteria in urine, which indicate the presence of actual fecal bacteria (that make people sick). Urine samples were diluted and passed through a membrane filter in order to determine if any fecal coliform were present (see Section *4.3.5 Fecal Contamination* for a complete description of the methodology regarding testing for total coliform).

The majority of the tests returned low concentrations of *E. Coli* in the urine. However, there were two, specifically, that returned relatively high quantities of *E. coli.* For example, in Massachusetts, Class A waters, which are permitted for swimming, have less than 20 colony forming units per 100 milliliters of water (CFU/100 ml) of *E. coli.* Class C waters, which are only permitted for boating and fishing (indirect contact with the water), must have *E. coli* concentrations less than 1000 CFU/100 ml. Typical wastewater, on the other hand, is in the range of 100,000 to 500,000 CFU/100 ml. So we see that the results shown in Figure 6.1 indicate that the health risks, while usually non-existent, are still a factor in some urine containers.

Figure 6.1: *E. Coli* Levels in the Urine Samples



<u>Storage Time</u>

There were 21 households surveyed that stored their urine in a jerry can inside the toilet's vault. One household used a soak-away pit where a tube, with one end connected to the toilet and one end buried in the ground, carried the urine away to the soil. The storage time for the urine ranged from 0 to 7 months, but the average reported time was 1.9 months (n = 9, σ = 2.7 months). KWAHO recommends a 1-month storage time for urine.

<u>Perceived Health</u>

Users were also asked if they believed that they had benefited in health (improved sanitation) from the collection of urine. Out of the 17 people that collected urine, 11 said they believed to have increased health benefits.

6.5.2 Feces

<u>Fecal Contamination</u>

The feces are dangerous until processed for the allotted time (6 months in Kenya). However, due to the focus of this research on agricultural application, it was determined that the author's limited field time would be best spent investigating reuse value of urine because it contains more nutrients than feces. Therefore, no tests were conducted to determine the coliform levels in the feces.

<u>Storage Time</u>

Adequate storage times to allow desiccation of the feces and die-off of fecal pathogens have been tested and determined by a variety of researchers (Feachem et. al., 1983). Users need to follow specific storage procedures, which are partly determined by the climate in which they live, to allow the feces to become safe for handling and reuse.

As noted in Section *2.7* on different types of ecological sanitation, there are many documented ways to store, process and reuse human excreta. In the case of the households that I visited, everyone defecates into a polythene plastic bag which serves as a liner to a (approximately) 40-liter basket or bucket. When the bag is full, it is removed from the toilet vault, tied off, and left to mature for a period of time before reuse. KWAHO recommends that users allow at least 6 months of drying/processing time for the feces to manure. Reported storage time, however, was as little as 2 months. One respondent even admitted that "I just wait until [the feces] are completely dried out" without mentioning a specific time period. Many people reported a storage time of 6 months, as noted by an average reported storage time of 4.6 months ($n = 13$, $\sigma = 1.9$).

<u>Perceived Health</u>
Another indicator of perceived value is a reported impact on human health. When asked if the users thought the toilet had a positive health benefit, 14 out of the 17 that are reusing the feces said yes. It should be noted, however, that for some of the households, this is their first toilet. So the perceived health impact of going from no facilities to almost any kind of toilet would likely be positive. However, most people "upgraded" from a pit latrine to the skyloo, and reported a perceived positive health impact due to the dirty conditions of many of the pit latrines.

6.6 Discussion

6.6.1 Reuse

From the responses of households regarding the use of the processed urine and feces, household agriculture is the most prevalent method employed. This indicates that households are adopting the skyloo for reasons that are in line with the theoretical basis of ecological sanitation. Given the economic findings in Chapter 5, however, we realize the agricultural value of the urine and feces[(25)] products of the system could be marginal. Households may simply not know the actual worth of the processed urine and feces, and are using the system under the assumption that the products are more valuable than they actually are. It is also possible that the material actually benefits households in direct and tangible ways. The relative value of the processed urine and feces should be the subject of further research.

Even with the relatively high rates of reuse, we can see that there is still aversion to reuse as noted by the moderate amount (about one-third of the households) of non-reuse of households excrement. Non-reuse can include burial or dumping of the feces or urine in the ground, or simply leaving it in "processing" and neglecting reuse options when the feces is ready (Figure 6.2).

Figure 6.2: Five bags of unused feces still in "processing" stage. The feces basket and urine container are behind the bags.

[(25)] Given the relative amounts of nutrients in feces as compared to urine, it is safe to assume the value of feces is low even though tests were not performed to determine the actual nitrogen and phosphorous values.


Photo: Robinson, 2005

An overwhelming majority of households claimed that they could use more manure, but less than half said they would use more urine if they had it. This indicates that there is a demand for both urine and feces, but far less for urine. Moreover, over 40 percent of households thought that the amount of urine collected was a more than they felt they could use or wanted to handle. Considering the nutrient content of urine it should, in theory, be in greater demand for agricultural application. Therefore we can also conclude that the urine is somewhat undervalued in the community. This could be because the users simply do not know that urine has more nutrients than feces, as so much attention is put on the process of recycling the feces for safe pathogen die-off.

6.6.2 Community Perception

While some households received negative comments from their neighbors regarding the reuse of human excrement, there was still an overwhelmingly positive response that the skyloo was a good toilet. At the end of the visits with households, the respondents were always asked if they wanted to make any other comments about their toilet. Fourteen users independently said that they would like to see this type of toilet disseminated more widely among the members of their community. Some requested this so that it would help change neighbors' negative attitudes, but this still demonstrates users' support of and belief in the skyloo system.

6.6.3 Heath Concerns Regarding Reuse

We see that urine, as the literature suggests, is not a large health threat. However, as shown by sample 009 and 021, urine can contain relatively large amounts of *E. coli*. Therefore, users must be aware of this, treat urine as if all samples have this much fecal contamination initially, and allow a sufficient storage time before the urine is reused.

Another potential health concern is shown by the storage time of the feces. Users should heed the 6 month processing time as set by KWAHO. Given that the average processing time is less than this amount, we can conclude that the feces storage time might be problematic with respect to safe handling of the material.

7 Acceptance of the Skyloo

7.1 If Not Reuse, Then What?

As we saw in Chapter 6, about 30 percent of households, even though they own an ecosan toilet, do not reuse the material that it produces. This suggests that at least a portion of people are not comfortable using feces and urine, and are continuing the dominant cultural practice of using "drop and store" sanitation (i.e. a pit latrine). Yet the recipients of these toilets still put in a great deal of effort in applying for an ecosan toilet and contributing materials to the construction (see Section *3.5* on KWAHO's Ecosan Program). If the recycled feces and urine for agricultural use are not desired products and are easily replaceable with cheap available fertilizers, then there must be additional reasons that the households apply for the ecosan toilet. This chapter looks at some of these reasons in order to provide insight into what other factors influence uptake of the skyloo toilet.

7.2 Factors that Influence Acceptance of the Skyloo

Skyloo owners were asked to describe things they liked and disliked about the skyloo. From these answers, general factors that influence the acceptance or non-acceptance of the skyloo were developed. First, discrete responses were identified. These responses were clustered into similar groups and similar groups were then categorized. Six main categories of factors that influence users' acceptability of the skyloo toilet emerged. These factors are:

- ◊ Operational factors regarding the recycling process and maintenance of the toilet
- ◊ Factors that relate to the agricultural product that is produced,
- ◊ Factors which are external to the process or physical structure of the skyloo,
- ◊ Physical characteristics of the toilet and structure,
- ◊ Individual's personal considerations or situations regarding the toilet, and
- ◊ Financial factors.

These major factors and minor categories are summarized in Table 7.1. Households' responses generally fell into these categories, but there was some variation in terms of frequency and positive versus negative responses. Some categories were reported more often than others, some categories contained mostly negative responses, and some were mostly positive. In the following sections, the categorical responses of the factors listed in Table 7.1 are explored in more depth and sorted by positive and negative aspects.

Comparing Table 7.1 to Table 2.6 *Factors that Affect Household Adoption of Sanitation* shows that all the factors derived from the data fit into the general categories identified in the literature. However, not all of the categories identified in the literature were relevant in this study. Particularly, ecological sanitation has no colonial legacy and, therefore, was not an issue. Public or governmental enforcement and nomadic pastoralim were also marginal factors. Nearly all other factors identified in Table 2.6 are represented in some form in Table 7.1.

Table 7.1: Factors that Influence the Acceptance of the Skyloo

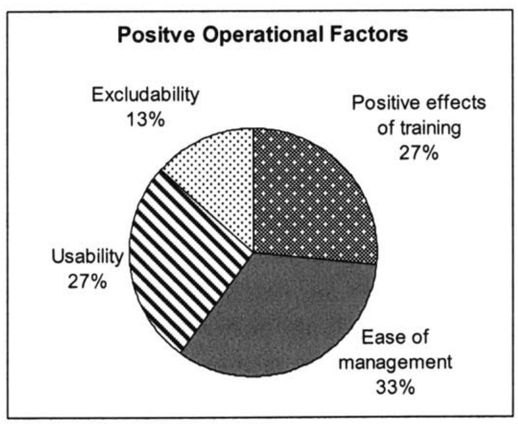
Operational	Agricultural Product	External	The Physical Toilet	Personal/ Individual	Financial
Training Positive (education, limits access) Negative (difficult for visitors, excludes children, improper use = hygienic consequences) **Management/ maintenance** **Usability**	**Recycled product** Manure & urine production Handling of feces Smell issues Can be close to house (not smelly)	**Environmental conditions** Soils Hydrology **Space issues** Permanent structure	**Physical Structure** Chamber Back slab Materials issues Additions Contractor/ Mason issues **Aesthetics** External structure Ability to keep clean	**Physical limitations** Elderly Lame persons **Cultural norms/ preferences** Community perception Social status Personal revulsion Local customs **Perception of hygiene** Positive (no flies, improved sanitation over pit) Negative (perception of handling & exposure)	**Materials subsidy** **Savings due to manure production**

7.3 Operational Factors

Operational characteristics of the skyloo consist of all training, management, and usability issues. Operational factors are important because one needs to learn how to use and care for the skyloo in ways that are much different than the ways one would care for and use other locally available sanitation options such as a pit latrine.

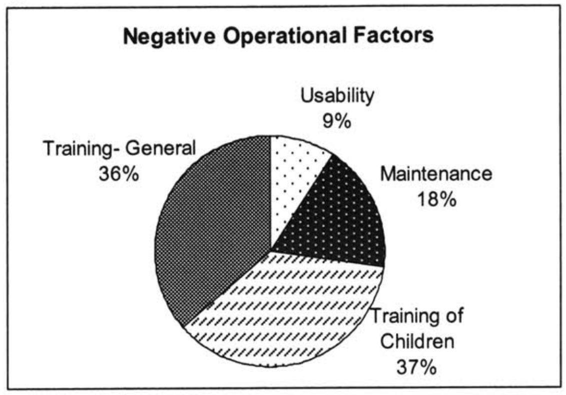
7.3.1 Positive Operational Factors

Users reported that the skyloo was easy to manage and easy to use, showing that training for the owner of the facility is not difficult task to undertake. Some even reported that the training required for the skyloo was a benefit—it forces users to be "more aware of sanitation issues" and, thus, has educational value. The fact that people needed training to use the toilet was also sited as a positive aspect because it excludes some users from the facility as well, and therefore keeps the toilet from becoming used by neighbors.



7.3.2 Negative Operational Factors

Training issues were the most reported negative aspect within operational factors. While a few of responses about training were positive, the overwhelming majority were negative. Children, especially, were reported to have a difficult time using and being trained to use the skyloo. One owner reported that her child used it backward; another said that "the children think its fun to play with the ash and dump it down the hole." Training issues also arise when visitors come to a household that has a skyloo because the visitors have not received the proper training to know how to use it. One user reported that he was even still trying to "train" his family members, as he was the one that originally wanted the skyloo, and he has yet to convince them of its merits. A consequence of improper training, as one respondent noted, is that the toilet will stink and that dangerous health issues can come about.



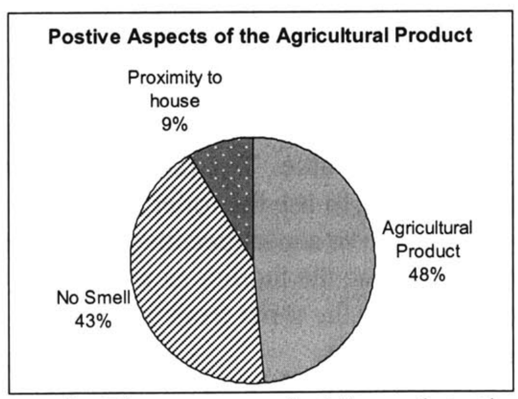
Other negative factors that were reported were problems with the feces container filling too fast or too slow (maintenance). One interesting comment regarding the general usability of ecosan toilets was made by a man who commented that during menstruation women are "not free," meaning that they cannot use a recycling toilet because they have nowhere to dispose of their feminine hygiene products.

7.4 Agricultural Product

One of the most obvious and unique aspects of ecosan is that it produces an agricultural product. This can, in theory, be a great advantage to a household that is active in agriculture. However, in the skyloo, this requires handling one's own feces and urine to get the product. Users, therefore, can view the manure/fertilizer product that comes from the toilet as valuable, but with a cost.

7.4.1 Positive Aspects of the Agricultural Product

The largest responses of any category related to positive aspects of the agricultural product. This high frequency of responses might be attributed to the fact that I was accompanied by a KWAHO staff member, and the users felt compelled to express their gratitude by noting the value of the feces and urine. Even so, many households were obviously excited about the products and seemed to genuinely appreciate the products from the toilet.



Another response that was very frequent among the household was that the toilet didn't smell. The process of adding ash to the feces after defecation dries out the feces. This eliminates the smell that almost always accompanies other pit latrines.

7.4.2 Negative Aspects of the Agricultural Product

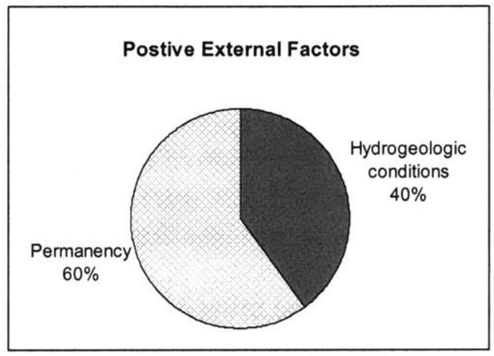
Interviewees expressed concern about handling the feces and urine. Generally, people did not like handling the feces and urine out of simply an innate aversion to their own excrement. One household member summed up the general sentiment by noting, "If your heart is not strong, you could vomit."

7.5 External Factors

There are also factors that do not relate to the physical structure or the recycling process of the Skyloo. These external factors, such as environmental conditions and the amount of space available in a homestead for a toilet can be very important in a user's uptake of the skyloo.

7.5.1 Positive External Factors

Positive aspects of the skyloo that are related to external factors fall into two categories: ambient environmental conditions (hydrogeologic) and that the facility is a permanent structure that does not need to be moved. In areas where the soils are loose (sandy) or the water table is high, pit latrines can easily collapse or become flooded. In these areas (and at this economic level) it is necessary to have a toilet that is completely above ground and does not rely on a dug pit to collect and dispose of the feces.



A pit latrine will also eventually fill up. Many respondents liked the fact that the skyloo is a permanent structure and will never need to be relocated. This saves space in the homestead, but there is also a savings in the labor required to build another pit and the finances needed to pay for costs associated with a new toilet.

7.5.2 Negative External Factors

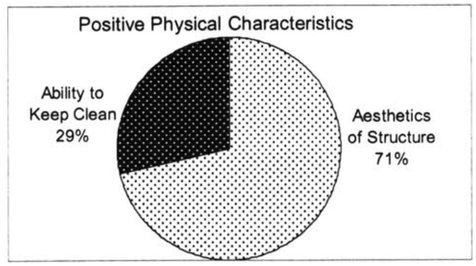
There were only two instances in which environmental conditions were reported as a negative aspect of the skyloo. One household had a snake living in the chamber, and another complained that it was too hot inside the structure during the dry season.

7.6 The Physical Structure of the Toilet

Physical characteristics of the skyloo include construction/design and aesthetics of the structure to users. These factors influence the user's daily interaction with the facility and dominate the user's physical experience with the toilet. It is also interesting to note that the physical features can manifest themselves in human sentiment in ways such as aesthetic appreciation for the structure or pride in ownership, as was frequently expressed by users.

7.6.1 Positive Physical Characteristics

The two sub-categories of positive physical characteristics regarding the skyloo were the aesthetics of the structure and the ability to keep it clean. In comparison to a pit latrine, in which the superstructure was often made of mud walls, the skyloo toilets were very pleasing to the eye. Many interviewees commented that the skyloo "...adds beauty to my homestead," "it is attractive to the compound" and "it is nice to look at."

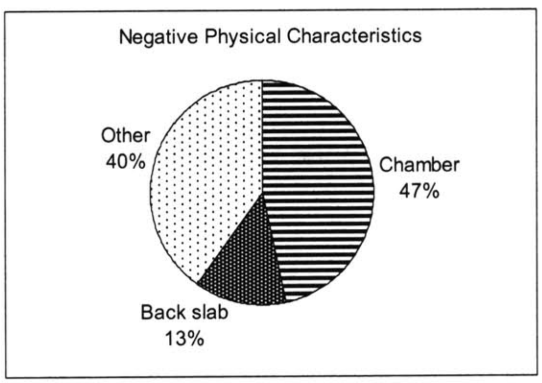


Additionally, the floor of most pit latrines is dirt. The skyloo's cement slab floor makes cleaning, washing with water, and sweeping possible and easy.

7.6.2 Negative Physical Characteristics

There were two main complaints about the construction of the skyloo. The most reported issue was the construction of the lower chamber where the feces and urine are collected. Most of these complaints were that the chamber is too small, and a few others also reported that water got into the chamber when it rained.

The back slab of the toilet, which one removes to access the feces and urine containers, received 2 negative household complaints. The back slab is constructed of rebar and concrete, usually about 3-4 cm thick and about 1 meter square. Although this makes the back slab very heavy, it was purposely designed in this manner to keep children and animals out of the storage chamber. However, many of the toilet's back slabs were heavy to such a degree that many women and some men could not physically move it.

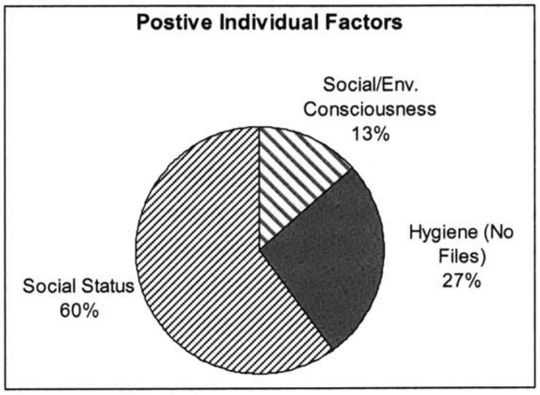


Other negative physical characteristics include leakage into the superstructure where the vent pipe goes through the roof, that there is no inner lock on the door, and when the door is closed there is no fresh air. One user had a soak-away pit built for his skyloo, which drains urine into the ground. It was clogged at the time we visited that home. One household asked the masons (which KWAHO trains and subcontracts) to make some custom modifications to his toilet. They would not accommodate his request to build the urine storage container on the outside of the chamber and, therefore, he was unhappy with the construction.

7.7 Personal or Individual Factors

This category contains responses on how an individual perceives or relates to his/her toilet. These factors are diverse, and range from how the household perceives the hygienic aspects of the toilet to individual's physical constraints regarding the use of the toilet to the social status that one perceives gaining from acquiring a skyloo.

7.7.1 Positive Individual Factors



The most reported positive factor in this category was an increase in social status from the addition of a classy new structure to their compound. While this is closely tied to the *Aesthetics* of the toilet (in the *Physical Characteristics* category), responses were differentiated based on respondent's focus on the toilet's physical beauty versus an implication of how the community is envious, curious, or gives the owner compliments about the structure. One owner commented, "I am famous in my community," and many noted the prestige that accompanies the ownership of the skyloo. Another user noted that "because of the [skyloo], many visitors come see it, now even the white man has come!" For some households, the social status was linked to the community's economic perception of them as well:

> ...Many people inquire about [the skyloo] because it is unique in this sub-location. They say, "You are so poor, how did you get this?" It gives people the impression that I am not as poor.

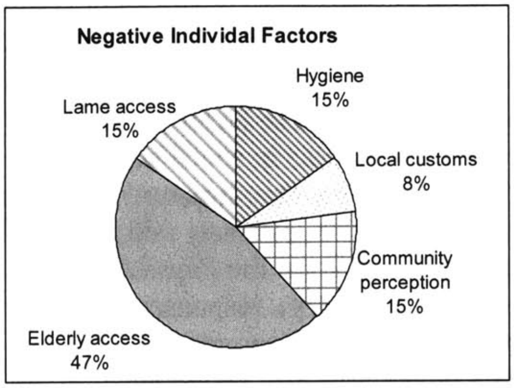
Although this has economic implications, it is fundamentally a statement about this woman's increase in social status and how the community's perception of her changed due to the skyloo toilet.

Another oft-cited positive factor related to the absence of flies and therefore the positive hygienic ramifications. Users often simultaneously noted that the toilet has no smell and no flies, and although these factors have the same origin (due to the way the feces are dehydrated with ash), they do not have the same repercussions. Smells are aesthetic and flies relate to hygiene perception.

Two users gave comments that suggested they like the toilet because of the environmental ideal that it represents.

7.7.2 Negative Individual Factors

There were many comments that related to negative individual factors. Community perception, as noted earlier, is a negative external factor that some users face. The local customs of the community influence the community's perception of the user, and some of these customs were reported as a specific deterrent to the toilet's use. For example, in Luo custom, a man's mother-in-law can not use the same toilet as he. It is also part of Luo folklore that pouring ash on a person's feces is a way to curse the person with witchcraft. It certainly follows that any believer in this custom would not want to pour ash on their own feces! Some Luo also believe that looking at feces increases your chance of diseases of the eye.



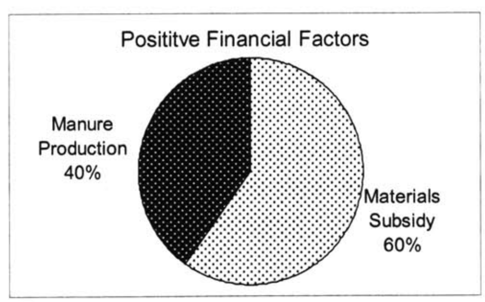
The most reported were factors, however, were those that relate to individual's personal physical limitations. Particularly elderly community members had difficulty climbing the steps to access the raised toilet. Two respondents commented on the fact that the toilet is also difficult for the physically handicapped to use and access.

7.8 Household Financial Factors

Household financial issues are fundamentally important to the acceptance or rejection of the system due to the low income levels of most of the users in this study. Users will compare the cost of the skyloo to the cost of the most common other toilet used by their peers. In this case, the toilet of comparison is the pit latrine. Pit latrines are generally considered to be a cheap and affordable option for many Kenyans, including most of the households that were interviewed.

7.8.1 Positive Financial Factors

Financial factors were reported in two categories: a savings in the cost of construction due to KWAHO's materials-matching (subsidy) program and the savings in the cost of purchasing manure and fertilizer due to the free production from the toilet. The response that the skyloo is a "cheap toilet" was often cited. In this case, the toilet is cheap in comparison to building a pit latrine. It is partially (if not wholly) "cheap" to the user because of the materials subsidy provided by KWAHO. KWAHO claims that the materials subsidy is an incentive for users to try ecosan, but they maintain that an ecosan toilet, in and of itself, requires a similar amount of capital to the construction of a pit latrine. Section *7.11.2: The KWAHO Materials Subsidy* discusses this further.



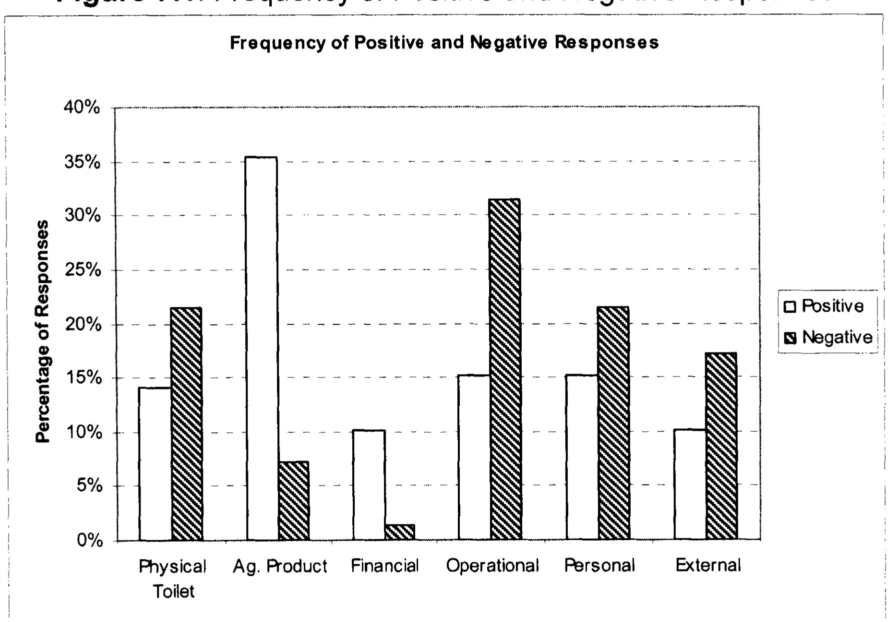
7.8.2 Negative Financial Factors

There was only one negative response that had to do with the cost of the system. One household (that was very rural and at an extremely remote site) reported the expense of picking up the KWAHO-provided materials at the KWAHO office, and transporting them to his home was a large negative factor associated with the toilet because he had to hire external transportation to get the materials to his home.

7.9 Frequency of Positive and Negative Responses

Figure 7.1 shows the frequencies of responses by households to questions about what they liked and disliked about their skyloo toilet. The percentage values in each major category are reported as a percentage of overall positive or negative answers.

Figure 7.1: Frequency of Positive and Negative Responses

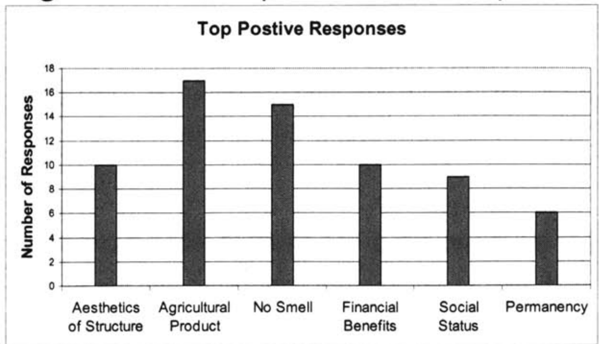


Positive: n = 99; Negative: n = 58

Overall, the comments about the agricultural products of the skyloo engendered the greatest positive responses and the operational issues represent the greatest negative factors. For factors that people viewed as positive, the other major categories carried similar weight (all 10-15 percent each of the total responses). Regarding the aspects households didn't like about the skyloo, the physical toilet, personal issues and external characteristics were all reported with similar frequency. Household financial issues and, to some extent, the negative aspects of handling the agricultural product were marginal.

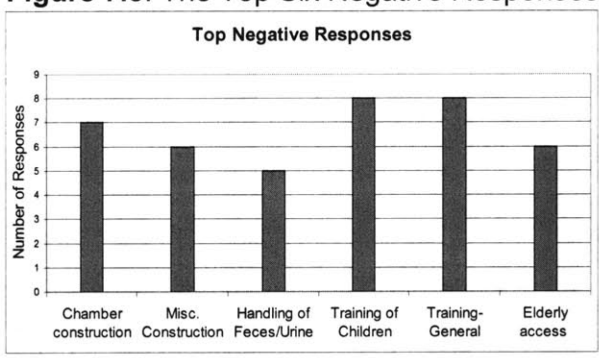
Figure 7.2 and 7.3 show the top six positive and negative aspects of the skyloo as reported by the owners. Aside from the agricultural product, the most frequently cited benefit of the skyloo is that it does not smell badly. The aesthetics and social status also received widespread attention, as did the fact that the toilet required little upfront costs or that the users thought the manure saved them money.

Figure 7.2: The Top Six Positive Responses



The top two negative responses both related to the training of individuals. Assuming that most of the problems regarding construction of the toilet could be fixed, the other major negative aspects are that the elderly have trouble accessing the toilet and that one must handle the excreta when maintaining the toilet.

Figure 7.3: The Top Six Negative Responses



7.10 Residual Pit Latrines

One interesting factor that the structured interviews did not capture was the fact that nearly all of the households still had and used their old pit latrines. Over half of the households interviewed that were actively using the skyloo said that at least some of the members of the household use something different than the skyloo toilet.

For some households, only the elder or most senior used the skyloo. This is consistent with the common perception that the skyloo is a nice, new facility that is admired and a privilege to use. Often the children were not allowed to use the skyloo (reportedly because of the high potential for children to use it incorrectly) and were required to use the old pit latrine. There were also members of some households that simply did not like the idea of using a toilet that stores and holds one's feces and urine.

Lastly, the presence of residual pit latrines is indicative of the fact that changing one's customs and habits is often difficult. This was surprisingly confirmed by the fact that even the KWAHO staff opted to use their old pit latrines instead of using the demonstration skyloo that was built at their office!

7.11 Discussion

7.11.1 The Skyloo's Comparative Advantage

An important cross-cutting factor in many of the positive and negative aspects of the skyloo is its comparison to other available technologies. The skyloo is both attractive and unattractive relative to the widely used pit latrine. For example, one of the skyloo's noted advantages is its ability to be built in soils and hydrologic conditions in which a pit latrine would fail. However, to a community that has a piped sewerage, soils and hydrology have little bearing on the functionality of their sanitation system. In this case, the skyloo could be a disadvantage compared with the prevailing local technology, given the same local environmental conditions.

In fact, many of the factors in Table 7.1 are *relative* advantages or disadvantages when considered in comparison with other available technologies. The fact that the skyloo "eliminates flies and smells" is only true when compared to a pit latrine or other primitive toilets. This "positive aspect" of the skyloo would likely not even occur to anyone with a flush or pour-flush toilet. Similarly, it might be the case that the skyloo is only aesthetically pleasing because pit latrines are usually not built with such nice materials. If the skyloo looked like most pit latrines, would people like it?

Finally, to people with indoor plumbing that discharges to a sewerage network, the fact that the skyloo is a permanent structure would not appear to be anything special. However, a pit latrine fills up and a new pit has to be dug. With the skyloo, this is not necessary (but is still necessary with other local ecosan technologies such as the arborloo or the fossa alterna).

7.11.2 KWAHO's Materials Subsidy

The materials subsidy that KWAHO provides was reportedly an advantage to the skyloo. Owners claimed that the skyloo "is a cheap toilet," which is likely due to the materials that KWAHO provides the users in the initial building stages (see Section *3.5.2* on the KWAHO's ecosan program). Yet KWAHO also claimed that the actual total cost of the skyloo is similar to the cost of an average pit latrine. A KWAHO officer explained:

> The cost of digging the pit for a latrine can be around Ksh 100 (US $1.32)[(26)] for each foot. At a depth of 20 feet, the cost of digging the pit alone can reach Ksh 2000 (US $26). When you add the cost of pouring and laying the slab, and building the superstructure, costs can rise to the same level as the skyloo (~Ksh 8000/ US $105). The cost savings of the skyloo becomes even more apparent when one factors in the permanence of the skyloo—that does not need to be replaced, whereas a pit latrine will eventually fill up.

However, a pit latrine that is about 20 feet deep in this region takes about 15 years for a family to fill (BG Associates, 2003). To the consumer, the present comparison between

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[(26)] In January 2005, US $1 = Ksh 76

building a skyloo that is "permanent" or a pit latrine that must be replaced in 10-15 years are not economically very different, because the cost of replacing the pit latrine is so far into the future and of no immediate savings. The financial repercussions of, say, even an extra thousand Kenyan Shillings that must be paid for the skyloo *today* can be prohibitive.

For financial comparison, the cost of an average pit latrine in nearby areas is reported to be about Ksh 3500 (US $46) to Ksh 4500 (US $59) (BG Associates, 2003). The average VIP latrine ranges from Ksh 9500 (US $125) to Ksh 16800 (US $221). From these comparisons, the skyloo—at a reported cost of Ksh 8000 (US $105)—seems to have a distinct economic advantage in a savings of upfront capital costs when compared to a VIP latrine, but a greater cost than the ubiquitous pit latrine. However, it also seems logical that cheaper materials could be used to build an "improved" toilet similar to the VIP, and dug to a shallower depth, so that costs could come down and be more financially competitive with the skyloo. Regardless, given the affordability of the pit latrine, it is possible that households will be reluctant to pay full price for the skyloo.

It is also possible that people are excited about receiving a skyloo because it is cheap *now*, and that they are possibly "putting up with" the recycling aspect of the toilet in order to receive it. This makes even more sense when we couple the offer for an inexpensive tiolet with a nice new built structure for the home compound. Andreas Knapp (2004b) notes that programs that have subsidized VIP latrines in this region have mostly failed because there are very few VIPs that have been built voluntarily by users. A similar fate could befall the skyloo.

7.11.3 Relevance of User's Like and Dislikes about the Skyloo

We can see that there are many factors aside from the recycling process that are important to users. In order for a new sanitation option to be even considered by users, it has to have similar building costs and costs of operation as other relevant options. So we know financial savings are an important underlying factor in the user's support of ecosan.

Some of the most important issues related to the skyloo, not including the production of agricultural products, are:

1. *The exclusion certain user groups, namely children, the elderly, and "uneducated" visitors*

Children and visitors who are not used to the skyloo are generally problematic users because they are not easily trainable or do not have the training necessary to operate the toilet correctly, respectively. Elderly persons have difficulty squatting in the toilet and climbing the stairs to get into the facility.

2. *There is no smell from the skyloo when it is used correctly*

One of the most reported benefits of the skyloo is that it does not have a "toilet" smell that accompanies most pit latrines.

3. *Social status & aesthetics*

Additionally, the uniqueness, solid workmanship, and nice appearance of the skyloo boost user's social status and add to the attractiveness of their home.

4. Hydrogeologic conditions
If the environmental conditions of the area are not conducive to a pit latrine, this can greatly increase the comparative advantage of the skyloo toilet. Adverse hydrogeologic conditions can almost guarantee that a household will value and use a skyloo.

5. Construction issues
Finally, there were many comments about various construction issues that, for the most part, are problems that could be corrected either by KWAHO or by the households themselves.

This analysis shows that the aesthetic value, the economic benefit of a cheap toilet, the social status, user's environmental conditions, the fact that the toilet is not smelly, and that it has fewer flies might all separately, or in combination, be responsible for convincing people to use an ecosan toilet. Responses also suggest that people are excited about the recycled feces and urine, and household's fertilizer use shows that the products might, indeed, have a positive economic impact. Further explorations should investigate the time and maintenance of the skyloo in comparison to a pit latrine, the economic implication of these, and how this might impacts user's demand for the skyloo. It can now be seen that there are a handful of other factors upon which the skyloo can be promoted and are of similar (if not more) importance to the user than the recycling aspects of the toilet.

8 Conclusions and Recommendations

8.1 Introduction

This thesis began by questioning households' motivation to break normal cultural conventions, and embark into the largely unaccepted practice of reuse of feces and urine. This chapter first summarizes the main findings from the field research concerning this question, and then draws some general conclusions about these findings. Finally, recommendations are made for NGOs and other organizations and agencies who promote ecosan toilets, specifically the skyloo, and for governments of developing countries regarding ecosan in local and national sanitation policy.

8.2 Major Findings

The first question of this thesis asked about the agricultural value of the urine from the skyloo toilets. Although the nitrogen and phosphorous levels were lower than expected as compared to the literature, this difference is most likely due to dietary intake. The nutrients available from the urine in the average skyloo toilet have a limited economic value (on average US $12 per year for the study population). This economic value could contribute a monetary savings to some people depending on their fertilizer use (by replacing some of the fertilizer bought) or general economic status (by providing better crops for sale or household consumption). The likelihood that these economic savings are important to users will expectedly depend on a variety of factors such as pre-existing economic status or size of the household's agricultural enterprise.

The second question asks how excreta is managed after it leaves the skyloo. The two main methods of reuse for both feces and urine are application to household agriculture by about two-thirds of households and disposal (no reuse) by the other one-third of households. No other methods of reuse of excreta were observed. About 30 percent of the households reported that their community viewed them negatively for using an ecosan toilet. Also, users reported that the feces are not always allowed to process for the recommended amount of time, which potentially has direct health consequences, while the urine is often stored for a longer period of time than recommended.

The third question seeks to understand the aspects of the skyloo that users like and dislike. There are many attractive features of the skyloo, only one of which is agricultural reuse. The other major attractions seem to be the aesthetic value and social status that come with the toilet, and that the toilet is affordable to the user. There are also many negative factors related to the skyloo, but only some of which relate to the recycling and reuse of excrement. The major negative factor relates to training issues, especially regarding the training of children. Other negative aspects noted were reflective of handling the feces and urine, and the accessibility of the toilet to the elderly (a person with bad knees or a bad back can have difficulty climbing the stairs or squatting in the toilet).

The laboratory analysis was able to estimate the economic value of the agricultural material that came from the toilet, yet the magnitude of the value was still in question. However, the high frequency with which households reported the material from the toilet as a benefit suggests this value is significant to many users.

8.3 Conclusions

8.3.1 Conclusions Regarding the Research

The fundamental research question originally asks why people would adopt an ecosan toilet, even in the face of cultural norms. This research shows that that ownership of an ecosan toilet is related to a variety of reasons other than the reuse of human excrement. It should be noted that the conclusions here regard the ownership of a skyloo toilet and stigmas associated with owning an ecosan toilet, not specifically why people are willing to recycle human waste.

Because we are exploring why people would break cultural norms to own this kind of toilet, the major cost to the user with which we are concerned is negative community perception of the owner. Eight the 26 households reported that they felt their neighbors looked down upon them, or that they received some kind of community pressure about their toilet. One user attributed it to jealousy: "When you have a good thing, some people have to dislike you." Another user told us that even though no pressure was given to her directly, "people sometimes look down upon me, but don't tell me." At least two households had dissenters within the household. One noted that

> People just can't imagine that someone would want to store feces—my sister won't weed a tree for a week after I apply the manure. I encourage others in my district to apply, but they can't image storing their feces.

The respondent of one of the invalidated surveys[(27)] enthusiastically commented on her neighbors' negative perception of her. She said neighbors called her "*wakeli*," which is a tribe in Kenya whose members are apparently known to hold job positions related to sewage or excreta removal. It is possible that this negative perception might even be her own, and could be a reason she didn't use the toilet in the first place.

This negative perception is countered by many positive responses from owners about gaining status within their community for having such a nice, new, and sturdy structure in their home compound. There are other additional positive factors that could potentially outweigh the greater community's negative perception. Yet negative aspects of the skyloo were also reported by skyloo owners. Table 8.1 summarizes the positive and negative factors associated with the skyloo.

Table 8.1 Major Positive and Negative Aspects of the Skyloo

Positives	Negatives
1. Manure production	1. Training issues, esp. with children
2. Aesthetics and social status	2. Construction issues with the skyloo
3. Fewer flies and bad smells	3. Elderly have trouble with stairs
4. Permanent toilet structure	4. Handling human feces and urine
5. Good investment for the household	5. Negative community perception
6. Works in adverse hydrogeologic conditions	

[(27)] There were two invalidated surveys in which the interviewee reported answers about feces and urine reuse that could not have been true after observing the toilet, which had clearly not been in use for some time. See Section *4.2.2.*

The positive factors presented in Table 8.1 show some possibilities that exist regarding why a household would want to own a recycling toilet, even given all the potential negative factors on the right. Even given the negative community pressure associated with reusing human excreta, which was initially thought to be a large obstacle to the adoption of the skyloo, these perceived benefits appear to be significant. Table 8.1 represents a more refined, ecosan-focused version of Table 2.6 (*Factors that Affect Household Adoption of Sanitation*) which was developed from several relevant readings from the literature.

This production of nutrient-rich products should be viewed as a positive externality of this kind of toilet, but it remains to be seen if it can be viewed as a major cost savings or substantial economic benefit. If a household is predisposed to this kind of externality (e.g. a "faecophilic" household with a household garden), owning a skyloo may have clear positive benefits to the household. However, if a household is deeply concerned about community perception, the nutrient value produced by this toilet alone might not be great enough to overcome that. However other factors, such as the aesthetics of the toilet or the savings in upfront costs, might govern the household's appreciation of the skyloo.

Finally, hydrogeologic factors can almost guarantee use and user satisfaction of the skyloo in this flood-prone region of Kenya, as an above-ground structure is the only kind of decentralized toilet that can properly function in areas with loose soils and/or a high water table.

8.3.2 Potential Survey Improvements

In addition to conclusions related to the research, there are also some conclusions that can be drawn regarding improving the research methodology. Several improvements could be made to the survey instrument as it was used in Kenya. First, the survey could include more in-depth questions about the reuse practices to characterize more closely the methods of agricultural application and to gauge how truthful the interviewee is revealing reuse information. Questions to include would explore how much was reused, where it was reused (have them show the interviewer), over what size piece of land it was reused, and ask about the specific method the steps a user takes when reusing feces or urine.

An interesting second addition to the survey could be to record other types of toilets that the households have on their property and how many people use them. There were many pit latrines still in use—knowing which toilet the majority of the people in the household chose to use, and why, would allow us to know who used what and aid in understanding why the people who like the skyloo use it.

Another user group that could be included in a comprehensive assessment would be non-users of ecological sanitation. Talking with other community members would gather information from people that do not know about ecosan, people that are opposed to ecosan, and people who perhaps are open to ecosan but do not currently own one. Questions about wider community perspectives of ecological sanitation could provide information about community acceptance and potential, community-wide barriers to ecosan, potential aspects on which to focus for promotion.

8.3.3 Potential Lab Improvements

As noted in Section *5.3*, the color of the urine was a shocking and interesting, yet unexpected, feature of the urine samples. Should urine tests be performed in a developing area such as this again, it is recommended that one be prepared to test for blood in urine, or another form of diagnostic test to explain such a range of colors.

A final conclusion regarding the improvement of the lab work regards more adequate documentation of urine storage. To improve understanding of the kinetics of urine in developing countries, the laboratory tests should try to include the amount of time the urine container had been in use prior to taking the sample. It would also be helpful to include a question about the last time urine was deposited into the container prior to sampling.

8.4 Recommendations

Two types of recommendations follow from this research. First, there are several considerations for improving the promotion and marketing of the skyloo. Second, recommendations are made regarding training users that have ecosan toilets to ensure safe and hygienic reuse of feces and urine.

8.4.1 Promotion of the Skyloo

Promote Other Benefits of the Skyloo

The skyloo agricultural production from the skyloo is only one of the many benefits of the toilet, and its universal economic value is not clear. Benefits of the skyloo toilet should be promoted, such as the fact that the skyloo has no flies or smells when it is used properly, or that this type of toilet has great environmental value because it protects water sources from fecal contamination and nutrient pollution. Promoters of the skyloo should also target areas with adverse hydrogeologic conditions in which the skyloo may be the only viable type of toilet for those settings. These types of positive aspects could be given much more weight, as they are likely to resonate with a many different types of users.

If households do not perceive the reuse aspects of the toilet as a benefit, burying the feces and/or urine after it has been processed still provides environmental health benefits as compared to open defecation in the bush, similar to those of the pit latrine. However, other benefits of the skyloo can be noted such as its advantages with respect to flies, smells, and hydrogeologic conditions. The beneficiaries of the skyloo should also be explicitly made aware of the costs associated with this kind of toilet, and that the amount of manure/fertilizer from an average family is equivalent to one 50 kg bag of diammonium phosphate (DAP) per household per year, at best. This will ensure a household's long-term commitment to this type of sanitation, and prevent sinking resources into toilets that will not be used.

Possibility for Economies of Scale

There might be economies of scale associated with collective or public ecosan style toilets. Adoption of ecosan by schools or other institutions would certainly produce more gross product than a household unit, but it is unclear how much labor, management, and materials of such a system would be needed to scale up. If the incremental cost of labor is less than the incremental increase in production, ecosan at this scale may be more efficient with respect to producing agricultural inputs. However, it is predicted that the social and/or institutional capacity of the receiving community must be high for this system to work. Pilot projects are being conducted in many parts of the world to evaluate the effectiveness of ecosan in communal or public facilities (Nanning, 2001; Luebeck, 2003).

Construction Alternatives

Construction issues were the largest reported complaint about the skyloo. Many of these complaints are easily fixable with design modifications to the structure of the toilet. Some complaints could be fixable if masons were trained to customize toilets, within limits, to individual household specifications. In general more follow-up evaluation of user's satisfaction and feedback to system designers and builders would likely increase user's acceptability of the skyloo.

One issue that was often mentioned, for example, was that the urine container sits behind the feces container in the lower chamber of the skyloo. The two containers do not fill at the same rate, and when the urine container is full one must remove the feces basket in order to access it. A modified design in which access to the chamber is placed on the side of the chamber, instead of the back, would allow access to either container. Alternatively, the urine container could be outside of the chamber altogether. One KWAHO member had a skyloo with such a design, which made it much easier to access.

A double-vault construction, which has been used in some places, would remove the need to handle fresh feces. In the skyloo, the bag of feces must be taken out when full and therefore the fresh feces on top must be seen, moved, and managed in order to remove the bag from the container. A double-vault in which there are two chambers side-by-side and alternately used (see the Fossa Alterna in Section *3.3.2*) would allow all processing of the feces to happen on the floor of the lower chamber, therefore removing the need for the user to touch, see, or deal with the feces until it is safe and no longer resembles feces. A double-vault construction would also significantly increase material costs for building the skyloo—the economic feasibility and community interest in such a product should be further explored.

Many of the back slabs of the toilets visited were excessively heavy. Standardizing production methods of the back slab, or at least adopting reasonable specifications for the weight of the back slab, could help mason's produce slabs that are light enough for the average homeowner to move without too much difficulty.

One frequent complaint about the structure was that the lower storage chamber is too small. A larger unit could easily be built. Assuming the average person excretes 51 kg of feces per year (Jonsson and V., 2004) and that the density of feces is near the density of water (in reality sometimes it is less dense than water, sometimes it is more), a chamber of about 1 m^3 should provide adequate space for a family of 5 people for 6 months of use on the storage chamber floor. For bucket collection, such as KWAHO promotes, this volume should be about ¼ larger for a 6 month retention time. However, in a bucket collection system the chamber can, in practice, be much smaller because the feces can be stored anywhere (the 6 month retention time is not necessary) because they are collected in the mobile plastic bag.

"Experimental" Test Garden
For potential applicants who are skeptical about the agricultural value of feces and urine, a field experiment site could be constructed. KWAHO, for example, has a field behind their Maseno office that is ideal for such a purpose, and already has a demonstration skyloo that has fallen into disuse. Such demonstrations are seemingly common among some organizations, and have been well documented in the past few years.[(28)] It is a relatively simple task to show the positive impact on vegetables that are grown with the products of the skyloo as compared to those that are grown without.

Reduce the Materials Subsidy
As noted in section 7.11.2, KWAHO's contribution of construction materials likely has a very high impact on households' desire to own and use the toilet. This subsidy policy is valuable to encourage users to try the new technology, as heavy incentives are the only way to overcome long-time habits. After the program is more established, however, it will be necessary to see if the technology has the potential to be adopted on its own.

Over time, a way to test the community's interest in the technology (and not just in a subsidized, and therefore inexpensive, toilet) could be to bring its initial capital costs nearer the level of other, more traditional, alternatives. This would mean decreasing the construction materials subsidy that KWAHO currently provides, or devising ways to construct the skyloo with materials that are cheaper (a thatched wall construction, for instance, rather than expensive corrugated iron) and that could be added to the list of materials that are to be provided by the beneficiary.

8.4.2 Recommendations for Health

Appropriate Storage Time
Section *6.5.1* revealed that the average storage time for urine was about 2 months, actually longer than the one-month recommendation proposed in the *Guidelines for the Safe Use of Urine and Faeces in Ecological Sanitation Systems* (Schönning and Stenström, 2004). The average storage time for feces (see Section *6.5.2*) was reported to be about 4.5 months—shorter than the recommended 6 months that KWAHO recommends and is within the range of safety as noted by Schönning and Stenström

(28) See http://www2.gtz.de/ecosan/english/publications-projects.htm.

(2004). This inconsistency implies that reuse is likely based more on convenience rather than recommendations for safe reuse. Follow-up education and training is needed to reinforce safe reuse of this material. Safe reuse is crucial to health and well being of the users and their surrounding community as well as to the success an ecosan program. Incorrect storage could lead to a greater incidence of feces-related diseases among users. If the community suspects that an ecosan toilet will make them sick, all incentive for experimentation with the "new" technology is gone.

Instruction Poster

Some users suggested that an instruction poster could be left in the skyloo. This would help new users to more easily understand how the toilet works, and would provide ongoing users with a simple checklist to make sure they are continually using the skyloo correctly. Any such poster should be based on pictures, using as few words as possible so as to not marginalize illiterate users.

Follow-up Training Events

Follow up training events could be a way to encourage users to interact with other ecosan owners and share experiences. Such events would help to reinforce the methods of safe reuse, disposal, or application. During user interviews, many users asked how they are supposed to use the feces and urine in their fields. Presumably, they were instructed about this when they received the toilet, but more frequent reinforcement and training will greatly help users understand and remember the principles and strategies of reuse. Such events could be held at the promoting organization's office and be billed as a fun community gathering.

Reuse in Aquaculture

Although aquaculture was not widely observed in practice in this area in Kenya due to its location on Lake Victoria (with abundant fish), it seems that farm-raised fish might be a viable economic endeavor for people in this area. The excreta from the skyloo can be used to increase the productivity of fish ponds, and can be an additional reuse option. When skyloo owners were presented with the question of the use of excrement in feeding fish, however, most participants reacted with curiosity or disgust. The only use that KWAHO actively promotes is use in agriculture.

8.5 Policy Considerations

While this thesis develops some questions regarding the potentially low economic value of the material from the toilet and presents unresolved questions about proper processing by users, households were overwhelmingly supportive of the technology. Ecological sanitation technology still appears to be a good sanitation option that governments should support.

Three main policy considerations follow from this research. First, ecological sanitation works toward achieving the Millennium Development Goals, as set forth by the United Nations, by providing sanitation coverage in areas where other low-tech sanitation options are not feasible. Ecosan fills a special niche in developing countries that are trying to provide sanitation to its populace while maintaining the ecological integrity of its water resources. Therefore, a second consideration is the potential for ecosan to play a valuable role in regional integrated water resource management plans. While it is true that households are not likely to be as concerned about such regional issues, this is a major challenge for national governments and regional municipalities. A final consideration is how governmental institutions could consider forming guidelines for ecological sanitation at a national or municipal level.

8.5.1 Working Toward the Millennium Development Goals

As noted in Section 2.1, ecological sanitation is attractive to international development experts for three main reasons: it provides sanitation coverage, a potential agricultural resource, and prevents pollution of water resources. Ecological sanitation, on a regional level, works toward both Target 9 (reversing the loss of environmental resources) and Target 10 (halving the proportion of the world without access to basic sanitation) of the Millennium Development Goals (MDGs) by protecting environmental resources and providing access to basic sanitation, respectively.

Ecosan realistically has the potential to have a limited, but valuable, contribution to the MDGs. The social hurdles associated with the reuse aspects of the toilet make adoption slow with a toilet such as the skyloo. However, it has been shown that the toilet's design has unique application in certain environmental conditions with a high water table or loose soils where the more common pit latrines will not work. The toilet might be able to provide valuable agricultural resources to the poor, or provide some cost savings to those who regularly purchase fertilizer. Yet it remains to be seen if adoption will be sustained without NGO support, or communities will begin to voluntarily adopt ecosan toilets in Kenya, as has been shown to happen in Ethiopia (Drangert, 2004).

In rural Kenya, 57 percent of the population lacks access to proper sanitation facilities (WHO, 2004). For part of this population a pit latrine, which is the only affordable household sanitation option, is not a viable option due to a high water table or loose soil conditions. An above-ground toilet, which must deal with the feces in a way other than deposition into the ground, is the only feasible improved sanitation option available. The skyloo is an above-ground toilet that is an appropriate, affordable option for people in this situation.

It is therefore concluded that household-level ecosan fills a special niche as a method of sanitation provision in developing countries such as Kenya, as shown in Table 8.2. This niche is most loosely defined by households that practice agriculture, with more certain adoption among communities that are faecophilic, people to whom the economic value of the processed feces and urine can have an impact on a household's finances, places that have a high water table or loose soils, or those that are particularly conscious of environmental issues.

Table 8.2 The Niche of Household-Level Ecological Sanitation

◊ "Faecophilic" ◊ Poorer households (where the material can have a greater economic impact) ◊ Geographies with a high water table ◊ Geographies with loose soils ◊ Environmental consciousness	} Households that practice agriculture

8.5.2 Integrated Water Resource Management

Ninety percent of the wastewater discharged in developing countries is discharged directly into water resources without any treatment (Esrey, 2001; Schlick, 2001). Lake Victoria has gained world-wide attention for its problems with water hyacinths in the past decade, the cause of which is at least in part due to eutrophication of the Lake's waters (Mailu, 2001). Ecological sanitation addresses this environmental issue by dealing with nutrient-rich excrement on-site and not sending it "away" to other destinations like Lake Victoria or Kenya's Tana River.

The environmental case for ecological sanitation as a part of integrated water resource management is important, and many developed-world examples of ecosan are founded on this principle. Industrialized and developing countries alike face harsh nutrient pollution problems that result in eutrophication of lakes and a depletion of aquatic natural resources. Ecosan is an exciting prospect to many experts because it has the potential to obviate water resource problems in developing countries that developed countries already have. Lesser developed nations have the opportunity to "leapfrog" developed countries and adopt more appropriate, environmentally sustainable technologies. Indeed, the environmental argument may be one of the strongest reasons for governments to consider ecological sanitation as a large-scale option in some areas.

8.5.3 Guidelines for Ecological Sanitation Programs

General sanitation policy guidelines have been developed by several authors (see Ellegde, 2003; GZT 2003; and Elledge, 2002). However, sanitation policies specific to ecosan have not been attempted. Developing regulations for the specific details of the technology may prove to be difficult due to the variety of ecological sanitation technologies. One of the challenges for governments and municipalities who want to incorporate alternative sanitation practices is to frame legislation in such a way that will allow for experimentation with alternative technologies, and also manage the associated risks.

Any country or municipality that is considering developing policy guidelines regarding ecological sanitation technologies should first consider the question of safe reuse. The pathogenic risk associated with excrement is the major reason for worldwide concern the need for adequate sanitation. EcoSanRes produced *Guidelines on the Safe Use of Urine and Faeces in Ecological Sanitation Systems* (Schönning and Stenström, 2004) which provides a complete review of the health risks associated with excrement and ways that excrement could be reused properly. One way for policymakers to try to deal with the safe processing of excrement could be to explore setting common guidelines for organizations that promote ecosan to ensure the safe promotion of the reuse of feces. While it is not reasonable to expect most governments in developing countries to have the capacity to regulate households, it might be feasible for organizations that promote ecosan to register with the government. The government could work with organizations to develop appropriate guidelines that ensure safety of reuse. One danger in government regulation is that it may stifle organizations' ability to experiment in finding more efficient methods of ecosan promotion, excreta processing, and excreta reuse. Therefore, adequate flexibility should be included in any policies.

Governments should also consider the economic ramifications of ecological sanitation for communities, especially in relation to the economic value of labor and time. As Ron Sawyer notes, "We simply don't have the experience to work out the full costs to collect, transport, store, process, and apply the liquid and solid fractions from the toilets" (McCann, 2005). Is this kind of sanitation an economic sink? Does the time required for maintenance and processing "cost" more than the product that comes out of the processing? Do household finances fluctuate in such a way that this toilet provides an economic stability to their life (in they don't have to purchase as much fertilizer). Does the ecological value outweigh the value of time associated with the maintenance, if the agricultural products do not? These questions are beyond the scope of this research, but should be considered in further policy exploration of ecological sanitation.

Finally, ecosan could be a great educational tool to teach communities, especially children, about hygiene and sanitation in general. If the possibilities for scaling-up (see Section *8.4.1*) prove to be a viable, integrating ecosan into schools could have an added advantage of inherently teaching children about the links between fecal material and health. In learning how to use an ecosan toilet, it would be imperative that the user know how to properly dispose of the excrement, and the reasons and methods to promote pathogen die-off in the material.

8.6 Summary

The skyloo is a viable option for excreta management for some households. It has tangible benefits which are especially relevant to households who practice agriculture and are in need of basic sanitation, and support many regional, governmental, and municipal goals common to developing nations associated with protection of water resources and widespread sanitation coverage. This research shows that the value of the agricultural product from a skyloo is limited, but useful—especially to poorer households. The frequency with which households noted the agricultural material as a positive benefit of the toilet supports the finding that the product is valued by users. Further research in this field could focus on quantifying the total economic impact of an ecosan toilet—not only taking into account the value of the manure and urine, but also the value of the time spent maintaining an ecosan toilet, and broader views of community perspectives on urine and fecal reuse.

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Appendix A: Questionnaire

«Ecological Sanitation in Maseno»

PASSPORT OF THE QUESTIONNAIRE

A. Number of the questionnaire |___|___|___|

B. City ______________________________ Area ______________________________

C. Date of interview: DD |___|___| MM |___|___|

D. Interview started at: Hrs |___|___| Minutes |___|___|

E. Interview ended at: Hrs |___|___| Minutes |___|___|

F. Name of the interviewer: ____________________Signature: ________________

G. Language of the interview

Swahili	1	
Local dialect	2	|__________________________|
English	3	
Other	4	|__________________________|

INTRODUCTION I

Hello, my name is _________________. My colleagues and I are working to improve sanitation systems in Kenya. We are interviewing families with EcoSan toilets that KWAHO helped install. We are trying to understand what you like and dislike about these systems, and how to improve them. In this survey we would like to talk to the person who usually handles the material from your EcoSan toilet.

H. Is that person currently available to talk with us? ***(Circle one).***

Yes	1	***CONTINUE TO INTRODUCTION II***
No	2	

I. When would be a good time to come back to talk to that person? ***(Write this down).***

Day |_____|_____|

Time: Hrs|____|____| Minutes|____|____|

INTRODUCTION II.

Hello, My name is _______________. My colleagues and I are working to improve sanitation systems in Kenya. We are interviewing families with EcoSan toilets that KWAHO helped install. We are trying to understand what you like and dislike about these systems, and how to improve them. In this survey we would like to talk to the person who usually handles the material from your EcoSan toilet.

J. Are you this person? ***(Circle one).***

Yes	1	
No	2	***GO BACK TO QUESTION H.***

If you have problems with your toilet, we would like to know about them. If you have ideas about how to fix these problems or improve the toilet system, we would like to know this also.

Here is a form that explains that you are not obliged to take part in this survey and you can refuse to have a conversation with me, but I would like to ask you to help me understand how better we can improve these types of toilets. ***(Give the SURVEY CONSENT FORM to the participant. The participant retains one signed copy, file the other signed copy. Continue with the survey.)***

Please remember that we are very interested in knowing how you truly feel about the EcoSan toilet. Honest answers will help us provide better toilets to others in the future, and may be able to help us improve on your existing system. Thank you for your help. Are you ready to begin the survey?

A. RESPONDENT INFORMATION

First, we will ask you some general information about yourself:

1. What is your status in the household?

Father	1	*43 %*	
Mother	2	*48 %*	
Grandfather	3		
Grandmother	4		
Single adult	5		
Child	6	*4 %*	
Other ***(Write this down.)***	15	*4 %*	|________________________|

2. What is your age, please?

|______________years_old_| *(Average age = 49 years old)*

3. Sex of the respondent. ***(Mark without asking).***

Male	1	*48 %*
Female	2	*52 %*

B. HOUSEHOLD AGRICULTURE

I will now ask you a few questions about agricultural practices in your household:

4. Does your household grow plants? For example, do you have crops in your garden?

Yes	1		*100 %*
No	2	***Move to question 10***	

5.

a. Are you the person who cares for the plants?

Yes	1	***Move to question 6***	*100 %*
No	2		

b. If no, who takes care of the plants? |_________________________|

6. Is fertilizer used on the plants?

Yes	1		*71 %*
No	2	***Move to question 15.***	*23 %*
Don't know	99		

7. What kinds of plants do you grow? |______________________|

8.

a. Do you use any commercial fertilizers?

Yes	1		*48 %*
No	2	***Move to question 9.***	*52 %*
Sometimes	3		
Don't know	99		

b. How much do you pay for the commercial fertilizers?

|_____________Kshs per kilogram_| *(Of those that bought it, average = Ksh 4000)*

c. How much do you use? |_______________kilograms per year_| *(Of those that used it, average = 97 kg)*

9.

a. Do you use any animal fertilizers?

Yes	1		*100 %*

No	2	***Move to question 15.***	
Sometimes	3		
Don't know	99		

b. How much do you pay for the animal manure?

|_____________Kshs per kilogram_| *(Average = Ksh 0)*

c. How much do you use? |____________kilograms per year_| *(Most not sure, but average of those who answered = 420 kg)*

Move to question 15.

10. If your household grew plants, do you think you would be the person who takes care of them? ***(Circle one.)***

Yes	1	
No	2	

11. Do you think your household would like to use fertilizer on the plants? ***(Circle one.)***

Yes	1	
No	2	***Move to question 13.***
Don't know	99	***Move to question 13.***

12. What kind of fertilizer do you think you would use? ***(Write this down.)***

|_______________________|

13. How much do you think you would be willing to pay for it? ***(Write this down.)***

|___________Kshs_per_kilogram _|

14. What kinds of plants do you think you would use it on? ***(Write this down.)***

|__________________________|

C. GENERAL

I will now ask you some questions about your EcoSan toilet and what you do with the material from it:

15. When was your EcoSan toilet built? Month |____|____| Year |____|____|

16. Why did you want an EcoSan toilet? ***(Open ended, please write this down).***

17. How many people live in your home? |_______________people_| *(Average = 8 people)*

18.

a. How many people use the EcoSan toilet? |__________________people_| *(Average = 4.8 people)*

b. If this number is different from question 18, is there a reason that not everyone uses the EcoSan toilet? ***(Open ended, please take notes.)***

C. FECES REUSE

FECES PROCESSING STORAGE/TIME

I will now ask you a series of questions about what you do with the feces from your toilet.

19. How do you store the feces during the processing time? (visually verify)

In the toilet's vault	1		
No storage	2	***Move to question 21.***	
In a plastic bag that is removed from a collection bucket	3		*100 %*
Other ***(Write this down.)***	15	|_________________|	

20. Most recently, how long did you store the feces before you used it or emptied the container?

|__________months_| *(Average = 4.6 months)*

REUSE OF FECES

The next few questions ask about the things your household does with the material when you clean out the toilet vault or when you dispose of the feces. Have you *EVER* done any of the following with feces when you remove it from its container?

21. Bury it in the ground?

Yes	1	29 %
No	2	*71 %*
Don't know	99	

22.

a. Used it in a household garden?

Yes	1		*65 %*
No	2	***Move to question 23.***	*35 %*
Don't know	99	***Move to question 23.***	

b. Do you think it has had a positive effect on the plants?

Yes	1	*100 %*
No	2	
Don't know	99	

23.

a. Used it in a group (community) garden?

Yes	1		
No	2	***Move to question 24.***	*100 %*
Don't know	99	***Move to question 24.***	

b. Do you think it has had a positive effect on the plants?

Yes	1	
No	2	
Don't know	99	

24.

a. Used it in a commercial farm?

Yes	1		*6 %*
No	2	***Move to question 25.***	*94 %*

Don't know	99	***Move to question 25.***	

b. Do you think it has had a positive effect on the plants?

Yes	1	*100 %*
No	2	
Don't know	99	

25.

a. Used it in aquaculture?

Yes	1		
No	2	***Move to question 26.***	*100 %*
Don't know	99	***Move to question 26.***	

b. Do you think it has had a positive effect on the fish?

Yes	1	
No	2	
Don't know	99	

26.

a. Have you ever sold it for money?

Yes	1		
No	2	***Move to question 27.***	*100 %*
Don't know	99	***Move to question 27.***	

b. If you have sold it, how much do you get paid for it? |______________Ksh per kg_|

27.

a. Have you ever traded it for other goods?

Yes	1		
No	2	***Move to question 28.***	*100 %*
Don't know	99	***Move to question 28.***	

b. If so, what did you trade it for? |____|

28.

a. Have you ever given it away?

Yes	1	

No	2	***Move to question 29.***
Don't know	99	***Move to question 29.***

b. What does that person do with it? |_____________________________|

29. Do nothing with it?

Yes	1	*12 %*
No	2	*82 %*
Don't know	99	*6 %*

30. Other uses?

Yes ***(Write this down.)***	1	|_________________|	*6 %*
No	2		*94 %*
Don't know	99		

31. How much of the matured feces do you use? |_________________%_| *(Average = 73%)*

If less than 100%, do you do any of the following with the extra material that remains?

32. Bury it in the ground?

Yes	1	*50 %*
No	2	*50 %*
Don't know	99	

33.

a. Sell it?

Yes	1		
No	2	***Move to question 34.***	*100 %*
Don't know	99	***Move to question 34.***	

b. How much do you sell? |_______________%_|

c. How much money do you sell it for? |________________________Kshs_per_kilogram_|

34.

a. Traded it for other goods?

Yes	1		

No	2	***Move to question 35.***	*100 %*
Don't know	99	***Move to question 35.***	

b. If so, what did you trade it for? |____|

35.

a. Give it away?

Yes	1		
No	2	***Move to question 36.***	*100 %*
Don't know	99	***Move to question 36.***	

b. How much do you give away? |______________%_|

c. What do the people that you give it to use it for? |__________________________|

36. Throw it away (with other household garbage)?

Yes	1	
No	2	*100 %*
Don't know	99	

37. Are there other ways that you have disposed of the feces?

|____|

D. URINE REUSE

URINE PROCESSING STORAGE/TIME

I will now ask you a series of questions about what is done with the urine from your toilet.

38.

a. Do you collect urine from your toilet?

Yes	1	***Move to question 39***	*95 %*
No	2		*5 %*

Move to question 39.

b. If no, what happens to the urine?

It goes to a soak-away pit (to the ground)	1		*100 %*
We intentionally evaporate it from a flat surface	2		
Other	15	|________________|	

Move to question 40.

39. Most recently, how long did you store the urine (after the container was full) before you used it or emptied the container?

|__________months_| **OR** |___________weeks_| *(Average = 1.9 months)*

REUSE OF URINE

The following questions ask about what your household does with the urine when you empty the urine container. Have you *EVER* done any of the following with urine when you remove it from its container?

40. Let it soak into the ground?

Yes	1	*33 %*
No	2	*67 %*

Don't know	99	

41.

a. Use in a household garden?

Yes	1		*67 %*
No	2	***Move to question 42.***	*33%*
Don't know	99	***Move to question 42.***	

b. Do you think it has had a positive effect on the plants?

Yes	1	*92 %*
No	2	*8 %*
Don't know	99	

42.

a. Use in a community garden?

Yes	1		
No	2	***Move to question 43.***	*100 %*
Don't know	99	***Move to question 43.***	

b. Do you think it has had a positive effect on the plants?

Yes	1	
No	2	
Don't know	99	

43.

a. Use in a commercial farm?

Yes	1		*11 %*
No	2	***Move to question 44.***	*89 %*
Don't know	99	***Move to question 44.***	

b. Do you think it has had a positive effect on the plants?

Yes	1	*100 %*
No	2	
Don't know	99	

44.

a. Use in aquaculture?

Yes	1		
No	2	***Move to question 45.***	*100 %*
Don't know	99	***Move to question 45.***	

b. Do you think it has had a positive effect on the fish?

Yes	1	
No	2	
Don't know	99	

45.

a. Sell it?

Yes	1		
No	2	***Move to question 46.***	*100 %*
Don't know	99	***Move to question 46.***	

b. If you have sold it, how much do you get paid for it? |_________Ksh per Kilo_|

46.

a. Give it away?

Yes	1		*6 %*
No	2	***Move to question 47.***	*94 %*
Don't know	99	***Move to question 47.***	

b. What does that person want it for? |_______________________________|

47. Do nothing with it?

Yes	1	*6 %*
No	2	*88 %*
Don't know	99	*6 %*

48. Other uses?

Yes ***(Write this down.)***	1	|_____________________|	*11 %*
No	2		*72 %*
Don't Know	99		*17 %*

49. How much of the processed urine do you use? |__________%_| *(Average = 65 %)*

If less than 100%, what do you do with the urine that remains?

50. Bury it in the ground?

Yes	1	*86 %*
No	2	
Don't know	99	*14 %*

51.

a. Sell it?

Yes	1		
No	2	***Move to question 52.***	*100 %*
Don't know	99	***Move to question 52.***	

b. How much do you sell? |____________%_|

c. How much money do you sell it for? |____________Kshs per kg_|

52.

a. Give it away?

Yes	1		
No	2	***Move to question 53.***	*100 %*
Don't know	99	***Move to question 53.***	

b. How much do you give away? (Write this down.) |____________%_|

c. What do the people that you give it to use it for? |_______________|

53. Throw it away (with other household garbage)?

Yes	1	*33 %*
No	2	*67 %*
Don't know	99	

54. Are there other ways that you dispose of the urine? |_______________|

E. VALUE

GENERAL

Now I'd like to know some of the things you like or don't like about your toilet.

55. What are some of the things that you like about your EcoSan toilet?

56. Out of these, what things do you like MOST about your EcoSan toilet?

57. What are some of the things you dislike about your EcoSan toilet?

58. Out of these, what things do you dislike MOST about your EcoSan toilet?

59. Do you have any suggestions on how to make the Skyloo better or improvements that you would like to see? What are these? ***(Open ended).***

60. How often do you maintain your facility?

|____________times per month__| **OR** |____________times per week__|
(Average = 3.7 times/week)

61. Do you ever feel like you spend too much time tending to the toilet?

Yes	1	*23 %*
No	2	*77 %*
Sometimes	3	

62. Do you ever wish you had more time to tend to it?

Yes	1	*38 %*
No	2	*62 %*
Sometimes	3	

63. Do you feel like the amount of time you spend on it is acceptable?

Yes	1	*68 %*

No	2	*23 %*
Sometimes	3	*9 %*

FECES VALUE

Do you think you have benefited from use of the processed feces in any of the following ways?

64. With money?

Yes	1	
No	2	*94 %*
Sometimes	3	*6 % (from sold crops)*
Don't know	99	

65. With better plants/crops?

Yes	1	*69 %*
No	2	*31 %*
Sometimes	3	
Don't know	99	

66. With better feedstock for aquaculture?

Yes	1	
No	2	*100 %*
Sometimes	3	
Don't know	99	

67. In health (improved sanitation)?

Yes	1	*82 %*
No	2	*18 %*
Don't know	99	

Do you have any of the following problems with reuse of the matured feces from your toilet?

68. It smells badly.

Yes	1	
No	2	*81 %*
Sometimes	3	*19 %*

69. I think people in my family have gotten sick from it (it has worsened sanitation).

Yes	1	
No	2	*100 %*
Sometimes	3	

70. My neighbors look down upon the practice of reusing human feces.

Yes	1	*19 %*
No	2	*71 %*
Sometimes	3	*10 %*
Don't know	99	

71. What other problems do you have with reuse of the matured feces? ***(Open ended, please take notes.)***

72. Are you happy with the quality of the feces?

Yes	1	
No	2	*94 %*
Don't know	99	*6 %*

73. Do you ever feel like you have too much feces to deal with?

Yes	1	***Move to question 76.***	*19 %*
No	2		*81 %*
Sometimes	3		
Don't know	99		

74. If you had more fecal material, do you think you would use it?

Yes	1		*83 %*
No	2	***Move to question 76.***	*17 %*
Sometimes	3		
Don't know	99		

75. How much more do you think you could use? |__________________kilos_| *(Average = 205 kilograms)*

URINE VALUE

Have you benefited from use of the processed urine in any of the following ways?

76. With money?

Yes	1	
No	2	*100 %*
Sometimes	3	
Don't know	99	

77. With better plants/crops?

Yes	1	
No	2	*62 %*
Sometimes	3	*38 %*
Don't know	99	

78. With better feedstock for aquaculture?

Yes	1	
No	2	*100 %*
Sometimes	3	
Don't know	99	

79. In health (improved sanitation)?

Yes	1	*65 %*
No	2	*35 %*
Don't know	99	

Do you have any of the following problems with reuse of the urine?

80. It smells badly.

Yes	1	*5 %*
No	2	*86 %*
Sometimes	3	*9 %*

81. I think I or people in my family have gotten sick from it (it has worsened sanitation).

Yes	1	
No	2	*100 %*
Sometimes	3	

82. Neighbors look down upon the practice of reusing urine.

Yes	1	*14 %*
No	2	*76 %*
Sometimes	3	*10 %*
Don't know	99	

83. What other problems do you have with reuse of the matured urine? ***(Open ended, please take notes.)***

84. Are you happy with the quality of the urine?

Yes	1	*75 %*
No	2	*12 %*
Don't know	99	*12 %*

85. Do you ever feel like you have too much urine to deal with?

Yes	1	***Move to question 88.***	*43 %*
No	2		*57 %*
Sometimes	3		
Don't know	99		

86. If you had more urine, do you think you would use it?

Yes	1		*75 %*
No	2		*17 %*
Sometimes	3	***Move to question 88.***	
Don't know	99		*8 %*

87. How much more do you think you could use? |____________liters_| *(Average = 100 liters)*

88. Is there anything else you would like to tell us about your experiences with your toilets? ***(Open ended).***

We are now finished. This is the end of the survey. Thank you very much for taking part in this interview!

INTERVIEWER! DO NOT FORGET TO FILL IN THE QUESTIONNAIRE PASSPORT

Appendix B: Improved Questionnaire

The following questionnaire is a revised version of the questionnaire presented in Appendix A to aid in future research studies. Questions that (in hindsight) did not have direct relevance to the research have been omitted. Additional information and improvements to the questionnaire, as suggested in Chapter 8, are described in bold capital letters in boxes throughout this appendix. The specific questions are left for the researcher to develop which are comfortable for the researcher to ask, and for the researcher to field test in the research community.

A. HOUSEHOLD AGRICULTURE

I will first ask you a few questions about agricultural practices in your household:

1. Does your household grow plants? For example, do you grow crops in a garden?

Yes	1	
No	2	***Move to question 7***

2.

a. Do you take care of the plants?

Yes	1	***Move to question 3***
No	2	

b. If no, who takes care of the plants? |_________________________|

3. Is fertilizer used on the plants?

Yes	1	
No	2	***Move to question 12.***
Don't know	99	

4. What kinds of plants do you grow? |______________________|

5.

a. Do you use any commercial fertilizers?

Yes	1	
No	2	***Move to question 6.***
Sometimes	3	
Don't know	99	

b. How much do you pay for the commercial fertilizers?

|_____________Kshs per kilogram_|

c. How much do you use? |_______________kilograms per year_|

6.

a. Do you use any animal fertilizers?

Yes	1	

No	2	***Move to question 12.***
Sometimes	3	
Don't know	99	

b. How much do you pay for the animal manure?

|____________Kshs per kilogram_|

c. How much do you use? |____________kilograms per year_|

Move to question 15.

7. If your household grew plants, do you think you would take care of them? ***(Circle one.)***

Yes	1	
No	2	

8. Do you think your household would like to use fertilizer on the plants? ***(Circle one.)***

Yes	1	
No	2	***Move to question 11.***
Don't know	99	***Move to question 11.***

9. What kind of fertilizer do you think you would use? ***(Write this down.)***

|______________________|

10. How much would you be willing to pay for it? ***(Write this down.)***

|___________Kshs_per_kilogram _|

11. What kinds of plants do you think you would use it on? ***(Write this down.)***

|_________________________|

B. GENERAL

I will now ask you some questions about your EcoSan toilet and what you do with the material from it:

12. When was your EcoSan toilet built? Month |____|____| Year |____|____|

13. Why did you want an EcoSan toilet? ***(Open ended, please write this down)***.

14. How many people live in your home? |_______________people_|

15.

a. How many people use the EcoSan toilet? |__________________people_|

b. If this number is different from question 18, is there a reason that not everyone uses the EcoSan toilet? ***(Open ended, please take notes.)***

DO YOU HAVE ANOTHER TOILET?
WHAT KIND OF TOILET IS IT?
DO YOU LIKE THIS TOILET OR THE ECOSAN TOILET BETTER? WHY?
WHAT DO YOU THINK ARE THE ADVANTAGES AND DISADVANTAGES OF EACH KIND OF TIOLET?

C. FECES REUSE

FECES PROCESSING STORAGE/TIME

I will now ask you a series of questions about what you do with the feces from your toilet.

16. How do you store the feces during the processing time? ***(visually verify)***

In the toilet's vault	1	
No storage	2	***Move to question 18.***
In a plastic bag that is removed from a collection bucket	3	
Other ***(Write this down.)***	15	|_____________________________|

17. Most recently, how long did you store the feces before you used it or emptied the container?

|__________months_|

WHAT INFLUENCES HOW LONG YOUR STORE THE FECES? THE TIME OF YEAR FERTILIZERS ARE USUALLY APPLIED TO AGRICULTURE, THE AMOUNT OF TIME NEEDED FOR SAFE REUSE, THE SIZE OF THE STORAGE FACILITY, LACK OF A STORAGE FACILITY, OTHERS?

REUSE OF FECES

The next few questions ask about the things your household does with the material when you clean out the toilet vault or when you dispose of the feces. Have you *EVER* done any of the following with feces when you remove it from its container?

18. Bury it in the ground?

Yes	1	
No	2	
Don't know	99	

19.

a. Used it in a household garden?

Yes	1	
No	2	***Move to question 20.***
Don't know	99	***Move to question 20.***

b. Do you think it has had a positive effect on the plants?

Yes	1	
No	2	
Don't know	99	

20.

a. Used it in a group (community) garden?

Yes	1	
No	2	***Move to question 21.***
Don't know	99	***Move to question 21.***

b. Do you think it has had a positive effect on the plants?

Yes	1	
No	2	
Don't know	99	

21.

a. Used it in a commercial farm?

Yes	1	
No	2	***Move to question 22.***
Don't know	99	***Move to question 22.***

b. Do you think it has had a positive effect on the plants?

Yes	1	
No	2	
Don't know	99	

22.

a. Used it in aquaculture?

Yes	1	
No	2	***Move to question 23.***
Don't know	99	***Move to question 23.***

b. Do you think it has had a positive effect on the fish?

Yes	1	
No	2	
Don't know	99	

23.

a. Have you ever sold it for money?

Yes	1	
No	2	***Move to question 24.***
Don't know	99	***Move to question 24.***

b. If you have sold it, how much do you get paid for it? |______________Ksh per kg_|

24.

a. Have you ever traded it for other goods?

Yes	1	
No	2	***Move to question 25.***
Don't know	99	***Move to question 25.***

b. If so, what did you trade it for? |________________________________|

25.

a. Have you ever given it away?

Yes	1	
No	2	***Move to question 26.***
Don't know	99	***Move to question 26.***

b. What does that person do with it? |______________________|

26. Do nothing with it?

Yes	1	
No	2	
Don't know	99	

27. Other uses?

Yes ***(Write this down.)***	1	|________________________________|
No	2	
Don't know	99	

28. How much of the matured feces do you use? |______________%_|

If less than 100%, do you do any of the following with the extra material that remains?

29. Bury it in the ground?

Yes	1	
No	2	
Don't know	99	

30.

a. Sell it?

Yes	1	

No	2	***Move to question 31.***
Don't know	99	***Move to question 31.***

b. How much do you sell? |_____________%_|

c. How much money do you sell it for? |______________________Kshs_per_kilogram_|

31.

a. Traded it for other goods?

Yes	1	
No	2	***Move to question 32.***
Don't know	99	***Move to question 32.***

b. If so, what did you trade it for? |______________________________________|

32.

a. Give it away?

Yes	1	
No	2	***Move to question 33.***
Don't know	99	***Move to question 33.***

b. How much do you give away? |_____________%_|

c. What do the people that you give it to use it for? |________________________|

33. Throw it away (with other household garbage)?

Yes	1	
No	2	
Don't know	99	

34. Are there other ways that you have disposed of the feces?

|____|

COULD YOU PLEASE DESCRIBE THE WAY YOU USE THE FECES IN YOUR GARDEN, IF YOU DO? (INCLUDE THE TIME (SEASON) OF APPLICATION, THE AMOUNT APPLIED, TYPE OF PLANTS TO WHICH IT IS APPLIED, DIFFERENCES IN APPLICATION TO DIFFERENT PLANTS, AND HOW THESE METHODS WERE LEARNED (I.E. FROM AN ORGAINZIATION, SELF-EXPERIMENTATION).

D. URINE REUSE

URINE PROCESSING STORAGE/TIME

I will now ask you a series of questions about what is done with the urine from your toilet.

35.

a. Do you collect urine from your toilet?

Yes	1	***Move to question 35.b***
No	2	***Move to question 35.c***

b. If yes, how do you store (after the container is full) it?

In a container beside the vault	1	
In a separate container	2	
Other	15	|____________________|

Move to question 36.

c. If no, what happens to the urine?

It goes to a soak-away pit (to the ground)	1	
We intentionally evaporate it from a flat surface	2	
Other	15	|____________________|

Move to question 37.

36. Most recently, how long did you store the urine (after the container was full) before you used it or emptied the container?

|__________months_| **OR** |__________weeks_|

REUSE OF URINE

The following questions ask about what your household does with the urine when you empty the urine container. Have you *EVER* done any of the following with urine when you remove it from its container?

37. Let it soak into the ground?

Yes	1	
No	2	
Don't know	99	

38.

a. Use in a household garden?

Yes	1	
No	2	***Move to question 39.***
Don't know	99	***Move to question 39.***

b. Do you think it has had a positive effect on the plants?

Yes	1	
No	2	
Don't know	99	

39.

a. Use in a community garden?

Yes	1	
No	2	***Move to question 40.***
Don't know	99	***Move to question 40.***

b. Do you think it has had a positive effect on the plants?

Yes	1	
No	2	
Don't know	99	

40.

a. Use in a commercial farm?

Yes	1	
No	2	***Move to question 41.***
Don't know	99	***Move to question 41.***

b. Do you think it has had a positive effect on the plants?

Yes	1	
No	2	
Don't know	99	

41.

a. Use in aquaculture?

Yes	1	
No	2	***Move to question 42.***
Don't know	99	***Move to question 42.***

b. Do you think it has had a positive effect on the fish?

Yes	1	
No	2	
Don't know	99	

42.

a. Sell it?

Yes	1	
No	2	***Move to question 43.***
Don't know	99	***Move to question 43.***

b. If you have sold it, how much do you get paid for it? |_________Ksh per Kilo_|

43.

a. Give it away?

Yes	1	
No	2	***Move to question 44.***
Don't know	99	***Move to question 44.***

b. What does that person want it for? |______________________________|

44. Do nothing with it?

Yes	1	
No	2	
Don't know	99	

45. Other uses?

Yes *(Write this down.)*	1	|____________________________|
No	2	
Don't Know	99	

46. How much of the processed urine do you use? |___________%_|

If less than 100%, what do you do with the urine that remains?

47. Bury it in the ground?

Yes	1	
No	2	
Don't know	99	

48.

a. Sell it?

Yes	1	
No	2	***Move to question 49.***
Don't know	99	***Move to question 49.***

b. How much do you sell? |_____________%_|

c. How much money do you sell it for? |______________Kshs per kg_|

49.

a. Give it away?

Yes	1	
No	2	***Move to question 50.***
Don't know	99	***Move to question 50.***

b. How much do you give away? (Write this down.) |______________%_|

c. What do the people that you give it to use it for? |__________________|

50. Throw it away (with other household garbage)?

Yes	1	
No	2	

Don't know	99	

51. Are there other ways that you dispose of the urine? |________________|

COULD YOU PLEASE DESCRIBE THE WAY YOU USE THE URINE ON YOUR CROPS, IF YOU DO? (INCLUDE THE TIME (SEASON) OF APPLICATION, THE AMOUNT APPLIED, TYPE OF PLANTS TO WHICH IT IS APPLIED, DIFFERENCES IN APPLICATION TO DIFFERENT PLANTS, AND HOW THESE METHODS WERE LEARNED (I.E. FROM AN ORGAINZIATION, SELF-EXPERIMENTATION).

E. VALUE

GENERAL

Now I'd like to know some of the things you like or don't like about your toilet.

52. What are some of the things that you like about your EcoSan toilet?

53. Out of these, what things do you like MOST about your EcoSan toilet?

54. What are some of the things you dislike about your EcoSan toilet?

55. Out of these, what things do you dislike MOST about your EcoSan toilet?

56. Do you have any suggestions on how to make the Skyloo better or improvements that you would like to see? What are these? (Open ended).

TIME VALUE:
HOW MANY HOURS DO YOU SPEND CLEANING YOUR FACILITY EACH WEEK?
HOW OFTEN MUST YOU REMOVE THE FECES FROM THE COLLECTION CONTAINER?
HOW OFTEN MUST YOU REMOVE THE URINE FROM THE COLLECTION CONTAINER?
HOW LONG DOES IT TAKE YOU TO PERFORM THESE ACTIVITIES?
CAN YOU DESCRIBE THE PROCESS THAT YOU GO THROUGH TO WHEN YOU PERFORM THESE ACTIVITIES?
WHAT OTHER ACTIVITES WOULD YOU BE DOING IF YOU WERE NOT MAINTAINING YOUR TOILET?
DOES THE MAINTENANCE OF YOUR TOILET TAKE AWAY FROM YOUR TIME DOING THESE OTHER ACTIVITIES (AND ARE THESE ACTIVITIES INCOME-GENERATING OR NOT?)?

FECES VALUE

Do you think you have benefited from use of the processed feces in any of the following ways?

57. With money?

Yes	1	
No	2	
Sometimes	3	
Don't know	99	

58. With better plants/crops?

Yes	1	
No	2	
Sometimes	3	
Don't know	99	

59. With better feedstock for aquaculture?

Yes	1	
No	2	
Sometimes	3	
Don't know	99	

60. In health (improved sanitation)?

Yes	1	
No	2	
Don't know	99	

Do you have any of the following problems with reuse of the matured feces from your toilet?

61. It smells badly.

Yes	1	
No	2	
Sometimes	3	

62. I think people in my family have gotten sick from it (it has worsened sanitation).

Yes	1	
No	2	
Sometimes	3	

63. My neighbors look down upon the practice of reusing human feces.

Yes	1	
No	2	

Sometimes	3	
Don't know	99	

64. What other problems do you have with reuse of the matured feces? (Open ended, please take notes.)

65. Are you happy with the quality of the feces?

Yes	1	
No	2	
Don't know	99	

66. Do you ever feel like you have too much feces to deal with?

Yes	1	***Move to question 69.***
No	2	
Sometimes	3	
Don't know	99	

67. If you had more fecal material, do you think you would use it?

Yes	1	
No	2	***Move to question 69.***
Sometimes	3	
Don't know	99	

68. How much more do you think you could use? |__________________kilos_|

URINE VALUE

Have you benefited from use of the processed urine in any of the following ways?

69. With money?

Yes	1	
No	2	
Sometimes	3	
Don't know	99	

70. With better plants/crops?

Yes	1	
No	2	
Sometimes	3	
Don't know	99	

71. With better feedstock for aquaculture?

Yes	1	
No	2	
Sometimes	3	
Don't know	99	

72. In health (improved sanitation)?

Yes	1	
No	2	
Don't know	99	

Do you have any of the following problems with reuse of the urine?

73. It smells badly.

Yes	1	
No	2	
Sometimes	3	

74. I think I or people in my family have gotten sick from it (it has worsened sanitation).

Yes	1	
No	2	
Sometimes	3	

75. Neighbors look down upon the practice of reusing urine.

Yes	1	
No	2	
Sometimes	3	
Don't know	99	

76. What other problems do you have with reuse of the matured urine? (Open ended, please take notes.)

77. Are you happy with the quality of the urine?

Yes	1	
No	2	
Don't know	99	

78. Do you ever feel like you have too much urine to deal with?

Yes	1	***Move to the end.***
No	2	
Sometimes	3	
Don't know	99	

79. If you had more urine, do you think you would use it?

Yes	1	
No	2	***Move to the end.***
Sometimes	3	
Don't know	99	

80. How much more do you think you could use? |____________liters_|

81. Is there anything else you would like to tell us about your experiences with your toilets? ***(Open ended).***

ANOTHER QUESTIONNAIRE COULD BE DEVELOPED FOR HOUSEHOLDS THAT DO NOT OWN ECOSAN TOILETS. THIS QUESTIONNAIRE COULD FOCUS QUESTIONS AND TOPICS SUCH AS:
1. WOULD YOU USE A TOILET THAT COLLECTED AND STORED URINE AND FECES? 2. WOULD YOU USE SUCH A TOILET IF YOU WERE RESPONSIBLE FOR MAINTAINING IT (STORING THE FECES AND URINE)? 3. WHAT WOULD YOU THINK OF YOUR NEIGHBOR, FOR INSTANCE, IF HE/SHE BEGAN TO USE A TOILET LIKE THIS? 4. WOULD YOU LIKE USING A TOILET THAT DID NOT HAVE FOUL ODORS OR ATTRACT FLIES? 5. WOULD YOU LIKE USING A TOILET THAT LOOKED LIKE THIS (SHOWING A PICTURE OF THE SKYLOO)?

6. **WOULD USE AND MAINTAIN A TOILET THAT COLLECTS AND STORES FECES AND URINE IF IT HAD THESE TWO POSITIVE ATTRIBUTES (NO SMELL, NO FLIES, AND LOOKED LIKE THE ONE IN THE PICTURE)?**
7. **HOW MUCH WOULD YOU BE WILLING TO PAY FOR IT?**
8. **WOULD YOU USE AND MAINTAIN SUCH A TOILET IF YOU KNEW YOU WOULD RECEIVE ENOUGH MATERIAL TO FERTILIZE XX AMOUNT OF LAND?**
9. **HOW MUCH MATERIAL WOULD BE BENEFICIAL TO YOU?**
10. **HOW MUCH WOULD YOU PAY FOR A TOILET THAT COULD DO THIS?**
11. **WOULD YOU EAT CROPS THAT HAD BEEN FERTILIZED BY HUMAN MANURE (FECES) OR HUMAN FERTILIZER (URINE)?**

Appendix C: Laboratory Supply List

Quantity	Item	Supplier
	Dilutions	
1	Pipette (100-1000 µL) #12	Oxford
~200	Pipette tips (1 mL)	VWR
25	Pipette tips (5 mL)	VWR
1	100 mL plastic graduated cylinder	Nalgene
1	25 mL glass graduated cylinder	Pyrex
2	100 mL plastic beaker	VWR
1	250 mL pastic volumetric flask	Nalgene
	Spectrophotometry	
1	Spectrophotometer DR/2010	Hach
1	Spectrophotometer DR/2010 Power Cable	Hach
1	Spectrophotometer DR/2010 Power Pack	Hach
1	COD Vial Adapter	Hach
1	10 mL Vial Adapter	Hach
	Electrification	
2	3-prong to 2-prong adapter	x
2	110 - 220 mV converter	x
3	Kenya power outlet adapter (configuration 1)	x
3	Kenya power outlet adapter (configuration 2)	x
	Sample Collection	
4	Whirlpack bags 100 mL- 25 bags/pk	VWR
1	Syringe	VWR
2	Extraction tube (~2 feet in length)	x
	NH_3-N supplies	
100	AmVer Diluent Reagent Vials (Test 'n' Tube)	Hach
100	Ammonia Salicylate Reagent Powder Pillows	Hach
100	Ammonia Cyanurate Reagent Powder Pillows	Hach
4	Micro funnels	Hach
5	25 mL glass sample vials	Hach
1	Vial Rack (Cardboard box with self-made holes for vials)	x
2	NH4 Methods from Manual (Hach #10031)	Hach
	Urease	
1 bottle	Urease Canavalia ensiformis (Jack bean)	Sigma-Aldrich
1	Urease Methods	Sigma-Aldrich
2 or 3	Freezer pack(s)	x
	Ortho-phosphate supplies	
2 pair	10-ml Bottles, matched pair	Hach
1 pk./ 100 count	PhosVer 3 Phosphate Reagent	Hach
1 pk./ 100 count	Phosphate Pretreatment	Hach

2	P Methods from Manual (Hach #8048)	Hach
	pH readings	
1 set	ph "All in One" Buffer Kit (includes: pint bottles of 4, 7, and 10 pH buffers, and electrode storage solution	Thermo Orion
1	pH meter	Thermo Orion
1	pH electrode	Thermo Orion
1	ThermoOrion Manual	Thermo Orion
3	9-Volt battery	x
	Microflitration	
300	47mm paper	Millipore
100	Petridishes with pads	Millipore
1	Filter assembly holder	Millipore
50	M-ColiBlue reagent	Millipore
1	Tube to connect filter to hand pump	Millipore
1	Hand pump	VWR
1	Forcepts (tweezeers)	x
1	Screwdriver	x
2	MF Methods	x
	Incubator	
	Chemical-Filled Balls	Amy Smith
1	MiniMate Cooler (insulated container) #6	Igloo
1	Mesh bag (for boiling balls)	x
1	Foam insulating cover?	x
1	Thermometer	x
	Steralization	
50-pack	Hand sanitizer	x
0.5 liters	Methanol	x
3	Lighter/matches	x
1	Squeeze bottle (for sterylized water)	x
1	Tissue Wipers (Light-Duty) box- 280 wipes	VWR
	Miscellaneous	
3	Lab marking tape	x
3	Lab marking pens	x
1	Nail clippers (for powder pillows)	x
200	Rubber lab gloves	x
1	Customs letter	Susan Murcott