
CASE STUDY: INTERNATIONAL COMPOSTING TOILET SYSTEMS

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January 2, 2013

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PURPOSE & SCOPE

The purpose of this report is to provide a baseline study of existing technologies for sanitation worldwide. Evaluation of the technologies' successes and shortcomings will inform the construction of guidelines and practices for the Thermopile Project, a small-scale , centralized composting process of human waste.

EXECUTIVE SUMMARY

This case study addresses the current technologies implemented worldwide for composting human waste in developed and developing countries. Systems include composting toilet systems, urine diversion systems, vacuum toilet and plumbing systems, vault latrines and centralized composting systems. Many of the systems explored have struggled to reach the temperatures or pH required for pathogen destruction and sanitization. User acceptance was not achieved in many systems that lacked proper maintenance, education, outreach, marketing or that drastically altered cultural and religious practices of use. Some problems arose in systems such as odor, fly breeding and system backups or reaching capacity sooner than anticipated. Owner or operator negligence of the systems were the primary cause of system and project failure.

The majority of these systems lack the ability to ensure that proper temperatures are achieved in the composting process in order to eliminate all harmful pathogens. The Thermopile Project is a properly designed system with sufficient protocols, data collection and recording to ensure the composting environment is sufficient to eliminate all pathogens. This project is designed to overcome the barriers seen by regulators with an end goal of implementing the process worldwide with a high acceptance rate.

This study includes analysis of six international composting toilet system manufacturers, Clivus Multrum, WC-Dubblatten, Aquatron Separator, Enviro-Loo, Rota-Loo and TerraNova. Specific buildings or villages where these systems are implemented are also included when the information was available.

SYSTEM MANUFACTURERS

Clivus Multrum

www.clivus.com

USA, Canada, Australia, Korea

Clivus Multrum is one of the world's largest composting toilet system manufacturers. Clivus distributes to Australia, Scandinavia, Chile, Israel, Korea, the Netherlands, Russia, the United Kingdom, the United States and several other countries. With several models to choose from and over 70 years of experience in the industry, Clivus Multrum offers systems for a wide variety of applications. They advertise that their systems eliminate all harmful pathogens from human waste where the finished solid compost can be used in home gardens and the liquid compost can be mixed with water and used to irrigate flowers, trees and grass. Clivus Multrum offers waterless, micro-flush and vacuum flush systems. Clivus Multrum also provides graywater recycling systems.

Implementation

A few examples of locations with Clivus Multrum composting toilet systems are as follows, however a more extensive study of Clivus Multrum can be found in Case Study: Composting Toilet Systems in the United States (Pecora, 2012).

Australia

- Eungella Dam, North Queensland
- Pajingo Mine, Cartyers Towers, Queensland
- Dhimurru Land Management, Northern Territory
- Kanyana Park, Dulong, Queensland
- Edithvale Wetlands, Vic.
- Kata Juta, Northern Territory

Sweden

- The Stockholm Archipelago Foundation
- Susedalen, E6 Motorway Service Area
- Dalsland and Nordmarken camping sites

Dubbletten

www.dubbletten.se

Sweden

The WC-Dubbletten toilet is a urine separating composting toilet system that was designed and first distributed in Sweden. The Dubbletten uses 0.5dL of water to flush with and provides an option to flush after urination.



According to Lens et al (2008) the solid waste can be applied to land after six months, however owner and co-founder, Bobby Mrozowski recommends the waste is composted in a dual holding tank for six months prior to being composted outdoors for a year before it is used. Most Dubbletten systems are installed with a dual composting tank where the first tank is used for a period of six months, and then left to begin the composting process as the other tank is used for the next six months. After this twelve-month period, the tanks are emptied into an outdoor composting pile for twelve months. Dubbletten toilets store urine until it is ready to be used as fertilizer, when it is then diluted with water to achieve a 10:1 ratio.

Aquatron

www.aquatron.se

Sweden

The Aquatron system is a mechanical separator that uses the momentum of water after flushing, along with centrifugal force and gravity to separate liquid and solid wastes. It can be used with standard water closets with flushing volumes from 3 to 6 liters, but can also be used with urine-separating toilets. The solid waste falls into a composting chamber where it is composted by bacteria, and if desired, worms. The liquid proceeds to a UV unit, which kills bacteria and viruses. The liquid is then considered graywater and can either be reused or infiltrated.

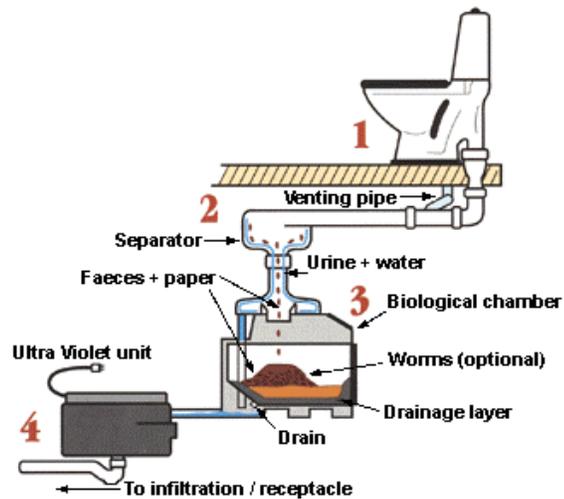


Figure 2: Aquatron Separator (www.aquatron.se)

Enviro-Loo [Enviro Options]

Waterless Toilet, non-separating

South Africa

www.enviro-loo.com

The Enviro-Loo is a unique system where solid and liquid waste is combined until it reaches the composting chamber. The underground chamber contains a sloped perforated plate, which divides the container into



Figure 3: Enviro-Loo (www.enviro-loo.com)

two compartments. The urine and water seep through the plate where it is collected in the bottom compartment. The solid waste moves down the sloped plate where it is aerobically decomposed. A vent out of the composting chamber in combination with a solar heated compartment aids in creating negative pressure in the system, which eliminates odors from venting through the toilet fixture. Air is drawn into the system through a side inlet pipe and the toilet fixture itself. The airflow passing through the system causes the urine to evaporate quickly and gasses to escape through the vent pipe. The vault is emptied every 6 months to 3 years depending on use, however the maximum capacity for this system is 20 users per day.

Enviro Options' Enviro-Loo won the Intel Environment Award in 2005.

Implementation

The Enviro-Loo is implemented at the Council for Scientific and Industrial Research in Pretoria, the Cape Leopard Trust and in the city of Cape Town, South Africa.

Rota-Loo [Environment Equipment Pty Ltd.]

www.rotaloo.co.uk

Australia

The Rota-Loo is manufactured by Environment Equipment Pty Ltd and is a rotating drum composting toilet system. The company was established in Australia in 1974 and is distributed worldwide. Each turntable contains six to eight drums that can easily be emptied from outside the bathroom. The technical information states that by the time the "full" drum rotates back into use, the content will have reduced by 2/3rds. There is a constant fan blowing warm air over the wedge-shaped composting bins to help speed up the decomposition process. Because of this design, the rotating drum must sit directly below the toilet fixture. Because water is not used for flushing, the composting is done aerobically which eliminates the anaerobic decomposition smell associated with sewers and septic tanks. Rota-Loo toilet fixtures come in both a straight drop and a urine diverting design. In using the straight drop toilet design, the urine filters through the solid waste and through small holes in the bottom of each drum where it is collected in the bottom chamber. A steady warm airflow is provided with a small fan that pulls air through the toilet fixture and solid waste and over the liquid, thus evaporating the urine.

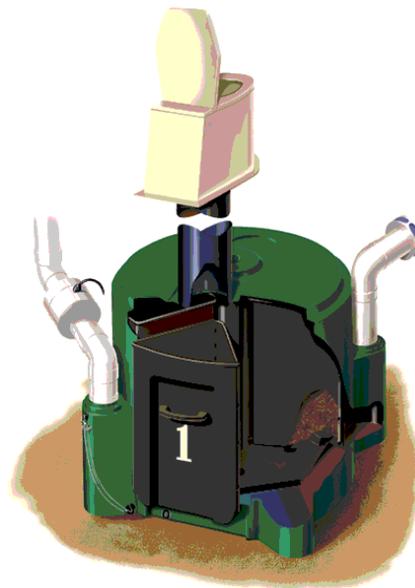


Figure 4 Rota-Loo System

www.rotaloo.co.uk

The Rota-Loo composting system is approved by the Environmental Protection Authority and Health Departments throughout Australia. It is available in the US, Canada, Australia, New Zealand and Europe.

TerraNova

Germany

www.berger-biotechnik.com

The TerraNova composting toilet system was modeled after the Clivus Multrum systems. The composting chamber is insulated and connected to each toilet (4 toilets are able to connect to one composting chamber) by a vertical pipe. The container is vented to the roof and an electrical and wind powered fan supply oxygen in order to aid in the composting process as well as create a negative seal to prevent odors from venting through the toilet fixture. The chambers are designed to compost both human waste as well as kitchen and garden waste. It is advertised that the material can be removed and used after at least 2 years. These systems can be implemented easily in multi-story buildings with a capacity of one to eight households.

INTERNATIONAL SYSTEM IMPLEMENTATION

Africa

Ecological sanitation implemented urine-diversion dehydration toilets (UDDT) in rural Dayet Ifrah in Morocco. The project was adopted and accepted by the residents primarily because of social marketing that showed the residents how beneficial the system is over the common practice in Dayet Ifrah of defecating in nature.

The first system implemented in Dayet Ifrah was comprised of two alternating pits. After about a year of use, the pits are alternated. Ash is used as an additive to cover excrement and destroy *E. coli* and *Enterococcus* spp. After the filled pit is allowed to sit for a year, the contents are emptied where they are either allowed to decompose further, or used as a manure fertilizer.

The systems were widely accepted in Dayet Ifrah. The systems provided not only a valuable practice for recycling human waste, but provided a private and secure place to defecate, in contrast to their previous defecating in nature practice (Abarghaz, Mahi et al, 2012).

China

The Swedish International Development Cooperation Agency (SIDA) is a Swedish governmental agency focusing on international development. SIDA and

EcoSan have partnered to develop ecological sanitation in developing countries. Swedish ecological sanitation activities started in the northwest Guangxi province under the SanRes Programme in 1997 and since has spread to 17 provinces in China and installed 685,000 rural urine diversion dry toilets.

The current project is located in Hoazhaokui Village in the Dongsheng District in the Erdos Municipality. Donsheng is one of the richest mining towns in China however only one-third of households in the city have flush toilets. In a population of 400,000, the remaining two-thirds of the population share 370 public toilets, most of which are pit latrines.

Phase I of the Erdos Eco-Town Project (EETP) includes building a neighborhood of 40 four to five-storey buildings and 16 two-storey buildings in the southern Haozhaokui Village. These structures will house 826 households for a total of 2,900 people. In Northwestern Hoazhaokui, an Eco-Station will be built that will process all waste from the 56 buildings. It will be equipped to treat and recycle graywater as well as compost fecal material. The composting combines feces and kitchen waste with added carbon and “effective bacteria” to compost at high temperatures.

By the end of 2005, 32 four and five storey buildings were completed and sold. Specially designed urine diversion toilets were installed with direct chutes to a basement feces container and urine storage tanks. The toilet fixture has a push handle to deposit sawdust before and after use. Feces drops into bins located in the basement which are collected every three months and composted along with kitchen waste at the local eco-station. When the urine tanks are full, a vacuum truck removes the liquid for fertilizer. The urine diversion plumbing is designed to avoid crystallization by sloping the outdoor pipe steeper than 0.5% and ensuring the pipe diameter is no less than 100mm.

After nine months of the project being installed and used, the only problems involved odors and people using water to clean the bowl. The odor problem was due to the project not being fully completed with fans, airtight fittings etc. Another problem was the psychological resistance of the people using these non-modernized systems in their urban environment. Overall, the project and systems performed as anticipated (Zhu, 2006).

The China-Sweden Erdos Eco-Project is an attempt to generate data, technologies and policies required to bring about major change in the way human settlements relate to the environment.

A similar project was also conducted in Gerbers, Stockholm in a nursing home that was converted into a cooperative living apartment building (Winblad & Simpson-Hebert, 2004).

El Salvador

Ecological sanitation has been promoted in El Salvador by the Ministry of Health, UNICEF and several non-governmental organizations and has resulted in the installation of over 400 household double vault urine diverting toilets and single-vault solar toilets. After approximately five years of use, a study was done on 118 double vault urine diversion toilets and 38 solar toilets in El Salvador. Tests measured temperatures, pH and microbial properties.

It was found that temperatures were barely reaching above the ambient temperature, and therefore it was assumed that aerobic composting was not taking place. In the solar toilets, temperature varied depending on the time of day and outside temperature. From microbial analysis, neither toilet produced material that could be classified as Class A biosolids by the USEPA. Biosolids from the solar toilets contained a higher concentration of coliphage and *C. perfringens* (the chosen indicators along with fecal coliform), but was effective in eliminating *Ascaris ova*. In contrast, approximately 41% of the double vault urine diversion toilet material contained *Ascaris ova*. Currently, composted waste is being disposed of or used in agricultural application, however this study conducted by Emory University shows that agricultural application may not be the most hygienic and sanitary practice due to the lack of pathogen destruction (Moe & Izurieta, 2003).

Germany

The village of Flintenbreite in Lübeck, Germany has integrated a sanitation concept with vacuum toilets and a biogas plant. The population of Flintenbreite is approximately 350. The biogas plant processes blackwater and kitchen waste. The vacuum flush toilets use 0.7 liters of water per flush and a vacuum system for all blackwater transportation. Once the blackwater has reached the biogas plant, it is treated anaerobically with solid biowaste to produce liquid fertilizer and biogas. Biogas is in turn used for heat and power generation along with natural gas. The energy balance of this project is positive due to the utilization of biogas for electricity and the elimination of chemical and industrial fertilizers (Winblad & Simpson-Hebert, 2004).

TerraNova composting toilets have been installed in Germany for several decades. The ecological settlement of Bielefeld-Quelle has been using these toilet systems since 1999 in a four-story building and a public kindergarten. When asked for feedback, members of this settlement complained of the heavy lifting required during maintenance of the toilets and would prefer not to spend the time or labor on system maintenance. Starting in 1995, an old villa in Rostock, Germany was renovated into shops and restaurants with TerraNova composting toilets and Aquatron separators. The composting toilets were for customers, however regulations stated that restaurant waiters must use a flush toilet, so Aquatron separators were attached to low flush toilets to serve this purpose. This

project was given a limited 7-year approval and after data demonstrated the composting toilets were hygienic and sanitary, the project was given a subsequent 7-year approval. The project overall was a success and was attributed to a widespread understanding of how the system works (Berger, 2003).

Haiti

Sasha Kramer co-founded Sustainable Organic Integrated Livelihoods, or SOIL, in Port au Prince, Haiti in 2006. The project began implementing double vault urine diverting composting toilets throughout the city of Port au Prince. Since 2009, the project steered away from the double vault and replaced the systems with a 15-gallon drum collection system. The drums are collected once a week and brought to a centralized composting facility located at the city dump. The composting facility processes 3,000 to 5,000 gallons of waste per week and to date has produced over 600,000 gallons of compost. The most common cover material is sugarcane bagasse, peanut shells have also been used but do not allow for the aeration in the piles as well as the bagasse. The composting takes place in bins constructed of pallets insulated with bagasse on a concrete floor with a drain for leachate. Collected leachate is added back into the middle of the pile. Finished compost is sold at \$6 per cubic yard and currently being used for nursery planting and rehabilitation of the composting site in order to replant native species. A study done by the CDC reported the levels of *Ascaris* eggs were dying off as quickly as the *E. coli* in SOIL's composting process (Kramer, personal communication, 2012).

SOIL has provided safe ecological sanitation (EcoSan) to over 20,000 Haitians displaced by the 2010 earthquake and continue to serve 9,000 Haitians currently still in displaced persons camps and 5,000 people in Cap-Haitian (Flammer, 2012).

Mexico

In 2003 Tepoztlán, Mexico began a project to retrofit buildings and structures with urine diverting single- and double-vault composting toilet systems. The population of Tepoztlán is 34,000. The project is focused on designing a range of eco-san toilet programs, developing urine-harvesting systems (such as waterless urinals for both men and women), establishing eco-stations, addressing the graywater challenge, advocating for sustainable wastewater management, developing municipal environmental and municipal sanitation regulations and conducting environmental communication and education outreach (Winblad & Simpson-Hebert, 2004).

Panama

144 active double vault urine diverting (DVUD) composting latrines were analyzed in a six-year study of the Bocas del Toro region of Panama. The analysis

included taking measurements of temperature, pH, moisture content, carbon-nitrogen ratio, and presence of pathogens. It was found that composting latrines do not reach the temperatures required for pathogen destruction. The latrines were operating within the pH range ideal for aerobic decomposition, but only 17% of latrines measured a pH of 9 or above required for pathogen destruction in non-thermophilic composting. The recommended amount of sawdust and wood ash were not sufficient in reaching the ideal carbon-nitrogen ratio for aerobic composting. After six months of composting, pathogens and helminthes were still present in the material.

The average temperature recorded in the composting latrines was 29.5°C and it was determined that for a six-month composting period, temperatures of at least 42°C were necessary. The average pH value of the 46 samples taken was 7.7, which is ideal for thermophilic composting but a pH of at least 9 is necessary for pathogen destruction without thermophilic composting. The average moisture content was 46% of the five samples analyzed in the lab. Carbon-Nitrogen ratios varied between 5.4 and 9.2, which is about a third to a fourth of the desired ratio. *Ascaris lumbricoides* (roundworm eggs) were found in all five samples of compost, with *Trichuris trichura* (whipworm) and *Taenia solium* (pork tapeworm) present in one and two samples of the five respectively. *E. coli* levels were 800 CFU/g which is lower than EPA Class B biosolids requirements. Overall the compost was not reaching the necessary temperatures or pH to destroy pathogens (Mehl, Kaiser, Hurtado et. al (2010).

Palestine

SIDAs sponsored EcoSan Pilot Project in Palestine implemented 30 facilities in individual households from 2000 to 2002. The project also built capacity in operating and maintaining these dry sanitation systems in partnership with Palestinian Hydrology Group (PHG). This project focused on the water situation on the West Bank, where there is deteriorating groundwater, inadequate rainfall, polluted springs, no fresh surface water, and high costs of water supply and wastewater disposal. According to Winblad (2002) “80% of the rainwater falling on the West Bank (average 350-450mm/year...) is appropriated by Israel. Municipal piped water systems can provide only 45% of demand for the Palestinian population.” Dry sanitation, urine-diverting systems are ideal for Palestine’s, dry, hot climate and the availability of lime powder from quarries and workshops is abundant.

After review of 20 of the 28 systems put in place, many were operating as expected. Some had a faint smell and it was assumed that liquid was entering the fecal container and insufficient lime ash was being added. Many residents emptied urine and anal cleaning water into cesspits or septic tanks, while some diluted with water and fertilized tomatoes and olive trees. For residents who had already emptied the fecal chambers, some used it at the base of olive trees while others dumped it with their household waste.

The social aspect of these systems was widely accepted as handling of fecal material in Palestine is not taboo as it is in many other parts of the world. The obvious water savings are evident to residents and allows more water for use in the household. The system also provides a free fertilizer for use in home gardens. SIDA and EcoSan have conducted certain microbiological tests that have shown in most cases after a couple months all viruses are totally eliminated. The project overall is considered to be a success (Winblad, 2002).

South Africa

South Africa has been attempting to eradicate the sanitation backlog that presented itself during the apartheid. In an attempt to provide sanitation to South Africans, the government has considered a ventilated improved pit latrine (VIP) “as the basic minimum requirement for sanitation technology.” Unfortunately, it seems as though many problems have arisen from this technology.

Some of the issues reported with VIP’s is that the pits are filling up faster than calculated, non-degradable objects are going into the pits, disinfectants used are disrupting pit stabilization, poor construction has led to fly infestation, odor and structural integrity, greywater is added due to lack of graywater disposal locations and the necessary anaerobic activity is lacking.

The risk of building VIPs without a structure for disposal and removal of the contents in the pit makes handling of the waste quite risky. “Long term operation and maintenance support must be considered when scaling up in the use of the technology.” While dry sanitation VIPs are able to provide longer term and safe sanitation, if they are mishandled, they too can be proven to be risky in regards to pathogens and helminth eggs. Along with the issues listed above and odors do not make this technology socially acceptable and does not allow for the upgrading of on-site systems (Bhagwan, Still, Buckley & Foxon, 2008).

Emzamweni High School in South Africa is rurally located in the KwaZulu-Natal province where ecological sanitation was implemented as a demonstration project. Most sanitation in South Africa is comprised of failing pit latrines. The school principle and teachers were responsible for teaching their pupils how to correctly use the facilities. Educational materials were printed and presented, but to no avail, the system failed due to lack of maintenance. Weeks after the toilets were built, they had already been vandalized with rubbish in the toilet vaults, feces in the urine trough, insufficient ash additions, cleaning had not been conducted regularly and the facilities had begun to look like the previous abused, malodorous pit latrines. The failure of this project was due to the negligence of the school principle and teachers to ensure proper use of the system, which was hypothesized due to lack of resources (Austin, 2003).

Sweden

The Elias Fries School in Hylte Kommune in Sweden has approximately 300 students under the age of twelve. The school has urine diverting toilets and Aquatron Separators. The urine is held in tanks and is emptied twice a year by farmers who use it as fertilizer. The feces is composted for one year after emptying the underground tanks and is used within the school yard, although it is a very small amount. This system has run successfully since 1995 (Druitt, 2009).

Many of the 250-inhabitants of the eco-village Kullön near Stockholm also installed Dubbletten toilets. The case of Kullön is interesting because of how the municipality became involved. After the installation of the Dubbletten systems, the urine was stored in tanks with the intention of being used as fertilizer by farmers nearby. However, due to lack of organization, urine was not collected between 2001 and 2005 and overflowed into the wastewater treatment plant. The municipality, who originally did not want to be involved, was forced to interject themselves into the project. The municipality is currently responsible for contracting farmers to collect urine from the storage tanks in Kullön. The price of storage, transportation and spreading of urine has caused residents to pay a higher price for wastewater services. The urine is currently transported to Hankunge, a farm approximately 25 kilometers away from Kullön. Hankunge stores the urine for six months in a 340 m² storage container equipped with floating hexagonal pieces that limits the amount of gasses and odors emitted. After the six months of storage, the urine is applied on arable land (Druitt, 2009).

Dubbletten systems are implemented in the Understenhojden eco-village in Bjorkhagen, Sweden (a few km south of central Stockholm). The residents of Understenhojden installed Dubbletten toilets where the urine and water are stored in two 40-m³ series-tanks. About once a year, the urine is transferred to a holding tank by Lake Bornsjon until it is later used for fertilization of cereal crops. The remaining solid waste and graywater continues onto a biological treatment plant on site, which is not permitted at this time for land application due to the high Phosphorus levels. The treated water does however meet the BOD (biological oxygen demand) and hygiene requirements for land application. Overall, the residents are satisfied with their urine-separating toilets (Druitt, 2009).

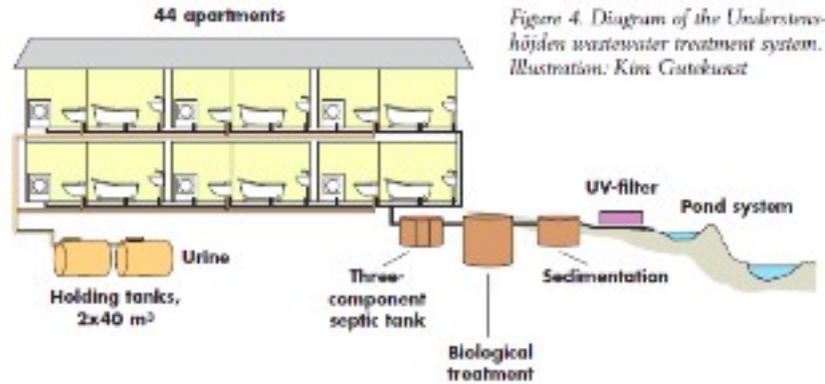


Figure 1: Understenhöjden Village Sanitation Treatment (*The Swedish Eco-Sanitation Experience*)

The municipal housing company of Ekoporten renovated an apartment building in 1996 in the town of Norrköping, Sweden and installed Aquatron separators. The 18-apartment building stores urine for land fertilization, feces is mixed with kitchen and garden waste along with wood pellets and composted for use in vegetable and flower gardens (Winblad, 2004).

Uganda

Two months after a series of urine-diverting vault toilets were built in Ddimu, Uganda, the toilets were deemed almost unusable. The stench radiating from the toilets were unbearable, flies had flocked to the area in large quantities and the fees being charged for use were quite high. The quick failure of this project resulted from the poor understanding of the technology, poor community participation, insufficient operations and maintenance and cultural and religious taboos. The community was “re-sensitized” after three months of the toilet construction, and the project began to improve and function more properly (Kaggwa et al, 2003).

United States

Citilogs in Massachusetts is currently working with the United States Environmental Protection Agency, the State of Massachusetts and the City of Cape Cod to implement a series of Dubbletten-Aquatron systems. The hopes of this implementation is to license the Dubbletten-Aquatron system as a state approved plumbing device, which they can then leverage to surrounding state authorities to expand the implementation country-wide. Two EPA agents highly recommend the system after becoming familiar with the system in Australia. The main advantage, according to Chief of Operations at CitiLogs, Stubby Warmbold, is that because the Aquatron relies primarily on centrifugal force, toilet fixtures can be placed 60 feet horizontally from the Aquatron system. This distance is not achieved by conventional foam flush or dry toilet systems. This system is not

currently in use in the United States, however because of the state of sanitation in Cape Cod, the system is especially attractive and they are planning to implement 18 systems in the near future (Warmbold, personal communication, 2012).

Viet Nam

The United Nations Millennium Task Force on Water and Sanitation put forward among others, a pledge for governments to “support sanitation solutions that are technically, socially, environmentally and financially appropriate”. In doing this, it is important to recognize the centuries old practice of applying raw human waste as agricultural fertilizer. This tradition has since been abandoned by Europe, but is still prevalent in China and Viet Nam, regardless of the health consequences of handling such material. According to the National Institute of Hygiene and Epidemiology in Hanoi, Viet Nam more than 75% of farmers were reported to be using fresh or partially composted human waste as fertilizers. Professionals believe that this practice is largely in part the reason for the estimated 22 million Vietnamese with hookworm infection and the 530 million people in China infected with *Ascaris*.

The most common Vietnamese sanitation system is a double-vault latrine where farmers can store waste until it is needed on the land. In a project in Xom Ha, 30% of latrines were destroyed in order to gain access to the human waste for fertilizer. Legislation has now been put in place in Viet Nam that requires farmers to comply with the minimum six-month composting time period prior to application on agricultural land. Due to the common crop rotation in Viet Nam, with 3 crops per year, it would be more likely that farmers would empty the vaults every four months instead of the required six.

It is proposed by Jensen et al (2005) that sanitation technology in places such as Viet Nam be focused on shortening composting time to fit within the agricultural schedule of the farmers and not only focus on hygiene, but on safe fertilizer production as well in order to achieve the utmost success.

Yemen

Several multistory buildings in Yemen have implemented urine diverting composting toilet systems. In buildings anywhere from 5 to 9 stories high, straight drop toilet systems have been built with squatting holes built into the floors of apartments. The feces drop through the squatting hole into a vault located at street level, where it is periodically collected. After collection, fecal material is dried on the roof of neighborhood public bathhouses and used for fuel to heat water later on. Urine is drained away from the squatting hole and goes through an opening in the wall where it is drained on the outside of the surface and eventually evaporates. This system has been in use for hundreds of years in Yemen (Winblad, 2002).

FINDINGS

Through studying several composting toilet projects implemented worldwide, a common theme of uncertainty underlies the majority of the systems. Whether the uncertainty stems from improper use or it is related to the inadequacy of the piles to reach the temperatures or pH to ensure pathogen destruction, the uncertainty of the process in general hinders the widespread acceptance of the technology. With systems failing around the world, this process becomes more and more risky in the eyes of regulators and the necessity for a safe and routine process is strong. The Thermopile Project provides regulators and societies with the data and protocols to ensure safe handling and complete pathogen destruction in a simple, easy to use design.

The findings in this study closely mirrors those found in the United States' composting systems. Most, if not all composting toilet systems in the United States do not operate as intended and advertised, specifically in regards to achieving proper temperatures for pathogen elimination. These shortcomings are addressed and solved by the Thermopile Project and have impact when applied worldwide, in developed and developing countries alike.

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