THERMOPHILIC CO-COMPOSTING OF HUMAN WASTES IN HAITI

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ABSTRACT

Sustainable Organic Integrated Livelihoods (SOIL) is an organization that has been working on ecological sanitation in Haiti since 2006. Haiti has the lowest sanitation coverage in the western hemisphere and prior to 2011 had no centralized waste treatment sites. In 2009 SOIL developed Haiti's first waste treatment site to treat human faeces using thermophilic co-composting. Since the earthquake in 2010, SOIL has worked to improve its composting design that eliminates pathogens and creates a nutrient rich compost for re-use in agricultural and reforestation projects.

SOIL's thermophilic composting process uses bagas (a sugarcane by-product) and human faeces to create a composting environment which reaches and maintains temperatures of over 65°C for a period of more than 1 month. Temperatures are monitored regularly at the site and a more recent focus on the edges of the bins has revealed that the temperatures are not homogeneous throughout. During the summer of 2012 SOIL collaborated with the US Centers for Disease Control and Prevention (CDC) to test for specific pathogen die off rates within the compost piles including E. coli, Ascaris and Vibrio cholera. While initial results have shown rapid destruction of basic indicator pathogens, more definitive results concerning the presence of the more resistant pathogen, viable Ascaris, are expected during the fall of 2012.

Compost produced by SOIL is currently used in experimental gardens as well as in a land rehabilitation project in Port-au-Prince's municipal landfill. In order to ensure that this compost is pathogen-free, SOIL will continue to refine the composting design, including piloting a new turning scheme, and identify a method of regular testing of the compost.

Keywords: COMPOST, ECOLOGICAL SANITATION, HAITI, SOIL, THERMOPHILIC COMPOSTING

INTRODUCTION

Waste Treatment in Haiti

As of 2010, only 26 % of the approximately 10 million people living throughout Haiti (44% urban, 19% rural) had access to improved sanitation (WHO/UNICEF, 2012) and no formal waste treatment facilities existed. Those without access to improved sanitation either practiced open defecation, or used plastic bags or unimproved pits, and existing latrines and septic tanks were disposed of in canals and other waterways throughout the country.

DINEPA (Direction National de l'Eau Potable et de l'Assainissement), the government agency responsible for the country's water and sanitation, was created in March of 2009 (Corps Legislatif, 2009). Prior to DINEPA, individual municipalities were responsible for managing sanitation and waste treatment independently. Common practice allowed desludging entities from both the formal and informal sectors to dispose of untreated sludge in open fields, estuaries, and solid waste dumpsites.

On January 12, 2010, nearly a year after DINEPA's inception, a catastrophic 7.0 magnitude earthquake struck Haiti, prompting the creation of over 1,300 spontaneous IDP camps to house the estimated 1.5 million people who lost their homes. The earthquake and subsequent cholera outbreak in October 2010 lead to what would become the largest-ever international humanitarian effort. To remove the human wastes from the camps, DINEPA and the international community managed desludging fleets disposing of 900m^3 of sludge each week in hastily dug pits in the Port au Prince dump, before finally constructing waste stabilization ponds in September of 2011 (UNOPS, 2012). Located on the outskirts of Port-au-Prince, these stabilization ponds are the first of 8 similar facilities planned by DINEPA to be constructed around the country (UNICEF, 2012).[1]

Unfortunately, although the sanitation situation in Haiti is improving, there is a tremendous gap between DINEPA's waste treatment capacity and the amount of waste being produced by the country's population. Additionally, DINEPA faces significant funding challenges, limiting the possibility for expansion and capacity building, which in turn prevents DINEPA from effectively meeting the needs of the population. As a result, diarrheal disease remains one of the leading causes of death in children under five, while cholera has claimed more than 7500 lives in just under two years (MSPP, 2012).

SOIL 2006-2012

Founded in 2006, SOIL (Sustainable Organic Integrated Livelihoods) is a 501(c)3 US-based non-profit organization dedicated to protecting soil resources, empowering communities, and transforming wastes into resources in Haiti. SOIL has focused on working with communities to promote Ecological Sanitation (EcoSan), where human faeces and urine are viewed as nutrient-rich resources to be captured and used to replenish the environment, rather than wastes to be discarded. EcoSan promotes a cycle from waste to resource, working to rebuild Haiti's depleted soils using nutrients and organic matter from human waste. Following this idea of "closing the cycle" SOIL works not only to improve sanitation coverage but also to transform and re-use the nutrients captured for agricultural and reforestation purposes.

After piloting various EcoSan toilet models, SOIL installed 50 permanent double-vault, urine-diversion toilets in and around the city of Cap-Haitien, believing that the decomposition occurring within the closed toilet vaults would produce quality compost. After opening the first vault in 2008, SOIL discovered that, in Haiti's humid climate, secondary composting would be necessary to render the final product safe for re-use. In late 2009, SOIL purchased land for a permanent secondary-composting site in nearby Limonade and constructed the first compost bins as part of a project with Oxfam-Great Britain. Just a few months later, the earthquake hit and SOIL's focus turned to the emergency response.

In March 2010, Oxfam-GB approached SOIL to do an EcoSan pilot project in the camps of Port-au-Prince. Working closely with the initial pilot community, the SOIL team designed an elevated, temporary UDT that diverted urine to a soak-away pit and collected faeces in sealable 15-gallon drums. SOIL implemented a weekly collection system where filled drums were removed from the sites and replaced with clean drums.[2] Sugarcane bagas was also provided to sites on a weekly basis to be used as cover material. Encouraged by the tremendous success and high demand for the clean and odour-free EcoSan toilets, SOIL continued to expand operations

[1] A 2nd was opened, also in Port-au-Prince, in May of 2012
[2] Sufficient drums provided for two weeks of operations at each toilet site

until reaching a peak in October 2010 of 200 toilets across 32 sites, supporting an estimated 23,000 Port-au-Prince residents.

This new toilet design marked a significant transition in SOIL's strategy, as the toilets' functionality and the transformation of faeces collected were now dependent on off-site, centralized composting facilities. In June 2010, SOIL began developing compost bins that utilized the principles of thermophilic co-composting to safely treat human faecal waste and transform it into nutrient rich compost.[3] By September 2010, SOIL was operating Haiti's only waste treatment facility and was composting approximately 5,000 gallons of waste each week.[4]

THERMOPHILIC COMPOSTING

<u>Phases of Microbial Activity</u>

Although there are a variety of composting methods, thermophilic composting is a rapid aerobic decomposition process performed by microorganisms that reaches temperatures over 45°C. The advantages to a thermophilic system as opposed to mesophilic or "ambient" systems include higher rates of degradation and rapid inactivation of pathogens. A successful thermophilic composting process is marked by three distinct phases, each with different microorganisms and temperature levels:

1. Mesophilic or moderate-temperature phase: Lasting from a few hours to a few days, this phase is characterized by mesophilic microorganisms (MMO) breaking down soluble, easily degradable compounds, releasing heat and increasing the general temperature.
2. Thermophilic or high-temperature phase: Remaining in this phase for up to several months, the MMOs are outcompeted by thermophilic microorganisms (TMO) as the temperature rises above 45°C. The TMOs rapidly break down high-energy compounds during this phase, and high rates of human pathogen destruction are observed above 50°C.
3. Curing or Maturation Phase: Lower supplies of degradable high-energy material lead to a drop in temperature and MMOs are able to again outcompete the TMOs and break down the remaining organic material. Reaching a stage of full decomposition could take several months (Jenkins, 2005).

Phase length varies greatly and is dependent on the type of organic matter being broken down, as well as the ability to maintain optimal conditions for the microorganisms in the respective phases (see next section).

<u>Optimal Environmental Conditions</u>

Thermophilic composting relies on microbial activity, optimized by controlling the following factors:

- Carbon/Nitrogen Ratio – A ratio of 30/1 allows for rapid decomposition and because human faeces have a ratio of 6-10:1, carbon-rich materials must be added to achieve this.
- Aeration – Decomposition in thermophilic systems is reliant on aerobic microorganisms, although a balance must be found for airflow, as a low flow will result in odors and poor digestion, while high flows could cause heat loss and slow process (Harlan G. Kelly, 1993).
- Moisture content – Ideal conditions would be 45-60%, as anything lower would be too dry for needed microbial activity while too much moisture could lead to anaerobic conditions.
- Ambient temperature –Potentially a limiting factor for reaching thermophilic conditions, although environments with temperatures between 0-10°C have been shown to reach core temperatures of 66°C (Rosa Margesin, 2006).

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[3] With the initial help of humanure expert Joe Jenkins.

[4] Including bagas used as cover material, where the faeces-bagas ratio varied by site

<u>Pathogen Destruction</u>

While the type and quantity of pathogens will depend on local sanitary conditions as well as climate, there is always a high risk of finding pathogens within human faeces. Parasitic varieties of bacteria, viruses, protozoa, and helminthes can all be found, with some varieties pertinent to Haiti listed in Table 1.

Table 1 Human Pathogens in Haiti

Type	Name
Helminth	*Ascaris*
Bacteria	*Salmonella typhi*
Bacteria	*Vibrio cholerae*
Bacteria	*Escherichia coli*

The pathogens listed in Table 1, as well as many other human pathogens that can be found globally, represent a significant human health risk if ingested. They can cause various illnesses, some of which are fatal if left untreated. It is possible to eliminate human pathogens in thermophilic systems by following standard procedures for achieving die-off, primarily maintaining high temperatures for a sufficient period of time. Below is a graph that shows die-off over time for *Ascaris* and *Vibrio cholera,* among others.

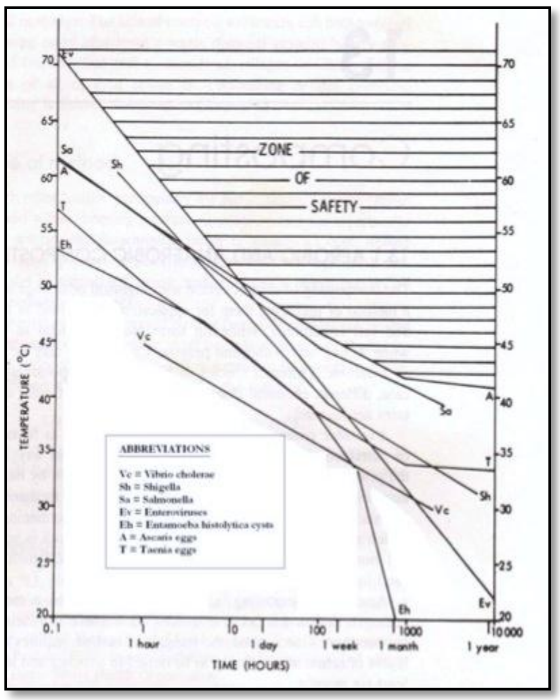

Figure 1 Pathogen Die-off at Sustained Temperatures **(Cairncross, 1999)**

One can observe from this graph that although there are other pathogens that are more resistant to heat in the short term, *Ascaris* is the most resistant over time. While varying slightly depending on agency and country, the basic standards require what the graph in Figure 1 refers to as the “Zone of Safety.” The WHO, for example, requires matter containing human faeces to be subjected to temperatures greater than 50°C (122°F) for at least one (1) week to ensure adequate reduction of human pathogens (WHO, 2006)**.** The US Environmental Protection Agencies standards are a bit different. For consideration as a Class A Biosolid, which is indicative of the pathogen density and regulations regarding land application, matter must be held at 55°C for three days in a static pile, or 55°C for 15 days in a windrow situation where the matter will be turned a minimum of five times (US EPA, 1994). This ensures that pathogen density will be reduced enough for the biosolids to be used for land application.

SOIL'S COMPOSTING PROCESS

Compost Engineering

Despite SOIL's confidence in its current composting practices, the foundation continues to refine its bin design to achieve higher levels of control and homogeneity within the system. The most current designs have a treatment capacity that varies between approximately 14 and $18m^3$, consistently filling at a rate of about two weeks since mid-2010.[5]

SOIL's bins are designed to use locally available, low-cost materials without jeopardizing any of the necessary factors to achieve sustained high temperatures. The bins are built on a 100mm thick cement foundation that also has a 150mm high wall around the perimeter. Set at controlled gradient in order to direct excess liquid to a corner outlet for collection, the foundation's main purpose is to prevent leachate from filtrating into the surrounding soil. Bins are covered by an angled roof of metal sheeting that at its lowest point is 2.5m from the top of the walls, allowing more precise control over the moisture content within the pile.

The bin walls are built out of wooden pallets, secured into the foundation by wooden 2x4s to maintain the bin's form. These pallets are also modified with additional slats, providing additional support for holding bagas but leaving sufficient space to facilitate aeration of the pile. One of SOIL's designs also includes an inner holding wall made of thick metal mesh to allow a 6-inch thick wall of bagas on four sides.

Once the physical structure is in place, there is additional preparation required prior to introducing faecal mixtures into the bins. As the temperatures in the pile will naturally be hotter in the centre and cooler on the sides, an insulating layer is created on all sides of the compost bin. The walls, with or without the thick mesh layer, are filled with bagas. There should also be a bagas layer on the pile's foundation, a minimum of 150mm (6") thick. An additional cover of bagas upon filling the bin is necessary to hold areas with high pathogen density away from the sides where temperatures are lower.

Compost Operations

Compost Team

There is a drum collection and drop-off schedule for the SOIL offices in both Cap-Haitien and Port-au-Prince. After drums arrive at a SOIL composting site, SOIL's trained compost teams empty and disinfect the 15-gallon drums on the same day as collection for a fee of 20 Haitian Gourdes (<0.50USD) per drum. SOIL's compost teams, as well as all employees that are potentially coming into contact with faecal matter, adhere to strict disinfection and hygiene protocols. The protocols exist to protect the health of employees and those they come into contact with, as well as to avoid (re) contaminating older compost piles. Although SOIL's disinfection and hygiene procedures are not within the scope of this paper, SOIL continues to improve its efforts at reducing risk within each step of the process.

Drum Monitoring

As many of the drums are coming from public toilets, SOIL inevitably has to be mindful of trash, chemicals, and other non-biodegradable items present in the drums. Not only could non-biodegradable objects create impermeable barriers to aeration and create unnecessary work in preparing the final product, but chemicals can also be harmful to the microorganisms necessary for proper thermophilic composting. SOIL's intensive education and monitoring practices at public toilets, including weekly supervision, have lead to very low incidence of improper use and early warning for potential issues, but the compost teams also are careful to check the contents of the drums before emptying them into the larger pile. A labor intensive drum tracking system is in place, with each drum numbered so that the SOIL compost teams can identify the origin of each drum and the sanitation staff can follow-up with users and operators.

[5] Assuming no "coning" of the pile

Carbon source for cover material and co-composting

In the six years that SOIL has been constructing and managing EcoSan toilets, cover materials have represented one of the most consistent challenges. Using appropriate cover materials, added to toilets in sufficient quantities, can ensure a properly functioning compost system. While there are a number of cover materials that could be appropriate, SOIL has found that sugarcane bagas and peanut shells work well for toilet users as well as in its composting system. SOIL piloted small woodchips from *Amyris elemerifera,* a byproduct of essential oil production, as a potential cover material. Unfortunately, although they were very successful with toilet users, the woodchips decomposed too slowly to work effectively with SOIL's composting system.

Another variable for the compost team to track is the consistency of the drums, i.e. the amount of bagas or other cover material used in relation to faeces. SOIL's general rule of thumb is to apply one 15-gallon drum of dry bagas per three drums of the faeces/bagas mixture. However, this practice can be modified based on the compost team's observations and recommendations. Mixing dry bagas in with the faeces/bagas mixture ensures proper moisture content as well as creating a good carbon/nitrogen ratio within the pile. This practice also helps reduce potential disease vectors (flies, birds) and unpleasant odors.

Leachate

As the compost bins fill, one of the compost controller's responsibilities is to manage the excess liquid, or leachate, that flows through the output at the corner of the bin. As the liquid may hold valuable nutrients and should not be lost, SOIL's common practice is to pour this leachate back into the pile until it can be absorbed and the flow towards the outlet ceases.

In addition to pouring the leachate, or "*ji kaka,"* over the pile, SOIL began to collect small volumes of urine from urinals installed in areas conveniently located near its compost site or on natural routes to/from the site. Recognizing that urine's nutrient value is much greater than faeces, urine is poured over the compost bins while in its maturation phase, boosting the nitrogen levels in the final compost. Although SOIL would like to complete more research on the measurable benefits of adding urine to compost piles, the logistical costs and time constraints during the post-earthquake emergency activities required a much more operation-centered focus.

Compost Stages

While there are three (3) microbial phases in thermophilic composting systems, SOIL manages the compost bins in 2 distinct stages: a controlled "hot" stage and a "windrow" or maturation stage:

- "Hot" Stage: This stage begins from the moment the first drum is emptied into the compost bins and concludes a minimum of 4 months from the day the last drum is emptied. Temperatures and moisture content are monitored[6] during this period as both the initial mesophilic phase and thermophilic phase occur in this stage. On average, temperatures reach 50°C in the center of the pile within 24 hours from the time the last drum is added. Precaution is taken to ensure no contamination between piles.
- Windrow Stage: At the end of four months, the now-sterile contents of the compost bin are moved into windrows. Although this has been done by hand in the past, SOIL now uses a bobcat[7] to efficiently create windrows with increased height (reducing total surface area). The biosolids will remain in windrows for a minimum of two months to allow for the remaining organic material to be broken down. Temperatures continue to be monitored during this phase, and the length of this stage is often longer when the temperatures in the pile have not yet reached ambient levels.

[6] Moisture content visually monitored by periodically digging into pile
[7] Brand name for a small, front-loading vehicle

Although the system described above could be completed in six months, SOIL has kept piles in both stages for extended periods of time due to time and logistical restraints, a low demand for finished compost, and slower than expected decomposition rates, indicated by temperatures remaining above 50°C.

Pathogen Control

Testing for Pathogens

Although SOIL's method of monitoring temperature should ensure pathogen die-off throughout the pile, periodic testing for the presence of pathogens within the final compost is the only way to confirm a properly functioning system. SOIL would like to test for *E. coli* as the standard microbiological indicator for faecal contamination and *Ascaris* ova, which is prevalent in Haiti and is the most resistant pathogen. While *E. coli* is not very difficult to eliminate in a thermophilic composting system, evidence that viable *Ascaris* ova have been destroyed could serve as a reliable indicator that all other human pathogens were eradicated.

While laboratories that perform basic soil testing do exist in Haiti, they either lost most of their equipment during the earthquake or have been proven to be unreliable. Even when functional, the laboratories in country do not have the ability to test for the presence of viable *Ascaris* ova, which is the most important indicator pathogen. SOIL continues to look for laboratories both in Haiti and in the Dominican Republic that will be able to give us definitive results.

During the summer of 2012, SOIL completed a short collaboration with the US Centers for Disease Control and Prevention (CDC) to achieve a more thorough evaluation of the pathogen die-off in SOIL's composting system. The objectives of this evaluation were to not only confirm whether the "final" compost is free of pathogens, but also to determine the die-off curves for *V. cholera*, *Ascaris* and *E coli.* within the bins, and at what age the compost bins can be considered pathogen free. SOIL requested that the CDC conduct microbiological analyses in multiple locations and depths within numerous bins at SOIL's temporary compost site in Port-au-Prince.

Although SOIL expects to receive the final report, including the results on *Ascaris* viability, at the end of this October, encouraging information was received from the *E coli.* results. After two weeks in the middle of the bins, the *E coli.* show a reduction from 10^5 *E coli.* to almost zero. From the corners, the same reduction was found within the first 4-6 weeks. After two months, all of the samples taken from the bins were negative for *E coli.*

Temperature monitoring

From the first day of dumping, SOIL's compost team monitors the temperature within the bins. Recognizing that high temperatures towards the center of the pile are not representative of all areas of the pile, SOIL modified the temperature monitoring protocol in early 2012 to focus on the areas likely to be the coolest. The temperature readings are now taken from 5 specific predetermined points within each bin (see Figure 2). The first four points (1-4) are all specific distances from the side of the bins (75-300mm) while the last reading (#5) provides what is likely the hottest area of the pile.

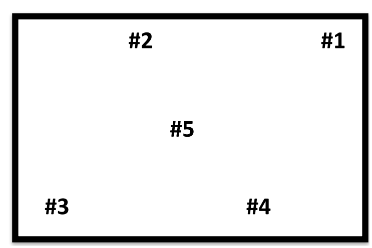

Figure 2 Temperature Points

These readings are taken every 2-3 days to ensure that the compost is reaching and maintaining temperatures high enough for pathogen die-off throughout the pile. Data taken from of two compost bins, using two different methods of recording temperatures, are provided in Figure 3 and Figure 4 below.

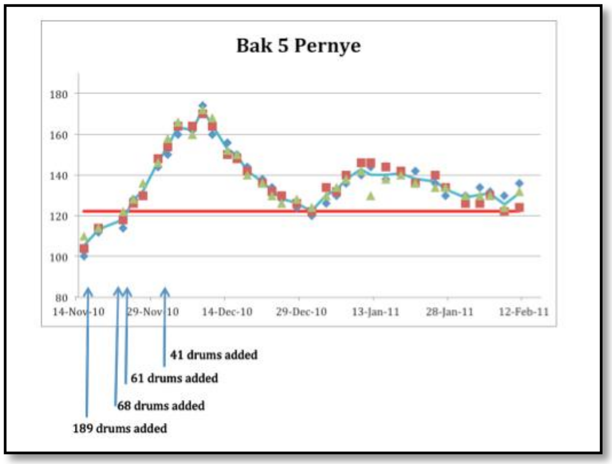

Figure 3 Compost Bin Temperatures for Batch 5

In Figure 3 one can see that even before the last drums are added at the end of November, the bins have already moved well above 50°C (122°F, shown by the red line). This temperature stays above this mark for over two months, reaching a peak of 76°C (170°F) and signalling high pathogen die-off rates within the pile.[8]

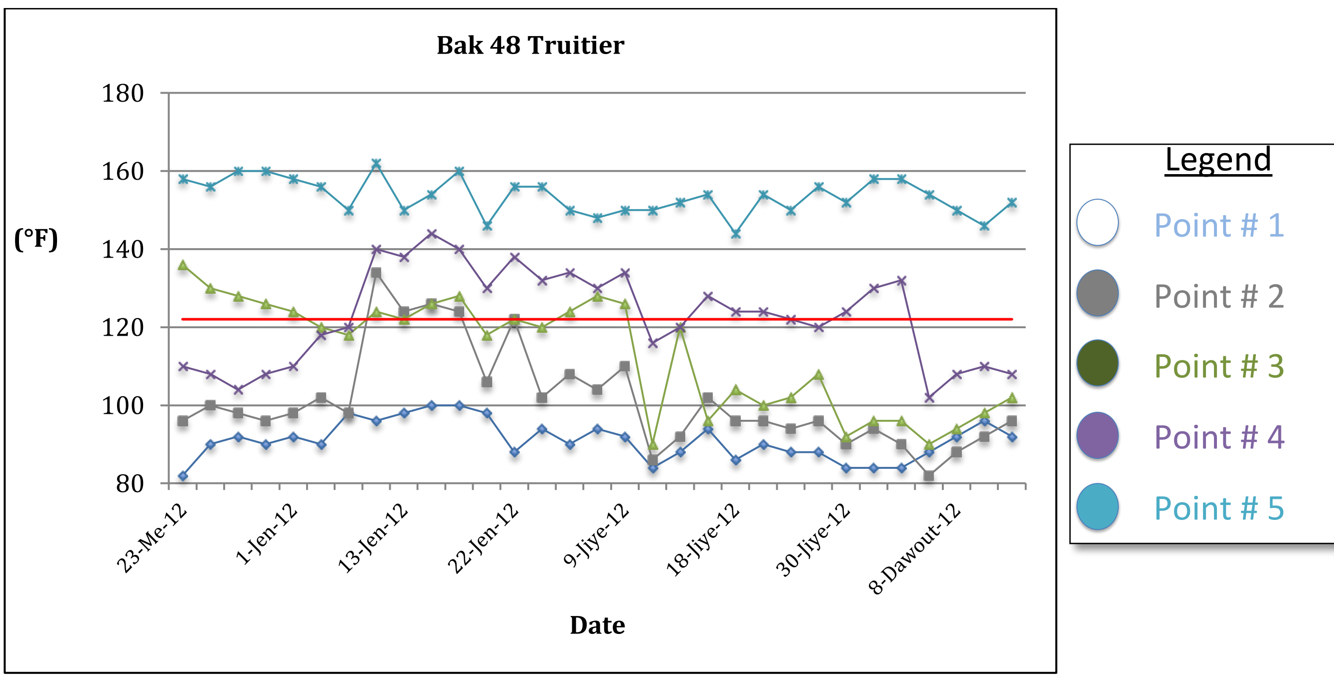

Figure 4 Compost Bin Temperatures with 5pt System

In Figure 4, with the modified temperature taking methods, shows that only one of the points (#5, from the middle of the bin) remains above the 122°F mark. Although the other 4 points graphed here are very close to the edges of the bin, the varied trajectories cast doubt as to whether the final compost can be claimed as "pathogen-free." Although three of these four points do reach 122°F for the last two weeks in June of this year, the point closest to the corner (#1, at 8cm) remained largely between 80 and 90 degrees Fahrenheit (27-32°C). While this could be cause for concern, SOIL observed the temperatures rise again to peaks of 69°C (156°F) at the end of August 2012 when the contents of this pile were moved to windrows. In response to concerns about achieving high temperatures throughout the pile SOIL has recently begun piloting a system of pile "turning" to create more homogenous decomposition within the piles (see "Moving Forward" section).

Compost Use

Nutrient Testing

Although the facilities do not exist in Haiti, SOIL was able to do some initial testing through the University of Florida and Stanford University in 2011 but it has not yet been possible to obtain NPK values for the most recent compost batches. When comparing SOIL's compost and the compost made solely with bagas that is sold on the market in Haiti, these initial tests suggest that SOIL's compost has a C/N ratio that ranges between 12 and 17 to 1. The second sample had a significantly higher ratio of 29:1, which could result in slower nutrient release and indicate incomplete decomposition. This is an area for future research and SOIL is actively seeking academic partners to participate in this work.

Experimental gardens

In Cap-Haitien and Port-au-Prince, SOIL has been using its compost in experimental gardens to showcase its effects in cultivating various crops. The gardens have included edibles such as corn, tomatoes, bananas, and sweet peppers. SOIL has also been experimenting with fruit trees including papaya, banana, cherry and avocado and currently maintains a nursery with over 5000 trees.

Land Rehabilitation

SOIL has recently undertaken a land rehabilitation project in Truitier, Port-au-Prince's municipal dumpsite for solid wastes and the location of its temporary composting site. Opened in the earlier 1980's and currently serving an estimated 3 million people from the metropolitan region, this site not only receives solid waste but also has also historically served as an unofficial site for both private companies and "bayakou" (informal latrine emptier) to dispose of sludge from latrines and septic tanks from around the city. SOIL is beginning to experiment with using compost produced on site to re-introduce mahoganies and native palm species as well as a number of fruit trees, transforming a space that has been a barren, polluted wasteland for many years into a refuge for native species.

MOVING FORWARD

Pilot Turning Scheme

Analysis of SOIL's temperature readings in its compost bins show that while the centres of the piles sustain sufficiently high temperatures to ensure pathogen die-off, there is more variation in the corners and sides. Beginning in September of this year, SOIL is piloting a "turning" scheme with its compost bins that will increase the rate of decomposition and ensure that all material in the piles reaches the required temperatures. The Port-au-Prince temporary composting site has been redesigned, with the bins arranged to facilitate compost turning and optimize the space's transformation and rehabilitation (see Figure 4).

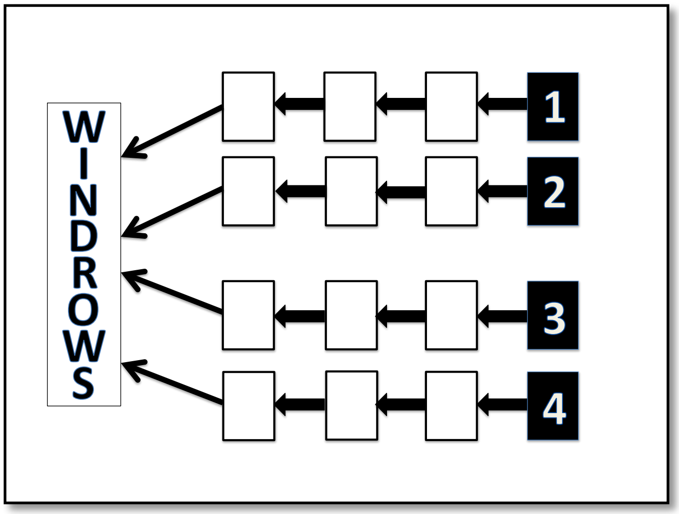

Figure 4 Pilot Turning Scheme

The basic principle of the turning scheme being piloted is that the compost will be turned three times, in one month intervals, before a final move to the windrow section. The compost bins marked 1 to 4 in Figure 4 will receive the “fresh” faeces and then be monitored for a full month before being moved to the bin adjacent. Temperatures will continue to be monitored with the five-point system and a new irrigation system is in place to ensure that the material maintains enough moisture throughout to facilitate decomposition. This system has been designed to accommodate SOIL’s current waste intake.

Pathogen and Nutrient Research

Now that SOIL has reached a stage where the operations are functioning smoothly, the work will become much more research focused. SOIL is currently seeking academic partners both within Haiti and abroad to assist with pathogen and nutrient monitoring of the composting systems (both the static bin system and the new system of turning once per month). The foundation is also interested quantifying the nutrient impact of adding urine.

CONCLUSION

In the six years since its inception, SOIL has gone through a number of changes, the most significant being the transition from double-vault UD toilets to the uptake and development of a thermophilic composting system to treat faecal matter. As SOIL continues to perform agricultural experiments with the compost being produced, a major focus will be to refine the composting methods to increase the rate of decomposition and ensure high pathogen die-off rates in its system. The foundation hopes to collaborate broadly with researchers and government officials in the coming years to refine its composting procedures and develop national standards relevant to Haiti. SOIL also has discussed the possibility of installing long term composting facilities at the new government waste treatment sites going in around the country that could accommodate not only faecal matter from UDT toilets but also latrine wastes and bio sludge.

REFERENCES

Cairncross, S. a. (1999). *Environmental Health Engineering in the Tropics: an Introductory Text, Second Edition.* Chichester: John Wiley and Sons.

Caroline Schonning, T. W.-N. (2007). Microbial risk assessment of local handling and use of human faeces. *Journal of Water and Health , 5* (1), 117-128.

Corps Legislatif. (2009, Mars 25). Loi cadre portant organisation du secteur de l'eau potable et de l'assainissement. *Le Moniteur, Journal Officiel de la Republique d'Haiti , 164* (29), pp. 1-12.

DINEPA. (2010, Fevrier 10). Cadre strategique du secteur EPA suite au tremblement de terre du 12 Janvier 2010. *1*, 19. Port-au-Prince: DINEPA.

Harlan G. Kelly, H. M. (1993). Autothermal Thermophilic Aerobic Digestion of Municipal Sludges: A One-Year, Full Scale Demonstration Project. *Water Environment Research , 65* (7), 849-861.

Jenkins, J. (2005). *The Humanure Handbook: A Guide to Composting Human Manure* (Vol. 3). Grove City, PA, USA: Jenkins Publishing.

MSPP. (2012). *Rapport de cas: 20 Septembre, 2012.* Port-au-Prince: Ministere de la Sante Publique et de la Population (MSPP).

Rosa Margesin, J. C. (2006). Biological activity during composting of sewage sludge at low temperatures. *International Biodeterioration and Biodegradation , 57* (2), 88-92.

Schonning, C. (2002). Evaluation of the microbial health risks associated with the reuse of source-separated human urine.

UNICEF. (2012). *Excreta treatment facility-Morne à Cabri-UNICEF.* Retrieved September 20, 2012, from Humanitarian Response - Haiti: http://haiti.humanitarianresponse.info/Portals/0/Information%20Management/Project%20sheet%20%20UNICEF%20Morne%20Cabri.ENG.pdf

UNOPS. (2012). *Rebuilding Haiti: Annual Report 2011.* United Nations Office for Project Services (UNOPS). Port-au-Prince: UNOPS.

US EPA. (1994). *EPA Guide to the Part 503 Rule.* US Environmental Protection Agency, Office of Wastewater Management. Washington D.C.: US EPA.

WHO. (2006). *Guidelines for the safe use of wastewater, excreta and greywater. Volume 4: Excreta and greywater use in agriculture.* World Health Organization. Geneva: World Health Organization.

WHO/UNICEF. (2012, March). *Haiti: improved sanitation coverage estimates (1980-2010).* Retrieved September 22, 2012, from Joint Monitoring Programme for Water Supply and Sanitation: www.wssinfo.org