Practical Paper

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 and, in 2009, developed the nation's first waste treatment site to treat human faeces using thermophilic co-composting. Since the earthquake in 2010, SOIL has developed a composting design that eliminates pathogens and creates a re-usable nutrient-rich compost. This paper provides an overview of SOIL's thermophilic composting model in a low-resource setting, highlighting the mechanisms of effective pathogen elimination in the system. SOIL's model creates a composting environment in static bins that reaches and maintains temperatures of over 65 °C for more than 1 month. Temperatures are monitored regularly and have been revealed not to be homogeneous throughout the piles. A 2012 collaboration with the US Centers for Disease Control and Prevention (CDC) showed rapid pathogen die-off rates within the compost piles, reducing *E. coli* levels to below detection levels within 14 weeks and rendering *Ascaris* ova not viable within 8 weeks. In order to increase the efficiency of the process and ensure that this compost is pathogen-free, SOIL will continue to refine the composting design, including piloting a new turning scheme, and identifying a procedure for regular pathogen testing.

Key words | compost, ecological sanitation, Haiti, soil, thermophilic composting

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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.

DINEPA (Direction National de l'Eau Potable et de l'Assainissement), the government agency responsible for water and sanitation, was created in March of 2009 (Corps Legislatif 2009). Prior to DINEPA, the respective 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, a catastrophic 7.0 magnitude earthquake struck Haiti, prompting the creation of over 1,300 spontaneous internally displaced persons (IDP) camps to house the estimated 1.5 million homeless people. The earthquake and subsequent cholera outbreak in October 2010 led to what would become the largest ever international humanitarian effort. DINEPA and the international community managed desludging fleets, which were responsible for transporting and disposing of 900 m^3 of sludge each week from the camps into hastily dug pits in the municipal dump, before finally constructing the first set of waste stabilization ponds in September of 2011 (UNOPS 2012).

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

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DINEPA from effectively meeting the needs of the population. As a result, diarrhoeal disease remains one of the leading causes of death in children under 5, while cholera has claimed more than 7,500 lives in just under 2 years (MSPP 2012).

SOIL after 2010 earthquake

In March 2010, Oxfam Great Britain (GB) approached SOIL to do an EcoSan pilot project in the IDP camps of Port-au-Prince. Working closely with the initial pilot community, the SOIL team designed an elevated, temporary urine-diversion toilet (UDT) that channelled urine to a soak-away pit, collected faeces in sealable 15-gallon drums and utilized locally available sugarcane 'bagas' as a cover material. A weekly collection system ensured that filled drums were removed from the sites and replaced with clean drums. SOIL continued to expand operations 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 composting to safely treat human faecal waste and transform it into nutrient rich compost. By September 2010, SOIL was operating Haiti's only waste treatment facility and was composting approximately 5,000 gallons of waste each week.

SOIL'S THERMOPHILIC COMPOSTING PROCESS

Compost structure

SOIL's compost bin designs have a treatment capacity of approximately 18 m^3, consistently filling every two weeks since mid-2010. These bins are constructed with wooden pallets that are secured to a graded cement foundation that prevents groundwater contamination and channels excess leachate to a corner collection point. An angled metal roof, allowing for moisture control of the pile, also covers the bins.

To increase temperature homogeneity during the composting process, an insulation layer of bagas is created on all sides: the pallet walls are filled with bagas, a 150 mm (6″) layer is placed on the foundation and a 6″ finishing layer is added when the bin is filled. Additional slats are installed on the pallets in the walls to provide holding support for the bagas but leaving sufficient space to facilitate aeration of the pile.

Compost operations

Compost team

SOIL's trained compost teams empty and disinfect the 15-gallon drums on the same day as collection. The compost team members adhere to strict disinfection and hygiene protocols that exist not only to protect the health of themselves and those they come into contact with, but also to avoid (re-) contaminating older compost piles.

Drum monitoring

SOIL's intensive education and monitoring practices at public toilets, including weekly supervision, have led to very low incidence of chemicals or solid waste being transported in the drums to our compost site. The compost teams are tasked with verifying that no material is emptied in the bins that could negatively impact the composting process. In addition, they monitor the consistency of the drums (i.e. the amount of cover material used in relation to faeces) and add additional cover material depending on their observations. A labour intensive drum tracking system is in place, with each drum numbered so that the SOIL compost teams can identify the origin of each problematic drum and the sanitation staff can follow up with users and operators.

Carbon source for cover material and co-composting

Using *appropriate* cover materials, in *sufficient quantities*, is necessary for a properly functioning compost system. While there are numerous possibilities, SOIL found that sugarcane bagas was effective both in the toilets as well as the bulking agent in the compost bins. Woodchips from *Amyris elemerifera*, a by-product of essential oil production, were piloted but then suspended after extremely long decomposition periods were observed. Adding bagas during the emptying process at the compost site helps ensure proper moisture content as well as creating a good carbon/nitrogen ratio within the piles. This practice also helps reduce potential disease vectors (flies, birds) and unpleasant odours. SOIL's protocol calls for adding one drum of dry bagas for every three drums of the faeces/bagas mixture that are emptied. In practice, however, this is modified based on the compost team's observations and recommendations.

Leachate and urine application

As the compost bins fill, one of the compost controller's responsibilities is to manage the excess leachate that is collected in a drum at the corner of the bin. As the liquid may hold valuable nutrients, this leachate is poured back into the pile until it can be absorbed and the flow towards the outlet ceases. In addition to re-applying the leachate, SOIL began a urine collection scheme in areas located near the compost site. Recognizing its high nutrient value, the urine is poured over the compost bins while in its maturation phase in an attempt to boost the nitrogen levels in the final compost. The leachate and urine both also help with maintaining adequate moisture within the bins.

Compost stages

While there are three microbial phases in thermophilic composting systems, SOIL manages the compost bins in two distinct stages, a controlled 'hot' stage and a 'windrow' or maturation stage:

- 'Hot' stage: This stage begins with the emptying of the first drum and concludes 4 months from the day the last drum is emptied. Temperature and moisture content are monitored during this period as the thermophilic phase occurs during this stage and temperatures often reach 50 °C in the centre of the pile within 24 hours from the time of emptying.
- Windrow stage: After 4 months, the contents of the bins are moved into windrows where they remain for a minimum of two months. Temperatures continue to be monitored as the remaining organic material is broken down.

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 as well as slower than expected decomposition rates, indicated by temperatures remaining above ambient.

Pathogen control

Haiti and international standards

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

These pathogens 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 that ensure the maintenance of high temperatures over a period of time. While varying slightly depending on agency and country, SOIL follows the World health Organization (WHO) standard that requires matter containing human faeces to be subjected to temperatures greater than 50 °C (122 °F) for at least one week to ensure adequate reduction of human pathogens (WHO 2006).

Temperature monitoring

From the first day of dumping, SOIL's compost team monitors the temperature within the bins. Recognizing that high temperatures towards the centre 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. Previous to this modification,

Table 1 | Human pathogens in Haiti

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

temperatures were taken from random points within the bins as opposed to the corners. The temperature readings are now taken from five specific predetermined points within each bin (see Figure 1). The first four points (1–4) are all specific distances from the side of the bins (75–300 mm) while the last reading (#5) provides what is likely the hottest area of the pile.

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 two compost bins, using two different methods of recording temperatures, are provided in Figures 2 and 3 below.

In Figure 2, where drums were being added until the end of November, the bin temperature had already moved well above 50 °C (122 °F, shown by the red line). This temperature stays above this mark for over 2 months, reaching a peak of 76 °C (170 °F) and signalling high pathogen die-off rates within the pile.

In Figure 3, with the modified temperature taking methods, only one of the points (#5, from the middle of the bin) remains above the 122 °F mark. Although three of the remaining four points do reach 122 °F for the last two weeks in June, the point closest to the corner (#1, at 8 cm) remained largely between 80 and 90 °F (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. SOIL has recently begun piloting a system of pile 'turning' to create more homogeneous decomposition within the piles (see 'Moving Forward' section).

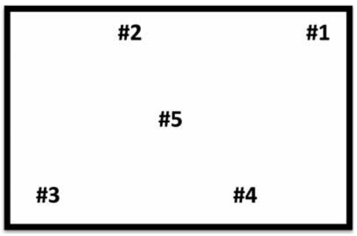

Figure 1 | Temperature points.

Testing for pathogens

Although SOIL's deliberate temperature monitoring indicates high pathogen die-off, periodic pathogen testing is necessary to confirm the efficacy of the process. During the summer of 2012, SOIL completed a collaboration with the US Centers for Disease Control and Prevention (CDC) to achieve a more thorough evaluation of the pathogen die-off in our composting system. The objectives of this evaluation were not only to confirm whether the 'final' compost is free of pathogens, but also to determine the die-off curves for *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 our temporary compost site in Port-au-Prince.

These analyses showed that while *E. coli* levels were reduced to acceptable levels (below 1,000 CFU/g) within six weeks of the bins filling and non-detectable levels

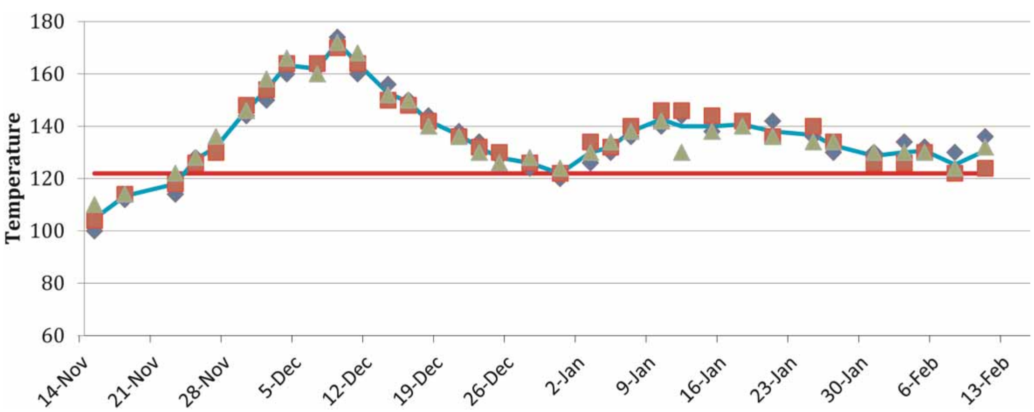

Figure 2 | Temperature monitoring in 2010.

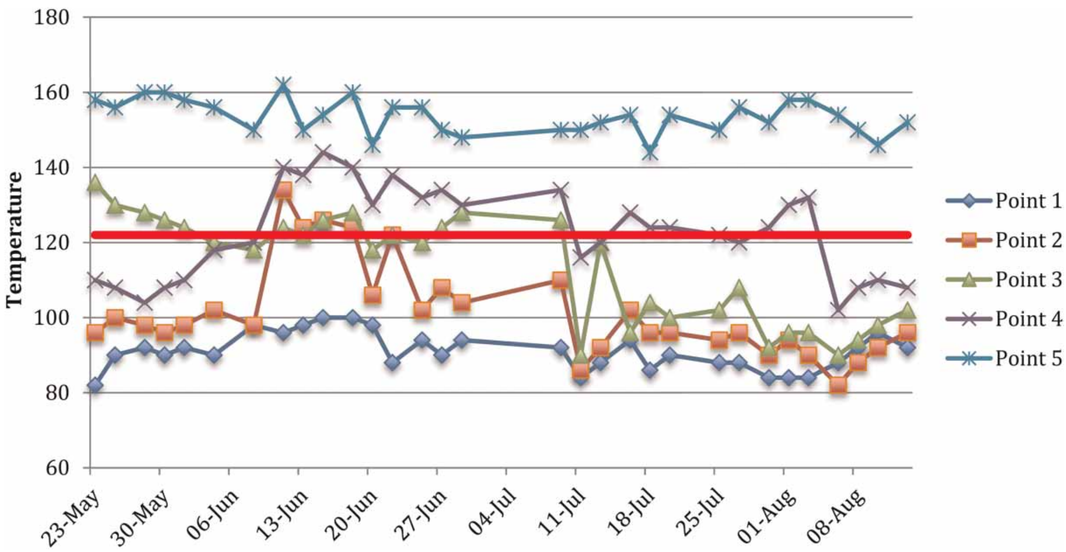

Figure 3 | Temperature monitoring with 5-point system.

within 14 weeks, the more resistant *Ascaris* viability had a die-off curve of eight weeks. None of the 'final' compost samples were found to have any viable *Ascaris* ova or *E. coli* present (Berendes *et al*. 2013). These tests confirmed that SOIL's composting process effectively eliminates human pathogens from the bins well before the compost would be deemed ready for re-use. Additionally these tests indicated that given the similar die-off curves for *E. coli* and *Ascaris*, future pathogen testing can focus specifically on *E. coli* as an indicator and regular testing for *Ascaris* is not necessary. This is critical in that *Ascaris* testing is labour intensive and not possible in Haiti with current lab facilities.

MOVING FORWARD

Pilot turning scheme

Although the CDC results indicate that SOIL's static piles are adequately killing pathogens, this method requires significant space and time, and temperatures at the edges of the bins do not always reach sufficient temperatures to meet WHO standards. For these reasons, beginning in September of 2012, SOIL began piloting a 'turning' scheme that will hopefully increase the rate of decomposition as well as the likelihood of all material in the piles reaching the required temperatures quickly. 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).

In this scheme, the compost bins marked 1 to 4 in Figure 4 will receive the 'fresh' faeces and be monitored for a full month before being moved to the bin adjacent. Over the following four months, the material is turned again at one-month intervals according to the arrows until it reaches the windrow section. Each month after turning the piles are watered with approximately 40 gallons of urine. Temperatures will continue to be monitored with

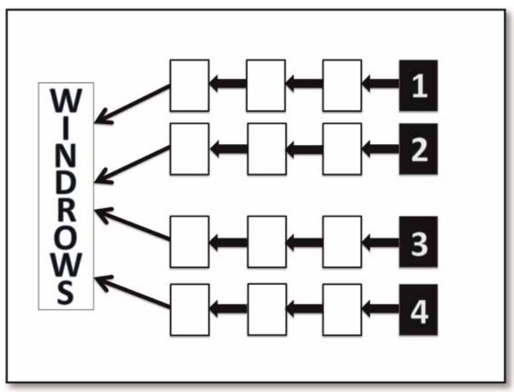

Figure 4 | Pilot turning scheme.

the 5-point system and a new irrigation system is in place to ensure that piles receive sufficient moisture to facilitate decomposition.

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. The system that SOIL developed is able to reach well above the 50 °C (122 °F) threshold and remain there for more than two weeks, signalling high pathogen die-off. Despite finding lower temperatures in the corners of SOIL's current model, the 2012 CDC analysis showed that within eight weeks resistant pathogens like *Ascaris* are eliminated and the more general faecal contamination indicator *E. coli* is reduced to an acceptable level. 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 our system.

We hope to collaborate broadly with researchers and government officials in the coming years to refine our 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.

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