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IN AN UNCERTAIN ENVIRONMENT

Thermophilic composting of human wastes in uncertain urban environments: a case study from Haiti

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BRIEFING PAPER

After the January 2010 earthquake in Haiti nearly 1.5 million people in the capitol were living in camps without access to sanitation. In response to the crisis, international agencies installed thousands of toilets within weeks. However, the absence of waste treatment facilities in the country further complicated the sanitation response. The first treatment facility constructed post-earthquake was a thermophilic composting site designed to treat the wastes from 20,000 earthquake victims living in camps. Despite multiple hurricanes, a cholera epidemic, and political unrest, the SOIL composting facilities have treated over 500,000 gallons of human waste in the past three years, converting it to pathogen free compost, over 10,000 gallons of which has been sold for use in agriculture and reforestation projects. The experience of thermophilic composting in Haiti is unique in scale and duration and can have global implications for waste treatment in both emergency and development contexts.

Introduction

Sanitation and waste treatment in Haiti

As of 2010, only 26% of the approximately 10 million people living throughout Haiti had access to improved sanitation (WHO/UNICEF, 2012) and no formal waste treatment facilities existed. Those without access to improved sanitation practiced open defecation, or used plastic bags or unimproved pits. Existing latrines and septic tanks were emptied into canals and other waterways throughout the country. As a result, diarrheal disease remains one of the leading causes of death in children under 5, while cholera has claimed more than 7900 lives in just over two years time (MSPP, 2013).

DINEPA (Direction National de l'Eau Potable et de l'Assainissement), the government agency responsible for Haiti's water and sanitation, was created in March 2009 (Corps Legislatif, 2009). Before 2009, 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, a catastrophic 7.0 magnitude earthquake struck Haiti, prompting the creation of over 1,300 spontaneous camps to house an estimated 1.5 million people whose homes were destroyed. The earthquake and subsequent cholera outbreak in October 2010 lead to the world's largest-ever international humanitarian effort to date. To dispose of human wastes from the camps, DINEPA and the international community managed desludging fleets, depositing sludge each week into hastily dug pits in the Port-au-Prince municipal dump (Photograph 1), before finally constructing waste stabilization ponds in September 2011 (UNOPS, 2012, Photograph 2). Located on the outskirts of Port-au-Prince, these stabilization ponds represent the first of 8 similar facilities that DINEPA plans to construct around the country (UNICEF, 2012).

Within the first year of operations the stabilization ponds began malfunctioning as a result of excessive trash in the latrine waste. The government is seeking alternative methods of treating latrine wastes and investigating options for composting biosolids from the existing ponds. There is a pressing need for alternative waste treatment research to identify methods for treating and valorising human wastes. Haiti's sanitation situation is extreme but not unique, and many of the problems experienced in Haiti can be found in other countries experiencing uncontrolled urbanization. Haiti exemplifies an uncertain environment and, as such, successful sanitation interventions in Port-au-Prince can serve as a model for other countries struggling with injustice, poverty, and environmental degradation, and for those recovering from disasters.

Photograph 1. Uncontrolled waste disposal, Port-au-Prince dump, Aug 2010.

Photograph 2. DINEPA waste stabilization ponds at Morne a Cabrit, Sept 2012

Sustainable Organic Integrated Livelihoods (SOIL)

SOIL (www.oursoil.org) has been working in Haiti since 2006 promoting the responsible use of ecological sanitation (EcoSan), where human wastes are converted into valuable compost. Since building Haiti's first EcoSan toilet in 2006, SOIL has gone on to become one of the most well-known sanitation providers in Haiti with clean, popularly-received and effective toilets and waste treatment facilities around the country. SOIL has established strong partnerships with the non-profit, business, and government sectors, and a robust information-sharing and educational program that has helped increase the use of EcoSan by organizations, businesses, and institutions around Haiti and by international NGOs. SOIL's sanitation approach incorporates the entire sanitation cycle—toilets, treatment, and reuse. As of December 2012, SOIL had constructed over 500 ecological toilets, treated more than 500,000 gallons of waste at composting sites in Port-au-Prince and northern Haiti, and sold more than 10,000 gallons of compost for agriculture and reforestation efforts.

SOIL case study in Haiti 2010-2013

Following the January 2010 earthquake in Port-au-Prince, SOIL implemented an emergency sanitation response program that included the construction and maintenance of 200 urine-diversion (UD) toilets in 32 Internally Displaced Person (IDP) camps for earthquake victims, and the establishment of the capitol's first waste treatment site in June 2010.[i] This paper will focus primarily on the waste treatment aspect of this project, as the emergency sanitation component is addressed in other documents (Kilbride, 2013). Rather than a detailed technical overview, this briefing will explore both the benefits and risks associated with thermophilic composting of human wastes and the lessons learned from SOIL's work in Haiti.

Traditional sanitation options such as latrines or septic tanks are not safe for implementation in many of Port-au-Prince's camps, both from a public health and an environmental perspective.. Many camps are located in dense urban areas, often with high water tables. In response to this unique set of conditions, SOIL modified a permanent double vault UD design to allow for collection and off-site treatment of wastes. The emergency UD toilets constructed in the camps are fitted with sealable 15-gallon plastic drums, which collect the faeces (urine diverted to soak-away) and carbon cover material[ii] and are replaced when full by paid toilet managers. SOIL staff collect the drums weekly for transportation to the composting facility for treatment.

SOIL has tested many models for composting human wastes, all involving a batch system where toilet wastes are mixed with sugarcane bagas (25% by volume) in discrete container units of 9–18 m^3. Though research is on-going, the most successful designs to date are between 15–18 m^3, with walls made of pallets stuffed with carbon material to allow airflow and retain moisture. These construction and operation standards are designed to optimize 3 factors critical to successful thermophilic decomposition: 1) C/N ratio, which should ideally be ~30:1 (Jenkins, 2005), 2) sufficient aeration to support the aerobic microorganisms responsible for creating thermophilic conditions (Harlan, 1993), and 3) moisture content which should ideally remain between 50-60% (Jenkins, 2005). For more detailed information on SOIL's composting operations, additional reports are available in the reference section; (Preneta, 2013, Kramer, 2011).

Depending on the environmental and land tenure issues, a permanent cement foundation can be installed below the piles to ensure that no leachate reaches the ground.[iii] Building on the lessons from the Port-au-Prince composting site (Photograph 3), SOIL's northern office established an offsite composting facility in Limonade (Photograph 4) to treat wastes from UD toilets with drum systems in Cap-Haitien, Haiti's second largest city.

Photograph 3. SOIL compost site in Port-au-Prince, Dec 2012.

Photograph 4. SOIL compost site in northern Haiti, Jun 2012.

SOIL's compost sites are closely monitored and temperatures are taken 2-3 times per week from fixed points in each pile, starting on the day the last drum is emptied and continuing until the compost is processed and removed from the site for use or sale. We have consistently found that temperatures at the centre of the pile achieve the WHO standard for the safe treatment of human waste by maintaining a temperature of above 122° F for at least 7 days (WHO, 2006), (see Figure 1). A recent study by a fellow from the Centers for Disease Control and Prevention (CDC) in the US showed that despite lower temperatures in the corners of the bins, indicator organisms such as *Escherichia coli* and *Ascaris lumbricoides* are reduced to levels below detection within 2 months of composting (Berendes *et al.*, 2013).

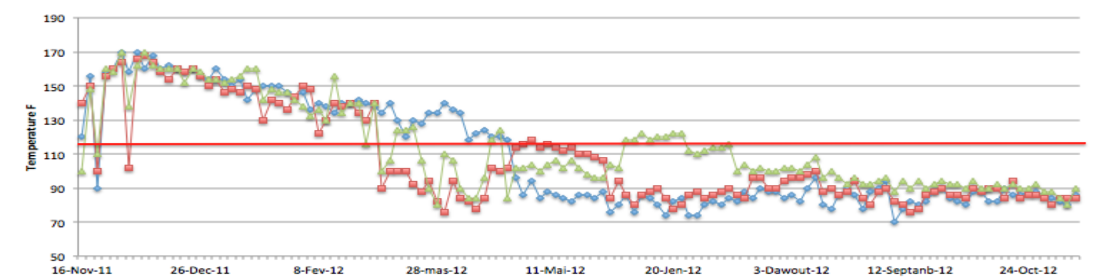

Figure 1. Compost temperatures in a bin in Port-au Prince over a 1 year period
Source: SOIL data

Compost is considered ready for re-use when temperatures in the pile return to ambient levels, generally within 6 – 9 months. After confirming the safety of the final product using IDEXX testing for *E.coli,* SOIL staff pass the compost through a 2 cm^2 sieve, bag it and sell it for 100 HTG ($2.40 USD) per 5 gallon sack. Significant amounts of compost are also diverted to SOIL's demonstration gardens where experiments are underway to determine ideal compost input rates for various crops. SOIL has sold more than 10,000 gallons of this compost to nurseries, organizations and individuals for use in agriculture and reforestation projects and used more than 25% of our production to date in our own experimental gardens.

Preliminary data indicate that there are significant reductions in volume of the wastes treated over the 9-month period of decomposition. SOIL estimates up to an 80% reduction in volume in our piles, meaning that, of the more than 500,000 gallons of waste treated, approximately 100,000 gallons of compost will be produced. This quantity of compost could be sold for approximately $45,000 USD representing a significant but incomplete cost recovery for the operation. SOIL's compost site in Port-au-Prince has been able to sell the contents of one compost bin (approximately 2.6 m3) for ~ \$320 US. Labour costs include: 1) dumping ~\$285, 2) turning of the piles 4 times ~\$142 and 3) passing the compost ~\$35. Total labour costs are ~\$462, meaning that compost sales can cover ~69% of labour inputs. This calculation does not account for infrastructure investments, general site maintenance or transport and collection of the wastes (which could be covered by user fees). However, it should be noted that these figures may change with a newly implemented turning system at the compost sites and addition of further data (Preneta et al., under review).

To date, the composting facilities have been at a small pilot scale and funded through donor contributions. The goal moving forward is to develop a system for cost recovery in the sites though compost sales and tipping fees from other sanitation providers. Though developed in the wake of one of the world's most devastating natural disasters, these sites now represent a significant infrastructure investment that can be used for on-going development work. After multiple hurricanes, a cholera epidemic and sporadic political unrest the compost sites continue to meet the objectives of safe waste treatment, environmental protection, compost production and the elimination of pathogens.

Benefits, limitations and risks associated with thermophilic composting

Like all technologies, thermophilic composting has benefits and risks associated with it and, although the process of composting has been studied for centuries, rigorous academic research on large-scale composting of human wastes is lacking. This section will evaluate some of the benefits of thermophilic composting as well as the risks involved and specific measures that can be taken to mitigate those risks.

Benefits associated with thermophilic composting

Composting of human waste is promoted primarily for its environmental and social benefits, which include increased plant production, soil carbon storage (Ryals and Silver 2013) and reduced greenhouse gas emissions relative to anaerobic waste stabilization ponds (Vanotti, 2008). The conversion of contaminated human wastes to fertile soil has the potential for increasing agricultural production, reducing erosion through improved reforestation efforts, and generating livelihood opportunities.

The simple infrastructure requirements relative to more advanced technological approaches allow for rapid implementation in the wake of a disaster. In post-earthquake Haiti where no waste treatment facilities existed, SOIL's composting waste treatment site was the first to begin operations following the earthquake. The infrastructure itself is not dependant on an energy source (critical in developing countries where power supplies are unreliable) and materials for construction can be sourced locally. Additionally, the straightforward operation and maintenance facilitate locally managed repairs and on-going service provision. Compost bins are sturdy and weather resistant and are generally unaffected by unpredictable natural events such as earthquakes or hurricanes.

An additional benefit associated with the composting of human wastes is the system's durability: the presence of solid wastes in the incoming toilet materials does not pose a serious problem to the overall functioning of the system. This is particularly important given that toilets are often used for garbage disposal due to the city's lack of solid waste management. In traditional waste management systems solid waste can cause serious problems, as has been the case with urban waste settlement ponds in Port-au-Prince.

Finally, composting of human wastes produces a marketable resource that can be sold as a means of partial cost recovery. Although composting systems are rarely profitable operations, they are often cheaper than alternative treatment processes because of the additional revenue provided by compost sales.[iv]

Limitations and risks associated with thermophilic composting

The primary risks associated with any waste treatment system are the risks of worker exposure to human pathogens and environmental contamination. SOIL has strict hygiene procedures for all staff and visitors to the compost sites which include protective clothing, showers, hand-washing stations with chlorinated water and visible printed procedures for safe handling of human wastes. SOIL has had independent environmental impact assessments performed at both composting sites indicating that the composting processes undertaken on the land do not pose a significant environmental risk and, particularly in the case of the Port-au-Prince site located in the city dump, may even improve the surrounding environment (Nyman, 2013).

These systems are reliant on vigilant temperature monitoring and/or laboratory pathogen testing to ensure the safety of the final product, which can pose a problem in countries where there is a lack of regulation and oversight, or areas where microbial testing facilities are not available. If compost is to be sold to the general public it is essential that composting facilities test their product periodically.

Finally, a limitation associated with the composting of human wastes is the amount of suitable land required for operation, which can be scarce in dense urban environments. SOIL's site in Port au Prince has the capacity to treat the wastes of approximately 10,000 people on 0.6 hectares, so a considerable amount of land would be required to treat wastes for a city of 2 million, such as Port-au-Prince (~120 hectares, or just over ½ the size of the current city municipal landfill site).

Lessons Learned

- Proper maintenance of the site is dependant on staff reliability and engagement. The importance of staff education and encouragement cannot be overlooked. The conversion of human wastes into a resource can be a source of great pride, which can help reduce the stigma associated with waste management.
- Carbon material added to human waste in both toilets and compost piles must be tested for its capacity to retain moisture and aeration and ability to rapidly decompose during the composting process.
- Compost facilities should be situated away from residential areas to avoid issues around operations and changing perceptions.
- Extensive education is needed in areas around a potential composting facility in order to understand potential benefits and facts around public health impact.
- Constant dialogue with government stakeholders is essential to the sustainability of the site and increases the likelihood that successes are scaled and mistakes are not replicated in future projects.

Directions for future research

This paper represents only the preliminary results of SOIL's research and in the coming years the objective is to expand our research objectives to include the following:

- Experimentation with treating human waste from traditional latrines using thermophilic composting.
- Collaboration with DINEPA to test the potential for thermophilic composting of sludge from the stabilization ponds.
- On-going pathogen die-off research, focusing on environmental contamination and the efficacy of SOIL's compost turning process relative to the former static pile system.
- Development of a business model for the sustainable management of SOIL's composting facilities.

Conclusion

SOIL's emergency intervention after the Haiti earthquake represented one of the largest and most successful examples of EcoSan technology implementation in an emergency context. It is unique in that the emergency program has now begun to transition towards development initiatives, building off the investments made through emergency donations. Instead of having a solely short-term impact like many emergency interventions, the benefits of SOIL's sanitation intervention extend far beyond the dignity of a toilet, to the provision of long-term infrastructure and the production of a valuable resource that can begin to rebuild Haiti's soils.

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Note/s

[i] This work was supported initially by financing from Oxfam Great Britain and later the 11th Hour Project and numerous small foundations and individual donors.

[ii] Carbon cover material used in Haiti is primarily sugarcane bagas, however SOIL has also experimented with shredded peanut husks and sawdust.

[iii] SOIL's compost site in Port-au-Prince is not cement-lined for 2 reasons: 1) it is in the city dump where the environment has been polluted by incoming trash for 25 years, so the risk of groundwater contamination is not significant (Nyman 2013) and 2) SOIL has only verbal permission to use the land through the Haitian government, but without signed papers the site has been viewed as "temporary," preventing large infrastructure investments. The site in Limonade in northern Haiti is on a 10-year lease to SOIL, is located close to farmlands and has not previously been a dumpsite. As such the compost bins in Limonade are cement-lined to prevent leachate contamination of the environment.

[iv] Jeff Ziegenbein, Project Manager of the Inland Empire Regional Composting Facility, the largest fully enclosed biosolids composting facility in North America, stated that "the facilities rarely operate at a profit from compost sales. A good portion of their revenue stream is generated from tip fees from the waste. Compost sales generate revenues to help keep recycling costs low." February 28, 2013.

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