THERMOPHILIC COMPOSTING AS A SANITATION ALTERNATIVE GIVELOVE.ORG PROJECT, SANTO VILLAGE, LEOGANE, HAITI - A CASE STUDY

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ABSTRACT

After Haiti's devastating earthquake in January of 2010, sanitation became non-existent there in many areas. GiveLove.org, founded by actress Patricia Arquette and Rosetta Getty, with Program Director Alisa Keesey and Compost Instructor Lucho Jean, taught local personnel how to establish sanitation systems based on thermophilic (hot) composting. Visits to Haiti by the author, who was also a volunteer composting consultant for GiveLove during this time period, documented these systems in schools and orphanages. By 2012, the organization had built over 30 toilets for over 4,000 users, and trained 15 Compost Managers. The most recent project, started in 2012, involved a village-wide system that serviced about 250 households. The "small village system" at Santo Village in Leogane, Haiti, is the subject of this paper.

The self-managed system utilized sugar cane bagasse as the primary carbon-based cover material. It was used to cover the contents of the toilets as well as the contents of the compost bins. The toilets are designed with either 20 liter or 60 liter recycled plastic receptacles used to collect toilet material. The toilet contents are covered with bagasse inside the toilet, then composted in bins located on-site, away from the toilets and the houses. Urine is not separated, nor is toilet paper. Food materials are also used as a compost feedstock, if available. Temperatures of the compost piles are monitored. The compost system requires no turning of the piles. The bins are walled using recycled wooden shipping pallets turned on edge and are approximately 2.4 meters wide by 3.2 meters long by 1.2 meters deep.

The sanitation system is based upon the utilization of the thermophilic, or heat-producing composting process, which is effective in eliminating human pathogens. The objective is to create an above-ground static organic mass, made primarily of material collected in toilets, that reaches a temperature of at least 55C (131F) sustained for at least three days throughout the entire mass. The U.S. Environmental Protection Agency requires a three day period at 131F for static aerobic compost piles to be considered hygienically safe, because this time and temperature combination has been shown to be deadly to human disease organisms. The compost piles in Haiti are sustaining temperatures at or above 55C for months, much more than the required time period. The use of sugar cane bagasse as a cover material in the bins minimizes the exposed surface area of the compost and maximizes heat retention. This containment system also eliminates odors and flies and helps prevent vermin such as dogs and other animals from accessing the compost. Soap and water used to clean toilet receptacles are added to the compost piles, thereby creating a closed system.

The process relies on local management by Haitians, compost training, a dedicated compost management crew, public education, access to and transport of carbon-based cover materials to the toilet sites, and constructive use of the finished compost. This project created many tons of odor-free, hygienically safe, agriculturally valuable, finished compost.

KEYWORDS: humanure, Haiti, thermophilic composting, compost toilet, sanitation, ecosan, dry toilet, ecological sanitation, village compost toilet system, bagasse, Santo Village, Habitat for Humanity, Architecture for Humanity, GiveLove.org, Patricia Arquette, Alisa Keesey, Lucho Jean, sanitation without water, sanitation without electricity, Otji toilet, Leogane, Rosetta Getty

INTRODUCTION

A thermophilic compost sanitation system is based on the concepts and principles of hot composting. There are three basic components required for such a system to operate successfully: 1) the toilet itself; 2) the carbon-based cover materials; and 3) the compost bins.

COMPONENT #1 — THE TOILET

The toilet is simply a collection device, container, or receptacle. Its purpose is only to collect human excrement, both urine and feces, in a waterproof container. The "toilet material" is collected in the receptacle before it comes into contact with the environment; human excrement does not contact soil or water. The toilet material is not referred to as "waste" because nothing that goes into a humanure toilet becomes wasted. The discarded organic material is all constructively recycled via composting. Hence, the word "humanure" has become popular when referring to human excrement that is recycled through composting systems. The term "waste" is not used, associated with, or appropriate when discussing composting systems because composting involves neither waste nor disposal. It is a system that recycles organic material, not a system that disposes of waste.

The size and type of toilet receptacle can vary from place to place, depending on availability and purpose. Five-gallon (20 liter) plastic receptacles are commonly used in a small-scale system because the receptacle can be easily carried by a single person. The receptacles can also be inexpensive or free, are water proof, can have lids, and can last a long time. This system is not to be confused with a "bucket toilet," which is human excrement deposited into a bucket without cover material, then discarded into the environment as waste. Bucket toilets, however, can easily be converted into humanure toilets by adding the other two components of the system: cover materials and compost bins. Larger toilet receptacles can also be utilized in humanure systems.

The purpose of the toilet is to collect feces, urine, paper, and the cover material so as to prevent unsanitary contact with the environment. No composting takes place inside the toilet. No water is used, no electricity is needed, no ventilation is required, and since the toilets don't smell when the contents are properly covered, they can be located indoors in any room where there is enough privacy.

Human excrement becomes prepared for thermophilic composting when it is combined with a carbonbased organic material, such as sawdust, rice hulls or sugar cane bagasse. This is done inside the toilet by the simple act of covering the toilet contents to prevent odor. Human excrements will not compost on their own because they're too wet and too high in nitrogen. By adding a carbon-based material to the toilet after each use, the toilet contents become balanced in carbon and nitrogen and the moisture level is optimized for composting, while completely blocking unpleasant odors and flies.

The purpose of thermophilic composting is to subject the toilet materials to robust microbial and biological activity which produces heat generated by thermophilic, or heat-loving, bacteria. This process is scientifically proven to destroy human pathogens, rendering the toilet material hygienically safe and achieving the true essence of "sanitation." The finished compost is also an excellent agricultural resource for revitalizing soils and for growing food.

"Urine diversion," the practice of diverting urine from solids, is popular in "dry toilets" that are not part of thermophilic composting systems. However, when utilizing hot composting, the urine provides essential moisture and nitrogen required to offset the dryness and carbon of the cover materials. When urine is removed from the toilet contents, the organic mass can be deficient in moisture and nitrogen and this can retard the thermophilic phase of the compost.

Paper products, such as toilet paper, toilet paper center cardboard rolls, etc., are encouraged to be added to the toilet contents. There is no reason to separate these into a trash bin when using a humanure toilet. Feminine hygiene products can also be added to humanure toilets, although the plastic components of these products will have to be manually removed from the finished compost because they do not decompose.

Humanure toilets can be designed for household use indoors, for single person or family use, or for group use where many people gather, such as at refugee camps, villages, schools, orphanages, etc. They can also be used as backup or emergency toilets when flush toilets are not available due to electrical outages or disaster scenarios.

COMPONENT #2 — THE COVER MATERIAL

Carbon-based cover materials are required for the humanure toilet system to function successfully. These materials cover the contents inside the toilets as well as the contents of the compost piles. Enough cover material of the correct consistency and moisture content is needed to totally and effectively eliminate odor and flies. The correct amount of cover material can be gauged by simply smelling the toilets or the compost piles. If there is an offensive odor, more cover material, finer cover material, or cover material with slightly more moisture content must be used. Likewise, if flies can be seen accessing the contents of the toilet or the compost pile, then more cover material must be used.

The cover materials must originate from "carbon based" plant cellulose material in order to promote thermophilic composting. One of the most widely used cover materials, for example, is sawdust from trees. Others include peat moss and rice hulls. Sugar cane bagasse, left over from the crushing, shredding and processing of sugar cane, is widely available in Haiti and useful for compost sanitation systems. Sawdust from the manufacturing of amyris oil was also being used there. Cover materials can be any somewhat dry plant material ground into the correct consistency, such as from coco coir and even from paper products.

Availability of appropriate cover material is essential to the successful operation of a humanure toilet system. The cover material must not be too coarse. Wood chunks, for example, are inappropriate. Even wood shavings are not ideal for use inside the toilets as they are airy and can allow odor to escape. Wood shavings can inhibit thermophilic composting due to the inaccessibility of the carbon to the compost microorganisms because the wood particles are too large, although wood shavings can be used successfully in larger compost piles where the temperatures stay higher for longer periods of time. Wood ashes should not be used as a cover material, nor should lime (ground agricultural limestone). These mineral materials inhibit microbial activity, whereas composting is designed to increase microbial activity, not to inhibit it.

When the cover material is from an appropriate source and of appropriate consistency for use in the toilet, the toilet contents can be covered such that no odor escapes from the toilet. This enables the toilet to be located indoors. However, if appropriate cover materials are not available or are not utilized, the toilet can emit unpleasant odors. Therefore, it is imperative to understand that the humanure toilet system is not appropriate for all people in all places and situations, any more than a flush toilet is. In woodland areas, tropical areas or any location where sawdust and/or other similar plant materials are available, the toilet works very well. In areas where agricultural byproducts may be collected and stockpiled for use, such a sanitation system can also work very well. The byproducts could include such things as grain chaff, pine needles, coffee grounds, distillery byproducts, cleanings from woolen mills, paper products ground to the right consistency, etc.

Cover materials are required for the compost bins as well as for the toilets. The compost bin cover materials can be coarser than the toilet cover materials. They can include grasses, hay, straw, pine needles, weeds, leaves, sugar cane bagasse or many other organic plant materials that are odor-free and do not attract flies. Such cover materials allow for the collection of large quantities of toilet materials in above-ground compost bins without creating unpleasant odors or attracting flies. They also contribute to the aerobic thermophilic microbial reaction by creating tiny interstitial air spaces in the compost piles.

If appropriate cover materials are not available, a compost sanitation system is not recommended. If the cover materials are available in limited quantities, humanure toilets can be successfully used in limited numbers.

The carbon-based cover materials balance the moisture and nitrogen in human excrement. This creates a desired "carbon to nitrogen ratio" that encourages reproduction of heat-producing microorganisms. By using enough cover material of the correct consistency to prevent odors from escaping the humanure toilet system, the correct balance of carbon to nitrogen can be achieved so long as urine is included. In addition, most food scraps and other organic materials available from human activity, even animal mortalities, can be added to the humanure compost bins to achieve high-quality compost.

COMPONENT #3 — THE COMPOST BINS

"Composting," by definition, is managed, aerobic, decomposition of organic material in such a manner that

internal biological heat is generated by microorganisms. It typically involves an above-ground pile of organic material (a compost pile) and the pile may or may not be enclosed in a container (a bin). If a system is unmanaged, anaerobic, or not generating biological heat, it is not composting by today's industry definitions. Most "dry toilets" are incorrectly referred to as "composting toilets," when in fact no composting is occurring. Some dry toilets, such as the humanure toilet, are part of a composting process where the actual composting takes place away from the toilet area, in compost bins.

All toilet materials that are collected must be composted above ground in an aerobic, thermophilic manner in order to achieve maximum sanitation. This requires the depositing of the materials into compost bins. The bins must contain the toilet material so it is not accessible to children, animals, vermin, or insect vectors.

The compost bin walls may be constructed of wood boards, masonry materials such as bricks, blocks or concrete; straw or hay bales (which can be reused as cover material after their function as side walls is completed); bamboo; poles or logs; wood shipping pallets turned on their sides, etc.

The bin contents begin with a "biological sponge" as the base layer. The sponge consists of plant materials such as straw, hay, weeds, grasses, bagasse, etc., piled approximately ½ meter deep in the bottom of the bin for the purpose of absorbing excess liquids that may collect when the pile is being constructed. Cover materials should also be collected along the inside walls of the compost bins when the toilet material is added in order to provide an organic layer between the toilet material and the inside walls of the bins.

The bins should be located on bare soil with the base shaped into a slightly concave configuration, allowing for the pooling of any excess liquid into the center of the bin, thereby preventing leaching out the bottom should unexpected heavy rains drench an uncovered bin, for example. Bins can also be constructed on concrete or other hard surfaces, although a soil base encourages beneficial soil organisms, including earth worms, to migrate into the compost pile. The soil will absorb moisture and act as a buffer for leachate, whereas concrete will not. Once the thermophilic phase begins, liquid is absorbed by the robust biological activity, hence the need for urine and possibly for rain water or graywater to moisten the compost mass.

Proper management of the compost pile is important, therefore experience and education are strongly recommended. Composting is as much an art as it is a science. The top of the compost pile must be kept covered at all times with clean cover material of sufficient quantity such that all unpleasant odors are eliminated. Also, the cover material must be appropriate in consistency so that flies cannot access the contents of the pile. Straw, grasses, leaves or hay scattered loosely, but adequately, over the compost pile, for example, work well for this purpose. Very coarse materials such as pond reeds, for example, will not. The cover material on top of the pile also absorbs rain water, acting like a roof during heavy rains, thereby preventing leaching. The top cover material will also prevent the pile from drying out.

Compost operations are typically executed in two basic manners: "batch" compost or "continuous" compost. Batch compost occurs when an entire compost bin is filled in a short period of time, perhaps in a few days or in a week or two. Continuous compost is when a compost bin is added to continuously for a long period of time such as a year. In either case, after the bin is filled, the compost should be covered with additional cover material and left undisturbed for approximately a year. In a hot, tropical environment, nine months retention time may be adequate.

HOW THERMOPHILIC COMPOSTING WORKS

Thermophilic composting is aerobic decomposition of organic matter that includes a hot stage dominated by heat-producing bacteria. The hot stage may last days, weeks or months, depending on factors such as the organic ingredients, the size of the compost mass, ambient temperatures, geographical location and/or time of year, and moisture content, among others. Thermophilic temperatures are generally in the range of 45 degrees Centigrade or hotter.

Much scientific research has been conducted regarding the efficacy of the thermophilic compost environment in destroying human pathogens such as viruses, protozoa, intestinal worms, and bacteria. Research has shown that human pathogens find the compost environment to be hostile and the pathogens will rapidly die off in such an environment. When Westerberg and Wiley composted sewage sludge which had been inoculated with polio virus, Salmonella, roundworm eggs, and Candida albicans, they found that a compost temperature of 47-55C (116-130F) maintained for three days killed all of these pathogens. Finished compost that has been subjected to adequate and well-managed thermophilic conditions typically contains "no detectable pathogens," regardless of the initial pathogen load. When human excrement can be rendered hygienically safe through the elimination of pathogenic organisms, the true essence of sanitation can be achieved. Refer to Table 1 for a partial list of pathogen thermal death points.

Compost piles will undergo several stages of decomposition in addition to the initial thermophilic stage. After the hot phase has ended, the organic material will continue the process of biological degradation and transformation into humus aided by non-thermophilic microorganisms, macroorganisms such as earthworms and other insects, and fungi. These additional stages allow for the further decomposition of the organic material to produce a final product that is plant-friendly and agriculturally beneficial. The composting process incorporates both the element of temperature and the element of time. Combined, they produce an end product that is safe, sanitary, pleasant smelling, stable, can be stored indefinitely and can be used for growing human food.

The compost must undergo a prolonged aging period of typically nine months to a year after it is collected. Otherwise, the compost will be immature and phytotoxic (it will kill plants). Maturity is reached when the compost pile cools down and the internal temperature is approximately the same as ambient temperature. At this point, the compost is suitable for growing food. There is no waste in this system. Instead, where other sanitation systems produce sewage and pollution, composting produces fertile soil and food for humanity.

Table 1
PATHOGEN SURVIVAL BY COMPOSTING OR SOIL APPLICATION
UnheatedComposting ToiletSoilAnaerobic(Three mo. min.ThermophilicPathogenApplicationDigestionretention time)Composting
Enteric viruses May survive 5 mo . Over 3 mo Probably elimKilled rapidly at 60C
Salmonellae 3 mo. to 1 yr Several wksFew may survDead in 20 hrs. at 60C
Shigellae Up to 3 moA few daysProb. elimKilled in 1 hr. at 55C
or in 10 days at 40C <i>E. coli</i> Several mo Several wksProb. elimKilled rapidly above 60C
Cholera vibrio 1 wk. or less 1 or 2 wks Prob. elim Killed rapidly above 55C
Leptospires Up to 15 days 2 days or less EliminatedKilled in 10 min. at 55C
<i>Entamoeba</i> 1 wk. or less 3 wks or less Eliminated Killed in 5 min. at 50C or <i>histolytica</i> 1 day at 40° C cysts
Hookworm 20 weeks Will survive May survive Killed in 5 min. at 50C eggs or 1 hr. at 45C
Roundworm Several yrs Many mo Survive well Killed in 2 hrs. at 55C, 20 (<i>Ascaris</i>) eggs hrs. at 50C, 200 hrs. at 45°C
Schistosome One moOne moEliminatedKilled in 1 hr. at 50°C eggs
Taenia eggs Over 1 year A few moMay surviveKilled in 10 min. at 59ºC, over 4 hrs. at 45ºC
Source: Feachem et al., 1980

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SANTO VILLAGE SANITATION

The Santo Village was a Habitat for Humanity (HFH) project¹ (see **Figure 1**). Habitat for Humanity and Architecture for Humanity (AFH) collaborated with the Leogane community to create a starter home village at Santo, near Leogane (see map at right), for the purpose of housing persons displaced and left homeless by the 2010 earthquake. A projected 500 homes were to be constructed and owner-occupied, each on a 150 square meter lot. Each home was expected to have its own toilet to avoid the maintenance concerns associated with shared sanitation systems. The primary concern was to establish a system with relatively low maintenance, cost and labor, based on a reliable and proven technology.

The sanitation systems already in use in urban areas of Haiti included:

- 1. Flush toilets connected to sewers;
- 2. Flush toilets and septic tanks;
- 3. Private improved latrines;
- 4. Communal toilets;
- 5. Traditional pit latrines;
- 6. Hanging latrines (defecation platform over a water source);
- 7. Open defecation.
- The systems broadly considered by AFH for use at the Santo Village included:
- 1. Municipal Septic (flushing);
- 2. Leech field septic (flushing);
- 3. Enclosed septic (pour flush/flushing);
- 4. Biodigestor (pour flush/flushing/dry);
- 5. Thermophilic (hot composting);
- 6. Enclosed long term composting (vermiculture optional, dry and pour flush composting);
- 7. Urine Diverting Dehydration Toilets (dry composting);
- 8. Ventilated Pit latrine;
- 9. Pit latrine

For practical considerations, one of which included poor access to water on the site, the options were narrowed down to:

- 1. Thermophilic Composting as implemented by Give Love (www.givelove.org)
- 2. Enclosed Long-Term Composting Toilet
- 3. Pour Flush Septic System
- 4. Pit Latrine
- 5. Urine Diversion Dehydrating Toilets as implemented by SOIL (www.oursoil.org)





OTJI TOILET — AFH'S FIRST CHOICE

Out of the five options listed above, Architecture for Humanity selected the Otji Enclosed Long-Term Composting System, a dry toilet that was developed in Otjiwarongo, Namibia. AFH cited advantages in maintenance, operational costs, social acceptability, health risk, reliability of the technology, environmental factors, and economics. The proposed cost for this system was \$533,700.00 USD.

The hot composting system proposed by GiveLove.org and priced at \$191,500.00 USD, had its drawbacks, according to AFH, including social acceptability. "The social acceptability of this system would probably be quite low as there is repeated contact with the humanure. Having to store humanure for collection may also be undesirable."

AFH's additional concern was health and risk. They stated, "There are large numbers of people coming in direct contact with the humanure, increasing the risk of contamination by pathogens. The toilet seat may have to be secured to ensure children cannot gain access to the humanure. Storage of humanure in the household prior to collection is a potential risk as is securing the bins when left out for collection. Compost managers



will need to ensure compost stations are also kept secure to ensure they are not accessed by unauthorized personnel. All tools and transport associated with the composting stations will have to be cleaned properly after use. Compost station staff will need to be very well trained and know what measures to take if temperatures are not being maintained according to guidelines."

AFH described the chosen Otji toilet as "a dry toilet system which collects humanure in a large perforated bucket in a chamber beneath the toilet [see illustration above]. A specially designed urine diversion toilet is used to divert 80% of the urine directly into a soak pit in the ground. This type of urine diversion toilet does not need special instruction for use. The remaining urine and solids are collected in the 90 liter bucket below. The remaining urine percolates through the solids and seeps into the soil. The bucket for a single family use usually fills up within 6 months. It is removed to the rear part of the chamber below the ventilation chimney to dry out the remaining solids and replaced with an empty bucket. When the second bucket fills, the dry solids are removed and returned to a hole in the soil, unless further composted. A black painted panel and large chimney vent help to remove smells from the toilet. Orientating the ventilation stack towards the sun is important for efficiency. On occasion this system has been installed with a small solar-operated fan for night ventilation." According to Ecosur South Network (EcoSur.org), the Otji toilet is considered "ideal for dry and hot climates."

Average annual rainfall in Otjiwarongo, Namibia, is 18 inches (0.457 meters). Average annual rainfall in Leogane is more than three times as much at 57.52 inches, or 1.461 meters². Despite the fact that Haiti tends to be much wetter than Namibia, the Otji system was installed anyway and in use for a period of time at Santo.

The villagers eventually complained about unpleasant odors coming from the Otji toilets, which could be smelled in the air throughout the village. The toilets became so unpleasant that villagers refused to use them, some preferring open defecation, and the system became abandoned.

A preliminary, unpublished internal review of the Otji toilet system yielded the following:

- 1. The toilet contents had a soupy consistency that was very wet, odorous and unpleasant.
- 2. When full, the 90 liter containers of raw excreta were expected to be lifted out of the sunken toilet

chamber, removed to another location, and buried safely according to the discretion of the user.

- 3. There were unknown costs for the Otji toilet user related to the removal and burying of the excrement. Costs include labor, transportation and possibly a disposal fee.
- 4. Wet fecal slurry was in the Otji buckets, on the buckets, and around the chamber floors. The chambers omitted strong odors. All of the 90 liter containers observed were covered with no-table insect infestations, flies, fly larvae, and feces.
- 5. The odors and flies may be a result of the spillage or overflow of feces and urine in the chamber due to a drop shoot that is too long or not designed properly for the toilet contents to fall entirely into the Otji bucket.
- 6. The fly infestation may pose a significant health risk since flying insects can spread disease. The uncleanliness of the chambers and hundreds of flies present a psychological barrier for the users. The Otji toilet chamber is very unpleasant and less likely to be cleaned or maintained.
- 7. Users were pouring "Clorox" and other household cleaning products into the toilets to control odors. They complained that the toilets "smelled very bad at night in the house," despite their location outside.
- 8. A user reported that her family of five had already filled one Otji bucket in just two months of use.
- 9. A user reported that they had exchanged the 90 liter Otji bucket for a smaller container so they could dump it more easily.
- 10. A user reported that they were going to stop using the Otji toilet because they would rather go outside than deal with the buckets.
- 11. Several users reported that they were concerned about the flies in the Otji chamber and did not want to touch the Otji buckets at all because they were very dirty.
- 12. Users expressed fear about disease and cholera, and fear of moving the Otji buckets or going into the chamber to clean it.

Other concerns listed in the internal review included:

- 1) The Otji buckets seem to fill faster than the six-month estimate.
- 2) The excreta in the Otji buckets does not seem to dry sufficiently in Haiti.
- 3) The Otji buckets may be too heavy to lift, move or transport safely.
- 4) The Otji buckets might overflow when in use.
- 5) Households will not manage the toilets because of fear of cholera and the work is very unpleasant.
- 6) The Otji toilet material is not pathogen free.
- 7) A proper maintenance schedule needs to be determined.
- 8) Users may opt-out of using the Otji toilet if the odors and insects are not controlled.
- 9) Users may try to dispose of the Otji toilet contents themselves, which could be a potential health hazard, a source of fecal contamination in the environment, and could cause community conflict when people dump untreated sewage.
- 10) Chemical additives such as motor oil and bleach used to control odors can cause environmental pollution, can make the excreta difficult to compost, and can render the toilet material unsafe for agricultural use.
- 11) Usable land on or near the site is required to bury toilet material from 500 homes four to six times a year.
- 12) There could be a high risk of failure if the toilet maintenance and disposal is left to the user.
- 13) Cleaning the chamber will expose household members to direct contact with untreated feces.
- 14) The feces/urine slurry in the buckets is not compost and should not be applied to soil or used for agricultural purposes.

DINEPA

The main Haitian public water institution is the National Directorate for Water Supply and Sanitation in the Ministry of Public Works, called DINEPA after its French acronym (Direction Nationale d'Eau Potable et d'Assainissement). All sanitation systems being installed in new sites in Haiti must adhere to the following minimum standards as defined by DINEPA:³

- 1. No less than one toilet per four families.
- 2. Toilet must be within fifty meters from the furthest user.
- 3. No less than one shower per four families.
- 4. One handwashing station per four families or one station per household toilet.
- 5. One toilet out of ten for elderly/disabled persons.
- 6. Excreta storage, treatment, and disposal must be at least thirty meters from any surface water source.
- 7. The bottom of a pit latrine must be at least 1.5 meters above the maximum height of the water table.

Minimum DINEPA standards for ecological sanitation require that:

- 1. Projects must be planned and designed in collaboration with the community and presented to the local authorities with a timeline for planned activities.
- 2. Projects must be designed to respond to informed choices on the part of the community and be demand driven no construction should occur prior to approval of the community.
- 3. Projects exceeding 500 beneficiaries must present their education and monitoring and evaluation framework and their toilet plans and compost hardware to DINEPA for review prior to construction starting.
- 4. All Ecosan projects must take into account worker protection through the provision of safety equipment and hygiene education. The health, safety and environment risk assessment should be presented for review to DINEPA.
- 5. Projects must have a strategy for access to a good cover material for the toilets, and a carbon source for the compost site.
- 6. Projects must include a strategy for the sanitization of excreta, whether it is in the toilet, onsite or offsite, and there should be a clear strategy for the reuse of the final product.
- 7. All composting areas must be planned to ensure restricted access and must have the capacity to treat organic material from all of the project toilets.
- 8. Where thermophilic composting is used, the standard rule for pathogen destruction is that temperatures throughout the pile must attain 50C for at least one week.³

GIVELOVE'S HOT COMPOST SANITATION SYSTEM AT SANTO

GiveLove's hot composting system was subsequently installed to replace the Otji toilets. After the community accepted the system by voting, the project was scaled up from 24 pilot homes to nearly 300 homes in February, 2012, over the course of one week. The Otji toilet sheds became the housing for the humanure toilets with plenty of room in the sheds left over for general storage. The hot compost system had been in use at Santo for two years and 10 months when the data for this paper was collected.

GiveLove constructed two composting sites at Santo (Figures 2 and 3), each surrounded by chainlink fence and razor wire to keep out vandals. Inside the compounds they constructed compost sheds with padlocked doors for storing equipment and materials (Figure 4). Water sources were situated in the compost sites to allow for cleaning purposes. Gravel "soak pits" were installed for dumping the final rinse water after cleaning toilet receptacles (Figure 5). The compost yards allowed access to large trucks through gates for the delivery of bagasse. Toilets were set up inside the compost yards for workers (Figure 6). Bagasse was dumped in large



The compost yard has become populated with banana trees.



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The compost shed provides a secure place to store tools and equipment.



The gravel soak pit provides a place to dump the final rinse from the toilet receptacles.

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Bagasse from a local sugar mill is dumped in piles inside the compost yard.

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piles inside the fenced in area and was delivered on a regular basis (Figure 7). The bagasse was free, but the hauling was expensive. The cost of hauling bagasse constituted about 1/3 of the operating costs of the program.

Sixteen compost bins were constructed in each compost yard. Each bin had a holding capacity of 10 cubic meters. Each bin was labeled (Figure 8). A compost team was trained (Figure 9).

Each household was provided with 20 liter, waterproof, plastic toilet receptacles, with lids, for the collection of toilet material. The receptacles were housed in "Loveable Loo" style wooden boxes (Figure 10), where they could be easily removed. A toilet was located inside each Otji toilet stall located behind each home (Figure 11).

The community received training in how the toilet system works and how to use it. Instructions are posted at toilets (Figure 12). When a toilet was used, the user covered the contents of the toilet with bagasse. When one looked inside a toilet, all that should be visible is bagasse. In this way, no odors escaped and consequently, no files were attracted to the toilet.

When a toilet receptacle became full, the user simply lifted the 20 liter container out of the toilet and set it aside in the toilet room, with a lid on it. In this manner, all toilet material was collected and nothing

was leaked or drained out into the ground. There was no human contact with excrement and nothing was polluting the environment or creating a health hazard.

Twice a week, as needed, the toilet user could carry their toilet receptacle, with lid, to one of the two compost yards, early in the morning when it was still cool outside. Here, inside the fenced compound, they would simply set their full (actually about 2/3 or 3/4 full) toilet receptacle on the ground for the compost workers to



THERMOPHILIC COMPOSTING AS A SANITATION ALTERNATIVE — SANTO VILLAGE, LEOGANE, HAITI — A CASE STUDY



Figure 12: Toilet instructions show how to cover the toilet contents and then wash hands afterward. [Photo by Givelove.org.]



take care of. The user would then take a clean, empty receptacle as supplied by the compost workers, put clean bagasse in it if they needed it, and carry it back to their home toilet.

The compost workers would then empty all of the toilet receptacles at once into a designated compost bin. Approximately 150 to 200 receptacles were collected twice a week and a single bin was filled in approximately a month's time. The 32 bins in use in the village each had a capacity to hold about ten cubic meters of organic material.

Once a bin was filled, it was covered over with a generous layer of bagasse and then allowed to compost undisturbed for a full nine months or more of "retention time." Temperatures of the piles were monitored and recorded (**Figure 13**), by checking the temperatures at various locations in the pile. Data showed that the average temperatures remained above 131F (55C) for three months or more, far above the EPA required three day period or the DINEPA required 50C for one week. These temperature results are typical for the humanure compost operations as seen by the author of this paper at other Haitian sites and elsewhere in the world. See **Figures 14, 15 and 16**.

Prior to adding any toilet material to a compost bin, first a "biological sponge" is constructed in the bottom of the bin (**Figure 17**). This is simply a thick layer of bagasse, approximately 1/2 meter deep. This provides an absorbent cushion of organic material to allow the first layer of toilet material to bed into. The sponge does not need to be bagasse. It can be any clean organic material such as straw, hay, leaves, weeds, grasses, etc., as long as the material is somewhat absorbant and in sufficient quantity.

The compost workers were equipped with long rubber gloves, high rubber boots, and coveralls (Figure 18). The collected toilet containers are all dumped at once over the surface of the pile (Figure 19), then the pile is covered with fresh and clean bagasse. The bagasse covering prevents odors from escaping, keeps flies from becoming attracted to the compost, and acts as protection from heavy rains and from drying sun. In effect, the organic material becomes layered into the bins in this manner — first a biological sponge, then a layer of toilet material (itself about 2/3 bagasse), then a layer of clean

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The compost manager at one of the Santo compost yards monitors a pile while Lucho Jean, compost instructor, looks on.

bagasse, then more toilet material and food scraps if available, more bagasse, etc., until the bin is heaping full (**Figure 20**). The contents will shrink to about half the original volume, or less, after the compost has fully aged (**Figure 21**), which is why the bins should be initially filled to capacity.

When the next dumping occurs, the bagasse cover is raked to the sides and the fresh toilet material then added. This causes the creation of a bagasse edge around the fresh material and prevents toilet material from falling through the openings in the pallets. It also insulates the sides of the compost and prevents the open, exposed surfaces that are characteristic of windrow composting. Because the toilet material is contained and enclosed in

this manner, there are no exposed surfaces and no need to "turn" the compost piles as is necessary when open piles, or windrows, are created.

Windrows and open, uncovered piles have a high surface area to volume ratio. What happens in that case is the center of the pile gets hot, but the outside surface of the pile does not. In order for the entire mass to be subjected to the internal, biological heat, it must be completely stirred up and the outer surfaces turned into the center, numerous times. This process is very labor intensive. Open compost piles with large, exposed surface areas also tend to be odorous and fly covered. These problems are easily solved by piling the organic material in an above-ground container such as the pallet bins used at the Santo site, and covering the compost with a clean cover material at all times. When the cover material is correctly managed by pulling it aside when adding fresh material, a blanket of cover material is formed around the edges of the compost pile, thereby eliminating exposed edge surfaces, allowing the entire mass to heat, while simultaneously preventing odor and fly problems. High temperatures can be confirmed along the edges of the compost using a compost thermometer. **Figure 22** is a screen grab from a video taken by the author of such a compost bin in Haiti. The thermometer is reading 131F (55C) at a depth of approximately six inches (15 centimeters) near the edge of the pile. Bagasse surrounds and covers the compost in this bin, preventing loss of heat.

After emptying, the toilet receptacles are given an initial rinse with water by the compost management team. This water can be dumped from receptacle to receptacle as they are being scrubbed with a long handled brush. The initial rinse water, or black water, is dumped into the active compost bin (the same bin the toilet receptacles are being emptied into). The receptacles are then rinsed again with water containing EM (Effective Microorganisms, purchased in Port au Prince). This is an optional stage. This water is also dumped into the active compost bin. Then the receptacles are sprayed inside and out with a bleach solution using a hand-pumped sprayer. This water is dumped into the soak pit. The diluted bleach solution is used as a disinfectant for the handles and exterior of the toilet receptacle as well as the inside. The cleaned receptacles are set in the sun to dry and then stored on site under a tarp until further use (Figure 23). The look and smell clean inside.

The finished compost has been independently lab tested (Soil Control Lab,Watsonville, CA USA). It is considered, mature, very stable, safe (tested for fecal coliform, salmonella and heavy metals), average in nutrients, a low nitrogen provider, high lime content, with an average nutrient release rate, a neutral nitrogen demand, high ash content, and sprouted healthy test plants (see attached test results).



Compost is beneficial for a number of reasons, including⁴:

- 1. SOIL ENRICHMENT: Adds organic material, improves fertility and productivity, suppresses plant diseases, discourages insects, increases water retention, inoculates soil with beneficial microorganisms, reduces or eliminates fertilizer needs, moderates soil temperature.
- 2. PREVENTS POLLUTION: Reduces methane production in landfills; reduces or eliminates organic garbage; reduces or eliminates sewage.
- 3. FIGHTS EXISTING POLLUTION: Degrades toxic chemicals; binds heavy metals; cleans contaminated air; cleans stormwater runoff.
- 4. RESTORES LAND: Aids in reforestation; helps restore wildlife habitats; helps reclaim mined lands; helps restore damaged wetlands; helps prevent erosion on flood plains.
- 5. DESTROYS PATHOGENS: Can destroy human disease organisms, can destroy plant pathogens, can destroy livestock pathogens.
- 6. SAVES MONEY Can be used to produce food; can eliminate waste disposal costs; reduces the need for water, fertilizers, and pesticides; can be sold at a profit; extends landfill life by diverting materials; is a less costly bioremediation technique.

The conversion of human excrement into compost eliminates the waste, pollution, disease, unpleasant odors, and insect problems normally associated with sewage. Ideally, the finished compost will be marketed and sold or exchanged for goods or at least given back to the community for food production. The Santo com-

munity was formed from persons displaced in the 2010 earthquake. They were not originally from Leogane and there was no agricultural connection to the community. The marketing and capitalization of the finished compost was not completed as part of the project objective and many tons of excellent compost are sitting in bins at Santo unused and overgrown with weeds. Future projects of this nature should have a plan in place for the utilization of the finished compost production commences.

It is interesting to note the unsubstantiated fears and concerns that caused the hot compost alternative to be initially rejected by AFH. This is not uncommon when the composting of human excrement is considered by persons with no experience in the process. For some reason, many believe that the process is unsanitary, odorous, fly-infested and exposes the toilet user to direct contact with human excrement, none of which is true. AFH stated that "*The social acceptability of this system would probably be quite low as there is repeated contact with the humanure. Having to store humanure for collection may also be undesirable.*" Yet, there was no contact with humanure other than what can be normally expected when using any toilet. On the other hand, the Otji toilet, the choice of AFH, required the user to periodically remove feces-coated, heavy, fly-infested, 90 liter buckets of raw excrement and dispose of them somehow, without any instruction or guidance for disposal. The undesirability of "having to store humanure for collection" was a non-issue with the hot compost system. The toilets were emptied and cleaned twice weekly by trained personnel. The Otji toilets, on the other hand, AFH's choice toilets, were expected to store excrement for up to six months while breeding swarms of flies and emitting intolerable odors that fouled the air of the entire village even disturbing people in their sleep.

It is unfortunate that these gross prejudices about hot composting persist in some sanitation and urban

		Pile 1	Pile 2	Pile 3	Pile 4	Pile 5	Pile 6	Pile 7	Pile 8	Pile 9	Pile10	Pile 11	Pile 12
		A	A	A	A	A	A	A	A	A	A	A	A
February	Week 1	148											
	Week 2	162											
	Week 3	150											
	Week 4	138											
March	Week 1	136	162	114									
	Week 2	129	154	122						Figur	e 15		
	Week 3	136	166	130						-			
	Week 4	134	146	114					50	nto	Villa	20	
	Week 5	130	148	130					Sa	πιο	VIIIa	ge	
								-				-	
April	₩eek1	130	130	150				Cor	nnog	st Te	mpe	rati	Ires
	Week 2	130	144	154				001	iipos		mpe	nait	100
	Week 3	128	160	148	148					0:4	- 0		
	Week 4	128	136	140	150		<u> </u>	1		510	e 2		
	Week 5	120	100	140		112	<u> </u>	†	1	1	1	1	
	THEER S					112							
May	Week 1	126	142	152	126	128							
may	Week 2	120	142	140	164	136							
	Week 2	124	130	136	134	140							
	Week 3	124	126	130	134	140		-					
	Week 4	120	132	132	150	140							
	HEEKS	166	152	142	150	142							
June	Week 1	122	126	136	146	146	160						
Julie	Week 2	126	128	128	140	140	156						
	Week 2	120	120	128	140	142	152			<u> </u>	<u> </u>	<u> </u>	
<u> </u>	Week 3	118	118	128	138	140	148	158		<u> </u>	<u> </u>	<u> </u>	
<u> </u>	Week 4	110	110	120	130	144	140	150		<u> </u>	<u> </u>	<u> </u>	
July	Week 1	118	120	122	134	134	142	120		<u> </u>	<u> </u>	<u> </u>	
July	Week 2	122	120	130	134	134	142	120		<u> </u>	<u> </u>	<u> </u>	
<u> </u>	Week 2	114	116	126	130	130	140	148		<u> </u>	<u> </u>	<u> </u>	
<u> </u>	Week 3	120	120	120	132	132	144	140		<u> </u>			
	Week 4	120	120	120	130	130	140	140					
A	11-11	116	118	120	128	128	142	144	156	<u> </u>	<u> </u>	<u> </u>	
August	Week 1	116	112	120	120	120	142	136	136		<u> </u>	<u> </u>	
	Week 2 Week 3	114	112	118	120	128	136	130	142	142	<u> </u>		
		114	116	118	124	128	136	142	144	142			
	Week 4	120	126				134	140	146	148	<u> </u>		
	₩eek 5	120	126	134	132	132	146	144	144	148			
	11-11	110	114	116	124	124	130	138	144	144			
Septembe		112	114	118	124	124	128	130	144	144	154		
	Week 2 Week 3				124	124					154		
		110 108	112 112	124 112	124	124	126 126	132 130	140 132	144 144	152		
	₩eek 4	100	112	112	122	122	120	150	132	144	150		
Ortel	U I. 1	102	10.4	110	112	114	124	100	120	124	140	154	
October	Week 1		104	110 108	112	114	124	122	130	134	142 150	154 160	
	Week 2	106	106				124	130	138	142			
	Week 3	104	108 104	108	114	116	118	124	130	138	148	156 152	
<u> </u>	Week 4	102	104	108	110	110	114	120	126	136	150	152	
	₩eek 5							118					
N	111-1	00	100	100	104	104	114	100	120	100	140	150	
November		96	102	100	104	104	114	120	120	128	146	150	100
	Week 2	104	104	104	110	112	118	124	124	128	142	146	162
	Week 3	102	104	104	108	108	112	120	126	126	140	144	158
	Week 4	100	100	102	104	108	112	120	120	124	140	140	140
	Week 5	100	100	100	104	106	112		122		134	140	140
		10.0			10.1	10.1	48.8		10.0	10.1	10.1	10.0	
December		100	98	100	104	104	108	114	120	124	134	136	148
	Week 2	98	98	98	102	104	108	106	116	110	130	136	134
	Week 3	100 92	98 94	100 98	100 100	100	100	98 106	100	114	122	130	130
	Week 4						100		110	110	120	130	126

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planning communities. For example, referring to the hot composting system, AFH adds, "There are large numbers of people coming in direct contact with the humanure, increasing the risk of contamination by pathogens. The toilet seat may have to be secured to ensure children cannot gain access to the humanure. Storage of humanure in the household prior to collection is a potential risk as is securing the bins when left out for collection. Compost managers will need to ensure compost stations are also kept secure to ensure they are not accessed by unauthorized personnel. All tools and transport associated with the composting stations will have to be cleaned properly after use. Compost station staff will need to be very well trained and know what measures to take if temperatures are not being maintained according to guidelines." All of these very serious sounding issues turned out to be non-issues after all. There were not large numbers of people coming into direct contact with humanure and the very idea is preposterous. Storage of humanure was already discussed. Training of







THERMOPHILIC COMPOSTING AS A SANITATION ALTERNATIVE — SANTO VILLAGE, LEOGANE, HAITI — A CASE STUDY



THERMOPHILIC COMPOSTING AS A SANITATION ALTERNATIVE — SANTO VILLAGE, LEOGANE, HAITI — A CASE STUDY





Cleaned and sanitized toilet receptacles wait to be picked up by toilet users.

compost managers is realistic and important and not a problem. What AFH failed to consider was that the hot composting system produced no waste and no environmental pollution and is relatively inexpensive, whereas the Otji toilet, although perhaps perfectly suitable for Namibia, collected "*waste*" for *disposal*, cost half a million dollars, and failed miserably. On the other hand, when properly managed and carried through to total fruition, the hot composting alternative can produce real monetary profit from the sale and use of the finished compost and thereby create a sanitation system that pays for itself. This is a case study that not only demonstrates how a village-wide compost sanitation system can be organized and carried out, but it also demonstrates how poor planning, prejudice, ignorance and irrational fear about hot composting can allow a winning system to be rejected for a losing one.

DATA FROM SANTO SITE⁵

PARTICIPANTS

- Number of households: 250-280 (averaging 4-5 people per household or 1,000-1,400 persons).
- Average number of households participating in the compost activities/compost day: 170-200.

COMPOST BINS

- Construction of bins = recycled shipping pallets on edge, fastened together.
- Number of compost bins needed to compost for 270 households: 32.
- Area needed to build compost bins with 1.5 meter walk area between each pile: 290 m²
- Dimension of compost bins: 2.4m X 3.2m X 1.2m.
- Internal volume of compost bins: 8 cubic meters.
- Capacity of compost bins when full: 10 cubic meters (piled high).
- Volume of compost in bin at maturation (after shrinkage): 4-5 cubic meters.

QUANTITY OF ORGANIC MATERIAL COLLECTED

- Approximately (400) 5-gallon toilet receptacles are collected each week (averaged over the life of the project), each approximately 2/3 full = 1,333.33 gallons toilet material collected/week = 5.047 cubic meters toilet material collected/week per 250 households.
- 20.19 cubic meters of toilet material is collected per month for 250 households.
- Collection is done twice per week.

COVER MATERIAL

- For every cubic yard of toilet material collected, two cubic yards of bagasse are needed.
- The bagasse is sources from 2km away at a sugar factory where it can be obtained free.
- 13.46 cubic meters of toilet cover material are needed per month for 250 household toilets.
- Assuming 250 households are using the toilets, then each household is using .054 cubic meters/month of toilet cover material = 14.26 gallons/month, rounded to 15 gallons per household per month for cover material utilized at the home.
- Assuming 13.46 cubic meters are needed per month for the household toilets, or 161.52 cubic meters per year, but we double that quantity to make sure we have enough for the bins (biological sponge, top cover, etc.), then we need 323 cubic meters per year for 250 households, or approximately 1.3 cubic meters per household/year.

COMPOST MANAGEMENT

- One team leader and five compost workers (four are women and two are men) work 4 hours each per week total (3 persons at each compost site), or 24 "man hours" per week total, to compost and clean approximately 300-400 toilet receptacles per week, total, at two sites. It takes less than a minute to clean each 20 liter toilet receptacle.
- Composting is done every Tuesday and Friday, at both sites. Households drop off full toilet receptacles and retrieve clean ones and bagasse as needed.

- The five-gallon toilet receptacles are usually no more than 75% full when delivered.
- Composting is done between 5 and 6 am because of the heat.
- Water from the first rinsing of toilet receptacles is deposited into a compost bin.
- Second rinsing contains Effective Microorgansims (EM) and is dumped into soak pit.
- Final rinse is with mild bleach solution (to disinfect the outside of buckets and handles) and is also dumped into soak pit.
- Buckets are dried in the sun to further sanitize, then set underneath a tarp.
- Total training time for compost workers was about 8 weeks, with a pilot group of 24 houses. After the community accepted the system by voting, the project was scaled up from 24 homes to 300 homes over the course of one week, in February, 2102. In a survey, 80% of households said they knew this system protected the ground water as well as their drinking water, which they collected on site.

COMPOST HARVEST

- Compost harvested/bin after 1 year processing: (45) 30 lb. bags or 2.5 cubic meters/bin.
- Number of compost bins harvested per year: 25 (33,750 lbs. compost total harvest).
- Number of cubic meters or bags harvested per year: 62.5 cubic meters or (1,125) 30 lb. bags.
- Tons compost harvested per year: 16.875.
- Metric tonnes of compost harvested per year: 15.30.

CONCLUSIONS

Compost sanitation systems can provide safe and pleasant toilet alternatives in developing countries where electricity, water or money are in short supply, so long as carbon-based cover materials are available and compost sanitation personnel are trainable. Santo provided a unique demonstration project because the users of the toilets participated in the process by delivering their toilet material to a trained composting crew.

The toilet users did not directly make any compost themselves or deal directly with humanure other than to excrete it into the toilets and cover it with bagasse. There were no reports of illness or diarrhea among any compost crew personnel.

There was no excrement draining into the ground or seeping into the environment from this sanitation system, as is common with other systems such as urine diversion toilets where urine is drained into soakpits. In fact, there is no organic waste at all since all of the organic material is collected and recycled by composting.

The compost heated up to the extent that any human disease-causing organisms, including cholera, can be expected to be reduced to non-detectable levels or eliminated entirely. This fact alone sets this system apart from any other toilet system. There are no other toilet systems that completely and constructively recycle all toilet materials and in the process sanitize and convert the material to create a valuable end product, and do it all without the need for electricity.

The composting system can easily be expanded to include all food scraps and other organic materials that are typically discarded in a village setting, including animal mortalities. If the finished compost were sold, the income generated could finance a sustainable enterprise, perhaps to the extent that door to door collection of the toilet receptacles would be economically feasible. Other potential sources of income from this system include constructing toilets, constructing toilet stalls (if needed), supplying cover material, and working on a composting crew. The finished compost can support gardens, farms, orchards, nurseries and landscaping operations.

The fact that compost sanitation systems are waste-free and instead produce compost suitable for growing human food should make this an attractive sanitation alternative anywhere in the world.

ABOUT

Joseph Jenkins is best known for authoring the Humanure Handbook — A Guide to Composting Human Manure — first published in 1995 and now in its 3rd edition. The book has been sold worldwide and published in foreign editions on four continents. He has been a compost practitioner in the United States since 1975 and has grown food with humanure compost for the past 37 years. His web site at HumanureHandbook.com offers videos, instructions and the complete Humanure Handbook free of charge. Jenkins also provides compost sanitation consulting services internationally. More information about the author can be found at http://www.CompostSanitation.com.

GiveLove.org was founded by oscar-winning actress Patricia Arquette and Rosetta Getty. Its Program Director is Alisa Keesey and its primary educator in Haiti is Lucho Jean. More information is available at GiveLove.org.

To see videos of the Santo Village compost project:

Village Compost Toilet System in Santo Village, Leogane, Haiti, Part 1 of 2 (https://youtu.be/VY5K2Jn7Om0)

Village Compost Toilet System in Santo Village, Leogane, Haiti, Part 2 of 2 (https://youtu.be/tKdZOeTaPo4)

To see more humanure compost videos: http://humanurehandbook.com/videos.html

To download this paper from the internet: http://humanurehandbook.com/downloads/Santo_Paper.pdf

- ¹ More information is available online at: http://openarchitecturenetwork.org/projects/santo_community_plan
- ² http://www.levoyageur.net/weather-city-LEOGANE.html
- ³ Santo Community Development Plan, Sanitation Recommendations Sept 4, 2011
- ⁴ Source: U.S. EPA (October 1997). Compost-New Applications for an Age-Old Technology. EPA530-F-97-047.
- ⁵ Provided by Alisa Keesey of GiveLove.org

ANALYTICAL CHEMISTS and BACTERIOLOGISTS Approved by State of California

SOIL CONTROL LAB

42 HANGAR WAY WATSONVILLE CALIFORNIA 95076 USA

TEL: 831-724-5422 FAX: 831-724-3188 www.compostlab.com

Account #: 4100531-1/1-6689 Group: Oct.14 C #28 Reporting Date: October 31, 2014

GiveLove 1006 Escalona Drive Santa Cruz, CA 95060 Attn: Alisa Keesey

Date Received: 16 Oct. 14 Sample Identification: Compost 12 Months- Thermophilic Treated Sample ID #: 4100531 - 1/1

Nutrients	Dry wt.	As Rcvd.	units	Stability Indica	ator:		Biologically
Total Nitrogen:	1.4	0.90	%	CO2 Evolution		Respirometery	Available C
Ammonia (NH ₄ -N):	24	15	mg/kg	mg CO ₂ -C/g ON		0.84	1.4
Nitrate (NO ₃ -N):	1500	930	mg/kg	mg CO ₂ -C/g TS	•	0.21	0.35
Org. Nitrogen (OrgN):	1.2	0.75	%	Stability Rat	•	very stable	very stable
Phosphorus (as P_2O_5):	0.64	0.40	%				
Phosphorus (P):	2800	1800	mg/kg				
Potassium (as K ₂ O):	0.43	0.27	%	Maturity Indica	ator: Cucum	ber Bioassav	
Potassium (K):	3600	2200	mg/kg	Compost:Vermi		1:1	1:3
Calcium (Ca):	5.2	3.2	%	Emergence (%)		100	100
Magnesium (Mg):	1.3	0.83	%	Seedling Vigor		100	100
Sulfate (SO ₄ -S):	140	90	mg/kg	Description	· /	healthy	healthy
Boron (Total B):	7.1	4.5	mg/kg	Decemption		nounny	nounny
Moisture:	0	37.3	%				
Sodium (Na):	0.29	0.18	%	Pathogens	Results	Units	Rating
Chloride (CI):	0.11	0.067	%	Fecal Coliform	< 2.0	MPN/g	pass
pH Value:	NA	6.60	unit	Salmonella	< 3	MPN/4g	pass
Bulk Density :	35	55	lb/cu ft	Date Tested: 16 C		in in the	pabo
Carbonates (CaCO ₃):	130	79	lb/ton	Date residu. 10 c			
Conductivity (EC5):	3.7	NA	mmhos/cm				
Organic Matter:	25.7	16.1	%	Inerts	% by weight	ł	
Organic Carbon:	19.0	12.0	%	Plastic	< 0.5	•	
Ash:	74.3	46.6	%	Glass	< 0.5		
C/N Ratio	13	13	ratio	Metal	< 0.5		
AgIndex	6	6	ratio	Sharps	ND		
Metals	Dry wt.	EPA Limit	units	Size & Volume		`	
Aluminum (Al):	19000		mg/kg	MM		t % by volume	BD g/cc
Arsenic (As):	< 1.0	41	mg/kg	> 50	0.0	0.0	0.00
Cadmium (Cd):	< 1.0	39	mg/kg	25 to 50	0.0	0.0	0.00
Chromium (Cr):	28	1200	mg/kg	16 to 25	0.0	0.0	0.00
Cobalt (Co)	9.7	-	mg/kg	9.5 to 16	0.0	0.0	0.00
Copper (Cu):	62	1500	mg/kg	6.3 to 9.5	4.3	3.7	0.93
Iron (Fe):	29000	-	mg/kg	4.0 to 6.3	10.3	7.5	1.12
Lead (Pb):	11	300	mg/kg	2.0 to 4.0	19.9	17.1	0.95
Manganese (Mn):	280	-	mg/kg	< 2.0	65.6	71.7	0.75
Mercury (Hg):	< 1.0	17	mg/kg			5 Light Materials	
Molybdenum (Mo):	1.7	75	mg/kg	.3560 medium	weight mate	erials, >.60 Heav	
Nickel (Ni):	39	420	mg/kg			Analyst	: Assaf Sadeh
Selenium (Se):	< 1.0	36	mg/kg			11	Salel
Zinc (Zn):	75	2800	mg/kg			and	Sabel

*Sample was received and handled in accordance with TMECC procedures.

 Account No.:
 Date Received
 16 Oct. 14

 4100531 - 1/1 - 6689
 Sample i.d.
 Compost 12

 Group:
 Oct. 14 C No. 28
 Sample I.d. No.
 1/1

INTERPRETATION:

Is Your Compost Stable?

16 Oct. 14Compost 12 Months- Thermophilic Treated1/14100531

Page one of three

Respiration Rate		Biodegradation Rate of Your Pile		
0.84 mg CO2-C/	+++			
g OM/day	< Stable	>Moderately Unstable>	Unstable	> < High For Mulch
Biologically Available Carb	on (BAC)	Optimum Degradation Rate		
1.4 mg CO2-C/	+++++			
g OM/day	< Stable	> <moderately unstable=""> <</moderately>	Unstable	> < High For Mulch

Is Your Compost Mature?

AmmoniaN/NitrateN ratio				
0.016 Ratio	+			
	VeryMature> <	Mature	> <	< Immature
Ammonia N ppm				
24 mg/kg	++			
dry wt.	VeryMature> <	Mature	> < In	nmature
Nitrate N ppm				
1500 mg/kg	+++++++++++++++++++++++++++++++++++++++	+++++++++++++++++++++++++++++++++++++++	+++++++++++++++++++++++++++++++++++++++	+++++++++++++++++++++++++++++++++++++++
dry wt.	< Immature	>	< Mature	
pH value				
6.60 units	+++++++++++++++++++++++++++++++++++++++	+++++++++++++++++++++++++++++++++++++++	+++++++++++++++++++++++++++++++++++++++	
	< Immature		> < Mature	> < Immature
Cucumber Emergence				
100.0 percent	+++++++++++++++++++++++++++++++++++++++	+++++++++++++++++++++++++++++++++++++++	+++++++++++++++++++++++++++++++++++++++	+++++++++++++++++++++++++++++++++++++++
	< Immature			> < Mature

Is Your Compost Safe Regarding Health?

Fecal Coliform		
< 1000 MPN/g dry wt.	++++++	
	< Safe	> < High Fecal Coliform
Salmonella		
Less than 3 /4g dry wt.	++++++	
	<safe (none="" detected)<="" th=""><th>> < High Salmonella Count(> 3 per 4 grams)</th></safe>	> < High Salmonella Count(> 3 per 4 grams)
Metals US EPA 503		
Pass dry wt.	+++++++	
-	<all metals="" pass<="" th=""><th>>I< One or more Metals Fail</th></all>	>I< One or more Metals Fail

Does Your Compost Provide Nutrients or Organic Matter?

Nutrients (N+P2O5+K2O)	
2.5 Percent	+++++++++++++++++++++++++++++++++++++++
dry wt.	<low> < Average > < High Nutrient Content</low>
AgIndex (Nutrients / Sodium	and Chloride Salts) ((N+P2O5+K2O) / (Na + Cl))
6 Ratio	+++++++++++++++++++++++++++++++++++++++
	Na & Cl > Nutrient and Sodium and Chloride Provider > Nutrient Provider
Plant Available Nitrogen (PA	N) Estimated release for first season
4 lbs/ton	+++++++++++++++++++++++++++++++++++++++
wet wt.	Low Nitrogen Provider> < Average Nitrogen Provider > <high nitrogen="" provider<="" th=""></high>
C/N Ratio	
13 Ratio	+++++++++++++++++++++++++++++++++++++++
	< Nitrogen Release > < N-Neutral > < N-Demand> < High Nitrogen Demand
Soluble Available Nutrients	k Salts (EC5 w/w dw)
3.7 mmhos/cm	+++++++++++++++++++++++++++++++++++++++
dry wt.	SloRelease> < Average Nutrient Release Rate > <high available="" nutrients<="" th=""></high>
Lime Content (CaCO3)	
130 Lbs/ton	****
dry wt.	< Low > < Average > < High Lime Content (as CaCO3)

What are the physical properties of your compost?

Pe	rcer	nt A	sh

Feitenit Asii								
74.3 Percent	+++++++++++++++++++++++++++++++++++++++							
dry wt.	< High Organic Matter > < Average > < High Ash Content							
Sieve Size % > 6.3 MM (0.25	")							
4.3 Percent	+++++++++++++++++++++++++++++++++++++++							
dry wt.	All Uses > < Size May Restrict Uses for Potting mix and Golf Courses							

Account N	lo.:
4100531 -	1/1 - 6689
Group:	Oct.14 C No. 28

INTERPRETATION:

Is Your Compost Stable?

Respiration Rate

Date Received Sample i.d. Sample I.d. No. 16 Oct. 14 Compost 12 Months- Thermophilic Treated 1/1 4100531

Page two of three

mg CO2-C/g OM/day 0.84 Low: Good for all uses

The respiration rate is a measurement of the biodegradation rate of the organic matter in the sample (as received). The respiration rate is determined by measuring the rate at which CO2 is released under optimized moisture and temperature conditions.

Biologically Available Carbon

Low: Good for all uses mg CO2-C/g OM/dav 14

Biologically Available Carbon (BAC) is a measurement of the rate at which CO2 is released under optimized moisture, temperature, porosity, nutrients, pH and microbial conditions. If both the RR and the BAC test values are close to the same value, the pile is optimized for composting. If both values are high the compost pile just needs more time. If both values are low the compost has stabilized and should be moved to curing. BAC test values that are higher than RR indicate that the compost pile has stalled. This could be due to anaerobic conditions, lack of available nitrogen due to excessive air converting ammonia to the unavailable nitrate form, lack of nitrogen or other nutrients due to poor choice of feedstock, pH value out of range, or microbes rendered non-active. Is Your Compost Mature?

AmmoniaN:NitrateN ratio

0.016 very mature

		the
Ammonia N	ppm	ste
24	very mature	in
Nitrate N pp	m	an
1500	mature	an
pH value		Fc
6.60	mature	ca
		cu
Cucumber F	Rinaeeav	

Cucumber Bioassay 100.0 Percent Composting to stabilize carbon can occur at such a rapid rate that sometimes phytotoxins remain in ne compost and must be neutralized before using in high concentrations or in high-end uses. This tep is called curing. Typically ammonia is in excess with the break-down of organic materials resulting an increase in pH. This combination results in a loss of volatile ammonia (it smells). Once this toxic mmonia has been reduced and the pH drops, the microbes convert the ammonia to nitrates. A low mmonia + high nitrate score is indicative of a mature compost, however there are many exceptions. or example, a compost with a low pH (<7) will retain ammonia, while a compost with high lime content an lose ammonia before the organic fraction becomes stable. Composts must first be stable before uring indicators apply.

Cucumbers are chosen for this test because they are salt tolerant and very sensitive to ammonia and organic acid toxicity. Therefore, we can germinate seeds in high concentrations of compost to

measure phytotoxic effects without soluble salts being the limiting factor. Values above 80% for both percent emergence and vigor are indicative of a well-cured compost. Exceptions include very high salts that affect the cucumbers, excessive concentrations of nitrates and other nutrients that will be in range when formulated to make a growing media. In addition to testing a 1:1 compost: vermiculite blend, we also test a diluted 1:3 blend to indicate a more sensitive toxicity level.

Is Your Compost Safe Regarding Health?

Fecal Coliform

< 1000 / g dry wt. Fecal coliforms can survive in both aerobic and anaerobic conditions and is common in all initial compost piles. Most human pathogens occur from fecal matter and all fecal matter is loaded in fecal coliforms. Therefore fecal coliforms are used as an indicator to determine if the chosen method for pathogen reduction (heat for compost) has met the requirements of sufficient temperature, time and mixing. If the fecal coliforms are reduced to below 1000 per gram dry wt. it is assumed all others pathogens are eliminated. Potential problems are that fecal coliform can regrow during the curing phase or during shipping. This is because the conditions are now more favorable for growth than during the composting process.

Salmonella Bacteria

Salmonella is not only another indicator organism but also a toxic microbe. It has been used in the Less than 3 3 / 4g dry wt. case of biosolids industry to determine adequate pathogen reduction.

Metals

Pass The ten heavy metals listed in the EPA 503 regulations are chosen to determine if compost can be applied to ag land and handled without toxic effects. Most high concentrations of heavy metals are derived from woodwaste feedstock such as chrome-arsenic treated or lead painted demolition wood. Biosolids are rarely a problem. Does Your Compost Provide Nutrients or Organic Matter? Nutrients (N+P2O5+K2O)

Average nutrient content 25

This value is the sum of the primary nutrients Nitrogen. Phosphorus and Potassium. Reported units are consistent with those found on fertilizer formulations. A sum greater than 5 is indicative of a compost with high nutrient content, and best used to supply nutrients to a receiving soil. A sum below 2 indicates low nutrient content, and is best-used to improve soil structure via the addition of organic matter. Most compost falls between 2 and 5.

Account No.:		Date Received	16 Oct. 14	
4100531 - 1/1	- 6689	Sample i.d.	Compost 12	Months- Thermophilic Treated
Group:	Oct.14 C No. 28	Sample I.d. No.	1/1	4100531

INTERPRETATION:

AgIndex (Nutrients/Na+CI)

Page three of three

6 Average nutrient ratio Composts with low AgIndex values have high concentrations of sodium and/or chloride compared to nutrients. Repeated use of a compost with a low AgIndex (< 2) may result in sodium and/or chloride acting as the limiting factor compared to nutrients, governing application rates. These composts may be used on well-draining soils and/or with salt-tolerant plants. Additional nutrients form another source may be needed if the application rate is limited by sodium or chloride. If the AgIndex is above 10, nutrients optimal for plant growth will be available without concern of sodium and/or chloride toxicity. Composts with an AgIndex of above 10 are good for increasing nutrient levels for all soils. Most composts score between 2 and 10. Concentrations of nutrients, sodium, and chloride in the receiving soil should be considered when determining compost application rates. The AgIndex is a product of feedstock quality. Feedstock from dairy manure, marine waste, industrial wastes, and halophytic plants are likely to produce a finished compost with a low AgIndex.

Plant Available Nitrogen (lbs/ton)

4 Low N Provider Plant Available Nitrogen (PAN) is calculated by estimating the release rate of Nitrogen from the organic fraction of the compost. This estimate is based on information gathered from the BAC test and measured ammonia and nitrate values. Despite the PAN value of the compost, additional sources of Nitrogen may be needed during he growing season to offset the Nitrogen demand of the microbes present in the compost. With ample nutrients these microbes can further breakdown organic matter in the compost and release bound Nitrogen. Nitrogen demand based on a high C/N ratio is not considered in the PAN calculation because additional Nitrogen should always be supplemented to the receiving soil when composts with a high C/N ratio are applied. **C/N Ratio**

13 Indicates maturity As a guiding principal, a C/N ratio below 14 indicates maturity and above 14 indicates immaturity, however, there are many exceptions. Large woodchips (>6.3mm), bark, and redwood are slow to breakdown and therefore can result in a relatively stable product while the C/N ratio value is high. Additionally, some composts with chicken manure and/or green grass feedstocks can start with a C/N ratio below 15 and are very unstable. A C/N ratio below 10 supplies Nitrogen, while a ratio above 20 can deplete Nitrogen from the soil. The rate at which Nitrogen will be released or used by the microbes is indicated by the respiration rate (BAC). If the respiration rate is too high the transfer of Nitrogen will not be controlable. **Soluble Nutrients & Salts (EC5 w/w dw - mmhos/cm)**

3.7 Average salts This value refers to all soluble ions including nutrients, sodium, chloride and some soluble organic compounds. The concentration of salts will change due to the release of salts from the organic matter as it degrades, volatilization of ammonia, decomposition of soluble organics, and conversion of molecular structure. High salts + high AgIndex is indicative of a compost high in readily available nutrients. The application rate of these composts should be limited by the optimum nutrient value based on soil analysis of the receiving soil. High Salts + low AgIndex is indicative of a compost low in nutrients with high concentrations of sodium and/or chloride. Limit the application rate according to the toxicity level of thesodium and/or chloride. Low salts indicates that the compost can be applied without risking salt toxicity, is likely a good source of organic matter, and that nutrients will release slowly over time.

Lime Content (lbs. per ton)

130 High lime content Compost high in lime or carbonates are often those produced from chicken manure (layers) ash materials, and lime products. These are excellent products to use on a receiving soil where lime has been recommended by soil analysis to raise the pH. Composts with a high lime content should be closely considered for pH requirements when formulating potting mixes.

Physical Properties

Percent Ash

74.3 High ash content Ash is the non-organic fraction of a compost. Most composts contain approximately 50% ash (dry weight basis). Compost can be high in ash content for many reasons including: excess minerilzation(old compost), contamination with soil base material during turning, poor quality feedstock, and soil or mineral products added. Finding the source and reducing high ash content is often the fastest means to increasing nutrient quality of a compost.

Particle Size % > 6.3 MM (0.25")

4.3 May restrict use Large particles may restrict use for potting soils, golf course topdressings, seed-starter mixes, and where a fine size distribution is required. Composts with large particles can still be used as excellent additions to field soils, shrub mixes and mulches.

Particle Size Distribution

Each size fraction is measured by weight, volume and bulk density. These results are particularly relevent with decisions to screen or not, and if screening, which size screen to use. The bulk density indicates if the fraction screened is made of light weight organic material or heavy mineral material. Removing large mineral material can greatly improve compost quality by increasing nutrient and organic concentrations.

Appendix		
	Estimated available nutrients for use when calculating application rates	
Plant Available Nitrogen (PAN) calculations:		lbs/ton (As Rcvd.)
PAN = (X * (organic N)) + ((NH4-N) + (NO3-N))		. ,
X value = If BAC < 2 then X = 0.1	Plant Available Nitrogen (PAN)	3.5
If BAC =2.1 to 5 then X = 0.2	Ammonia (NH4-N)	0.03
If BAC =5.1 to 10 then X = 0.3	Nitrate (NO3-N)	1.86
If BAC > 10 then $X = 0.4$	Available Phosphorus (P2O5*0.64)	5.2
Note: If C/N ratio > 15 additional N should be applied.	Available Potassium (K2O)	5.3