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MOVING TOWARDS ZERO WASTE: A CASE STUDY FROM KERALA, INDIA

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Abstract: The Amrita Institute of Medical Sciences is a 1450 - bed super-specialty hospital located in Kochi, Kerala, India. The hospital was founded by the world-renowned humanitarian and spiritual leader Amma, Sri Mata Amritanandamayi Devi, who envisioned an advanced center for serving the poor and suffering. Inspired by Amma's vision of zero-waste, the hospital undertook its journey with a view to also reducing massive greenhouse gas emissions that result from improper handling of waste. Today, the hospital manages its municipal solid waste on an industrial scale, composting some eight metric tons of organic waste daily. This case study outlines the path followed to achieve zero-waste. Alongside, the rehabilitation of a former dump site is described in detail; at this very site are carried out all composting operations of AIMS.

Key words: MSW, Thermophilic composting, Zero-Waste, Bio-Remediation

INTRODUCTION

The Amrita Institute of Medical Sciences (AIMS) was started in 1998 to provide advanced healthcare services at subsidized prices or even free, to the ailing who could not afford to pay. In the fifteen years since its inception, the hospital's annual patient turnover today averages over 780,000 outpatients and nearly 48,000 inpatients. This 1450- bed super-specialty tertiary-care health centre is now part of the Amrita Health Sciences campus.

The campus also has the Amrita Schools of Medicine, Dentistry, Nursing and Pharmacy. A Center for Nanosciences and Molecular Medicine undertakes research in tissue engineering and bone implants. The campus is part of Amrita Vishwa Vidyapeetham, a multi-campus, multi-disciplinary research and teaching university, accredited by NAAC (2007) with an A grade.

Massive Healthcare Infrastructure

The massive healthcare infrastructure on this campus includes 3,330,000 sq. ft. of built-up area, over 125 acres of land. The hospital has received the ISO 9001-2008 certification as well as accreditation from the NABH (National Accreditation Board for Hospitals and Healthcare Providers). Its clinical labs are certified by NABL (National Accreditation Board for Testing and Calibration of Laboratories).The state-of-the-art infrastructure includes 25 modern operating theatres, 210 fully-equipped intensive-care beds and a 24/7 telemedicine service. A total of 45 clinical departments including 12 super-specialty departments provide the best care possible.

The AIMS team comprises physicians, surgeons and other healthcare professionals; overall, there are over 4500 staff members and over 6500 faculty members. A networked Hospital Information System (HIS) helps digitize nearly every aspect of patient care, storing all patient information, lab test results and radiological images onlin e. In fact, AIMS has the distinction of being the first hospital in South East Asia to begin using a fully digital imaging service (http://amritatech.com/).

MATERIALS AND METHODS

Solid waste management

Helping ensure proper waste management for such a sprawling complex is not easy.

However, the hospital is dedicated to achieving its vision of zero-waste. Waste is carefully collected and segregation is encouraged at source. Recyclable materials are recycled. Bio-hazardous materials are incinerated in a modern incinerator installed on the campus premises. But, as in other Indian institutions, over 50% of the waste produced daily is organic. This waste is composted. It is estimated that nearly 8 metric tonnes of organic waste is daily composted at AIMS today.

The EPA (Environmental Protection Agency, USA) estimates that for every metric tonne of garbage that is put in a compost pile instead of a landfill, 2.5 metric tonnes of CO_2 equivalent are prevented from entering the atmosphere (EPA, 2007). Thus composting helps us prevent 7300 metric tonnes of CO_2 equivalent every year from further contributing to global warming and climate change. Undertaking of large-scale composting operations in India can present many challenges. This paper describes how these challenges were overcome and how our quest continues towards achieving zero-waste.

Thermophilic Composting

In February 2010, construction was initiated in order to have a permanent site that could handle the large volumes coming in daily. Since our goal was to move towards zero- waste, we decided to build exactly at the site that was formerly used as an open waste dump. Compost windrows could be easily constructed with just a roof on top. Most MSW sites in the West produce large volumes of compost employ windrows wherein the mixed materials for aerobic, thermophilic composting are piled in long rows, usually until one runs out of room. These can be about two meters wide, two meters high and as long as one wants them to be. Regular turning is required, otherwise the windrows become too hot and anaerobic.

We designed and built a sorting table so we could remove all the non-compostable items from the food waste received and got hand tools for turning the windrows. On March 29, 2010, while waiting for the roof to be completed, composting was initiated in open windrows. We covered the windrows with green netting to help mitigate the problem of flies. In thermal composting, a windrow can be built with whatever material is available that helps achieve the basic moisture and C:N ratio. Carbon present should be about 30 times the amount of nitrogen for the pile to heat up quickly and get the bacteria to work. At temperatures of 131°F - 160°F for 3-5 days, pathogen reduction can be assured (Tom and Nancy, 1996). Each day, more was added on to the windrows, until we ran out of space. Meanwhile, we understood that manually turning the windrows would be highly labor-intensive and unsustainable in the long term. We began our search for the right equipment that was available for purchase in India. We made phone calls as well as several trips to agricultural universities in Kerala and Tamil Nadu.

Surprisingly, our research showed that India offered little in terms of large-scale composting equipment. Not wanting to import equipment, we decided to design and fabricate equipment on our own. For this, we collaborated with the Amrita School of Engineering at the Coimbatore campus. Amrita University is a five-campus, multi-disciplinary university and eventually we were able to initiate composting of all organic waste on several of the Amrita campuses. However, this paper focuses mostly on our efforts towards zero-waste at the Health Sciences campus in Kochi, which is one the oldest and largest Amrita campuses. We hope that our efforts help inspire all other educational institutions in India as well to move towards zero-waste. In order to set India firmly on the path to sustainable development, zero-waste will be a key consideration (Anju *et al*., 2013).

We discovered that an organic farmer in Northern California had built a compost windrow turner for his tractor by modifying the rear axel from a heavy truck. When this farmer learned of our endeavors, he offered much guidance and helped us build our first windrow turner from a farm tractor we bought. We needed a shredder machine so that coconuts, twigs and dried leaves could be added to the compost windrows. In Coimbatore, we were able to find something that worked well with dry materials, but needed modification to handle wet food waste like banana stems and pineapple tops. Particle size is important for two reasons.

Decomposition occurs on the surface, so smaller particles imply a greater surface area. A variety of particle sizes enables better air flow in the piles.

Slowing we were perfecting our recipe for thermal composting of MSW. One morelarge piece of equipment was needed and this was the trommel seiver. Since we could not find anything commercially available for sale, the faculty and students at our School of Engineering went to work again. After it was ready, we took delivery, made the three-hour journey from Coimbatore to Kochi by road, and then boated the equipment over to the island where our windrows were located. The trommel seiver would allow us to filter the finished compost, and the largest particles could be added back to the new windrows. Better management of particle size would allow for better moisture and temperature control. With more consistent turning and aeration, we were beginning to produce high quality aerobic compost. Fig. 1 and 2 shows our composting facility that has the windrows within.

Although they don't necessarily like the hot climate, the piles are watered and thus the temperature is kept down enough for them to flourish. In addition to the product from the aerobic thermophilic composting, we use Gliricidia sepium (now planted at the site), a nitrogen-fixing leguminous tree whose soft leafy branches, when fermented in cow dung for about thirty days in large piles, make excellent feedstock for vermicomposting. Gliricidia sepium known as Chimacona colloquially, is seen planted as a living fence everywhere in Kerala. It must be decomposed enough for the worms to eat it quickly, but, again, after the initial pre-composting stage, it must be cooled enough for the worms to eat.

Vermicomposting

Proper processing of MSW requires an integrated approach. Even before the roof was completed, we decided to build an adjacent facility for vermicomposting, in order to produce the highest quality compost. Sophisticated high-tech flow-through or continuous-flow systems are used for vermicomposting in the West. After undertaking some research, we designed our own "open tank system" for AIMS, shown in Fig. 4. Here the pre-composted feedstock is not allowed to be piled up more than about 24" to maintain the cooler temperatures required by the worms. Shade is needed and moisture control is important. We built a water moat around the outside to prevent ants from entering. Ants can be vicious predators. We also built the floor in each section to drain to one corner, so as to collect the leachate. This leachate can potentially contain pathogens, because the worms have not usually had a chance to work through all the material in it.

We initiated our vermicomposting operations using a combination of two types of composting worms, *Eisenia foetida* and *Eudrilus eugeniae*. They have worked well together. windrow method. In the windrow

Fig. 1. Aerial View of the AIMS Composting Facility

Fig. 2. Open Tank System for Vermicomposting in AIMS

method, one can start with ready-to-eat feedstock and place a pile on the floor and add the worms. When the worms have worked over the initial pile, more feedstock can be added on one side, lengthening the windrow. As worms move to the new food, they double in population in approximately 60 days. This allows for the feeding of larger amounts of material at faster rates. As worms move down the windrow, the section towards the start is allowed to dry out, encouraging the worms to move towards the wetter and fresher feedstock. This drying-out process is important, for harvesting the compost. The oldest material is harvested and any worms recovered are sent back into the new piles.

RESULTS AND DISCUSSION

In our custom-designed system, windrows will run down either side, while in the center there will be two open tanks with a divider running down the middle, essentially making these like race tracks for the worms. In these two center sections, we expect the worms to be going in circles as we feed on one side of the pile only, leading the worms around the circle, harvesting before the finish line meets the starting line. Today, we are feeding the worms mostly pre-composted and filtered food waste. The pre-composting decomposes the food waste enough so that it is not too spicy or too thick for the worms. Some cow dung slurry is added to the pre-compost, to wet the material sufficiently. We find that *Eudrilus eugeniae* is well suited to South India. *Eisenia foetida* becomes troublesome when the temperature rises above 85^{o}F.

Bioremediation

The vermicomposting is important to us. We are using it to help with the bioremediation of the site of our operations. As stated earlier, this used be a dump where trash was often openly burned (Fig. 3). When we began, we already knew the soil was toxic without performing any tests. There were no ants, insects, worms, or birds. It was a dead zone. Testing the soil samples revealed a very high concentration of heavy metals. We spread the thermal compost obtained from the first six months over the cleaned areas. When we saw plants emerging

Fig. 3. Before (Open Dump Where Waste Was Burned)

from the compost, we knew we had achieved something significant. Insects returned and so did the birds. Slowly the microbial life in the soil increased. We brought in clean soil and layered it over the compost. The vermi-compost was added, and we began planting. Now we find worms in the very soil of our garden, which was once completely dead.

The bioremediation that has taken place was probably aided by fungal, or mycoremediation (Elaine *et al*., 2000). The extremely woody nature of the compost that was initially spread must have had some effect. We want to try with spreading even more wood chips and inoculating with beneficial fungi, such as mycelium. We would like to create a fungal mat, use beneficial fungi to help tie up salts and breakdown metals. In seeking to further improve the soil biology, we are now sending samples to a certified international laboratory for conducting biological assays. We want to know what beneficial microbes are there and not there in the soil for the various crops that are growing.

In our journey towards zero-waste, we realize that we need to find ways to clean the air, water and soil we have contaminated due to our thoughtless ways, and we need to do it now.

We have planted several cuttings of vetiver grass, a known hyper-accumulator of heavy metals. Now as we dredge the boating channels, we continue to plant vetiver on the banks for erosion control and further capture of heavy metals. When we earlier tested the river mud, we found heavy metal contaminants were present in the backwaters too. Today, when we test the soil at the site, the results obtained are very different. Heavy metal concentration is too low to be detected. Today we estimate that over 80% of the former land dump has been successfully rehabilitated. Here we have sown Ayurveda plants, fruits, vegetables and flowers (Fig. 4).

Fig. 4. After (A Totally Transformed Landscape)

CONCLUSIONS

Today, we compost 1.25 tonnes of organic waste daily at our Amritapuri campus and another 1.5 tonnes at our Coimbatore campus, helping significantly reduce our carbon footprint.

With our custom built turners, we are able to get about five turns in the first three weeks, following the industry standards for pathogen reduction. We get the fully matured compost in 4-5 weeks, as opposed to the expected 6-8 weeks. The success of our MSW composting has led to improvements in recycling as well, both in systems design and development of new equipment—from trash compactors and sorting equipment to pyrolysis technology.

Our goal includes creating academic partnerships with other universities for further research and development of technologies for management of MSW, helping turn waste into a valuable resource, and for bioremediation of degraded landscapes and waterways.

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