DESIGN OF HEAT ABSORBER FOR THE SOLID WASTES ENERGY RECOVERY

Arturo Mariano I. Figueroa [1]
[1] Graduate School of Engineering, Holy Angel University, Angeles City, Philippines
e-mail: arturofig@yahoo.com

ABSTRACT

This paper addresses the problem on high temperature level in sanitary landfill in order to prevent serious damages posed by temperature effects. A heat absorber for solid wastes energy recovery was designed and tested in a prepared solid wastes decomposition cell. The experiment shows the thermal characteristic of decomposition in the cell. Also the decomposition cell which serves as a miniature model of a sanitary landfill was able to generate heat similar to data as reported in literature. The experiment demonstrated that the 15.24 m long and 1.27 cm diameter heat absorber design shows promise in recovering waste energy from the organic waste decomposition. Follow up studies on application of recovered energy is also suggested.

Keywords**:** Energy Recovery, Organic Waste, Heat, Absorber

INTRODUCTION

Solid wastes as defined by Uriarte(2008) include " all materials resulting from human, animal, and economic activities that are normally solid and discarded as useless or unwanted. They include all discarded materials ranging from heterogenous mass of garbage from urban communities to the more homogenous mass of unwanted residuals from agricultural, industrial, and mining operations.'

Recent development in the management of solid wastes in the Philippines is the establishment of sanitary landfills. Slowly the country is graduating from the use of open dump sites which produce fires, smokes, and odors that pollute the air and embracing the use of sanitary landfills.

By tradition, the country practices the method of open dump sites for waste disposal but because it poses environmental and health problems to the Filipinos, this practice is now prohibited according to the Republic Act No 9003 known otherwise as Ecological Solid Waste Management Act of 2000. RA 9003 prohibits the use of open dumps for solid waste and gives permission for the construction and expansion of solid waste management facility.

As far as the implementation of RA 9003, it is not that easy after all, as revealed by statistics. For example, as reported by Tonette Orejas Inquirer Central Luzon(2012) " 20 of Pampanga's 22 towns are still maintaining 34 open dumps that the law on ecological solid waste management has rendered illegal and out of the 22 local government units in Pampanga, only nine are disposing of their garbage in the 70 hectare sanitary landfill in Capas, Tarlac being managed by the Metro Clark Waste Management Corporation ." Moreover, the report says that "out of the 421,264 metric tons of estimated annual waste generation of the province in 2011, only 43,057.08 MT were disposed of in the MCWMC sanitary landfill."

Overall, according to the Department of Environment and Natural Resources , "97.5% of the country's waste disposal facilities are still open dumpsites, with 936 open and controlled dumpsites and only 24 sanitary landfills, or a compliance rate of only 2.5%. One major reason for this is the lack of financing." (http://www.denr.gov.ph/article/view/5227).

The popularity of sanitary landfills in the United States started in 1940s and it took us more than half a century to adopt it. In the case of South Korea, an Asian neighbor, they are quite advancing in landfill utilization in the generation of methane and energy recovery(Ryu and Shin ,2013). A sanitary landfill, as defined by Uriarte(2008) is "a final disposal facility where solid wastes are buried in the soil in a safe and orderly manner. It basically involves the following steps- waste is deposited on land, then compacted using suitable equipment, and finally covered with sufficient layer of soil to prevent it from being a health or environmental hazard. As such, it is technologically unsophisticated procedure that relies on containment rather that treatment to achieve the objective of managing the waste so that it does not pose a threat to the environment or to public health and safety. However, they still require careful design and construction, following rigid engineering standards, as well as continuous maintenance and monitoring to ensure proper, trouble-free, and safe operations. The failure to recognize this need is often the cause of many problems in existing landfills." A good designed sanitary landfill is equipped with appropriate liners, surface run-off control and slope stabilization system, leachate collection and detection system, monitoring wells, gas vents, and appropriate final cover (Uriarte,2008; Rebullida,2000; Reddy,2011;Bagchi,2004)

With regard to the operation of sanitary landfills, what is of interest in this study is the temperature aspect of its operation. It is known that heat is generated in the processes occurring inside a sanitary landfill. The research study of Yesiller, Hanson and Liu (2004) revealed the importance of taking into account the full effect of high temperature in the operation of landfills. The researchers identified three areas in the operation of sanitary landfills that are critically affected by high temperature namely, 1) the effect of high temperature on the biochemical process in the decomposition of wastes, 2) the effect of high temperature on the mechanical and hydraulic properties of the wastes, and 3) the effect of high temperature on the engineering properties of sanitary landfill parts such as liners, covers, and the surrounding sub-grade soils.

The effect of temperature on solid waste decomposition is known to be in two ways, that is, short term and long term effects. The research of Hartz, Klink, and Ham (1982) as cited by Yessiler, Hanson, and Liu (2004) explained that short term effects is on issue of chemical reaction rates, while the long term effects is focused on the balance in the population of microbes in the decomposing wastes. For best growth of bacteria participating in the decomposition of wastes, the optimum temperature ranges from 35 0C to 45 0C, as confirmed by a number of researchers like Tchobanoglous, Theisen, and Vigil (1993), Cecchi, Pavan, Mussaco, Mata-Alvarez and Vallini (1993), De Walle, Chian, and Hammersberg (1978), Mata-Alvarez and Martinez-Viturtia(1986) all cited in Yesiller, Hanson, and Liu (2004).

The effect of high temperature on the engineering properties of wastes as evidenced by the decrease in shear strength of wastes which affect stability of waste slopes is reported by the study of Lamothe and Edgers(1994) as cited by Yessiler et al (2004). Furthermore, the behavior and a host of engineering properties of soil and geo-synthetic liner materials as well as subgrade soils as affected by temperature is reported by both Rowe(1998) and Mitchell(1993) as cited by Yesiller et al (2004). As of this time, little is known about the techniques to counter the problem as cited by Yesiller et al (2004). Although there are a number of schemes to recover heat from potential high energy content, such as hot flue gases from a diesel generator or steam from cooling towers or even waste water from different cooling processes such as in steel cooling, there are no studies yet on recovering heat from landfills.

In this study, the authors seem to agree that elevated temperature level in sanitary landfill, say higher than the above-mentioned optimum range should be addressed in order to prevent serious damages posed by temperature effects as cited in literatures. Hence, the conduct of this study.

The objectives of this research are as follows:

1.To design a heat absorber for solid wastes energy recovery.
2.To test the performance of heat absorber in a prepared solid wastes decomposition cell.

METHOD

Experimental set up and instrumentation

Heat absorber material and design

As shown in Figures 1 and 2, the researchers designed a heat absorber assembly using copper tube material, 1.27 cm in outside diameter and 15.24 m long. By using a spring bender, the 15.24 m long copper tube was transformed into 10 parallel tubes which fitted on a 0.609 m by 1.22 m plain galvanized iron sheet. This design has similarity with that of standard heat absorber for solar water system where the pipe-sheet combination provides greater heat transfer contact area. Water was used as a medium for heat transfer. During the experimental temperature measurement, water (in a 4 liter container) was circulated in the system using a small flow submersible aquarium pump(220 VAC, 10 W, Qmax 700 LPH). Volumetric flow was controlled by reducing current amperage using a Omni light dimmer (Max 500W) . The current controller was adjusted just low enough to cause small volume flow during the time of measurement. At any given time, the heat absorber contained approximately 1.70 li of water.

Decomposition cell

A double-walled decomposition cell (see Figure 3) was constructed following these dimensions, 1.22 m wide, 1.83 m long , and 0.91 m high. This decomposition cell is actually likened to a miniature landfill in this research. The inner wall was made of corrugated galvanized iron sheet while the outer wall was 4.76 mm marine plywood. Air that is in between the walls, serves as heat insulation. A perforated pvc pipe, 7.62 cm in diameter was placed at the bottom center of the cell and served as exit point for liquid leachate produced from the organic wastes decomposition. The content of this cell is a compacted organic wastes that is sandwiched with two layers of soil, bottom layer, and top cover.

Solid wastes (See Figure 4) in this research was organic materials consisting of dried leaves and seed shells of mahogany trees available at the research site(Richtown I Park, Sindalan, City of San Fernando) intended for this study. Initially, a layer of soil, 7.62 cm deep, was placed and compacted at the bottom floor of the decomposition cell. Then, organic solid wastes was piled and compacted on top of this soil layer, making a 30.48 cm deep solid wastes. The heat absorber was then laid in the middle of the cell as shown in Figure 5. It was then finally covered with another layer of compacted solid wastes. The solid wastes was basically sandwiched with two layers of soil material. Moisture was incorporated in the organic solid wastes as a standard factor for decomposition.

Data collection and analysis

Temperature measurements were taken using digital multi-meter(DT33 series) at two time periods (daytime and night time) for the heat absorber output and ambient condition (see Figure 6). The first temperature measurement was taken on July 20, 2013 and then continued until August 15, 2013. All in all, the experiment lasted for 27 days and terminated when the temperature output from the heat absorber leveled with that temperature measurement obtained during the start of the experiment.

RESULTS AND DISCUSSION

The temperature profile of the ambient water temperature and the heat absorber output temperature is shown in Figure 7.The pattern of the temperature profile of the heat absorber output is similar to that reported in literature, that is, a remarkable growth in the initial period, then reaching and maintaining a certain peak condition, and finally goes down gradually after a long period. During the first 100 hours of operation of the decomposition cell, there is a remarkable growth in the heat absorber temperature output, starting at 37 ^{0}C and reaching 50 ^{0}C in 5 days which is half the boiling point of water. This temperature level of waste decomposition also matches the data reported in literature concerning critical temperature experienced in sanitary landfills. Moreover, the profile shows that heat absorber temperature outputted above 40 ^{0}C for a period of 20 days. All in all, it took 27 days cycle until the observed final decomposition temperature leveled with that of Day 1 observation. Ambient water temperature levels shift from 28 ^{o}C to 32 ^{o}C.

The state of decomposition at the cell after 27 days is seen in Figure 8. Although the heat absorber output temperature was already declining towards the end, the picture does not suggest complete organic decomposition after 27 days. Possible factor that has slowed down decomposition is the high temperature generated between the 100 to 300 hours of operation. Literature reports that at such high temperature, biochemical processes is affected due to reduction in microbial population. Another issue is the moisture of the organic waste. Water was incorporated only at one time in the cell during the preparation. No more water was added in the system in a span of 27 days. Diminishing moisture then might have affected microbial actions. The results from this experiment suggest the critical role of temperature management in sanitary landfills. The thermal condition of the landfill in this experiment is reflected by the heat absorber output temperature.

CONCLUSION

In conclusion, the experiment shows the thermal characteristic of decomposition in the cell. Also the decomposition cell which serves as a miniature model of a sanitary landfill was able to generate heat similar to data as reported in literature. The experiment demonstrated that the 15.24 m long and 1.27 cm diameter heat absorber design shows promise in recovering waste energy from the organic waste decomposition. Follow up studies on application of recovered energy is also suggested

REFERENCES

Bagchi, A.(2004). Design of Landfills and Integrated Solid Waste Management. John Wiley & Sons, Inc

Epstein, E. (2011). Industrial Composting: Environmental Engineering and Facilities Management. CRC Press Taylor and Francis Group

Khan, M, and Islam, M.R. (2012). Zero Waste Engineering. Scrivener Publishing LLC.

Lamothe, D., Edgers, I. (1994) The effects of environmental parameters on the laboratory compression of refuse. Proc 17th Int Madison waste conf Dept of engineering Professional development, Univ of Wisconsin 592-604

Orejas, T.(2012). 34 open dumps still in use in Pampanga–Repor Philippine Daily Inquirer Retrieved on http://newsinfo.inquirer.net/202255/34-open-dumps-still-in-use-in-pampanga-report#ixzz2Z4hIxMpc

Rebullida, Ma.L.G. (2000). Resource Recovery In Solid Waste Management: Strategies, Initiatives, Policy Issues, University of the Philippines Center for Integrative and Development Studies

Reddy, P.J. (2011). Municipal Solid Waste. Processing, Energy Recovery, Global Examples, BS Publications

RA 9003(2000).Ecological Solid Waste Management Act of 2000. Retrieved at www.lawphil.net

Ryu, C. and Shin, D.(2013). Combined heat and power from municipal solid waste: current status and issues in South Korea. Energies 6. 45-57.

Uriarte, F.A. Jr (2008). Solid Waste Management. Principles and Practices. The University of the Philippines Press

______(2009) Number of sanitary landfills in the Philippines. Retrieved at http://www.denr.gov.ph/article/view/5227

Fig. 1. Copper coil

Fig. 2. Heat absorber design

Fig. 3. Decomposition cell

Fig. 4. Organic solid waste

Fig. 5. Heat absorber at the middle of solid waste

Fig. 6. Instrumentation

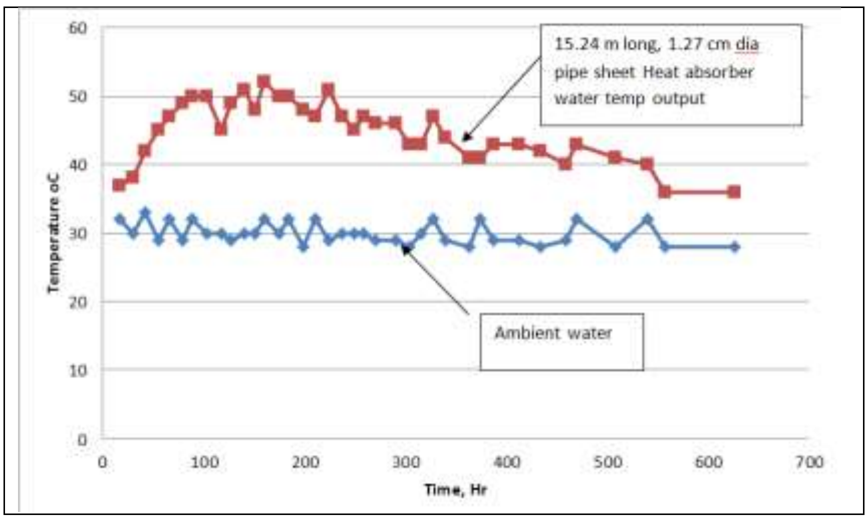

Fig. 7. Temperature profile

Fig. 8. State of the waste after 27 days