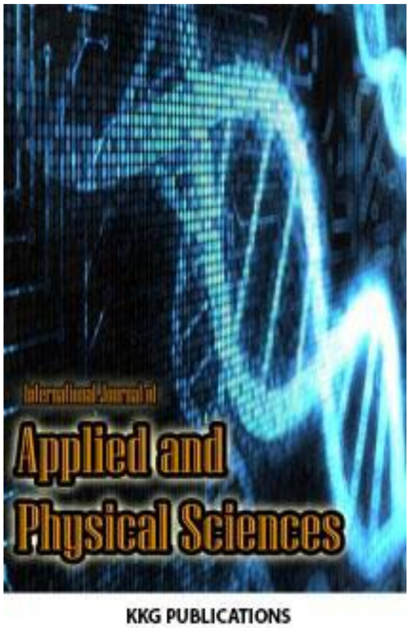

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EFFECT OF PILE HEIGHT ON HEAT GENERATED DURING ROTARY BIO-DRYING PROCESS FOR MUNICIPAL SOLID WASTE (MSW)

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Abstract. Bio-drying reduces moisture from Municipal Solid Waste (MSW) by using the heat from aerobic bio-degradation. This study aimed to investigate the effects of pile height on heat generated in rotary bio-drying process reactor for drying high initial moisture content MSW, allowing satisfied energy content biofuel. The MSW from the Administrative Organization of Tumbon Kaerai, kratumban Samutprakarn province, was used as a substrate. The influence of MSW height in the reactor on heat generation and evaporation were investigated. High surface area leads to low heat accumulates in MSW. The results were indicated that when the pile volume to surface area ratio (V/A) was equal to or greater than 0.6 and pile height more than 0.6 m, self-heating could be occurring inside the pile. However, the other parameters such as C/N ratio and turning frequency also need to considerate when the rotary bio-drying process is designed.

INTRODUCTION

With the growth of population and urbanization, solid waste management has become a serious environmental issue. People have been changing their life patterns for more sophisticated life styles which generating more wastes due to increasing consumption of resources. Direct dumping of MSW in uncontrolled disposal system is a prevalent practice in most developing countries in Asia. The problem on diminishing land for MSW disposal along with the increasing trend of waste and the depletion of fossil fuels have fostered the need to utilize and transform the waste into usable resources. The generation and composition trend of MSW stream in Asia is almost similar which consists of high fraction of organic waste and high moisture content [1]. The high water content will reduce the efficiency of its energy recovery by direct burning in incinerator and the feasibility of mechanical separation for beneficial utilization.

The bio-drying technology is biological transformation of MSW to be used as quality substitute fuel. The bio-drying technology, aiming to remove water with the help of microbial activities, is regarded as a good solution to reduce water content of MSW. It is a waste to fuel (Refuse Derived Fuel; RDF) and can solve the above problem [2].

In bio-drying processes, the drying rates are augmented by biological heat in addition to forced aeration. The major portion of biological heat, naturally available through the aerobic degradation of organic matter, is utilized to evaporate surface and bound water associated with the mixed sludge [3]. The moisture content in the MSW was reduced through two main steps: (1) water molecules evaporate (i.e., change of phase from liquid to gas) from the surface of waste fragments into the surrounding air; and (2) the evaporated water was transported through the MSW pile by the airflow and removed with the exhaust gases. Limited amounts of free water may seep through the waste MSW pile and be collected at the bottom of the bio-drying reactor as leachate [4].

As long as the MSW compost pile was sufficient size to insulate internal layers from ambient temperatures and no artificial aeration or turning occurs, most of the heat generated by the microorganisms will be trapped inside the pile. This can be accomplished by managing the transfer of heat generated in the composting mass and the surrounding atmosphere. This can be achieved in two ways: (1) since heat transfer is a surface phenomenon, heat retention in the bio-drying mass can be managed by varying the surface area to volume ratio of the bio-drying pile. This has a direct relationship to the pile dimensions (2) Providing aeration to the bio-drying would facilitate heat transfer by managing the pile turning process that could facilitate the provision of oxygen for aerobic decomposition and control of pile temperature [5].

The objective of this research was to observe the minimum pile height for ensuring accelerated mesophylls decomposition of organic waste in bio-drying process. In order to

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determine the relationship between heats generated and surface area to volume ratios of the MSW compost piles.

METHODS

Characteristics of MSW Feedstock

The characteristic of MSW for Administrative Organization of Tumbon (AOT) Kaerai will be observed for chemicals properties and composition such as bulk density, size distribution, and moisture content of raw MSW. The collected raw MSW was grinded by hammer mill then sorted with screening size 50 mm. The bulky waste such as carpet, yard waste whose size that bigger than 250 mm was rejected by hand. Only MSW size between 50 – 250 mm was used as feedstock for laboratory bio-drying process.

Experimental Equipment Setup

To investigate the heat generation with the height of MSW base on Volume/Surface area, the static vertical and horizontal reactor will be studied. Furthermore, the heat generation with the height of MSW in continuous rotating horizontal reactor (1.5 rpm) is also investigated.

The scheme of the laboratory scale to investigate the heat generation with the height of MSW in static vertical reactor was presented in Fig. 1.

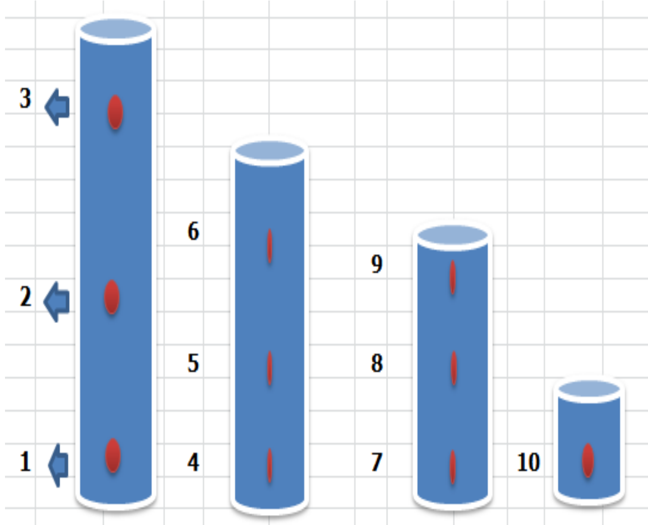

Fig. 1. The vertical reactor for heat generation investigation

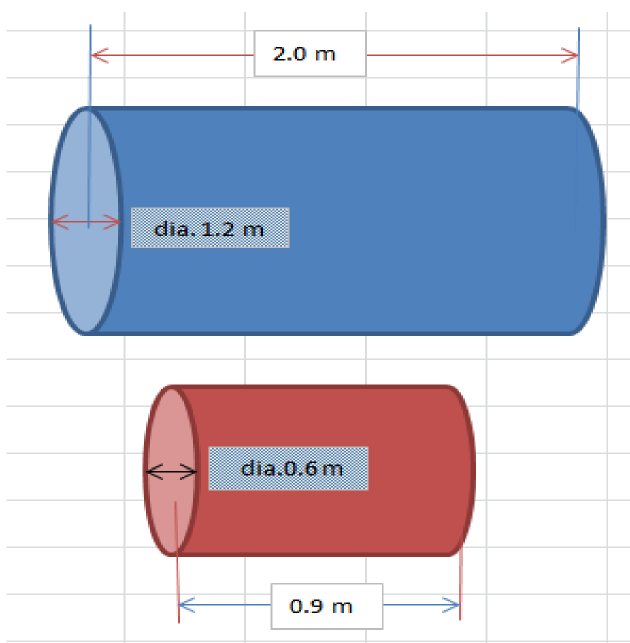

Fig. 2. The horizontal reactor for heat generation investigation

TABLE 1
THE EXPERIMENT SETUP FOR VERTICAL REACTOR DIMENSION AND VOLUME (V)/ SURFACE AREA (A) RATIO

Reactor	A	B	C	D
Height of reactor(m)	1.00	0.75	0.50	0.25
Height of MSW (m)	0.80	0.60	0.40	0.20
Surface Area (m^2)	0.0177	0.0177	0.0177	0.0177
Volume of MSW (m^3)	0.0141	0.0106	0.0071	0.0035
MSW Weight (kg)	3.2	2.4	1.6	0.8
Volume/ Surface Area	0.80	0.60	0.40	0.20

TABLE 2
THE EXPERIMENT SETUP FOR HORIZONTAL REACTOR DIMENSION AND VOLUME (V)/ SURFACE AREA (A) RATIO

Horizontal Reactor	Radius of Reactor (m)	Length of Reactor (m)	MSW Pile Depth (m)	Chord Length (m)	Surface area (m^2)	Volume of MSW (m^3)	Weight of MSW (kg)	Volume /Surface area
E	0.600	2.000	0.750	1.162	0.529	0.159	250	0.640
F	0.300	0.900	0.360	0.588	2.324	1.487	25	0.301

Note: the MSW Pile depth was design at 60% of the diameter of the reactor.

There were 4 reactors of PVC pipe with the diameter was 150 mm and the height was 1,000 mm, 750 mm, 500 mm and 250 mm.

All reactors were installed the thermocouple at the center of column thought the outer wall of the PVC column. The experimental data was reported as shown in Table 1. The temperature profile was recorded by data logger. The scheme of the laboratory scale process used for developing the experiment for investigate the heat generation with the height of MSW in horizontal reactor base on Volume/Surface area was presented in Fig. 2.

The experimental data was reported as shown in Table 2. The temperature profile was recorded by data logger. Then investigate the turning effect with the horizontal reactor diameter 1.2 m without air supply by compare the temperature profile of rotating and static reactor.

RESULTS

Temperature Profile for Vertical Reactor

According to direct relationship between heat generation rate and the waste decomposition rate, the temperature profiles can be used as an indicator for measuring decomposition rates of the piles. High heat generation cause the increasing of the bio-drying decomposition rate. The highest heat generation rates by the time has been recorded in reactor A and the lowest heat generation rates has been recorded in reactor D (Fig. 3). The temperature for reactor A was higher than 40 ° C after ten hours of decomposition and slowly decline after the seventh day. The highest temperature 45 °C was achieved on the third day of experiment. The V/A of reactor A was 0.8 and with the MSW height of 0.8 m. The temperature profile trend of reactor B was similar to the reactor A. Reactor B provided the highest temperature at third day for 42 °C

The V/A of reactor B was 0.6 and the height of MSW was 0.6 m. The lowest of heat generation was recorded in reactor D and C, with V/A was 0.2 and 0.4 respectively. The temperature in reactor C and D were close to ambient temperature throughout the decomposition.

Temperature Profile for Horizontal Reactor

For horizontal reactor E, the height of MSW in the reactor was 0.75 m close to reactor A. However, the V/A ratio of reactor E were lesser than reactor A. The V/A of reactor E was 0.64 which coincided with the reactor B. The height of MSW in the reactor F was 0.4 m which equal to the vertical reactor C and the V/A of reactor F was 0.30 which between the reactor C and reactor D (Fig. 4).

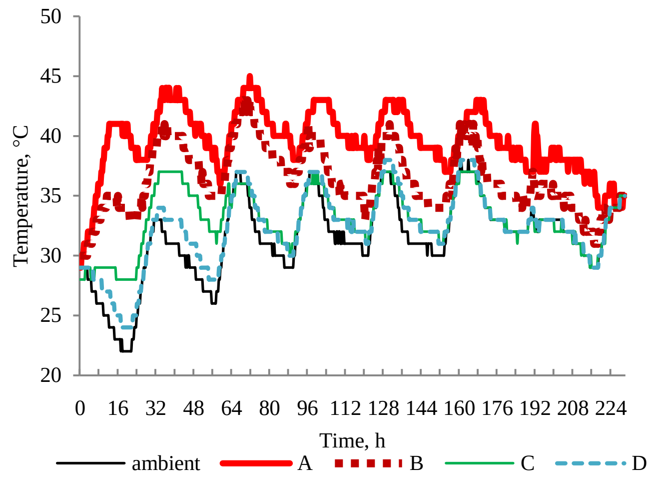

Fig. 3. Temperature Profile for 4 Trials in This Experiment and Ambient

Temperature

However, the observation on temperatures in each reactor was noted. The temperature for reactor E was higher than 40 °C in the first 4 day and slowly decline after to the end of decomposition. The highest temperature was 45 °C on the third day of experiment. Consider the temperature results of reactor F were similar to the reactor C. However, temperature profile of reactor F was only achieve up to 35 °C on the first day of the experiment and slowly decline to approach to an ambient temperature from the second day to the end of decomposition.

Temperature Profile with Continuous Turning Frequency

A comparison of rotating and static horizontal reactor experiments with a MSW height was 0.75 m and the V/A ratio was equal to 0.64 (Fig 5). The turning ratio was 1.5 rpm for rotation reactor. The temperature of static reactor was maintained nearly 40 °C from the first day to the fifth day of decomposition and slowly decline from third day to an ambient temperature till the end of decomposition. For rotation reactor the temperature was nearly an ambient temperature. The temperature in rotating reactor was 34 °C at the first day and slowly decline to an ambient temperature at the end of experiment.

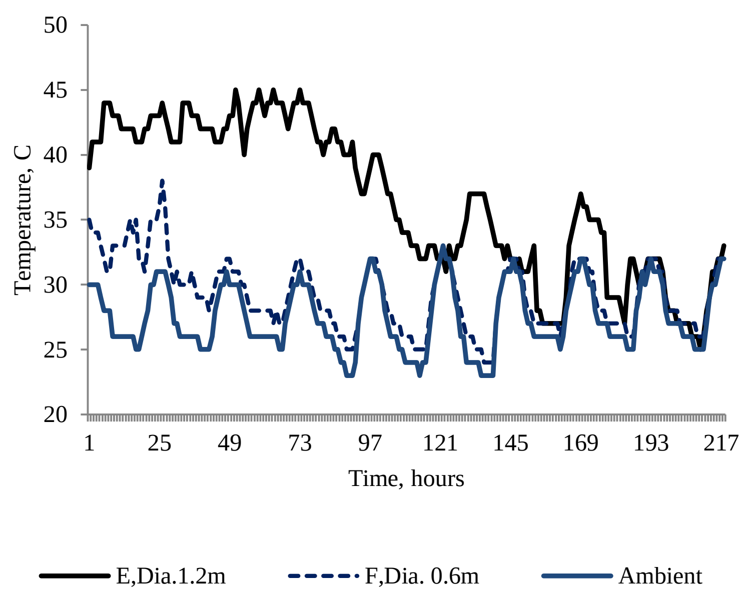

Fig. 4. Temperature profile for horizontal reactor

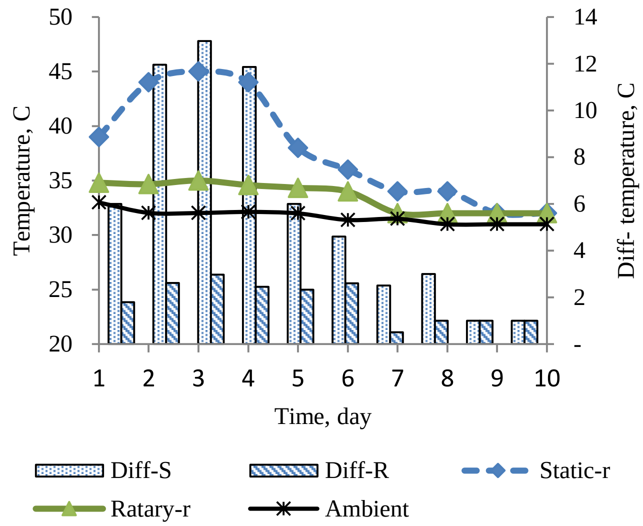

Fig. 5. Temperature profile for static horizontal reactor and rotating horizontal reactor

Experiment had evidence that proved the temperature of the static reactor was higher than the rotating reactor. The results showed that the static reactor has a temperature above ambient temperature up to 13 °C on the first day and gradually decreased over the decomposition. The temperature in the rotating reactor will be higher than the ambient temperature 3-4 °C only in the first few days and gradually decrease close to the ambient temperature in the last days of decomposition. The differences temperature in the reactor and ambient temperature of static reactor was 2-3 times higher than rotating reactor.

DISCUSSION AND CONCLUSION

Vertical Reactor and Pile Height for Heat Generation

The V/A of Reactor A, B, C and D were 0.8, 0.6, 0.4 and 0.2 respectively. The high V/A would induce higher heat generation in decomposition. For thermophillic vertical

bio-drying reactor, the optimum surface area was 0.7 m2 and a height of 1.1 m. At 1.1V/A ratio equal to the height of the reactor [6]. At the surface area of 0.12 m2 and a height of 1.0 m of waste which V/A equal to 1.0, thermophillic condition can be found [7].

Refer to many researches, V/A ratio should not less than 1 to induce thermophilic condition in off-tropic climate. With the high ambient temperatures in the tropical zone, heat transfer between the compost pile and the surroundings is much higher. This would enhancing the performance of compost piles with V/A ratios less than 1 to reaching and maintaining thermophilic temperatures during the active phase of composting. Nevertheless, composting performance based on heat generation and thermophilic temperatures which the higher V/A ratio provided the better performance. Although the Volume to Surface Area of the piles was same, the pile height can affect to decomposition rate of the compost pile [8].

The inhibition of thermophiles condition at low pH was an important key to explain the often observed lag phase in the transition from mesophilic to thermophilic conditions in the initial phase of composting. The pH started to decrease at the temperature of 46 °C and the initial pH was below 6.5. In large-scale composting with limited cooling would have a risk in low degradation rates by long period of low pH and high temperature stage [9].

To avoid the problem of a decrease in pH, V/A ratio should be considered. The pile height range of 0.6 to 0.8 or V/A between 0.6 to 0.8 would maintained the mesophillic temperature. However, Thailand is in the tropical zone, the heat from ambient can be enhanced to the thermophillic temperature.

Effect of Horizontal Reactor and Pile height for Heat Generation

The temperature of the reactor with a different diameter and length of the horizontal reactor were studied in term of mesophillic condition. The diameter of reactor E was 1.2 m and the length of 2.0 m. The waste height was 0.75 m and V/A was 0.64. Reactor F has with the diameter of 0.6 m and the length of 0.9 m. The waste height was 0.4 m and V/A was 0.30. Due to static bed operation, the temperature profiles pattern of reactor E and reactor F were similar.

Since the surface area of horizontal reactor was greater than the vertical reactor, heat convection which based on surface area would be more induced. Therefore, the bio-drying reactor should be designed and diameter of 1.2 m and the length of 2.0 m with the MSW height of 0.75 m.

Effect of Continuous Turning on Temperature

On the early stage of operation, the temperature of rotating reactor was 3 – 4 °C over the ambient temperature and gradually decreases to ambient temperature in the last days of the operation. In the static mechanically Air Blown Reactor (ABR), the observed temperature was higher than the Rotary Drum Reactor (RDR) which daily rotation as it dissipates the generated heat and interrupt the temperature rise. The RDR showed the lowest point of temperature was 23°C which could not maintained to themophillic condition [10].

The effects of different agitation regimes which consist of continuous (0.5 rpm) and semi-continuous agitation (5 min followed by 2 hr of static period). A biomass temperature was 60, 55-60 and 40-50 oC on the bio-drying rates of biodegradable municipal waste (BMW). A continuous agitation increased the loss of heat compared to the semi-continuous agitation regime where more of the metabolically generated heat was utilized for moisture removal [11]. Therefore, it can be said that a higher turning frequency improves oxygen transport thereby speeding up the reaction. Moreover, lower turning frequency could lead to partial anaerobic conditions in the inner part of the composting mass and a slower reaction rate. However, a higher turning frequency also led to a faster cooling of the composting waste because the reaction heat was stimulated to dissipate [12].

The continuous turning for 1.5 rpm was improved oxygen transport and faster cooling because the reaction heat was stimulated to dissipate. However, the temperature in the reactor was still mesophillic temperature that suitable to generated heat to evaporate on bio-drying process.

REFERENCES

[1] C. Visvanathan, J. Trankler, C. Chiemchaisri and B. F. A. Basnayake, *Municipal Solid Waste Management*, Bangkok Thailand, Asian Institue of Technology, 2004.

[2] F. Adani, D. Baido, E. Calcaterra and P. Genevini, (2002). “The influence of biomass temperature on biostabilization–biodrying of municipal solid waste,” *Bioresource Technology*, vol. 83, no. 3, pp. 173-179, 2002.

[3] S. Navaee-Ardeh, F. Bertrand and P. R. Stuart, “Emerging biodrying technology for the drying of pulp and paper mixed sludges,” *Drying Technology*, vol. 24, no. 7, pp. 863-878, 2006.

[4] L. M. Shao, Z. H. Ma, H. Zhang, D. Q. Zhang and P. J. He, (2010). “Bio-drying and size sorting of municipal solid waste with high water content for improving energy recovery,” *Waste Management*, vol. 30, no. 7, pp. 1165-1170, 2010.

[5] B. K. Bartha, “Development of a control strategy for the treatment of biological waste in a dynamic reactor," PhD Thesis, Technische Universität Dresden, Dresden, 2008.

[6] S. Santosa, I. Santosa, H, Prasetyo and Soemarno, “Design of biodrying MSW reactor,” *International Journal of Engineering Research and Development*, vol. 11, no. 12, pp. 36-43, 2015.

[7] D. Zhang, H. E. Pinjing, S. H. A. O. Liming, J. I. N. Taifeng and H. A. N. Jingyao, “Biodrying of municipal solid waste with high water content by combined hydrolytic-aerobic technology,” *Journal of Environmental Sciences*, vol. 20, no. 12, pp. 1534-1540, 2008.

[8] C. Malwana, T. K. Weerasinghe and S. Pilapitiya, “Determination of optimal pile dimensions during thermophillic windrow composting of municipal solid waste (MSW) in Sri Lanka,” *International Journal of Bioscience,Biochemistry and Bioinformatics*, vol. 3, no. 6. pp. 552-556, 2013.

[9] C. Sundberg, S. Smårs and H. Jönsson, “Low PH as an inhibiting factor in the transition from mesophilic to thermophilic phase in composting,” *Bioresource Technology*, vol. 95, no. 2, pp. 145-150, 2004.

[10] N. Rich and A. Bharti, “Assessment of different types of in-vessel composters and its effect on stabilization of MSW compost,” *International Research Journal of Engineering and Technology (IRJET)*, vol. 2, no. 3, pp. 2395-0056, 2015.

[11] I. Skourides, C. Theophilou, M. Loizides, P. Hood S. R. Smith, “Optimisation of advanced technology for production of consistent auxiliary fuels from biodegradable municipal waste for industrial purposes,” *Waste 2006 Sustainable Waste and Resource Management*, pp. 19-21, 2006.

[12] L. Rodríguez, M. I. Cerrillo, V. García-Albiach and J. Villaseñor, “Domestic sewage sludge composting in a rotary drum reactor: optimizing the thermophilic stage,” *Journal of Environmental Management*, vol. 112, pp. 284-291, 2012.

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