

# Conversion of municipal solid waste to refusederived fuel using biodrying

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## Conversion of municipal solid waste to refuse-derived fuel using biodrying

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**Abstract.** Municipal Solid Waste (MSW) in Indonesia comes from urban settlements, markets, and industries. MSW decomposes naturally and without being used at all. The purpose of this study to convert MSW to refuse-derived fuel (RDF) using biodrying. The research was conducted on a laboratory scale using a biodrying reactor. The biodrying process takes place aerobically with an airflow rate of 6 L/min, the highest temperature reaches 60°C on the third day and the water content on the 21<sup>st</sup> day is 32.65%. The final RDF calorific value is 6,102.82 cal/g. This calorific value is equivalent to low-energy coal (brown coal). RDF from MSW can be applied to the cement industry that requires heat >6000 cal/g, PLTU requires 5242 cal/g, the metal industry requires 6000 cal/g, and the paper industry requires 5240 cal/g to carry out the production process.

### 1. Introduction

The primary source of municipal solid waste in Indonesia come from urban settlement, market, office, and industrial area. In 2016 the amount of solid waste that entered the Banyuurip landfill in Magelang City was 71.82 tons/day [1]. MSW was not used at all and decomposed naturally in the Banyuurip landfill. MSW is a proven energy resource because solid waste contains sufficient energy/heat as a substitute for fuel [2]. According to SNI No.13-6011-1999, regarding the classification of coal resources and reserves, the lowest rank, soft and easily crushed type of coal contains high water content (10-70%) can be used as an energy source if it has a calorific value <7,000 cal/g.

The technology used to convert solid waste into energy (waste to energy) has developed. Pre-treatment of solid waste using biodrying technology can produce Refuse Derived Fuel (RDF). This technology is one of the best methods to maximize energy recovered into fuel products [3]–[5]. Municipal solid waste from the Banyuurip landfill has been studied as a mixture of paving block materials - a substitute for fine aggregate. Composition of portland cement (PC): sand (1: 3) + 15% sludge mixture produces a compressive strength of 197.080 kg/cm<sup>2</sup>. It meets the quality criteria B (can be used for car parking spaces) [6]. Alam, Oktawan and Wardhana (2014) planning to use the solid waste of Banyuurip landfill to be processed into organic fertilizer and plastic recycling [7]. Based on the plan, organic fertilizer production is estimated to be 15 tons per day and 150 kg of recycled plastic. However, this has not been realized in the field. Based on the energy aspect, municipal solid waste equal to fossil fuels because it contains oxidizable materials (mainly carbon and hydrogen), which can release energy, which is



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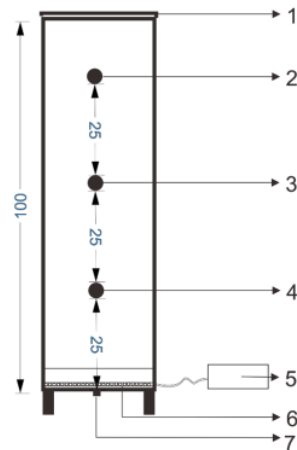
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quantified as heat. This energy can be used for heat production, power generation, and heat generation [4]. Therefore, other efforts are needed; such conversion of MSW to energy is an effort to increase MSW utilization. The purpose of this research is to convert solid waste from Banyuurip landfill to refuse-derived fuel using biodrying. RDF can be used for the cement industry, metal industry, and paper industry.

## 2. Methodology

The research was conducted in the greenhouse of the environmental laboratory, Environmental Engineering Department, Faculty of Engineering, Diponegoro University. The biodrying reactor is used to convert solid waste from the final processing plant to refuse-derived fuel using biodrying. Solid waste samples came from the Banyuurip landfill, Magelang Regency.

The biodrying reactor is made of plywood with dimensions of 30 cm x 30 cm x 100 cm. The reason for choosing a reactor with plywood material is to avoid direct sunlight because it can increase temperature and affect microbial activity. The first reactor is a control reactor (air flow rate 0 L/min), and the second reactor is a biodrying reactor (air flow rate 6 L/min). Both reactors are equipped with a cover made of geotextile non-woven so that air and water vapor easily escape the reactors. On one side of the reactor, three holes were made with a height of 25 cm (*BR*), 50 cm (*TR*), and 75 cm (*AR*) from the bottom. The hole serves to measure the temperature and the solid waste matrix sampling point. At the bottom of the reactor is given a leachate outlet hole, at the top 5 cm thick gravel is placed, then equipped with wire nets to limit the waste and gravel stones. Aeration is supplied via a hose connected to a ½ inch PVC pipe that is placed horizontally on top of the rock structure. PVC pipe is given a hole at the top for air distribution. Figure 1 shows the schematic of the biodrying reactor.



**Figure 1.** Schematic of the biodrying reactor: (1) non-woven geotextile cover, (2) bottom sampling hole (*BR*), (3) center sampling hole (*TR*), (4) upper sampling hole (*AR*), (5) aeration pump, (6) gravel 5 cm thick, and (7) leachate outlets.

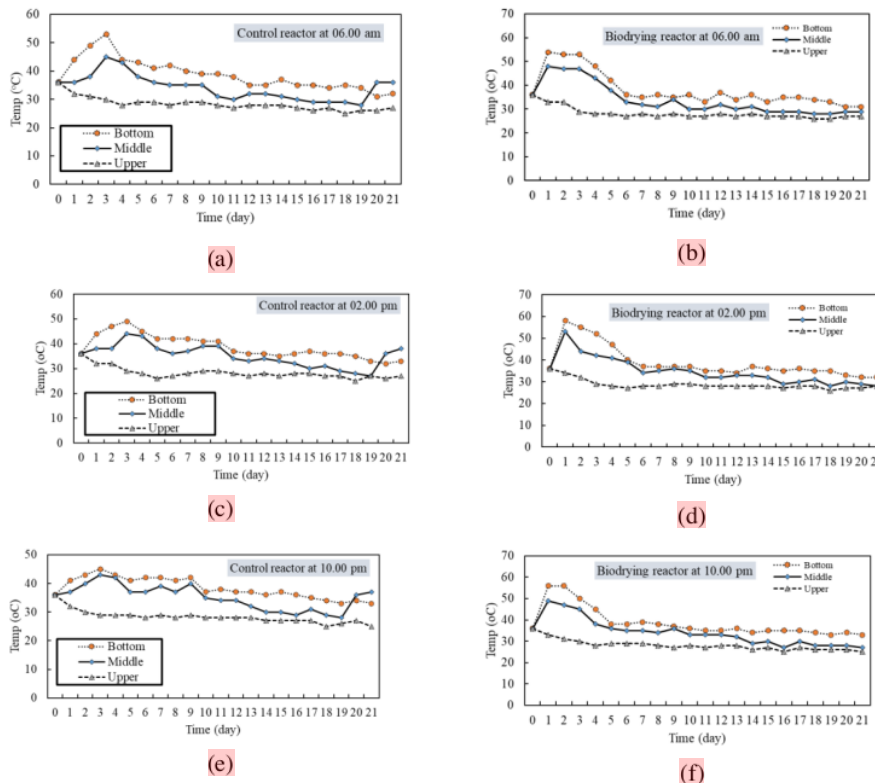
Municipal solid waste samples originating from the Banyuurip landfill, Magelang Regency. MSW are sorted based on the categories of food waste, leaf waste, plastic waste, and paper waste. The composition of solid waste (v/v) are 38.60%: 15.24%: 24.63%: 21.53%, respectively, for food waste: leaf waste: plastic waste: paper waste. The waste was chopped with 2-3 cm, mixed, and added with water until each reactor's water content is  $\pm 60\%$ . The waste was put into two reactors (reactor control and biodrying reactor) until it was full. The biodrying reactor was supplied with an airflow rate of 6 L/min, while the control reactor was not aerated. Airflow rate is provided using a blower, and airflow velocity is measured using a flow meter (Dyer, USA). The matrix's temperature was measured using a

thermometer every day at 06.00 am, 02.00 pm, and 10.00 pm for 21 days. Water content was measured daily using the gravimetric method. Calorific values were measured on the first day, peak temperature, 7<sup>th</sup>, 14<sup>th</sup>, and 21<sup>st</sup> days. Calorific value testing used a bomb calorimeter in the Sepuluh Nopember Institute of Technology environmental engineering laboratory, Surabaya. The leachate produced during the biodrying process was collected by flowing the leachate with a hose located under the reactor (if formed).

### 3. Results and discussion

#### 3.1 Temperature

The temperature measurement aims to determine the success of the solid waste conversion process from Banyuurip landfill to refuse-derived fuel (RDF) using biodrying. Temperature is an important factor affecting water evaporation and degradation of organic compounds in MSW [8]. The temperature measurement points in this study are at 3 points, namely the bottom of the reactor (BR), which is located 25 cm, the middle of the reactor (TR), which is located 50 cm, and the top of the reactor (AR) which is located 75 cm from the bottom of the reactor. Meanwhile, the measurement time was taken at 06.00 am, 02.00 pm, and 10.00 pm for 21 days. The results of temperature measurements in this study are shown in figure 2.



**Figure 2.** Temperature graph of solid waste matrix between reactor control and biodrying reactor. Graphs (a), (c), and (e) are graphs of reactor control temperature at 06.00 am, 02.00 pm, and 10 pm. Meanwhile, graphs (b), (d), and (f) are the temperature profiles of the biodrying reactor at 06.00 am, 02.00 pm, and 10 pm.

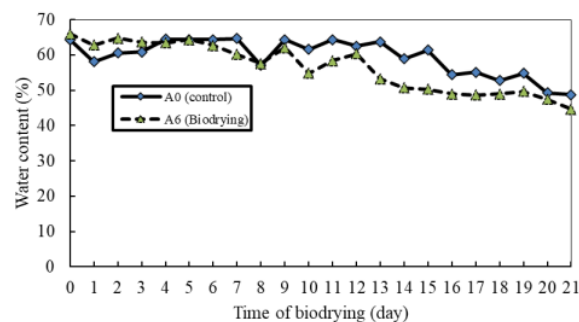
The solid waste matrix temperature can reach the thermophilic phase on the third day of 49°C and 60°C, respectively, for reactor control and reactor biodrying. The temperature in the biodrying reactor is higher than that of the control reactor. This is due to differences in the treatment of the airflow rate. The biodrying reactor gets aeration of 6 L/m while the control reactor is 0 l/m. This study's results correspond with previous research, which states that a different airflow rate causes the temperature difference in the reactor and the airflow rate of 1.13 L/min causes the solid waste matrix temperature to be higher than the airflow rate of 0.57 L/m [9].

The temperature in each reactor has decreased after passing the peak temperature until it is in the mesophilic phase. The control reactor decrease in temperature range 40°C-41°C on the 11<sup>st</sup> day, while the biodrying reactor decreased in the range of 35°C-39°C on the 11<sup>st</sup> day. The higher rate of air being given would quickly cool the material and stop microbial activity [10]. After the 11<sup>st</sup> day, each reactor experienced a steady decline in the mesophilic phase in the range of 30°C-39°C. This shows that microorganisms' activity is not too large to achieve biological stability after the biodrying process occurs [10]. The temperature decrease in the gradual biodrying process is an indication that the activity of microorganisms is going well [11]. In the biodrying process, the temperature will affect the degradation process. This temperature affects the biodrying product as indicated by the value of water content, ODS (organic dry solid), carbon, and ash [12].

### 3.2 Water content analysis

The biodrying process is evaluated based on the target moisture level or water content and its length to reach these levels. In general, the biodrying process should not exceed 21 days [10]. The water content is considered as a critical parameter for evaluating the efficiency of the biodrying process. Water content affects microbial activity and biodegradation of organic components during the biodrying process [13]. The water content decreases through two stages, namely the evaporation of water molecules (for example, changing the phase from liquid to gas) from the surface of the solid waste fragments to the surrounding air and evaporation of water, which is transported through the matrix with air discharge and reduction with exhaust gases [14]. Loss of water correlates with organic matter during the degradation process and is influenced by temperature and airflow and the combination of the two [15].

The results of measuring the water content in each reactor for 21 days are shown in figure 3. Measurement of water content is carried out every day with a sample of  $\pm 1$  gram. Measurements are made using the gravimetric method. The initial water content of solid waste in the control reactor was 59.90%, and the biodrying reactor was 62.74%. The water content is in accordance with the literature, where the optimum water content at the beginning of the biodrying process is between 50% - 65% [9, 10]. The initial water content is very important for the continuity of microbial activity. The too high water content will support anaerobic conditions because water will limit the matrix's oxygen transport space. In contrast, the low water content will slow down microorganisms' activity due to insufficient moisture and can lead to decreased drying performance.



**Figure 3.** Profile of the reduction in water content of solid waste in the Biodrying reactor at 02.00 pm.



Measurement of water content in each reactor showed fluctuating results. On the first day, the control reactor decreased by 4.10%, and the biodrying reactor decreased by 5.75%. The decrease in water content in the biodrying reactor is more significant than that of the control reactor. This is due to the absence of aeration discharge that enters the control reactor so that the reduction in water content that occurs is only due to leaching. Whereas in the biodrying reactor, there is an airflow of 6 L/min, which causes an evaporation process by means of water molecules evaporating from the surface of the solid waste to the outside air due to a phase change from water to steam, then the water evaporates from the material to the outside air because it is carried by airflow [16,17]. The factors that significantly influence the removal of water content are the heat generated by the decomposition of microbes during biodrying and the given airflow rate [16,18]. The lowest water content was achieved on day 21 for both the control reactor and the biodrying reactor. The control reactor's water content decreased from 59.90% to 47.85%, and the biodrying reactor decreased from 62.47% to 32.65%. The longer the residence time in the biodrying process, the less water content will be, so that the residence time and air discharge affect the water content of solid waste [9].

### 3.3 Calorific value

This research aims to convert solid waste at the Banyuurip landfill to refuse-derived fuel (RDF) using biodrying. The quality of RDF is known based on calorific value. The calorific value shows the maximum heat or heat energy content in the material, including solid waste released when the material is burned. This calorific value is expressed in heat energy units per mass unit, namely kJ/kg, kJ/m<sup>3</sup>, kcal/g, kcal/m<sup>3</sup>, Btu/lb, and Btu/ft<sup>3</sup>. The biodrying process can increase the calorific value by managing the municipal solid waste organic fraction (municipal solid waste) to reduce the water content to allow energy production to be used as energy recovery [19].

On the first day, the control reactor matrix has a calorific value of 4520.61 cal/g and the biodrying reactor of 4547.73 cal/g. When the peak temperature occurred on the 3<sup>rd</sup> day, where there was a high increase in microbial activity, the calorific value increased by 1.5%, while the biodrying reactor increased by 6.86%. This is probably due to the high water content at the beginning of the biodrying process. So, the heat generated from the biological decomposition process is used for the evaporation of solid waste matrix water. High microbial activity at peak temperatures will lead to increased nutrient consumption, affecting the resulting calorific value [14]. On the 21<sup>st</sup> day, the control reactor's calorific value has increased by 4.43% (4,724.10 cal/g), and the biodrying reactor is 34.19% (6,102.82 cal/g). Based on this, biodrying has successfully increased the MSW's calorific value from Banyuurip landfill, Magelang City. This is consistent with Mohammed, Donkor, and Ozbay [13], which states that giving aeration discharge will increase the decrease in water content and produce biodrying products with high calorific value. Moreover, Moisture content is the key parameter to increase the efficiency process. Additional pretreatment to reduce the moisture content is necessary [20]. Utilization of solid waste by increasing calorific value using biodrying is an excellent and effective solution for energy recovery and minimizing the amount of waste by mechanical separation [2,21].

The final RDF calorific value is 6,102.82 cal/g, this calorific value is equivalent to low-energy coal (brown coal). RDF from Banyuurip landfill, Magelang Regency can be applied to the cement industry that requires heat >6000 cal/g, PLTU requires 5242 cal/g, the metal industry requires 6000 cal/g, and paper industry requires 5240 cal/g to carry out the production process.

## 4. Conclusion

The conversion of solid waste to refuse-derived fuel (RDF) using biodrying is the main objective of this research. This study uses solid waste originating from the Banyuurip final processing site, Magelang City, which has not been utilized at all so far. The biodrying process takes place aerobically (air flow rate 6 L/min) produces a maximum matrix temperature of 60°C, which is generated from the biodrying reactor on the 3<sup>rd</sup> day. The water content of the solid waste matrix on the 21<sup>st</sup> day was 32.65%. The biodrying process successfully converted municipal solid waste into RDF with a final calorific value of 6102.82 cal/g. The calorific value is equivalent to low energy coal (brown coal). RDF from Banyuurip

landfill, Magelang Regency can be applied to the cement industry, which requires heat >6000 cal/g, PLTU requires 5242 cal/g, the metal industry requires 6000 cal/g, and the paper industry requires 5240 cal/g to carry out the production process. The pilot-scale needs to be done so that other factors that affect the quality of RDF can be optimized.

#### Acknowledgments

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