Update on waste reduction performance by waste-to-energy incineration pilot plant PLTSa Bantargebang operations

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Abstract. Many big cities in Indonesia are facing the problem of municipal solid waste (MSW) disposal. PLTSa Merah Putih, a waste-to-energy incineration pilot plant, was built as an alternative solution to reduce waste. This study aims to evaluate the performance of PLTSa Merah Putih Bantargebang in reducing volume of waste. During the first semester of 2021, the pilot plant has been running for 174 days and a total of 5647.1 ton of waste was burned generating around 1000 ton of ash. Based on the feeding waste and generated ash, the pilot plant can reduce over 79% of waste, even with high moisture content. The furnace and grate temperature can be maintained at 800℃ and 1000℃, respectively, to minimize harmful gases generation. This study showed that the waste reduction of PLTSa was comparable with the performance of other waste-to-energy pilot plants, which is in the range of 70-90%.

1. Introduction

The rapid population growth and urbanization in Indonesia have led to an increasing volume of municipal solid waste (MSW) generation. The MSW management has become a major environmental issue in big cities. Disposal of MSW in landfill, which is the main MSW management method in Indonesia, can cause a number of environmental risks on the surrounding area, such contamination of water and soil by leachate, and it is difficult to find new landfill site in big cities. In order to accelerate nation’s program on MSW management and its infrastructure, the Government of Indonesia has formulated policies on Presidential Regulation Perpres No. 35/2018 regarding the acceleration of construction of thermal generation facilities for converting waste into electricity with environmentally sound technology, which prioritizing the implementation on 12 major cities in Indonesia.

To support implementation of the regulation and promote waste-to-energy technology, the Agency for the Assessment and Application of Technology (BPPT) in cooperation with the Government of DKI Jakarta established a waste-to-energy pilot plant (referred to as PLTSa Merah Putih), which is located at Bantargebang landfill area, in 2018, and started operation at the end of 2019. The pilot plant uses incineration with energy recovery system that has been proven to treat MSW and generate electricity in many Asian countries, such as Japan, China, and Taiwan [1–3]. Incineration of MSW in Indonesia presents some unique challenges because of its mixed composition, high moisture content (>50%) and low calorific value [4]. In 2020, the pilot plant was continuously operated and a total of 9881 ton of MSW was burned generating electricity of 784 MWh [5]. In 2021, the operation of pilot
plant is continued, however, the performance of pilot plant in the first semester of 2021 has not been evaluated. Therefore, this study aims to evaluate the performance of PLTSa Merah Putih Bantargebang in the first semester of 2021 or after one year of operation.

2. Materials and methods

2.1. Pilot plant

The pilot plant was designed with a capacity of 100 ton MSW per day. The system components of WTE incineration at PLTSa Merah Putih Bantargebang is similar to that of general thermal power projects, including thermal system, heat recovery, power generation, and air pollution control. MSW collected from municipal area was unloaded from trucks at the pre-treatment unit. The metals and bulky materials were removed. The waste was then passed through a trommel screen. A first fine fraction is conveyed to a composting area, and the large fraction is then passed to a belt conveyor where recyclable materials are manually removed. The waste was then stored in open air area before being shipped to waste bunker. At waste bunker, the waste was stored up to 5 days before being dropped into the hopper by a grab crane. The waste leachate generated during storage in waste bunker was pumped to a wastewater treatment plant. The combustion of MSW at furnace was controlled by grate moving time and air supply.

The combustion chamber was equipped with an auxiliary burner fired with diesel fuel, which was used to start up the combustion process and when the MSW has a high moisture content. The walls of the furnace chamber were lined with vertical tubes containing water. Heat transfer from the hot combustion gases in the furnace boiled the water in the tubes, producing high temperature (380°C) and high pressure (38 bar) steam. The steam flowed from the incinerator to a 3000 rpm condensing steam turbine that drove a 750 kW electric generator; the thermal energy in the steam was converted to mechanical energy and then to electricity. After the steam exited the turbine, it was condensed, and the water was recycled back to the incinerator. A series of heat recovery sections, known as superheater, reheater, economizer, and air heater, was located downstream of the furnace chamber, which served to extract additional heat from the flue gas to improve overall energy conversion efficiency. After the exchange of heat, the temperature of the flue gas was brought to a value close to but not lower than 200°C, to avoid steam condensation that would boost the corrosive action of the flue gas. Thereafter, acidic gases (HCl, Cl₂, and SO₂) in the flue gas were removed through a dry scrubber, where a slaked lime was sprayed into the hot flue gas to absorb the pollutants. Activated carbon was also sprayed for the removal of dioxins and some heavy metals (e.g., mercury). The residue material, including fly ash, was collected in a fabric bag filter. The fabric filter were designed to catch approximately equal volumes of dust. The fly ash collected in the particulate matter control devices were conveyed to a storage silo. The purified flue gas was exhausted to the atmosphere through a stack. Meanwhile, the bottom ash drained from the furnace bottom was conveyed to a storage.

2.2. Waste burn process

The waste that will be burned at the PLTSa Merah Putih Bantargebang is processed first in the pre-treatment. The waste is separated so that hazardous materials such as glass, PVC, metal will not enter the combustion chamber [6]. The characteristics of waste as a material that is burned at PLTSa Merah Putih Bantargebang come from DKI Jakarta waste which has a low calorific value. After going through the pretreatment process, the calorific value increased until it reached 4021.32 kcal/kg, but the water content did not change much only a 5% difference [5]. The sorted waste then transported immediately using a dump truck to the PLTSa Merah Putih Bantargebang. At PLTSa Merah Putih Bantargebang, the sorted waste is temporarily stored in the waste bunker with a capacity of 500 tons. In the first weeks of January 2021, the sorted waste in the waste bunker reached full capacity. During operation, the sorted waste is transported by trucks three to four times a day.

In the waste bunker, the waste storage area is divided into two imaginary areas that aim to separate the newly arrived and old stock of sorted waste. The sorted waste has been treated with a mixing
treatment by grab crane. This treatment can be carried out when the grab crane does not feed the furnace chamber. The treatment was as flexible as possible depending on the condition of the waste. Operator experience in the terms of handling waste in the bunker plays an important role in this treatment. The waste is then fed into the incinerator hopper using a grab crane. Until this process, the waste in the hopper is then referred to as waste fuel.

The waste fuel at the bottom of the hopper is pushed into the furnace by hydraulic pushers through the static grate. The gate only allows waste smaller than 30 cm to enter. Therefore the size of the waste needs to be controlled and if it exceeds the size it will cause a clog in the hopper. The grate system used in the PLTSa Merah Putih Bantargebang incinerator consists of 4 grates. The first grates for the drying and ignition process, the second and third grates for the combustion process, and the last grates for the post-combustion process that forms ash. The ash then flows to the bottom of the furnace through bottom ash hoppers. The bottom ash hoppers control the rate of mass to bottom ash handling. The bottom ash handling consists of a transport conveyor which is covered by water. The water is needed for the cooling process in the ash disposal and is also used to seal the bottom ash hopper so that the negative pressure in the furnace can be maintained. Same as for bottom ash, fly ash produced is collected into the fly ash silo using a fly ash transport conveyor. The end of the ash handling is located near the stack. The fly ash produced is then used as material for the production of paving blocks using a paving block press machine at PLTSa Merah Putih Bantargebang which can produce 3000 paving blocks per day. The paving block production has been used for road pavement near the TPST Bantargebang office and several public facilities around the TPST Bantargebang.

2.3. Operational data collection

PLTSa Merah Putih Bantargebang has a main control room to monitor and control all processes, such as waste feeding, combustion process, electricity generation. The temperature of each grate can be monitored directly on the main control system. The flue gas or furnace temperature is measured at the neck of the furnace. This temperature is used to control the waste combustion process together with the steam temperature of the heat recovery steam generation. The temperature and the pressure of other process parameters are stored automatically by the system. Not every process parameter is measured automatically. Some parameters are recorded by an approximate method.

To indicate the condition of the waste, the moisture content of the sorted waste in the hopper is measured. Measurements were carried out manually each shift at several positions in the hopper using a portable moisture meter. The weight of the waste entering the hopper is determined by an approximate method. It is obtained by multiplying how much waste is picked up by the grab crane per shift using the calibration weight factor. The calibration weight factor was used because the load cell was damaged and could not be replaced due to the regulation of pandemic restrictions. The calibration weight factor is the average weight that can be taken by the operator using a grab crane. Calibration was carried out in February 2021. Four certified grab crane operators have their own style of crane operation, and each waste is a measure to find the weight factor. The average weight of waste is about 863 kg of waste per grab. The weight of ash is also calculated using a similar type of weight calibration. The bottom and fly ash operator also has their own style of ash handling operation. The amount of ash is then scaled to calculate the average weight. The weight factors for the bottom and fly ash are 36 kg per trolley and 36 kg per bag, respectively. The weight factor is multiplied by the number of trolleys or bags and then be transferred to the next unit.

The parameters of the waste incineration process were collected per shift. PLTSa Merah Putih Bantargebang operates 24 hours a day and is divided into 3 shifts. The 3 shifts provide 3 sets of daily process log sheet data. The data were then collected from January to June 2021 to determine the daily trend of the combustion process. Some data were omitted due to operational problems that did not come from waste or the incinerator grate system. For waste reduction, it is calculated by comparing the weight of the feeding waste with the ash produced. In addition, the grate temperature is also collected to understand the combustion process.
Waste reduction (%) = \frac{(\text{Weight of feeding waste} - \text{Weight of ash generated})}{\text{Weight of feeding waste}} \times 100\% \hspace{1cm} (1)

3. Results and discussion

3.1. Waste characteristic
To determine the characteristics of the waste used as fuel, testing is carried out in the laboratory every year. The comparison of test results can be seen in table 1. The waste used as fuel in the PLTSa Merah Putih Bantargebang has a water content of between 45-56%. The water content is classified as high to be used as fuel. The high heating value is around 4000 kcal/kg and has an ash content of about 20%.

|                         | 2020 Analysis [7] | 2021 Analysis [8] | Unit       |
|-------------------------|-------------------|-------------------|------------|
| Carbon (C)              | 41.17             | 46.35             | % dry weight |
| Hydrogen (H)            | 6.37              | 7.13              | % dry weight |
| Oxygen (O)              | 32.92             | 31.34             | % dry weight |
| Nitrogen (N)            | 0.78              | 1.00              | % dry weight |
| Sulfide (S)             | 0.07              | 0.098             | % dry weight |
| Chloride (Cl)           | 2.79              | 0.43              | % dry weight |
| Water cont. (as received) | 45.47            | 56.16             | % wet weight |
| Ash cont. (air dried)   | 14.27             | 26.44             | % dry weight |
| Volatile (air dried)    | 58.20             | 41.90             | % dry weight |
| Fixed carbon (air dried)| 4.81              | 2.87              | % dry weight |
| High Heating Value (HHV)| 4021.32           | 3976.81           | Kcal/kg    |

The challenge of using waste with a high-water content as fuel requires operating expertise by the operator. With a combination of experience and trial in the field, the waste can be burned and produce electrical energy.

3.2. Waste reduction performance
Figure 1 shows the waste reduction performance of the PLTSa Merah Putih Bantargebang. The y-axis shows the amount of waste feed, ash generated, waste reduction, and furnace temperature. The x-axis shows stable operating dates. The average amount of waste that is fed into the hopper to be burned in the first semester of 2021 is 83 tons per day. The burning of waste every day is different due to operational needs. Although the operation only collects the waste moisture data, it can be used as a sign of how much water needs to be removed from the waste. Humidity measurements carried out over a period of time in the first semester of 2021 showed that the water content of the waste was in the range of 65-73%. The burner was used to keep the furnace temperature high.

The operational cycle can also be seen in Figure 1 where every month there is scheduled maintenance. The once-a-month schedule is obtained from operational experience during 2020. This has an impact on the stability of the combustion temperature. For example on February 5-13, March 13-29, and May 11-26. Before maintenance is carried out, the combustion temperature tends to fall easily and is unstable. After maintenance, they can again be properly stabilized. Things that are carried out in maintenance to maintain combustion stability include cleaning the combustion air ducts and also lubricating the feeding system. However, there are also times when the combustion temperature drops drastically as seen on 23 February, 18 April, and others. The reasons that can be caused are very diverse, but in terms of managing waste as fuel, problems often arise due to blockages in the waste feeding system. For this reason, the role of pre-treatment in processing waste into energy in Indonesia is very important to maintain operational stability.
Figure 1. Average daily waste reduction in the first semester of 2021.

Waste combustion produces heat that is used for electricity generation. The heat generated needs to be stabilized in order to maintain steam for electricity production. Another then that, the combustion should reach 800°C combustion temperature to maintain environmentally friendly flue gas. As state in the material and method, PLTSa Merah Putih Bantargebang monitoring the temperature at the neck of the furnace and at the grates. Waste combustion temperature in the first semester of 2021 kept around 800°C as shown in figure 1. The temperature ensures of steam production reaches the desire condition at 320°C. Although it could reach more than 800°C, for refractory installation safety it holds so as not to exceed from maximum operating temperature which is 1200°C. Those conditions also keep waste reduction performance higher. The combustion process at the grate was kept higher than 800°C, especially for drying and combustion process at grate 1 – 3. After that, at grate 4, the post-combustion process lowers the temperature since the combustible material was gradually decreasing. At grate 4, the ash was generated and could be handled safely using the ash handling system.

The average waste reduction using PLTSa Merah Putih Bantargebang reached 79%. This value is still in the WTE incineration performance range, which is at 70-90% [9,10]. Although the reduction is still acceptable, it can still be improved. This improvement can be done if there is cooperation with all stakeholders, especially for the homogenization of waste characteristics from the source. Furthermore, the pretreatment process needs to be improved since the bottom ash still contains several unburned materials such as metal, glass, and building materials.

4. Conclusions
The waste reduction of the waste-to-energy pilot project plant, PLTSa Merah Putih Bantargebang, in the first semester of 2021 reached 79.9%. The combustion temperature at the furnace could achieve more than 800°C, while the grate combustion could reach 1000°C at the drying and combustion zone.

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