Value of the Ash Opacity on the Performance of Incinerator as a Result of System Variations

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Abstract. About 15% of the total population of Semarang City does not get any waste management service. The lack of the infrastructure for collecting and processing waste, transportation, and disposal of the waste in the unserved area is believed to be the causes of the problem. As a result, incineration becomes the solution chosen for some people. Unfortunately, incineration has adverse effects. The ash produced by the incineration contains pollutants. To reduce the ash, the pollutant control devices that can be applied to the incinerator are needed. It is also necessary to monitor air quality emissions to find out the ash opacity value of burning material. The modification into two variations was carried out to determine the performance of the incinerator. The first system variation uses the principle of spreading water on the ash produced by the incineration. While the second system variation uses the principle of passing the ash in the submerged water. The composition of the waste burned in the incinerator was 38.115% leaves, 3.458% branches, and 20.475% food scraps. The measurement of the opacity value is done at the inlet and outlet of the incinerator.

1. Introduction

Current waste management problem is related to human activities [1]. Managing waste by burning becomes one of the options to solve the problem [2]. It is done because it is relatively easy for some people. However, the remains of the incineration create ash that contains various kind of pollutants [3]. That being said, a technology to burn waste equipped with pollution control devices is needed, and one of them is incinerator. The design of the incinerator is made based on several considerations, inputs, and analyses. It also needs to consider the air needed during the incineration process, the initial incineration system, the amount of waste being incinerated, and the management of the ash resulted from incineration. The purpose of the incinerator is to change the shape of the waste to a smaller size [4]. Also, the incinerator in various countries is used as a power plant that utilizes heat energy in the device [5]. Incineration produces ash as a result of the remains of the process [6]. The intense concentration of the ash has much gas containing dust particles or particulates from the incineration process. The critical thing to note in the emission of air pollution by waste is the particulate emissions due to the incineration process [7]. The incineration process occurs due to a chemical reaction that runs fast and releases energy, light, and heat [8]. Complete incineration requires an adequate amount of oxygen and a suitable fuel composition [9].
Meanwhile, incomplete combustion can happen if the amount of oxygen is inadequate or does not mix with the fuel [10]. The need for oxygen \( (O_2) \) for the incineration process is affected by the percentage of carbon and hydrogen contained in a fuel [11]. Incineration using technology in the form of incinerator requires an initial evaluation. The initial evaluation is the feasibility of waste to be burned by knowing the water content, combustible content, and ash content. The thermal process (combustion) will produce residues (non-combustible parts) that cannot be burned [12]. Usually, the residue from combustion results in the form of ash, dust, and other residues [13]. In reducing air pollution due to combustion results, an air pollution control device is needed [14]. The air pollution control system has a function to control various pollutants that emerge, especially dust or particulates, acidic water, incomplete combustion gases such as CO, and combustion gases such as CO\(_2\), NO\(_x\), SO\(_x\), dioxin, and heat. This study aims to determine the influence of the system used on the incinerator to the value of the ash opacity produced. The incinerator used in this study is equipped with an air pollution control device [13]. To find out the performance of the incinerator, a modification is made into two system variations. Variation of the system is done in the contact area of the ash and water. The principle used in the first system variation is to spread water on the combustion fumes. In contrast, the second system variation uses the principle of passing combustion fumes in submerged water. The composition of the waste burned in this study is in the form of leaf, twigs, and food waste [15].

2. Methodology
The design of the incinerator is the beginning of this research stage [16]. The incinerator consists of six main parts, namely: (1) the combustion chamber, (2) the entry point of the waste, (3) the combustion ash chamber, (4) the sampling place, (5) the contact area of the ash and water, and (6) water reservoirs. An overview of the incinerator can be seen in figure 1.

![Incinerator Diagram](image)

**Figure 1. The incinerator**

The incinerator is equipped with a pollution control unit that is located in the contact area of ash and water. A modification into two-system variations is carried out on this incinerator in the contact area of ash and water. The first system variation is done by adding activated carbon and two pieces of iron ram into the contact area of ash and water. The placement of activated carbon lies in the second layer. As for the first and third layers, there are iron rams. The placement of these three layers is done above the ash inlet pipe, so it needs stones to carry these three layers. Figure 2 shows the placement of layers in the ash chamber.
In the second system variation, the addition of water to the ash chamber is carried out with up to the upper limit of the ash inlet pipe, which can be seen in figure 3. The volume of the water used in this second variation is 19.1 l. With the water in the contact area of ash and water, the bottom outlet of the contact area of ash and water is closed. That way, the water can be accommodated in the contact area of ash and water.

The next stage is the measurement of wastewater content. Before measuring the moisture content of waste, the waste that will be burned is collected and weighed first. Waste collection is done two times because it will be used for burning the first system variation and the second system variation. The type of waste that is burned is organic waste such as leaves, twigs, and food waste. The composition of the burned waste is 1.14 kg of leaf waste, 0.1 kg of branches and 0.61 kg of food waste. The measurement of wastewater content is carried out in an environmental laboratory by mixing the three types of waste. The results obtained from the measurement of wastewater content are 43.090% and 42.197%. The feasibility of the waste for combustion process has a wastewater content of less than 50%. So, it can be concluded that the waste is worth burning.

3. Results and discussion

The data of the opacity value are retrieved using the opacity meter tool. The measurement of opacity is done when the waste starts to burn. The composition of the burnt waste is an organic waste in the form of leaf, twigs, and food scraps with a total weight of 1.85 kg. The waste contained in the incinerator is divided into five parts so that the weight of waste per part is 0.37 kg. The waste with a weight of 0.37 kg will run out within five minutes. The process of entering waste into the incinerator takes about 1-2 minutes. Thus, the measurement of opacity is done at every third minute. Measurement starts at the inlet first. Then, within five seconds, the outlet is measured. The time required in the combustion process is 25 minutes, with five times of waste insertion [17].
3.1 First system variation

The result of the measurement of the opacity value in the inlet and outlet in the first system variation can be seen in figure 4.

![The Result of the Measurement of Opacity Value at the Inlet in the First System Variation](a)

![The Result of the Measurement of Opacity Value at the Outlet in the First System Variation](b)

**Figure 4.** The graphic of the measurement of opacity value in the first system variation, (a) Inlet, (b) Outlet

Figure 4 shows that the measurement of opacity value at the inlet and outlet of the incinerator using the first system variation always decreases. The opacity value of the inlet section has a more excellent value than the opacity value of the outlet. The difference in opacity value in the inlet and outlet is caused by the ash produced from combustion comes in contact with the distribution of water in the contact area of ash and water. The measurement of opacity takes place every third minute after the waste is being entered. Thus, the measurement of opacity value takes place at the 3rd minute, the 8th minute, the 13th minute, the 18th minute, and the 23rd minute. Waste that has been divided into five parts is completely burned in the 25th minute. Therefore, at the 28th minute, the opacity value is measured as the end of the combustion process.

Measurement at the inlet of the incinerator in the 3rd minute produces the highest value, which is 99%. In the 8th minute until the 18th minute, the results of the measurement at the inlet obtained are smaller than the first measurement (3rd minute). The results obtained at the measurements of the 8th minute, 13th minute and 18th minute are 60.1%, 33.4%, and 5.4%. That is because at the time of the first measurement, the burning coal that is produced ignites, and it is ready to be burned [18]. Whereas in the following minutes, the burning coal begins to dim.

The measurement at the outlet of the incinerator in the third minute is 79.7%. The measurement of the opacity value at the outlet in the following minutes has decreased. This is due to the contact between ash and the distribution of water in the contact area of ash and water [19]. According to the measurements at the 18th minute and 23rd minute, it is shown that the outlet of the incinerator is 0%. This indicates that the combustion process has begun. The burning process is complete in the 25th minute. Measurements are being retaken in the 28th minute to ensure that combustion is complete. This is indicated by the opacity value of the inlet and outlet of the burner, which is 0%.
3.2 Second system variation

The result of the measurement of ash opacity value can be seen in figure 5.

![The Result of the Measurement of Opacity Value in the Second System Variation](image)

Figure 5 shows that the opacity value of the inlet section of the second variation incinerator has fluctuated. The decrease in the opacity of the inlet section occurs in the 3rd minute to the 13th-minute measurement. On the other hand, the measurements in the 18th minute and 23rd minute have increased. The opacity value in the 18th minute is 78.3%, whereas in the 23rd minute is 86.4%. The increase in opacity is due to the process of entering waste which is faster than before. The process of entering waste in the 18th minute and the 23rd minute only takes one minute. Aside from that, in the 18th minute and 23rd minute, the temperature rises to 60°C. In the 28th minute, there is a very drastic decrease because there is no more waste to input in order to carry out the combustion process.

The measurement in the 28th minute is done as the end of the combustion process. The opacity value is still present at this minute due to the ash that is unable to pass through the water submerged in the contact area of ash and water. This causes the ash generated from the combustion process to gather in the combustion chamber [20]. The opacity value at the outlet in the design of the variation of these two incinerators is 0%. The opacity value indicates that there is no ash coming out of the outlet. It is marked by the high opacity value generated at the inlet of the incinerator.

4. Conclusions

Ash opacity values are measured at the inlet and outlet of the incinerator. The decrease in opacity occurs in the first system variation, namely 19.3%, 38.9%, 33.1%, 5.4%, 6.6%, and 0%. Water in the first modified system variation in the three layers in the ash chamber helps in reducing the opacity value. Whereas in the second system variation, there is no decrease in opacity in the incinerator. This is proven by the absence of ash coming out of the incinerator outlet, so the opacity value at the incinerator outlet is 0%. Therefore, it can be concluded that the use of the first system variation on the incinerator can minimize the ash generated from combustion. There is a need to re-modify the incinerator at the door of the combustion chamber and the entry point of the waste which is to be made more practical so that it is easier to be opened or closed. Modification of the location of the entry of waste is also needed so that the ash generated from combustion is not gathered at the place of the entry of waste. Design variations in the contact area of ash and water are needed so that the contact between ash and water can last longer.
5. References

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