# The Effect of Combustion Temperature on Exhaust Gas Emissions : New Multi-Level Drum Municipal Solid Waste Incinerator

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***Abstract.***

*Municipal solid waste (MSW) is a crucial problem in today's era where the growth of waste production continues to increase every year. One of the most effective thermal technologies used to reduce the volume of waste is through the incineration process. Incineration is the thermal-induced oxidation of waste to transform solid waste into inert ash and also sterilize or destroy hazardous chemicals and biological agents. A new multi-level drum incinerator was designed and fabricated with a plate thickness of 2 mm and a combustion chamber volume of 0.15 $m^3$ and a height of 4 meters made from a drum with a diameter of 60 cm and coated with 5 cm thick refractory. During the incineration process of MSW, the incinerator emits exhaust gases or pollutants such as $NO_x$, $SO_2$, HCl, CO, and dioxins, which are harmful to the environment. To reduce the production of these pollutants, a suitable combustion temperature is required to ensure that MSW is well converted. In this study, the combustion temperatures were set at 450$^o$, 500$^o$, 550$^o$, and 600$^o$C. After testing, the lowest pollutant results were obtained at a combustion temperature of 600$^o$C, with an average production of CO and $CH_4$ of 0.29% and 0.120%, respectively. At this temperature, the combustion process occurs more quickly, and the measured combustion temperature profile is more stable, thus reducing the production of incinerator exhaust gases.*

**Keywords:** *Incinerator; Combustion Temperature; MSW; Fueel Convertion Rate and Exhaust Emissions.*

## I. INTRODUCTION

The increase in population and socio-economic growth has resulted in an increase in the use of daily products which greatly affects the amount of solid waste. It is estimated that in the next 30 years, annual solid waste worldwide will exceed 3.4 billion tons per year [1]. There are several types of waste processing systems in landfills, including bail press, open dumping, controlled filling, sanitary landfill, incineration, and composting. There are various Municipal Solid Wastes (MSW) processing processes, one of which is the thermal process. In the thermal process, MSW is converted into gas, liquid or solid products depending on the type of waste and its processing method [2, 3]. Compared to other waste processing procedures, incineration has the advantage of reducing waste volume, generating electricity from the heat produced during combustion, and destroying pathogens [4].

Incineration is the thermal-induced oxidation of waste to convert solid waste into inert ash and also sterilize or destroy hazardous chemicals and biological agents [5-8]. Currently, there are three most common waste incineration technologies in the world, which are mechanical-grate, circulating fluidized bed combustion, and furnace combustion [9]. MSW incineration plays an important role in waste management systems worldwide, due to its fast volume reduction advantages of 80-90% [10]. However, the MSW incineration process releases various secondary pollutants, including acid gases, particulates, nitrogen oxides, heavy metals, and highly toxic organic pollutants [11, 12]. The temperature of the incinerator combustion is important to control as it greatly affects the emissions or pollutants from the incineration process [13]. The incineration process is controlled at temperatures <900$^o$C as the combustion temperature to decompose organic materials and stabilize heavy metals in fly ash [14]. In this study, the combustion temperature will be set at 450$^o$C, 500$^o$C, 550$^o$C, and 600$^o$C using MSW as fuel. The results of this study show the effect of combustion temperature on the emissions or pollutants generated from the combustion process.

## II. METHODS

### 2.1Feedstock Characteristics

The feedstock used in this study is MSW which is treated and characterized before the research begins as shown in Table 1. Figure 1 shows the waste taken from integrated waste management facility at Mengwi, Bali, Indonesia. The wastes are transported by waste trucks, then collected and sorted. Waste that cannot be recycled will be collected into one and called residue. The research samples will be randomly selected based on the field conditions at the time of collection, and will be dried under sunlight for 2 days to reduce their moisture content. Based on the proximate analysis using LECO TGA 701, the sample showed a low moisture content of 1.24% and a high volatile matter content of 91.96%, with the remaining being ash (5.12%) and fixed carbon (1.68%). The calorific value was determined using Parr Oxygen Bomb Calorimeter, and the result obtained was 6701.27 cal/gram.

**Table 1.** MSW Characteristic Proximate

| Sample | Moisture | Volatile | Fixed Carbon | Ash |
|---|---|---|---|---|
| MSW | 1.24 % | 91.96 % | 1.68 % | 5.12 % |

**Fig 1.** MSW from Integrated Waste Management Facility Mengwi - Indonesia.

### 2.2Method and Experimental Schematic

This study was conducted based on experiments or trials on a multi-level drum incinerator unit with variations in combustion temperature controlled electronically within the reactor. The raw material used was MSW, amounting to 7 kg with a moisture content below 10%. The emission gases produced were continuously tested using a Gas Analyzer GASBOARD-3100P SERIES and the data obtained were in the form of tables. The experimental approach method in this research was carried out in accordance with the research objective, which

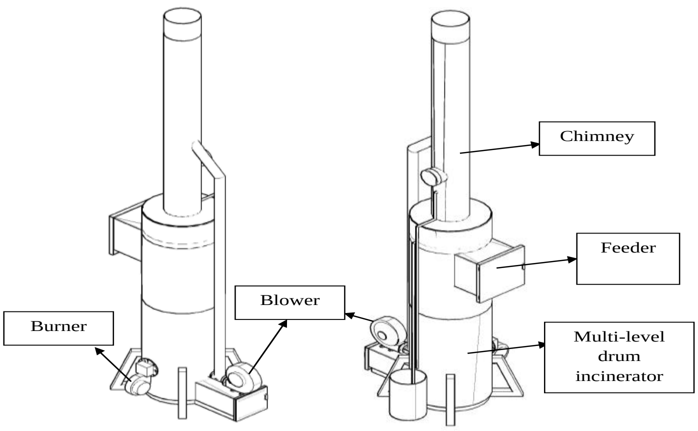


**Fig 2.** Multi-level Drum Incinerator Design.

The incinerator unit used was designed and fabricated for research scale with a capacity of 10 kg per hour. Figure 2 shows the schematic diagram of the Residual Waste Incinerator Unit used in this study. The incinerator reactor chamber functions to reduce residual waste with a plate thickness of 2 mm and a combustion chamber volume of 0.15 $m^3$ and a height of 4 meters made from a drum with a diameter of 60 cm and coated with 5 cm thick refractory. It uses a water scrubber system through spray nozzles and pumps. This incinerator also uses a purifier system that captures pollutants using a metal fiber mist filter.The research will be carried out in several stages.

irst, the preparation of the incinerator equipment and other supporting components such as blowers, burners, and water pumps. The assembly process is carried out for the supporting components with the incinerator, followed by the preparation of the research raw material, namely municipal solid waste or MSW. The MSW is taken from a solid waste processing site in Mengwi, Badung, Bali, where a drying process is carried out beforehand to obtain a moisture content of <10% by sun-drying method.The incinerator testing is equipped with a Gas Analyzer and Data Logger to read and store combustion temperature measurements. The first step is to feed MSW through the feeding door and ensure that water for the water scrubber is full. The combustion temperature setting is adjusted according to the research variable. When the burner is ignited, the gas analyzer and data logger are activated. The gas emission data is recorded at 10-second intervals during the combustion process until completion. Ash removal is done after the temperature inside the reactor cools down.

## III. RESULT AND DISCUSSION

### 3.1 Combustion Rate

After conducting research and testing, data results were obtained in the form of input mass, output mass, and operational time. The data can be used as a reference in determining the combustion rate of each temperature set. Combustion rate is the reactor's ability to convert waste fuel into combustible gas and heat or calorific value per unit time. In this study, the weight of the tested waste at each temperature set was 7 kg.

**Table 2.** Fuel Conversion Rate (FCR)

| Operating Temperature | Ash Mass (kg) | Operating time (hour) | FCR (kg/hour) |
|---|---|---|---|
| 450°C | 2,059 | 0,3 | 16,47 |
| 500°C | 1,624 | 0,23 | 23,37 |
| 550°C | 1,615 | 0,213 | 25,28 |
| 600°C | 1,504 | 0,205 | 26,8 |

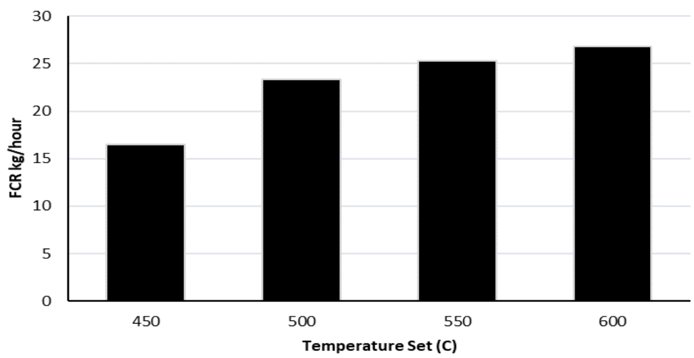


**Fig 3.** Relation between FCR and Temperature Set

Based on Table 2 and Figure 3, it is known that temperature set 600°C has the highest combustion rate compared to other temperature set. Along with the increase in combustion temperature, the combustion rate also increases or is directly proportional. This is because the decomposition process of materials occurs faster at high temperatures, but if the temperature is too high, it can cause dangerous reactions or toxic gases that can pollute the environment.

### 3.2 Combustion Temperature Profile

In the combustion process, temperature stability is crucial to consider as it affects combustion rate, material durability, and exhaust gas emissions. Based on Figure 4 below, the most stable temperature is shown to be in a combustion temperature set of 600°C. At this temperature, it will certainly result in the most optimal efficiency and very low burner fuel consumption. Whereas at a combustion temperature set of 400°C, there is temperature fluctuation indicating an unstable combustion temperature. This is because the temperature is too low to sustain continuous combustion process.

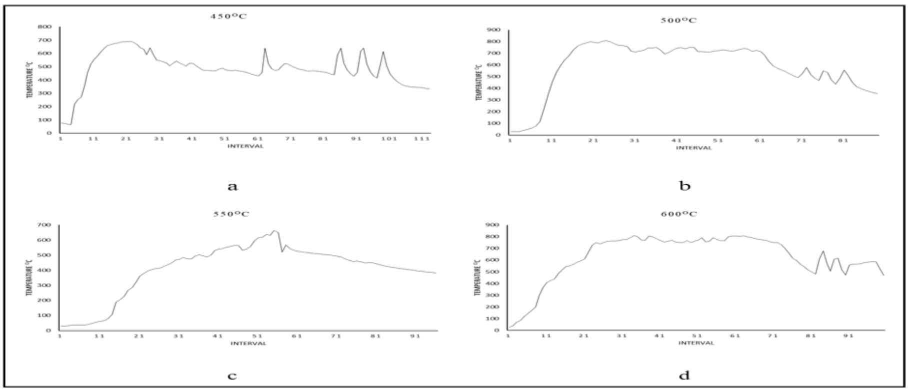


**Fig 4.** Temperature Profile of Each Temperature Set, a. Temperature 450$^{o}$C, b. Temperature 500$^{o}$C, c. Temperature 550$^{o}$C, d. Temperature 600$^{o}$C

### 3.3 The Exhaust Gas Emissions of the Incinerator

The incineration process produces several exhaust gas pollutants, including $NO_x$, $SO_2$, HCl, CO, and dioxins, which are often generated during the MSW combustion process [15-18].

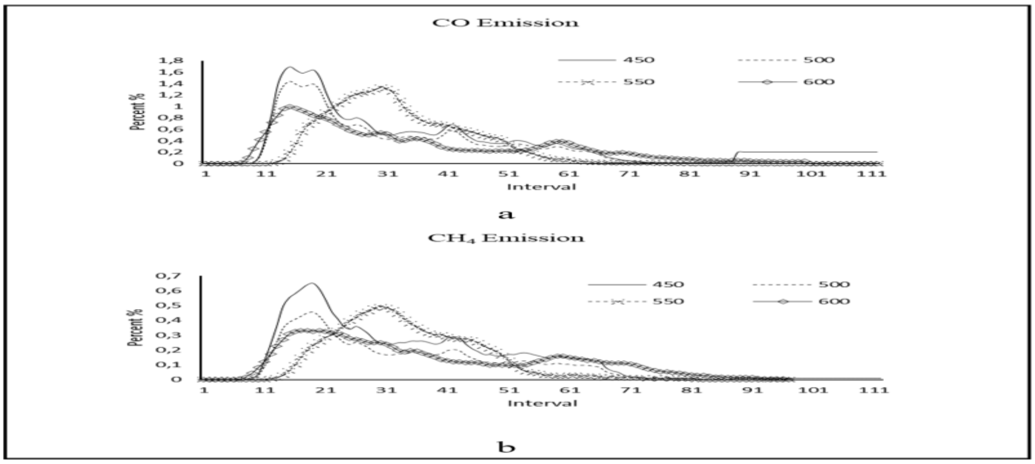


**Fig 5.** Emission Yield Incinerators, a. CO Emission, b. CH4 Emission

This study will compare the CO and $CH_4$ gas content in each variation. As seen in Figure 5, the production of CO and $CH_4$ gases in each variation is compared, with temperature set 600$^{o}$C producing the lowest concentration of CO and $CH_4$ at an average content of 0.29% and 0.120%, respectively. On the other hand, the highest emission production was obtained in Temperature set 450oC, with a CO and $CH_4$ content of 0.381% and 0.145%, respectively. This is due to the low combustion temperature and small combustion rate, which slows down the combustion process and results in the formation of emission gases or pollutants in the incinerator exhaust gas.

## IV. CONCLUSION

Based on the testing and measurements conducted on the multi-tiered drum incinerator with variations in combustion temperature set and its effects on exhaust gas emissions, it can be concluded that: Higher combustion temperatures can reduce pollutant production. In temperature set 600oC, the lowest CO and CH4 pollutant levels were obtained, with an average content of 0.29% and 0.120%, respectively. In this variation, the combustion temperature is more stable, resulting in a faster combustion rate.

## V. ACKNOWLEDGMENT

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