Estimating backyard waste burning emission: A case study of Tembalang Campus, Diponegoro University

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Abstract. This study analyzes the distribution and amount of CO, CO2, HC, and NOx gas emissions resulting from the open burning of backyard waste in Diponegoro University. The burned waste sample is taken from surrounding environment of Diponegoro University (Tembalang Campus) by taking 4 random samples (3 kg each). Emissions from CO, CO2, HC, and NOx gases were obtained from the 24 minutes combustion test. Furthermore, the gaseous pollutant emitted is measured using a gas analyzer. The burned waste comprised 73.77% of organic waste, 17.45% of plastic; 4.33% of paper; and 4.45% of other waste. The emission test results show that the highest CO, CO2, HC, and NOx emissions have occurred at 14, 20, 18, and 18 minutes, respectively. The combustion test reveals that an enormous amount of CO, CO2, HC, and NOx gas is emitted during uncontrolled waste burning. Because backyard wastes burning produce significant gaseous pollutants, several efforts are needed to reduce this practice.

1. Introduction

Pollution due to emission outputs from human activities continuously causes environmental damage [1]. Problems related to environmental pollution are becoming more complex as time goes on. One of the problems that have high urgency in Indonesia is the waste sector. In Indonesia, waste management tends to be not entirely optimal at the landfill [2]. Even based on one of the data from similar research that has been done previously, the distribution of waste based on its management, Batu City, Indonesia still has a figure of 28.5% of waste burned openly. In 2021 the emissions generated from waste burning activities in Batu City have a quantity of CH4 emissions of 0.032 Gg CH4 or equivalent to 0.671 Gg CO2-eq, N2O emissions of 0.0007 Gg N2O or 0.230 Gg CO2-eq, and CO2 emissions of 0.676 Gg CO2, bringing the total emission to 1.575 Gg CO2-eq. and there are still 60 tons/day of unmanaged waste [3].

Waste burning activities have the potential to produce CO2, CH4, and H2O gas emissions. These gases are included as greenhouse gases that contribute significantly to climate change [4]. GHG emissions contribute significantly to the cause of global warming [5]. Environmental impacts that will occur include extreme weather and climate. Obradovich’s (2018) and Ernyasih (2018) reveal that climate change and extreme weather are investigated further on human health. One of the direct impacts of extreme weather can cause acute respiratory infection (ARI). ARI cases from year to year continue to increase up to 11.2% [6,7]. Waste treatment by burning should be minimized or eliminated. Seeing more than 60 tons of unmanaged waste in Semarang City per day, which has excellent potential for this waste
to end up burning in open spaces, triggering the danger of contributing greenhouse gas emissions from waste burning activities contributing to greenhouse gases that harm the environment, one of which is CH₄ gas which has a level of danger 21 times more dangerous than CO₂ [8]. This study will analyze the emissions from waste burning activities and plan emission reduction strategies in Diponegoro University as pilot study. This research were not estimating the number of waste piles that may be burned in Diponegoro University.

2. Methodology
The first method is waste sampling which started by visual survey through Diponegoro University, Tembalang campus. Then, around 3 kg of waste were taken in 4 random places in the campus. The determination of waste that will be burned was taken based on a short interview with the clean workers. The waste are mixed and then weighed according to its composition. The waste is put back together in an burning chamber and burned to determine the emission. Laboratory test studies were used to analyze the burned waste composition and potential emissions of nitrous oxide (NOₓ), CO, carbon dioxide (CO₂), and hydrocarbons (HC). The collected waste are burned in the burning chamber within 24-30 minutes, or waited until the waste is completely burned. At the combustion time, the temperature is calculated using a thermogun and the concentration of oxygen and gas that comes out using a gas analyzer. After burning, 10 minutes of time are needed to release the high temperature and hot gaseous. After cooling, the fly ash and bottom ash are taken out until nothing is left in the incinerator. This burning test is repeated three (3) times to increase the accuracy of the data.

3. Results and discussion
Based on field observations, it is known that the condition of waste burned in Diponegoro University is still very mixed between wet and dry waste. The waste composition is in the form of plastic, twigs/leaves, cloth, paper, metal, rubber, and other compositions. The highest burned waste consisting of twigs/leaves/branches which has 73.77% from total waste that is burned in Diponegoro University, followed by plastic, paper and other waste about 17.45%; 4.33%; and 4.45%, respectively. The sample composition of the waste can be grouped based on the combustible and non-combustible fraction. The combustible waste fraction is in the form of samples with the composition of twigs/leaves, plastic, and cloth, for the non-combustible fraction in samples with other compositions, paper, and rubber. At the same time, the fraction of waste samples that cannot be burned is the metal waste. As it can be seen in Figure 1, around 300 ppm of CO and 12,000 ppm of CO₂ are released to the atmosphere during the combustion test. The NOₓ and HC also show that 120,000 ppm of NOₓ and 80 ppm of HC are emitted during uncontrolled waste burning which indicate a serious effect of uncontrolled waste burning. During the test, it is shown that the highest emission of CO, CO₂, HC, and NOₓ is occured after 12 minutes and slowly reduced after passing 20 minutes of burning. Since the waste as fuel is significantly reduced, the emission is also decreasing by time.

Regarding this result, the right strategy to reduce the emissions from the open burning of waste is essential. This strategy is needed to change the mindset and paradigm of the clean workers through an educational approach. The imposition of sanctions on people who burn waste openly and improvement of the waste management system through the provision of waste facilities is vital to reduce the waste burning on the campus [9]. Suppression of the amount of waste generated at the source through the simple 3R (Reuse, Reduce, Recycle) program involving clean workers to do sortation and composting may be another effective strategy to reduce waste burning. This waste reduction activity is expected to reduce emissions from the open burning process because the amount of waste can be reduced through proper backyard waste management [10, 11].

Permadi and Oanh reported that open burning significantly contributes to toxic emissions in two big cities (Jakarta and Bandung) in Indonesia compared to total anthropogenic emissions. However, the estimation may have high uncertainty due to the lack of activity inventory data for open waste burning. In Indonesia, household open burning is predicted to have a Pfrac ranging from 0.04-0.20. This number needs to be thoroughly explored [12]. Further, tree pruning and backyard waste dominated the
composition of waste burned. According to Alves et al., there are many possibilities for the emission of gaseous and particulate compounds from combustion. Mixed waste of different branches and leaves can emit 1,499 g/kg of CO₂, 147 g/kg of CO, 1.34 g/kg of PM, and 0.25 g/kg of organic carbon [13]. Therefore, the existence of plastic waste in burned waste piles is concerning. Burning of the waste can result in the emission of a small amount of dioxins and brominated flame retardants, which are toxic and harmful to human health [14]. Open burning of plastic waste was also found to increase the concentration of dioxin-like compounds in the Surabaya and Palembang landfill sites [15]. Overall, waste burning was found to directly contribute to air pollution via many forms of harmful compounds.

![Figure 1. CO and CO₂ concentration of backyard waste burning.](image1)

![Figure 2. HC and NOₓ concentration of backyard waste burning.](image2)

4. Conclusion
Research on the estimation emission of backyard waste burning in Diponegoro University was conducted by taking 4 random samples in Diponegoro University. After field observations, the composition of the waste burned is backyard waste which taking up to 70% of total waste that is burned and followed by plastic and paper waste. The burning simulation test reveal that there is significant
emission from backyard waste burning. The highest gaseous emission is NOx gas and followed by CO₂, CO, and HC indicating incompletely burned piles. Future research should estimate the number of piles that are burned in Diponegoro University and also Semarang City.

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