Biomass burning; ultrafine particles, concentration, and organ effect

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Abstract. Biomass burning has been known as a PM$_{0.1}$ emission source that may have an impact on health. In this research, we investigate biomass burning ultrafine particles, PM$_{0.1}$ in terms of the concentration and the exposure impact on mice organ. We used two biomass burning such as pine wood and grain straw burning. The smoke was exposed to the mice for 100 seconds, and the effect on the organ was observed including lung, kidney, liver, and erythrocytes. The effects on the organ damage were related to the PM$_{0.1}$ dose concentration. The particle dose concentration was calculated by summing the total concentration of an ultrafine particle in the smoke. The PM$_{0.1}$ concentration emitted by the pine wood burning was $1.4 \times 10^6$ particles/cm$^3$ meanwhile, the concentration of the grain straw burning was $2.7 \times 10^6$ particles/cm$^3$. We observed the exposure effects on the mice organ with the results as follows: every biomass burning produced PM$_{0.1}$ with a certain concentration. The effects of biomass burning PM$_{0.1}$ emission on organ depended on a kind of biomass and the particle dose concentration. Lung was the organ having the most effect on the biomass burning particle exposures among the other organs.

1. Introduction
Biomass emission has become a major air quality issues. The issues are not only related to the air quality reduction but also dealing with the increase of the human disease [1]. The biomass emission is formed by the burning [2] or heating organic compound [3]. The main source of biomass emission has been known such as the wood burning [4], organic material burning [5], or forest fire [6]. In the daily life, the biomass emission has been unconcerned due to the people main interest in vehicles emission [7] or industrial pollutant [8]. However, in the circumstance, the biomass emission especially PM$_{0.1}$ produced by the cooking process has become an unrealized factor that may influence human health [9]. Biomass burning emission may contain various types of particles and gaseous [10]. However, the main concern in this study is the particles with size less than 0.1μm (PM$_{0.1}$). This type of particles has been identified as very dangerous substances on the human health [11] due to the inhalable characteristic [12], spreading in the large area [13]. The particles have a reactive characteristic that induces the reactive oxygen series leading into tissues inflammation [14,15]. There are a much of evidence showing the particle effects on human health. Lung and skin are the most risked organ to be exposed by the PM$_{0.1}$ [16]. The other internal organs have the same potential by the fact that the ultra-small size allows the particles penetrate to the deeper human organ [17]. The previous studies present the impact of PM$_{0.1}$ on the human health such as kidney, liver [18], type II diabetes mellitus [19], asthma [20], and influenza-like illnesses.

Biomass has been considered as the alternative energy to replace the fossil fuel. The use of biomass may be the answer to the energy crisis [21]. The pinewood and grain straw was the example of the
biomass that may be able to use as the fossil fuel replacement [22]. However, the pine wood and straw burning may bring a new problem especially with the reduction of air quality. In this research, we observed biomass burning in terms of the impacts on the particle emission related to PM$_{0.1}$ emission on mice organ. This study was aimed to establish knowledge of biomass burning and the impacts on human health. This study was focused on the investigation of the biomass burning emission exposure on mice organ. The main interest was related to the PM$_{0.1}$ dose concentration on the mice organ effects.

2. Methods

2.1. PM$_{0.1}$ Concentration

We burned 50 grams of pine wood and grain straw in a chamber with the dimension of dimension 50 cm x 40 cm x 40 cm. The smoke was then introduced to a 30 cm x 20 cm x 20 cm chamber by a pump with the speed of 2.0 m/s where we exposed mice. The concentration of PM$_{0.1}$ in the smoke was measured using a P-Trak particle counter type 8525. The PM$_{0.1}$ dose concentration was calculated by the total PM$_{0.1}$ concentration using Equation 1.

$$C_{\text{con}} = Q \sum \int C(t) \, dt$$

With $C_{\text{con}}$ is the total concentration, $Q$ is the smoke debit, $C(t)$ is the measured concentration. The measurement was repeated for three times for each biomass burning [23].

2.2. The effect on the organ

In order to observe the effect of biomass emission burning in the mice organ, we used male mice with the average weight of 23.5 grams as the experimental animals. The mice were treated nicely based on the Brawijaya University ethical guide for the animal and human treatment ((No. 541-KEP-UB). Before exposed by the biomass emission, the mice were kept in the different-isolated cage to avoid the ambient PM$_{0.1}$ with the food and the water was provided ad libitum. The acclimation procedure was conduct for 3 days before the mice exposed by the emission to avoid stress during the research. The mice were divided into two main groups that consist of a control group and an exposed group. The exposure procedure was done by introducing the biomass emission of 3 minutes (180 seconds) into the exposure chamber with the dimension of 20 x 20 x 30 cm$^3$. The mice were kept in the exposure chamber for 100 seconds. The exposure was conducted twice a day in the morning and afternoon for 10 days. The mice were directly dissected by using cervical dislocation. The lung, kidney, blood, and liver were removed from the mice to be observed the alteration for each organ. The observation was proceeded by using an Olympus binocular microscope type Cx 31. The images were taken for 5 different areas with the magnification of 400 times. The alteration was observed in term of an alveolar enlargement for the lung, enlargements of tubular epithelial cells for the kidney, erythrocytes alteration consist of helmet cells, teardrops cells, and a parenchyma degeneration for the liver. The damage was calculated by using Equation 2 [23].

$$\text{Damage} \% = \frac{T_c - d_c}{T_c} \times 100 \%$$

$T_c$ = Total cells
$d_c$ = Damage cells

3. Result and Discussion

3.1 PM$_{0.1}$ concentration

Figure 1.a shows the measured concentration of PM$_{0.1}$ for the grain strain and pines wood burning. In the initial measurement, the PM$_{0.1}$ concentration of the grain straw burning was reached 1.10 x 10$^5$ particles/cm$^3$ while the PM$_{0.1}$ concentration of pine wood burning was 1.60 x 10$^5$ particles/cm$^3$. This result indicates that the pine wood burning produces a larger concentration of PM$_{0.1}$ rather than the grain straw burning. In order to calculate the particle dose concentration, all of the measured concentration was totalized by using Eq.1 and stated as a total concentration. The total concentration of pine wood
was calculated of $1.4 \times 10^6$ particles/cm$^3$ while the grain straw was $2.7 \times 10^6$ particles/cm$^3$. The comparison is present in the Figure 1(b).

Figure 1. (a) The measured concentration of PM$_{0.1}$ emitted by grain straw and pine wood burning in three minutes. (b) The total PM$_{0.1}$ concentration of different biomass burning.

3.2. The effect of biomass in the mice organ

The effect of biomass burning particles on mice organ was focused on the observation of the development of the tissue alteration. Figure 2(a) illustrates the alteration observed in the mice lung, liver and kidneys. The alveolar damage in term of the emphysema of the lung tissues is identified in the exposed samples. The black arrow in the Figure 2 shows the presence of the alveolar geometrical alteration that indicates the development of emphysema [24]. The yellow arrow expresses the necrosis that is identified by the pale cell without any nucleus. The blue arrow displays the presence the tubular epithelial cell that indicates the alteration of the kidney cell [23]. The red arrow shows the presence of the teardrop cell and helmet cell in the erythrocytes. We compare the histological images between the controls and the exposed organ to indicate the effect of the biomass particle exposure.

It can be seen from 2(b) shows the different organ alternation caused by the biomass burning exposure. The exposure of the pine wood burning emission with the higher PM$_{0.1}$ dose concentration results in more organ damage with the higher alteration level than the exposure of the grain straw burning emission. The alteration of the mice organ due to the pine wood burning emission is 44% for lung, 37% for liver, 27 for kidney, and 36 for erythrocytes. Meanwhile, the alteration of lung, liver, kidney, and erythrocytes caused by the exposure of the gain straw burning emission is 42%, 32%, 21%, and 26% respectively. The different alteration of the mice organ due to the pine wood and grain straw burning emission is 2% for lung, 5% for liver, 6% for kidney, and 15% for erythrocytes. This shows that every biomass burning has a diverse effect on the organ.
Figure 2. (a) The histological images show the alteration of the lung, liver, erythrocytes, and kidney before and after the biomass emission exposure. (b) The alteration level of the different mice organ.

The burning of biomass produces particle emission with the concentration depending on kind of biomass and burning rate [25], [26]. In this study, the burning of grain straw and pine wood emits PM$_{0.1}$ with the different concentration. The grain straw burning produces PM$_{0.1}$ with the rate of $2.17 \times 10^5$ particles/cm$^3$/minute. Meanwhile, the rate of the pine wood burning is of $5.55 \times 10^5$ particles/cm$^3$/minute that is higher rather than the rate of the grain straw burning. The different of PM$_{0.1}$ emission production of the different biomass burning may because burning efficiency [2], burning rate [6], burning process [27], [28], and chemical contents [29]. This study confirms that different biomass burning results in particle emission with the different concentration per a period of time.

The exposure of the biomass burning emission has a different effect on the mice organ. This study obtains that lung is the organ that overcomes most alternation among other investigated organ. This is followed by the damage of liver and erythrocytes. The kidney has the least effects on the biomass.
burning emission exposure. We focus the investigation of the PM$_{0.1}$ exposure effect on the mice organ in this study because the PM$_{0.1}$ characteristic that is the very small size of particles [30] and inhalable particles to the deeper human respiratory systems [12]. The particles penetrate into the human body by two mechanisms; by the respiratory process[17] and skin penetration[16] because of their size. The lung is the primary organ of the respiratory system receiving the large particle deposition [31]. The result is the highest damage that we find in this research that conforms to the previous study. The damage may be generated by an oxidation process on the alveolus wall [32]. Then, PM$_{0.1}$ penetrates to the alveolus and merges to the other organ by the erythrocytes via the cardiovascular system [33], [34]. We found that the lung overcame the second large damage. It can be understood that by the fact blood is mostly transported into the liver [35]. After penetrating lung epithelium, PM$_{0.1}$ are transported into the liver [36]. This leads to the high deposited concentration in the liver than the kidneys [18]. Consequently, the particles may have more impacts on the liver rather than on the kidney that we have found in this study. The different effect of PM$_{0.1}$ on the organ can be related to the deposited concentration on the organ [37]. The burning of different biomass emits a vary particle concentration. When the particles are exposed to the mice with a different concentration, the impact on the organ varies. This study has found that the exposure of particle emission with higher concentration results in more organ alteration.

4. Conclusion
The burning of biomass produces PM$_{0.1}$ with the concentration depending on the kind of biomass. The burning of pine wood biomass emitted the higher PM$_{0.1}$ concentration rather than the grain straw burning did. The effect of the PM$_{0.1}$ biomass burning emission on the mice organ was influenced by the particle exposure dose concentration. The cell alteration of the mice organ was obtained in a variation for each organ. The lung was mostly influenced by the biomass burning particle emission, then was followed by the liver, erythrocyte, and kidney.

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