

Assesment of PM_{2.5} emission from corn stover burning determining in chamber combustion

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Abstract. Chamber measurement were conducted to determine Particulate Matter (PM_{2.5}) emission from open burning of corn straw at Garut District, West Java. The of this study is to estimate the concentration of PM_{2.5} for two types of corn (corncoobs and cornstover) for five varieties (Bisma, P29, NK, Bisma, NW). Corn residues were collected and then burned in the chamber combustion. The chamber was designed to simulate the burning in the field, which was observed in the field experiment that meteorological condition was calm wind. The samples were collected using a minivol air sampler. The assessment results of PM_{2.5} concentrations (mg/m³) from open burning experiment in the chamber for five varieties of corn cobs (Bisma, P29, NK, Bisi, NW) was 9.187; 2.843; 7.409; 3.781; 1.895 respectively. Concentration for corn stover burn was 2.060; 5.283; 4.048; 5.306 and 5.697 respectively. Fluctuations in the value of concentration among these varieties reflect variations in combustion conditions (combustion efficiency) and other parameters including water content, biomass conditions and the meteorological conditions. The combustion efficiency (MCE) of the combustion chamber simulation of corncoobs ia lower than the MCE of corn stover, that the concentration PM_{2.5} more emitted from the burning of corn stover. The results of this study presented provide useful information for the development of local emission factors for PM_{2.5} from open burning of corn stover in Indonesia.

1. Introduction

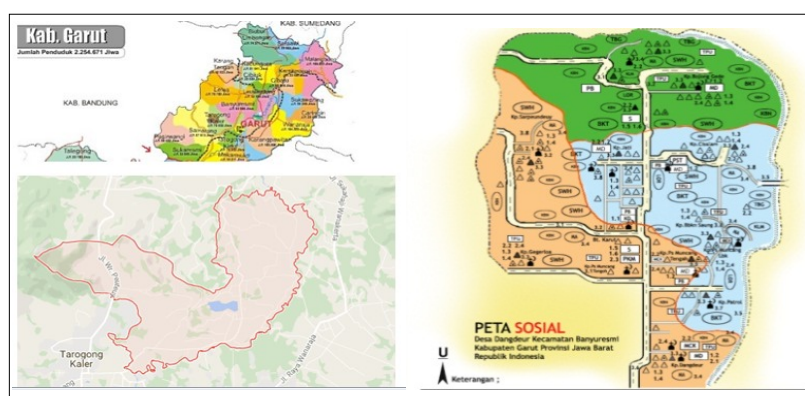
Field burning of corn straw was a common practice in Garut district, West Java. About 58% farmers burn corn straw after harvest for eliminate corn residue from the field. Corn straw burning was contributed more than 80% of the total biomass open burning emissions [1]. One of the major source of aerosol emissions emits type of particulate matter (PM) [2]. Many research projects have been initiated to assess the intensity of air pollution and to identify the major contributors. The purpose of this study was to estimating and analyzing PM_{2.5} emissions from burning straw during harvest season in West Java Province. In this study, laboratory simulation experiments were conducted to characterize concentration of PM_{2.5}. Burning experiments were carried out using the burning chamber of the Open Burning Test Facilities (OBTF) type[3]. Corn straw burning experiments were conducted in the chamber to simulate open burning in order to determine concentration of PM_{2.5} through real time equipment measurement. The chamber was designed to simulate open burning in the field, which was observed in the field experiments that meteorological condition was calm wind.



2. Experimental methods

2.1 Source of experimental material

Corn straw were chosen as representatives of agricultural crop residue. The corn straw is taken from a rural field in the Garut districts. Burning straw conducted into five varieties, they were collected from five villages (Baba kansaung, Batu karut, Cisalam, Bojong and Dangdeur) in the districts Banyuresmi, Garut. It is located at 6°56'49"-7 °45'00" South latitude and 107°25'8"-108°7'30" East Longitude. District Banyuresmi is located in the West Java Province it is about 66 km from Bandung. This district as one of the centers of corn production in West Java with corn production 6.3 tons/year (Figure 1).



LS1	= Babakan Saung Village
LS2, LS3, LS5	= Cisalam Village
LS4	= Batu Karut Village
LS6	= Bojong Village
LS7	= Dangdeur Village

Figure 1. A map showing the location of study area.

2.2 Experimental process

The Experimental has been performed in the combustion chamber system consisted of stainless-steel. The design of chamber is presented in Figure 2. Three sides of combustion zone are closed with heat durable steel sheet and one side is opened for the air circulation. The straw was burned to measure the weight before and after burning. During combustion, time was recorded and emission was measured using the same equipments and the same method. The experimental of $PM_{2.5}$ was collected a samplers minivol (Anderson 214 series) on the teflon filter (whatman 47 mm). The emission measurement equipments were installed in front of opened side chamber at ground level for 1 m height. Meteorological condition (temperature, pressure and humidity) and ambient air quality (concentration of CO and CO_2) were also measured.

2.3. Analysis methods

Particulate Matter quartz fiber filters of 47 mm in diameter (whatman international Ltd. UK) were used for Particulate Matter sampling. Before and after sampling filter were condition for 24 hours at desicator and weighted at five times after and before sampling using scale Boeco Germany with accuracy up to 0,00001 g and deviation of ± 0.00005 g. This value (m) is used in the calculation of gravimetric analysis to determine the concentration of $PM_{2.5}$ in aerosol burning corn straw. The net mass was obtained by subtracting the average of pre-sampling weights from the average of the post

sampling weight. All samples were analyzed for particulate matter (PM_{2.5}) mass methods gravimetry to be analyzed at Air Quality Laboratory Bandung Institute of Technology. For the QA/QC purpose during transport between field and laboratory locations, the filters were carefully placed in the filter holders and used for sample collection. After sampling the filters were taken out of the holder and placed in a petri dish. Blank filter was treated in the same way and used for the correction of the calculation results of concentration.[12]



Figure 2. Design chamber combustion.

2.4 Computing method

In order to estimate the concentration of PM_{2.5} of corn straw, burning experiments were conducted in the simulate open burning chamber. Calculation of burned corn straw was done by[19]

Particulate weight (M) were calculated using Equation 1

$$M_p = M_2 - M_1 \quad (1)$$

Where M_p is particulate weight (g), M_1 is filter's weight before sampling (g) and M_2 is filter's after sampling (g). The particulate weight (M_p) obtained is corrected by the weight of the blank filter.

Actual Volume (V_{act}) was determined using Equation 2.

$$V_{act} = Q \cdot t \quad (2)$$

where V_{act} is actual volume (m³), Q is flowrate (lpm) and t is sampling duration (minutes)

For conversion actual volume (V_{act}) to standard volume (V_{std}) was calculate using Equation 3.

$$\frac{P_{std} \times V_{std}}{T_{std}} = \frac{P_{act} \times V_{act}}{T_{act}} \quad (3)$$

where P_{std} is standar pressure at 1 atm, V_{std} is volume at standard condition ($P=1$ atm and T 25 °C) (Nm³), T_{std} is temperature at standard condition (25 °C), P_{act} is actual pressure (atm), V_{act} is volume aktual (m³) and T_{act} is actual temperature (°C).

The concentrations of PM_{2.5} emission, from the smoke emission Wet calculated on equation 4 and net burning smoke concentration Wet calculated on Equation 4:

$$C = \frac{M_p}{V_{std}} \times 10^6 \quad (4)$$

Where, C is concentration of particulate mass (mg / Nm³), Mp is particulate weight (g) and Vstd is calculated volume in standard state (Nm³), was done by Equation.5.

$$C \text{ PM}_{2.5} (\text{net}) = C \text{ PM}_{2.5} (\text{background}) - C \text{ PM}_{2.5} (\text{sampling}) \quad (5)$$

3. Results and discussion

3.1. PM_{2.5} concentration

In this study conducted an investigation into the estimation of PM_{2.5} concentration and chamber combustion characteristics of corn straw to five corn varieties (Bisma, P29, NK, BISI 18 and NW). Combustion characteristics is shown in Table 1.

Table 1. Characteristic of corn straw burning on chamber combustion

Parameter	Bisma (cobs)	Bisma\ (stover)	P29 (cobs)	P29 (stover)	NW (cobs)	NW (stover)	NK33 (cobs)	NK33 (stover)
Temp (°C)	30.7	34.9	34.7	29.2	36.6	30.2	32	31.3
P (mbar)	933.9	935	940	938.7	941.8	939.2	936	930.1
CO (ppm)	17.8	17.5	21.1	12.37	17.58	14.75	9.26	13.6
CO ₂ (ppm)	414.0	409.6	391	390.7	345.2	439.5	340.9	391.3
Waste weight (kg)	4	5	5	3	5	5	4	5
Ash Weight (kg)	0.32	0.5	0.21	0.25	0.21	0.6	0.3	0.9
Efficiency (%)	63.2	79.8	77.8	78.3	84.6	79.5	85.5	75.9

Varying concentration of PM_{2.5} was observed in the study for different varieties corn straw. Concentration PM_{2.5} from corn straw combustion in units of ug/m³. Summary value PM_{2.5} concentrations for corn residue (cobs and stover) for the five types of varieties is shown in Table 2.

Table 2. Concentration PM_{2.5} of corn residue burning (mg/m³)

	Corn cobs Avarage	Corn stovers Avarage
Bisma	9.187	2.060
P29	2.843	5.283
NK	7.409	4.048
Bisi 18	3.781	5.306
NW	1.895	5.697

Figure 3 illustrates the comparison value of PM_{2.5} concentrations for both types of corn residue (corn cobs and stover) for the five types of varieties. From the figure 3, this asses result show that average concentration of PM_{2.5} from the chamber combustion of five varieties of corncobs and cornstover was around 284.3 – 918.7 µg/m³ and 404.8 – 602.0 µg/m³ respectively. Level PM_{2.5} concentration from Bisma varieties of corn cobs had the highest than the other relative low. Variation of this value is influenced by the efficiency of the combustion simulation and the characteristic of the straw [17]. The combustion efficiency of corn corb is lower than the combustion efficiency of stover that the concentration PM_{2.5} more emitted from the burning of corn stover.

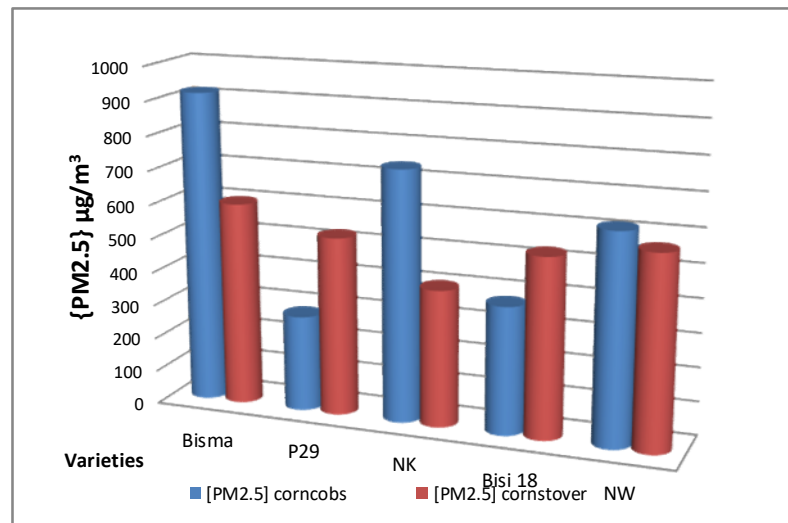


Figure 3. Level concentration of PM_{2.5}.

3.2. Analysis of PM_{2.5} emission

Particulate matter 2.5 micrometer emitted as a smoldering combustion product. The emission for PM_{2.5} observed in this study are slightly lower to those compiled by CAO (2008) [4] and Ni (2015). Concentration of PM_{2.5} is highly variable and dependent on the fuel type (corn varieties) and burning behavior (combustion efficiency). While PM_{2.5} has been established previously as a product of smoldering combustion [27]. Concentration of PM_{2.5} decreases with increasing MCE with a linear fit of $[PM_{2.5}] = -6.0997 (MCE) + 85.828$ with an R^2 value of 0.604. The inverse dependence of PM_{2.5} on MCE in our study is likely due to different PM_{2.5} content in the corn straw. For example, in our study, the straw type sampled (Bisma varieties) burned with the lowest MCE the concentration of PM_{2.5} was highest. Figure 4 shows the instantaneous excess concentration of PM_{2.5} as a function of combustion efficiency (MCE) for a single fire.

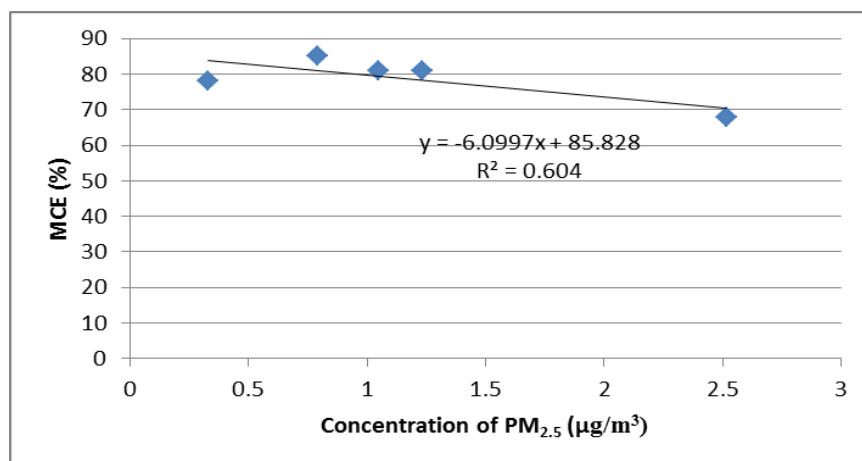


Figure 4. Concentration of PM_{2.5} as a function of MCE.

From this figure it is obvious that PM_{2.5} is undirectly correlated to combustion efficiency indicating that PM_{2.5} is a smoldering combustion product [27]. A possible explanation for the loop trajectory of PM_{2.5} as a function of combustion efficiency observed in Figure 1 is that at the beginning of flaming combustion, and completely, then as smoldering combustion diminishes the higher PM_{2.5} concentration of cornburning.

Comparison with field measurements of concentration for conrcob and corn stroves burning [3]. Result of comparison were presented in Table 3.

Table 3. Comparison of chamber burning with field measurement

PM _{2.5} Concentration	Chamber buning		Field burning	
	Corn cobs average	Corn stovers average	Corn cobs average	Corn stovers average
Bisma	9.187	2.060	6.48	5.23
P29	2.843	5.283	2.85	1.05
NK	7.409	4.048	6.42	0.33
Bisi 18	3.781	5.306	2.93	1.23
NW	1.895	5.697	1.67	0.79

There has been concentration previously measured in the field for PM_{2.5}, for five varieties. We determined the average concentration PM_{2.5} for all varieties of corn cobs and corn stover as well as the averages for all corn straw collected from Banyuresmi, disticts Garut. The average corn burning MCE for these two data sets presented the emission are in general higher for our laboratory data with chamber combustion than field burning.

4. Conclusion

- There are different concentration between five varieties of corn straw.
- This asses result show that average concentration of PM_{2.5} from the chamber combustion of five varieties of corncobs and cornstover was around 284.3 – 918.7 µg/m³ and 404.8 – 602.0 µg/m³ respectively.
- Variations of this value are influenced by the combustion efficiency of the combustion simulation and the corn residue charactersistic.
- Emision PM_{2.5} from straw burning on chamber are higher than field burning.
- The results of this study presented provide useful information for the development of local emission factors for PM_{2.5} from open burning of corn straw

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