Sains Malaysiana 42(9)(2013): 1289–1292

Evaluation of Particulate Emission from a Palm Oil Mill Boiler

(Penilaian Perlepasan Zarah daripada Dandang Kilang Minyak Sawit)

M. RASHID*, W.C. CHONG, M. RAMLI, Z.N. ZAINURA & J. NORRUWAIDA

ABSTRACT

A study to investigate the particulate emission from a boiler of a palm oil mill plant equipped with a multi-cyclones particulate arrestor was performed and reported in this paper. The particulate emission concentration was measured at the outlet of an 8000 kg steam/h capacity water-tube typed boiler of a palm oil mill plant processing 27000 kg/h of fresh fruit bunch (FFB). The particulate sample was collected iso-kinetically using the USEPA method 5 sampling train through a sampling port made at the duct of the exiting flue gas between the boiler and a multi-cyclones unit. The results showed that the particulate emission rates exiting the boiler varied from 8.51 g/s to 126 g/s with an average of 44.3±31.6 g/s. In terms of concentration, the average particulate emission concentration exiting the boiler was 7.75±4.71 g/Nm^3 (corrected to 7% oxygen concentration), ranging from 1.50 to 17.7 g/Nm^3 (@7% O_2) of the flue gas during the measurement. Based on the 27000 kg/h FFB processed, 6000 kg/h fiber and shell (F&S) burned and the capacity of the boiler of 8000 kg steam/h, the calculated particulate emission factor was 5.91±4.21 g particulate/kg FFB processed, 26.6±18.9 g particulate/kg F&S burned and 19.9±14.2 g particulate/kg boiler capacity, respectively. Based on the finding, in order to comply with the emission limits of 0.4 g/Nm^3, the required collection efficiency of any given particulate pollution control system to consider for the mill will be between 73 and 98%, which is not easily achievable with the existing multi-cyclones unit.

Keywords: Air pollution; carbon soot; emission factor; multi-cyclone; palm oil mill

ABSTRAK

Kajian terhadap pelepasan zarah dari dandang kilang minyak sawit yang dilengkapi dengan perangkap siklon berbilang telah dilakukan dan dilaporkan dalam kertas ini. Kepekatan pelepasan zarah diukur di aliran keluar dandang jenis tiub air yang berkapasiti 8000 kg stim/jam di kilang minyak sawit yang memproses 27000 kg/jam tandan buah segar (FFB). Sampel zarah telah dikumpulkan melalui pensampelan iso kinetik menggunakan kaedah USEPA 5 melalui lubang persampelan di antara dandang dan nit multi-siklon. Hasil kajian menunjukkan bahawa kadar pelepasan zarah adalah antara 8.51 g/s dan 126 g/s dengan purata 44.3 ± 31.6 g/s. Daripada segi kepekatan, purata kepekatan pelepasan zarah keluar dandang adalah 7.75 ± 4.71 g/Nm^3 (dengan kepekatan oksigen 7%), berjulat antara 1.50 hingga 17.7 g/Nm^3 (@ 7%O_2) dalam aliran gas semasa pengukuran. Berdasarkan 27000 kg/jam FFB yang diproses, 6000 kg/jam serabut dan tempurung (F&S) dibakar dan keupayaan dandang 8000 kg stim/jam, faktor pelepasan zarah yang dikira adalah 5.91 ± 4.21 g zarah/kg FFB yang diproses, 26.6 ± 18.9 g zarah/kg F&S yang dibakar dan 19.9 ± 14.2g zarah/kg kapasiti dandang. Kajian mendapati untuk mematuhi had pelepasan zarah sebanyak 0.4 g/Nm^3, kecekapan koleksi yang diperlukan oleh sistem kawalan pencemaran bagi kilang tersebut adalah antara 73 dan 98%, yang tidak mudah dicapai dengan unit siklon berbilang yang sedia ada.

Kata kunci: Faktor pengeluaran; jelaga karbon; kilang kelapa sawit; multi-siklon; pencemaran udara

INTRODUCTION

The palm oil milling industry is one of the key industries in Malaysia. In 2009, there were 411 millings in Malaysia with total capacities of 95 million tons FFB and average 90.53% of capacity utilization rate (MPOB 2010). One ton of FFB leaves 14-15% fiber and 6-7% shell and these are burned to generate energy for the palm oil mill itself. Generally, each mill has two boilers and this accounts to more than 800 boilers in the palm oil mill industry alone. It is expected that the number of palm oil mill will increase in the future.

Biomass energy is one of the sources that is widely used in many countries for heating, cooking and generate energy purpose. However, the biomass burning process releases tremendous amount of particulate emission, which contributes substantially to the regional air pollution problem. Particulate from biomass burning can be divided into accumulation mode and coarse mode. Fine particulate produced from the burning process undergoes nucleation and growth by coagulation while coarse particulate mostly formed by unburned solid fuel due to incomplete combustion (Linak et al. 2000). Particulate is categorized as one of the cloud condensation nuclei (CCN). It influence the formation of precipitation and clouds (Rose et al. 2008). This might contribute to climate change issue. Besides, the emission also imposes negative effect on human health

where fine particulate is easily deposited in our respiratory tract. Thus, more emphasis is given into the particulate emission problems and developing an emission factor as guidelines for estimating particulate pollution from a source has been carried out in many countries. Emission factors can be defined as emissions that are emitted by a particular source type based on specific of pollutants, process, age, size, control technology and other pertinent factors affecting the emissions (Wark et al. 1998).

Although palm oil mill industry has been in the country for many years, only limited studies were done in investigating the characteristic and emission of particulate from palm oil mill boilers in the past. To our best knowledge, our virtually there is no study has been done in obtaining particulate emission factor generated from the utilization of the F&S in the mill boiler. This paper is an attempt to develop particulate emission factor from a boiler of a palm oil mill plant that is capable of processing 27000 kg/h of FFB. In addition, the study was to investigate the degree of particulate emission control requirement in compliance with the current regulation.

Materials and Methods

Description of the Palm Oil Mill Plant

A palm oil mill plant located in southern part of Johor state was selected for the study. Johor is the largest oil palm plantation area in Peninsular Malaysia accounted 28.5% (687 906 ha) of total plantation area in 2008. Table 1 presents the detail of the mill and its boiler operating conditions. The mill processes 27000 kg of FFB per hour and leaving approximately 6000 kg/h of fiber and shell (F&S) as fuel for the boiler. The fiber and shell are feed into the boiler with the ratio of 70%: 30%, normally practiced by many mills.

Sampling Method

The particulate emission sampling was performed at the sampling port located between the boiler and the multi-cyclones unit. The sampling procedures were made following the USEPA Method 5 – 'Determination of particulate emissions from stationary sources'. Flue gas moisture content and volumetric flow rate was also determined using the US EPA method 4 – 'Determination of moisture content in stack gas' and US EPA method 2- 'Determination of stack gas velocity and volumetric flow rate (Type S-pitot tube)', respectively. *In situ* measurement of gaseous emission was also carried out using a portable gas analyzer (Telegan, Model 100). Several measurement of particulate emission at this location was made on three different sampling days.

TABLE 1. The palm oil mill and its boiler conditions

Parameter	Value
FFB processed	27000 kg/h
Operation duration	16 h, 24 h at peak season
Solid fuel (Fiber and shell)	6000 kg/h
Boiler manufactured year	1968
Boiler type	Water-tube
Maximum steam capacity	8000 kg/h
Stack diameter	1.2 m
Boiler outlet height and width	0.9 m, 2.4 m
Boiler temperature	700°C
Boiler pressure	300 psi

Particulate Mass and Concentration

Glass fiber filters paper (Whatman GF) was used as the collection medium in the sampling. The filters were dried in an oven for 24 h before and after sampling. The difference in weight represents the amount of particulate collected on filter media. The concentration of particulate in terms of g/Nm^3 (T=0°C, P=101.325kPa) was calculated based on the difference in the amount of particulate collected divided by the volume of air sampled, corrected to 7% oxygen concentration. Whereas, the particulate mass flow rates in g/h was calculated by the multiplying the volumetric flow rates of the stack gas in Nm^3/h with the concentration of particulate.

Particulate Emission Factor

The particulate emission factor (EF) based on the FFB processed, F&S burned and boiler capacity (BC) was calculated using (1), (2) and (3), respectively:

$$EF_{FFB} = \frac{\text{Particulate mass flow rate}(\frac{g}{h})}{\text{FFB processed}(\frac{kg}{h})} . \quad (1)$$

$$EF_{F\&S} = \frac{\text{Particulate mass flow rate}(\frac{g}{h})}{\text{F\&S}(\frac{kg}{h})} . \quad (2)$$

$$EF_{BC} = \frac{\text{Particulate mass flow rate}(\frac{g}{h})}{\text{Boiler Capacity}(\frac{kg}{h})} . \quad (3)$$

Results and Discussion

Table 2 presents the average value of all the parameters obtained in the study which include the average temperature of the flue gas exiting the boiler, flue gas moisture content and its volumetric flow rates, particulate emission concentration (corrected to 7% oxygen concentration) and emission rates, gaseous emission concentration as well as the calculated EF for the boiler.

Efficiency of Particulate Control System Requirement

As shown in Table 2, the particulate generated from the boiler ranges from 1.50 to 17.7 g/Nm^3 with an average of 7.75±4.71 g/Nm^3. The variation of particulate and gaseous emission is greatly influenced by the quantity and quality of F&S burned as well as the operating conditions of the

TABLE 2. Parameters obtained from the study

Parameter	Value (Mean±SD)
Boiler outlet temperature (°C)	476±54.4
Moisture content (%)	8.91±2.86
Volumetric flow rate (Nm^3/s) @ 273K	5.70±1.45
Particulate concentration (g/Nm^3) @ corrected to 7% O_2	7.75±4.71
Particulate mass flow rate (g/s)	44.3±31.5
Gaseous emission	
CO_2 (%)	3.08±1.73
O_2 (%)	16.7±2.44
CO (ppm)	1275±1391
NO_X (ppm)	22.5±23.9
SO_2 (ppm)	39.1±30.7
Particulate Emission Factor, g/kg	
i. based on 27000 kg/h FFB processed	5.91±4.21
ii. based on 6000 kg/h F&S burned	26.6±18.9
iii. based on 8000 kg/h BC	19.9±14.2

boiler at the time of the sampling. The high variation coefficient, CV= 61% based on the average particulate emission concentration clearly support the variation in the emission of the boiler.

Similarly, the particulate emission rates varied significantly ranging from 8.51 to 126 g/s, with CV=71% based on the average emission rate. A marked variation of particulate emission rates as observed in the study signifies the difficulty in maintaining the degree of particulate control by the air pollution control equipment installed downstream of the boiler.

Evidently, based on the particulate emission limit imposed on the boiler of 0.4 g/Nm^3, the calculated collection efficiency needed to comply with the regulation which is estimated to be between 73 and 98%, with an average of 92±6%. Such a high level degree of control is not easily achievable by the existing conventional multi-cyclone system currently installed in many mills. The fact that 50% cumulative particulate size distribution for WT type boilers reported to be between 9 and 10 μm, makes it more difficult to comply with the emission requirement (Rashid et al. 1997).

PARTICULATE EMISSION FACTOR

The emission factor is the useful information whereby the amount of particulate emission can be estimated based on certain characteristics of the industry or process. This in turns will assist in determining the degree of control of an air pollution control system needed.

As shown in Table 2, the calculated particulate emission factor based on the FFB processed, F&S burned, and boiler capacity, BC was 5.91±4.21, 26.6±18.9 and 19.9±14.2g/kg, respectively. Although the EF is meant for this specific boiler, it can also be used to estimate the emission of particulate from other palm oil mill boilers. As comparison, the particulate emission factor for wheat straw, rice straw, corn straw and cotton stalk burning is 8.75±4.18, 6.28±1.59, 5.31±1.79 and 4.53±0.95 g/kg, respectively (Cao et al. 2008). While it is reported that for vegetation fires like forest, savanna and grass, the particulate emission factor was 9.6±4.6, 6.3±3.0 and 4.7±2.1 g/kg, respectively (Janhäll et al. 2010). It is noted that the value of particulate emission factor of burning F&S in a palm oil mill boiler (i.e. 26.6±18.9 g/kg) as found in this study, is much higher than those biomass burning mentioned above. However, the conditions or the way the data was obtained may have caused the data to be different in all of these cases.

CONCLUSION

Study on the particulate emission factor of palm oil mill boiler revealed that the particulate emission factor based on fresh fruit bunch (FFB) processed, fiber and shell burned (F&S) and boiler capacity (BC) was 5.91±4.21 g particulate/kg FFB processed, 26.6±18.9 g particulate/kg F&S burned and 19.9±14.2 g particulate/kg BC, respectively. The finding also suggests that in order to comply with the existing emission limits, a highly efficient particulate pollution control system is required for such boiler. It is proposed that such study be extended to other palm oil mills to present a more comprehensive particulate emission factor for such an important industry in the country.

ACKNOWLEDGEMENTS

This study was funded by Yayasan FELDA and their financial support is greatly appreciated.

REFERENCES

Cao, G.L., Zhang, X.Y., Gong, S.L. & Zheng, F.C. 2008. Investigation on emission factors of particulate matter and gaseous pollutants from crop residue burning. *Journal of Environmental Sciences* 20(1): 50-55.

Janhäll, S., Andreae, M.O. & Pöschl, U. 2010. Biomass burning aerosol emissions from vegetation fires: Particle number and mass emission factors and size distributions. *Atmos. Chem. Phys.* 10: 1427-1439.

Linak, W.P., Miller, C.A. & Wendt, J.O.L. 2000. Fine particle emissions from residual fuel oil combustion: Characterization and mechanisms of formation. *Symposium (International) on Combustion* 28(2): 2651-2658.

Malaysia Palm Oil Board (MPOB), http://econ.mpob.gov.my/economy/EID_web.htm., 2010. Accessed: 15 Jan 2010.

Rashid, M., Ramli, M. & Rozainee, M. 1998. A field evaluation of particulate emission concentration in palm oil mill boilers. *Jurnal Teknologi* 1-6.

Rose, D., Nowak, A., Achtert, P., Wiedensohle, R.A., Hu, M. & Shao, M. 2008. Cloud condensation nuclei in polluted air and biomass burning smoke near the mega-city Guangzhou, China - Part 1: Size-resolved measurements and implications for the modeling of aerosol particle hygroscopicity and CCN activity. *Atmospheric Chemistry and Physics Discussions* 8(5):17343-17392.

Wark, K., Warner, C.F. & Davis, W.T. 1998. *Air Pollution: Its Origin and Control*. 3rd ed., Menlo Park, Calif.: Addison-Wesley.

M. Rashid*, W.C. Chong & J. NorRuwaida
Air Resources Research Laboratory
Malaysia-Japan International Institute of Technology
UTM Kuala Lumpur
54100 Kuala Lumpur
Malaysia

M. Ramli & Z.N. Zainura
Faculty of Chemical Engineering
Universiti Teknologi Malaysia
81310 Skudai, Johor
Malaysia

*Corresponding author; email: drrashid@ic.utm.my

Received: 14 August 2012
Accepted: 25 January 2013