

A FIELD EVALUATION OF PARTICULATE EMISSION CONCENTRATIONS IN PALM OIL MILL BOILERS

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Abstract. A field evaluation on particulate emission concentrations from two different types of palm oil mill boilers (i.e water-tube, WT, and fire-tube, FT type boilers) was performed using a standard stack sampling procedures. A total of 12 WT and 12 FT boilers were studied. Six of the 12 WT boilers were equipped with multi-cyclones as a means of controlling particulate emissions from the boilers, whilst all 12 FT boilers were without any form of air particulate control equipment. Results showed that the mean particulate emission concentrations from water-tube type boilers with and without particulate control equipment installed was 1.11 ± 0.58 g/Nm³ and 1.93 ± 1.40 g/Nm³ respectively. There was no significant difference in the particulate emissions between WT boilers with or without particulate control installed. It was found that only one out of the six WT boilers with particulate control was able to meet the emission standards limit of 0.40 g/Nm³ while others were still violating the standard. Meanwhile, the mean particulate emission from all 12 FT type boilers (all were without control) was 0.51 ± 0.27 g/Nm³, which was found to be significantly lower ($p \leq 0.01$) compared to the WT boiler emissions of without particulate control. Apparently, the characteristic of particulate size distributions generated by the two types of boilers could be an important factor affecting the findings and it is discussed further in this paper.

Keywords : air pollution, particulate, palm oil mill, boilers.

1.0 INTRODUCTION

There are more than 200 palm oil mill plants operating in this country. Each mill is usually equipped with at least a boiler with varying steam generation capacity of between 15 000 and 30 000 lb/hr. The two main types of boilers usually found in the mills are the water-tube (WT) and fire-tube (FT) boilers. Generally, the WT has a higher steam generation capacity than the FT type boiler and thus they are commonly found in most mills. Solid fuel consisting of palm waste fiber and shell are fed into these boilers to generate steam required by the plant.

As a result, tremendous amount of particles in the form of palm fiber and shell fly ash are being emitted by the boilers. However, comparative study on the particulate emissions concentrations from the two types of boiler are non-existent. Thus, it is the aim of this study to find out whether there is a difference in particulate emission concentrations between the boilers.

2.0 METHODOLOGY

2.1 Data Collection

This study was based on the actual field work data collected by our Environmental Research and Consultancy Group. A total number of 24 palm oil mills consisting of WT and FT boilers of various steam generation capacities were investigated. Twelve of the mills were WT type boilers and six of them were equipped with multi-cyclones particulate arrestor. On the contrary, all the other twelve FT type boilers were without any form of particulate pollution control equipment. Boilers were either manually or equipped with a screw-conveyor fuel-feeding system.

2.2 Particulate Sampling

The extraction of the particulate samples from the flue gas were taken in the stack downstream of the boilers or multi-cyclones particulate arrestor. The particulates were sampled in accordance to the U.S. Environmental Protection Agency (USEPA), Method 17 sampling procedure of 'Determination of particulate emissions from stationary sources : in-stack filtration method' (US Code of federal Regulation, 40CFR60). The method is a slight modification of Method 5 sampling procedures in which the particulate filter collection substrate is placed before instead of after the sampling probe as in Method 5. Detailed procedures involving the method of sampling is presented in reference [1].

3.0 RESULTS AND DISCUSSION

3.1 Water – vs Fire – Tube Type Boilers

Table 1 present the mean, standard deviation as well as the range of particulate emission concentrations measured from the WT and FT type particulate emission concentrations measured from the WT and FT type boilers which were either manually or equipped with screw-conveyor fuel-fed system. The mean particulate concentration emitted from WT boilers equipped with and without particulate control equipment was 1.11 ± 0.58 g/Nm³ and 1.93 ± 1.40 g/Nm³, respectively. The findings revealed that there was no significant difference in the particulate emissions between the boilers with and without particulate control equipment. Interestingly, it was found that only one of the boilers with particulate control equipment was able to meet the Department of Environment limits of 0.40 g/Nm³ whilst others were still violating the standards. As expected, the variability of the particulate emissions from the boilers without particulate arrestors was high (CV = 73%) compared to those equipped with control equipment (CV = 52%). This suggests that the installation of the multi-cyclones had somehow helped to reduce the amount of particulate concentration being emitted into the atmosphere. Evidently, as shown in Table 1, the highest particulate emission concentration from WT type boilers without any control equipment installed was 3.73 g/Nm³, which was approximately three times higher than 1.90 g/Nm³ being the highest value for boilers with particulate control.

On the contrary (Table 1), the mean particulate emission concentration from all twelve FT type boilers was 0.51 g/Nm³, with the minimum and maximum concentrations ranging from 0.25 to 1.20 g/Nm³, respectively. Table 1 shows that the FT type boilers emitted lower particulate emission concentrations despite having no means of particulate control equipment. Fifty percent of the boilers were observed to meet the emission standard and even the highest particulate emission concentration was found to be slightly below those of the WT type boilers with particulate control arrestors. Most of the FT type boilers studied have lower steam generation capacity within which is the range of 7 000 to 20 000 Ib/hr. Whilst in the case of WT type boilers, the steam capacity were ranged between 15 000 to 30 000 Ib/hr.

Based on the steam generation capacity alone, it is expected that the WT boilers would consume more fuel and thus, generate more fly ash than the FT type boilers. This observations was consistent with the present finding which shows that the average particulate concentration emitted by the WT boilers i.e 1.93 g/Nm³ (without particulate control equipment) was nearly four times higher than the FT type boilers i.e 0.51 g/Nm³ (Table 1). The difference was found to be significant ($p \leq 0.01$) between the two measurements.

Interestingly, as observed in this study, the particulate emitted by the FT type boilers were found to be less than those of the WT boilers, even though the latter were equipped with particulate control equipment. In fact, the present results clearly show that 50% of the FT type boilers were somehow able to meet the particulate emissions standard even though they were not installed with any form of

air pollution control device. As for WT type boilers, this finding clearly suggests that the particulate control equipment installed with most of them for some reasons were not efficient. Likewise, as for the FT type boilers, there may be an explanation of why some of these boilers were emitting particulate concentrations lower than the emission standard prescribed for such facility. This warrants us to further scrutinise on the characteristics of the particulate generated from the two types of boilers and this is discussed further in the next section.

3.2 Particulate Size Distribution

Attempts were made to measure the particulate size distribution emitted by the two different types of boilers. The particulate size distribution was measured using a high capacity Sierra Andersen four-staged in-stack cascade impactor which collects particles of different sizes on each of its impaction stages. The impactor was placed at the front-end of the sampling probe replacing a filter collection media as in Method 17. Particulate samples were collected directly inside the stack.

Figure 1 presents the cumulative size distribution of particulate emitted from two selected WT and FT boilers which shows that there is a wide difference in particulate size distribution between the two boilers. The FT type boilers seem to generate a finer size particles compared to the WT boilers. Gravimetrically, fine particles would weight less than the coarse size particles and this is exactly what happens in the case of FT boilers. The 50% cumulative particulate size distribution for FT particulate samples was found to be less than 1.5 μm whereas for the WT samples, this was between 9 and 10 μm (see Figure 1). The difference in the particulate size distribution generated by the two types of boilers is unclear. However, the authors believed that the characteristics of particulate generated is very much influenced by the design configuration of the boilers. On the whole, this findings helps to explain why most of the FT boilers were emitting less particulate concentration compared to WT type boilers.

3.3 Controlled vs Uncontrolled Particulate Emissions

Table 1 also presents the overall average particulate emission concentration with and with-out particulate pollution control equipment irrespective of the boiler type. Again on the whole, the results illustrate that there was significant difference in the particulate emissions between boilers equipped with or without pollution control equipment.

Figure 2 presents the particulate emission concentrations plotted against the steam generation capacity of boilers with and without pollution control equipment. The figure illustrates an interesting finding in that both the uncontrolled and controlled particulate emissions were exponentially related with boiler steam generation capacity but in the opposite direction. The best fit equations for both were:

Without Control	$E = 0.094 * X^{0.107X}$	1
With Control	$E = 3.646 * X^{-0.051X}$	2

Where E is the particulate emission concentration in g/Nm^3 , and X is the boiler steam generation capacity in metric ton/hr. Equation 1 indicates that for the boiler with uncontrolled emission, the amount of particulate concentration increases with as increase in the boiler capacity. This concur with the author's previous observation in which particulate emitted is very much dependent on the size or capacity of the mill boiler.

On the contrary, for boiler with controlled emission, the particulate concentration generated decreases with increasing boiler steam capacity (eq. 2). This finding seems to conform with a characteristic of a multi-cyclones in which the efficiency of the control equipment increases as the

dust loading (generated by the boiler) increases. A similar observation is noted in this study. However, eq. 2 should not be used to extrapolate particulate emissions for boilers capacity of lower than seven ton/hr.

It should also be noted that eq. 1 can be used to estimate the concentration of particulate emissions from a given mill boiler capacity and thus be able to calculate the removal efficiency required for a pollution control equipment. Based on this study, the required removal efficiency of particulate control for the uncontrolled boilers exceeding the standard limit varied from 11 to 90%. The application of multi-cyclones is sufficient as the control method in the industry for their performance is well within the required removal efficiencies.

4.0 CONCLUSION

A field evaluation of particulate emission concentration from two main types of boilers i.e water and fire tube in the palm mills has been discussed. The study indicated that there was no significant difference in particulate emission concentration between the water-tube boiler with and without particulate arrestor. It was found that the fire-tube boiler generates finer particulates size distributions compared to water-tube type boiler which contributes a significant difference in particulate emission concentration between them. The study revealed that most of the mills were still violating the standard emissions prescribed for the activity which presents a serious implication to the industry and environment. A detailed study on the performance of multi-cyclones installed in the mill is warranted and needs to be scrutinised.

REFERENCE

- [1] Wight G.D. Fundamentals of Air Sampling. Lewis Publishers, Boca Raton, Florida, (1994).

Table 1 Particulate emissions concentrations (g/Nm^3) from two different types of boilers in palm oil mills.

Boiler Type	N	Mean	Std	Range	CV
Water-Tube* (WT)					
Without Control	6	1.93	1.40	0.38 – 3.73	73%
With Control	6	1.11	0.58	0.25 – 1.90	52%
Fire-Tube# (FT)					
Without Control	12	0.51	0.27	0.25 – 1.20	53%
All boilers (WT + FT)					
Without Control	18	0.98	1.05	0.24 – 3.73	107%
With Control	6	1.11	0.58	0.25 – 1.90	52%

* Steam capacity of 15 000 – 30 000 lb/hr; # Steam capacity of 7 000 – 20 00 lb/hr; N = number of boilers; CV = coefficient of variation.

Department of Environment standard limit is $0.40 \text{ g}/\text{Nm}^3$ @ 1 atm, 0°C .

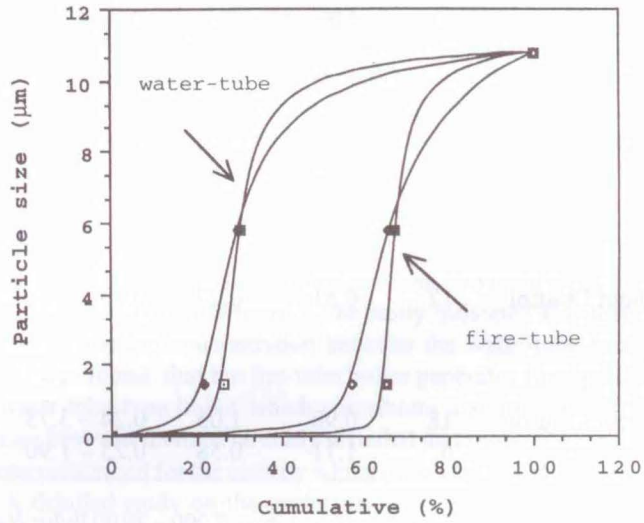


Figure 1 Particulate size distribution

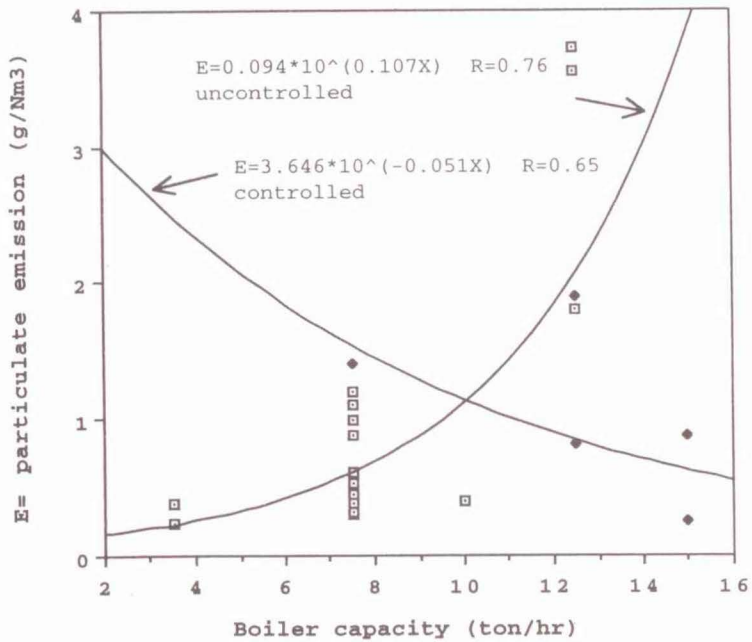


Figure 2 Particulate emission vs boiler capacity