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Emission profile of Pm, Pm10 and Pm 2.5 of Stationery sources from boilers using various Fuels – An investigation

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ABSTRACT

This study describes emission profile of PM, PM10 and PM2.5 of stationery sources from boilers employed in four industries, in small scale sector, with stack heights ranging from 12.5 to 51.5 m. Boilers in which four different fuels, kerosene (SKO), and furnace oil (FO), coal and briquetted wood were selected for PM, PM10 and PM2.5 emission studies. PM10 and PM2.5 emission was more from liquid fuels compared to the solid fuels.

Key words: *Air Pollution, Stack Monitoring, Bio Mass Fuel, Stack Emissions, PM10 and PM2.5*

Introduction

Stack heights for thermal power stations were fixed more than 100 meters for better dispersion of sulphur dioxide and particulate matter, where meteorological factors influence. But for stacks less than 50 meters, influence of meteorological factors will be less. Particulate matter contribution to ambient air from coal fired thermal power station with stack heights more than 100 m were studied in depth by many workers both in China and India. Emissions from these units released in to the atmosphere at higher altitudes, get well dispersed and transported to longer distances. Whereas particulate emissions discharged from stacks of 30 meters height, influence the ambient much more than that of taller stack on the neighborhood. There is limited scope for these emissions released, for diffusion and dispersion due the wind pattern. For better understanding of PM10 and PM2.5 contribution sources to ambient air, individual point sources have to be monitored. Most of the source apportionment surveys were carried out on model studies considering ambient air data through National Air Quality Monitoring data in the world. While large data on PM emissions is available on coal thermal power plants, very less data is available on small scale boilers using coal and other fuels like superior kerosene (SKO), furnace oil (FO) and briquetted wood. Also, in actual practice, as the boiler stacks with height less than 50 meters are in large numbers, their contribution to air pollution and thus environment is significant. Hence an attempt was made to monitor emissions from stacks of 30 m height. The objectives of this study were

1. Selection of steam boilers of various capacities.
2. Selecting the boiler based on different fuels used.
3. Quantification of the concentration of PM10 and PM2.5 emissions from these selected boilers.

Literature Review

Win *et al.* (2002), have studied the characteristics of emission from boilers where diesel containing sulphur in various proportions and bituminous coal were employed as fuel. The details are presented in Table 1. From these data, it is inferred that reducing sulfur and ash contents from heavier petroleum hydrocarbons considerably reduces PM2.5 emissions.

Table 1. Emissions from boilers (Win *et al.*, 2002)

Sulphur in	Emissions (mg/m^3)		
Diesel (%)	PM2.5	PM10	PM
0.7	34.23	43.54	50.22
0.2	9.76	9.86	9.80
0.05	1.93	2.09	2.09
Bituminous coal	38.0	77.00	91.00

Joey Villeneuve *et al*. (2012) concluded from their studies that large usage of biomass fuel in boiler as against fossil fuels requires stringent emission standards, making the boiler manufacturers to provide more efficient boilers and improved control technologies. While emissions from biomass fired boilers (Syahirch *et al*., 2014) was 2.33% of PM 2.5 and 13.7% of PM10 of the PM,in the coal fired boiler (Bing Pei *et al*., 2016) the PM2.5 average emission was 8.7 mg/m^3 and PM2.5/PM ratio was about 0.17.Jiayou Liu and Fengzhong Sun (2014) suggested that monitoring of PM10 and PM2.5 is essential for selecting type of control technologies to be adopted. Xing Zhang (2016) quoted in his report that the emission standards were debated at large as reported by Muthukrishnan(2015) that Indian coal power plants installed before 2003 is 100 mg/m^3, installed between 2003 and 2016 as 50 mg/m^3 and plants installed after 2016 as 30 mg/m^3 (Xing Zhang 2016).

Moti L Mittal *et al*. (2017) reported that estimated emissions from coal fired boilers of 86 thermal power plants in India, from the data existing, showed wide variation in quantity of coal usage, quality of coal and operating conditions, hence considerable variation in emissions. Zizhen *et al*. (2017) have studied on two conventional coal fired boilers of power plants by changing combustion and emission control technologies, showed improvement in reduction of PM2.5 emission.

Materials and Methods

PM2.5 is normally classified as primary and secondary particles. The primary particles are those emitted from the source and the secondary particles are those forms when released into the atmosphere. Many workers have studied in different ways, either using cascade impactors or cyclone separators for monitoring these coarse and fine particles. Some workers monitored using dilution techniques to understand the formation of secondary particles. In this study cyclone separator are used for monitoring PM10 and PM2.5 using method suggested by EPA. Typical sampling train with PM10 cyclone is shown in Figure 1for sampling PM10. Similarly, in the same sampling train PM10 cyclone was replaced with PM2.5 cyclone for sampling PM2.5. Stack temperature and stack velocity was found for selecting suitable nozzle to carry out iso-kinetic sampling.

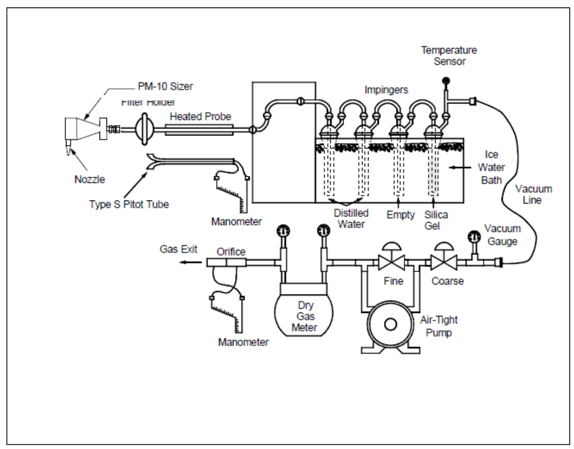

Fig. 1. Typical sampling train set up for PM10

Results and Discussion

Fuels selected for the study are SKO, furnace oil, coal and briquetted wood for burning in boilers employed for generation of steam. Details of the boilers selected for the study is given in Table 2. As per the methodology for sampling each boiler stack was monitored for PM, PM10 and PM2.5. The results obtained are shown in Tables 3, 4, 5 and 6.

From the results presented in the tables, it is inferred that

(i) in Boiler 1, with SKO as fuel, PM emitted varied 20.68 to 35.18 mg/Nm^3, PM10 varied from 11.44 to 17.74 mg/Nm^3 and PM2.5 varied from 8.93 to 12.8 mg/Nm^3.

Table 2. Stack Characteristics&Operating Conditions of Boilers during the Test Period

Particulars	Boiler -1	Boiler -2	Boiler - 3	Boiler - 4
Stack Height (m)	30.5	51.5	30.0	12.5
Stack Diameter (m)	0.97	1.2	1.0	0.25
Capacity of Boiler	2 t	25 t	8 t	1.5 t
Fuel	Kerosene	Furnace oil	Coal	Briquetted wood
Fuel Feed Rate(Kg/Hr)	26.2	1050	1500	100
Air Pollution Control Device (APCD)	No	Yes	Yes	No
Type of Control Device	-	Wet Scrubber	ESP	-

Table 3. Results of PM, PM10 and PM2.5 from boiler 1using SKO as Fuel

Sl. No.	Parameter	Results (No. of samples)									
		1	2	3	4	5	6	7	8	9	10
1	Temperature (°C)	82	83	85	79	89	93	100	73	86	90
2	Temperature (°K)	355	356	358	352	362	366	373	346	359	363
3	Velocity (m/s)	6.43	6.45	6.43	6.38	6.47	6.52	6.56	6.23	6.41	6.45
4	Gas Discharge (Nm^3/Hr)	14365	14473	14245	14375	14175	14128	13948	14281	14161	14093
5	PM 10 (mg/Nm^3)	12.12	11.44	12.11	12.86	15.16	12.38	13.14	17.74	16.72	12.98
6	Pm 2.5 (mg/Nm^3)	10.63	8.93	9.18	9.22	11.43	10.86	10.76	12.8	11.83	10.55
7	PM (mg/Nm^3)	23.9	20.68	22.86	23.7	30.88	25.28	28.4	35.18	30.48	27.58

Table 4. Results of PM, PM10 and PM2.5 from boiler 2using furnace oil as Fuel

Sl. No.	Parameter	Results (No. of samples)									
		1	2	3	4	5	6	7	8	9	10
1	Temperature (°C)	151	158	162	159	157	160	162	156	152	150
2	Temperature (°K)	424	431	435	432	430	433	435	429	425	423
3	Velocity (m/s)	6.21	6.26	6.29	6.12	6.26	6.28	6.29	6.25	6.07	6.05
4	Gas Discharge (Nm^3/Hr)	17777	17630	17551	17195	17671	17604	17551	17683	17336	17360
5	PM 10 (mg/Nm^3)	16.78	22.58	24.63	18.18	20.63	24.9	23.98	24.22	27.74	22.31
6	PM 2.5 (mg/Nm^3)	10.58	12.65	11.32	11.58	12.13	14.18	12.68	13.12	15.17	14.43
7	PM (mg/Nm^3)	57.8	60.38	57.4	55.81	59.71	58.84	56.32	73.24	93.81	76.52

Table 5. Results of PM, PM10 and PM2.5 from boiler3 using coal as Fuel

Sl. No.	Parameter	Results (No. of samples)									
		1	2	3	4	5	6	7	8	9	10
1	Temperature (°C)	121	118	112	102	108	118	110	126	117	106
2	Temperature (°K)	394	391	385	375	381	391	383	399	390	379
3	Velocity (m/s)	6.77	6.74	6.67	6.58	6.63	6.72	6.65	6.81	6.72	6.6
4	Gas Discharge (Nm^3/Hr)	14484	14530	14603	14790	14668	14487	14635	14387	14487	14679
5	PM 10 (mg/Nm^3)	64.78	65.11	62.91	74.82	66.23	59.27	64.22	57.75	63.48	56.25
6	PM 2.5 (mg/Nm^3)	34.64	37.26	32.54	43.71	37.82	34.48	35.56	32.63	33.71	31.22
7	PM (mg/Nm^3)	158	162	156	187	165	148	162	140	154	138

(ii) in Boiler 2, with furnace oil as fuel PM emitted varied 55.81 to 93.81 mg/Nm^3, PM10 varied from 16.78 to 27.74mg/Nm^3 and PM2.5 varied from 10.58 to 15.17mg/Nm^3.

(iii) in Boiler 3, with coal as fuel, PM emitted varied 138 to 187 mg/Nm^3, PM10 varied from 56.25 to 74.82mg/Nm^3 and PM2.5 varied from31.22 to 43.71 mg/Nm^3.

(iv) in Boiler 4, with briquetted wood as fuel, PM emitted varied 106.52 to 175.63 mg/Nm^3, PM10 varied from 32.51 to 53.37 mg/Nm^3 and PM2.5 varied from 19.18 to 31.56mg/Nm^3.

Comparative emission of PM, PM10 and PM2.5 from different fuels was given in Table 7 and graphical representation is shown in Figure 2. Comparative emission load of PM, PM10 and PM2.5 from different fuels was given in Table 8 and graphical representation is shown in Figure 3. Ratio of PM10 and PM2.5 to PM from boiler using different fuels are represented in Table 9.

In our studies (Table 7), we have observed that PM2.5 emission was 10.6 mg/Nm^3 for SKO fuel, 12.8 mg/Nm^3 for Furnace oil, 35.4 mg/Nm^3 for coal and 24.2 for briquetted wood. PM10 emission was 13.7 mg/Nm^3 for SKO fuel, 22.6 mg/Nm^3 for Furnace oil, 63.5 mg/Nm^3 for coal and 40.5 for briquetted wood.

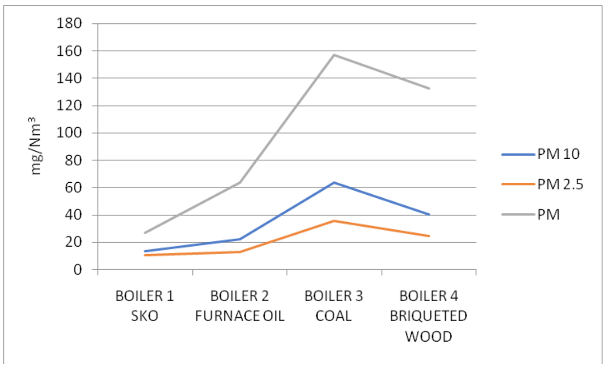

Fig. 2. Comparative emission of PM, PM10 and PM2.5 from boilers using different fuels

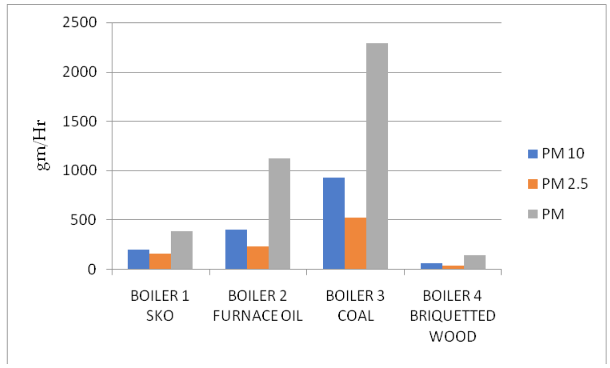

Fig. 3. Comparative emission load of PM, PM10 and PM2.5 from boilers using different fuels

From data on the ratio of PM10/PM and PM2.5/PM (Table 9),it can be seen that % of PM10 and PM2.5 were more compared to PM for SKO is around 50 and 40 approximately. While in case of furnace oil, the % of PM10 and PM2.5 around 35 and 20 approximately, and coal, % of PM10 and

Table 6. Results of PM, PM10 and PM2.5 from boiler 4using briquetted wood as Fuel

Sl. No.	Parameter	Results (No. of samples)									
		1	2	3	4	5	6	7	8	9	10
1	Temperature (°C)	63	68	129	135	167	132	143	158	151	147
2	Temperature (°K)	236	341	402	408	440	405	416	431	424	420
3	Velocity (m/s)	5.39	5.43	6.84	11.42	7.12	8.38	12.49	6.58	7.13	5.98
4	Gas Discharge (Nm^3/Hr)	1217	1208	1291	1475	1227	1570	1582	1158	1276	1080
5	PM 10 (mg/Nm^3)	35.63	32.51	43.61	40.82	33.26	42.28	44.64	53.37	40.12	39.12
6	PM 2.5 (mg/Nm^3)	21.14	19.18	25.88	24.35	20.54	25.14	26.22	31.56	23.62	24.18
7	PM (mg/Nm^3)	117.12	106.52	143.8	126.65	108.31	138.58	146.53	175.63	130.56	128.37

Table 7. Comparative emission of PM, PM10 and PM2.5 from different fuels

Parameter	Boiler 1	Boiler 2	Boiler 3	Boiler 4
PM10 (mg/Nm^3)	13.7	22.6	63.5	40.5
PM2.5 (mg/Nm^3)	10.6	12.8	35.4	24.2
PM (mg/Nm^3)	26.9	65.0	157	132.2

Table 8. Comparative emission load of PM, PM10 and PM2.5 from different fuels

Parameter	Boiler 1 g/Hr	Boiler 2 g/Hr	Boiler 3 g/Hr	Boiler 4 g/Hr
PM 10	195	396	926	53
PM 2.5	151	224	516	32
PM	383	1117	2287	138

Table 9. Ratio of PM10 and PM2.5 to PM from boiler using different fuels

Ratio	Boiler 1	Boiler 2	Boiler 3	Boiler 4
PM 10/PM	0.51	0.35	0.40	0.31
PM 2.5/PM	0.39	0.20	0.23	0.18

PM2.5 around 40 and 25 approximately, in case of briquetted wood, % of PM10 and PM2.5 around 30 and 20 approximately.

From Figure 3, it is inferred that the emission load from briquetted wood fired boiler of PM, PM10 and PM2.5 is 138 g/Hr, 53 g/Hr, and 32 g/Hr respectively, due to low velocity and discharge because the boiler runs on natural draft.

Conclusion

Four types of boilers were selected in medium scale industries with stack heights ranging from 12.5 to 51.5 m tall, using different fuels. Due to their low stack heights their influence on the nearby local ambient air quality will be high. The study showed liquid fuels generated higher percentage of PM10 and PM2.5 emissions compared to briquetted wood.

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