

Gaseous emissions monitoring and ash analysis of an industrial incinerator in Pakistan

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Abstract: A study was conducted on an industrial incinerator located at Kala Shah Kaku, Punjab, Pakistan to monitor and evaluate stack emissions (NO_x, SO_x, CO, VOC_s) and determination of heavy metals in bottom and fly ash of an industrial incinerator burning tobacco dust. Incinerated bottom and fly ash samples were collected. For the purpose of ambient air monitoring three different sides of incinerator were selected. The air emissions monitoring included emissions from right side of the incinerator (A1), emissions from left side of the incinerator (A2) and emissions from the main gate of the incinerator (A3). To determine heavy metals in bottom and fly ash, HACH and Merck procedure via spectrophotometer were used. Respirable Dust Sampler and Flue Gas Analyzer were used to monitor ambient air quality and stack emissions respectively. The results of ambient quality (SO_x, NO_x, CO, CO₂, PM& O₂) revealed that the emissions from A2 were comparatively higher than emissions from A1 and A3. With the help of Flue Gas Analyzer it was found that carbon monoxide (CO) emissions were higher than SO_x, NO_x and VOC_s. Bottom ash analysis by spectrophotometer showed that the heavy metals were below the detectable limits. The analysis conducted for heavy metals in fly ash by spectrometry as well confirmed that lead (Pb) and cadmium (Cd) were below the detectable limits and chromium was 1.96 mg/kg of the ash.

Keywords: Incineration, Tobacco, Ambient Air, Stack Emissions, Fly and Bottom Ash, Heavy Metals

1. Introduction

1.1. Incineration

Incineration is a waste treatment process of converting waste into ashes, flue gases and heat [1]. The process of incineration aims at reducing the volume, the toxicity and the reactivity of the waste and is thus a viable management strategy throughout the world for treating the increasing combustible municipal solid waste (MSW) that cannot be recycled [2, 3].

Concern has been raised in recent years over the environmental and health related impacts of incineration as this process leads to the emissions of trace quantities of metals and polychlorinated dibenzo -p-dioxins (PCDD_s) and dibenzo furans (PCDF_s), as well as other emissions [4-8]. Although incineration of MSW reduces greatly the volume (by about 90%), the mass (by about 75%) of MSW and provides energy but it cannot be considered the final solution of managing MSW [3, 9].

Incineration generates roughly 17 Mt of solid residues per year world-wide and it is estimated that this amount would be doubled within the next decade. It is very important that it is disposed in an environmentally acceptable manner [9, 10]. Moreover, the advancements in air pollution control measures in municipal solid waste incineration (MSWI) has shifted the constituents of concern from air emissions to the solid residues [11, 12].

Heavy metals (after undergoing gasification, oxidation, chlorination, condensation, coagulation, and nucleation), from the raw wastes, are condensed into incinerated residues and thus have a potential to impact the environment [13]. During MSWI, lithophilic metals such as Fe, Cu, Cr, and Al remain mainly in the bottom ash (BA) while Cd is volatilized and condensed to the fly ash. About two thirds of Pb and Zn were found in the bottom ash despite their high volatility [14]. Bottom ash represents about 80% of the residues and contains various substances that may pose a threat to the environment [10]. Decision making on the utilization, treatment or disposal of such

residues requires the evaluation of the environmental quality [12].

Chemical composition, mineralogical characteristics, and heavy metals leaching behaviors of municipal solid waste incineration bottom ash (MSWIBA) were the focused areas in most of the studies conducted during the last decade [2, 9,12-13,15-16] but the issue of toxicological consequences of MSWIBA has been limited to a few studies [17,18]. Despite rapid improvement in the analytical techniques in the recent past, there is a huge lack in the quantitative evaluation of the risk of a mixture of compounds (such as Bottom Ash) [18].

1.2. Study Area

One of the main commercial incinerators of Pakistan is located near Lahore and is approved by relevant Environment Protection Agency. It has handled over 400,000 kgs of different types of industrial hazardous waste and non hazardous wastes up till now. The wastes include raw and damaged materials, sludge from treatment plants, diapers, pesticides, plastic bottles, paints, tobacco dust and some expired goods etc [19]. During the present study the waste for incineration at the plant was tobacco dust of a leading Tobacco Company.

2. Methods

Composite sampling procedure was adopted to collect samples of tobacco bottom and fly ash.

2.1. Procedures for Heavy Metal Determination in Bottom Ash

Merckoquant Lead Test Kit and Spectroquant Nova 60 Spectrophotometer were used to determine lead concentrations in the bottom ash samples. 0.5 ml of reagent Pb 1 and Pb 2 was pipette out into a test tube along with 8 ml of pretreated sample. Sample was filled into the cell and was measured in the photometer.

For the determination of cadmium concentration in the bottom ash sample, Merckoquant Cadmium test Kit and Spectroquant Nova 60 Spectrophotometer were used. 5 ml of pre treated sample was pipette out and 0.20 ml of Cd 1 reagent and 1 level green micro spoon was added into reaction cell and closed tightly. The cell was shaken vigorously until the reagent was completely dissolved. It was left for 2 minutes to stand and the sample was measured in the photometer.

For the determination of chromium total concentration in the bottom ash sample, HACH procedure was used. 25 ml of sample was taken in 25 ml square sample cell. Content of one chromium 1 reagent powder pillow was added and swirled to mix. Sample cell cap was kept off. Prepared sample was placed into a boiling water bath. The timer was pressed to be okay for 5 minutes. At the reaction timer of expiration, the prepared sample was removed. Running water was used to cool the square sample cell to 25°C.

Then cap was removed. The contents of one chromium 2 reagent powder pillow was added and swirled to mix. Sample cell was then closed and was inverted to mix. The timer was pressed to be okay for 5 minutes reaction time period. During the reaction time 10 ml from the mixing bottle into a square sample cell was poured. Blank cell holder was wiped for zeroing. After zeroing, the sample was inserted into cell holder for reading. Reading on the display was noted [20, 21].

2.2. Determination of Heavy Metals in Tobacco Fly Ash

5 gram of ash sample was taken. 75 ml of 1:1 ratio of HNO₃ was prepared and was placed on the hot plate. When volume of sample was remained up to 15 ml it was filtered and its pH was maintained up to 3-4 with NaOH or HNO₃. After maintaining pH the volume of 75 ml with distilled water was prepared.

2.2.1. Use Digested Sample for Heavy Metals Analysis

A test tube was taken. At 515 nm, 0.5 ml of Pb-1 and Pb-2 reagent and 8 ml of digested sample was added in the test tube and was shaken. Reading was taken from the spectrophotometer.

At 515 nm, 1 ml of Cd-1, 10 ml of digested solution, 0.20 ml of Cd-2 reagent and 1 level green spoon of Cd-3 were added in the test tube and shaken well. Reading was displayed on the Spectrophotometer.

At 540 nm pH of the sample was checked, specified range: pH 1 – 9. To adjust pH dilute sodium hydroxide solution or sulfuric acid was added drop by drop. In a dry test tube 1 level grey micro spoon of Cr-1 and 6 drops of Cr-2 was added. Test tube was shaken vigorously to dissolve solid substances. 5.0 ml of sample was also pipette out and was mixed. Reaction time was one minute. After reaction time the solution was transferred into a corresponding cell. Method was selected with auto selector. Cell was placed into the cell compartment and the value on the display was noted [20, 21].

2.3. SO_x, NO_x, CO₂, PM₁₀, CO, O₂, VOC₅ Monitoring in Ambient Air

2.3.1. NO₂ Monitoring of Ambient Air by Respirable Dust Sampler

25 ml of NO₂ absorption solution was taken in the impinger tube and was connected to the sampling train. Air was passed for 30 minutes. After passing air the sample was shifted to the ice box. At 540 nm absorbance was observed in 25ml cell against absorption solution.

2.3.2. SO₂ monitoring of Ambient Air by Respirable Dust Sampler

10 ml of SO₂ absorption solution was taken in the impinger tube and was connected to the sampling train. Air was passed for 30 minutes. After passing the air, absorbed solution was transferred in the amber plastic bottle. In laboratory the sample was placed in 25 ml measuring flask along with the 1 ml of sulfanilic acid and was leaved for 10

minutes. 2 ml of formaldehyde solution, 5 ml pararosaniline reagent was added to make up the volume to 25 ml with the distilled water. At 540 nm absorbance was measured against distilled water.

2.3.3. PM_{10} Monitoring of Ambient Air by Respirable Dust Sampler

Glass fiber filter paper was weighed and placed in the high volume Respirable dust sampler. Air was passed for 1 hour. Filter paper was replaced. In laboratory filter paper was again weighed and results were calculated.

2.3.4. Monitoring of CO , O_2 , VOC_S of Ambient Air by VOC Meter

Entry Rae system PGM-3000 was used to determine CO , O_2 and VOC_S in ambient air. Instrument was ON. Reading was displayed on screen and was noted.

2.3.5. Monitoring of CO_2 of Ambient Air by CO_2 Meter

CO_2 meter was used to determine CO_2 in ambient air. Instrument was ON. Reading was displayed on screen and was noted.

2.4. Monitoring of Stack emissions (SO_x , NO_x and CO) by Flue Gas Analyzer

Testo 350-S Flue gas analyzer was used to determine stack emission gases. It has a pump that draws gases from the stack with the help of a probe. This probe is inserted into the stack for the collection of gas sample. Reading was displayed on screen of analyzer and was noted.

2.4.1. Monitoring of VOC_S in Stack emissions by VOC Meter

Entry Rae system PGM -3000 was used to determine VOC_S in stack emission. Instrument was ON. Reading was displayed on screen and was noted.

3. Results and Discussion

A1- Right side of the incinerator A2- Left side of the incinerator A3- Main Gate of the incinerator

3.1. Results of Analysis of Ambient Air Monitoring (SO_x , NO_x , CO , CO_2 , PM & O_2)

Table 1. Results of Analysis of SO_x , NO_x and PM , O_2 , VOC_S , CO & CO_2 Monitoring in Ambient air

Sr. No	Parameter	Units	A1	A2	A3	NAAQS
1	SO_x	$\mu g/m^3$	3.1	3.2	4.5	120
2	NO_x	$\mu g/m^3$	35.6	32.5	46.2	40
3	PM	$\mu g/m^3$	137.8	135.5	140.8	150
4	O_2	%	20.9	20.5	20.5	-----
5	VOC_S	ppm	1	2	1	-----
6	CO	ppm	0	15	0	-----
7	CO_2	ppm	382	416	434	-----

Table 2. Results of Analysis of Monitoring of stack emissions (SO_x , NO_x , CO and VOC_S)

Sr.No	Parameter	Units	Value	NEQS
1	SO_x	mg/Nm^3	7	1700
2	NO_x	mg/Nm^3	17	400
3	CO	mg/Nm^3	149	800
4	VOC_S	ppm	1	-----

Table 3 Results of Analysis of Heavy metal in fly and bottom ash (BDL= Below Detection Limit)

Sample	Cd (mg/kg)	Cr (mg/kg)	Pb (mg/kg)
Bottom Ash	BDL	BDL	BDL
Fly Ash	BDL	1.96	BDL

Emissions of SO_x , NO_x , PM_{10} , O_2 , VOC_S , CO , CO_2 were the parameters considered for ambient air monitoring.

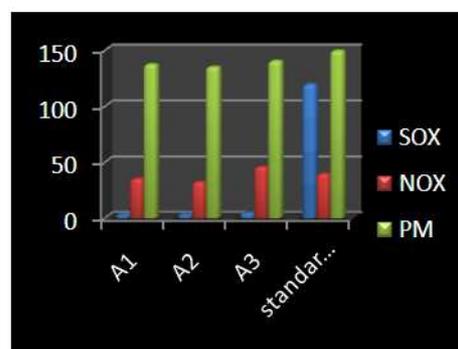


Figure 1. Comparison of SO_x , NO_x and PM Monitoring results of Ambient air of incinerator

The result shown in “Fig.1” depicts that the emission concentration of NO_x at A3 was higher than National Ambient Air Quality Standards. Emissions of PM_{10} were also comparatively higher than SO_x and NO_x in all the three areas i-e A1, A2 and A3. Comparison of these results with Air Quality Index (AQI) cleared the picture of PM_{10} . It can be clearly interpreted that the emissions from the incineration plant were not under compliance, as the AQI has termed emissions between 101-150 $\mu g/m^3$ to be unhealthy in the Area 3 (A3) as compared to A1 and A2 [22, 23].

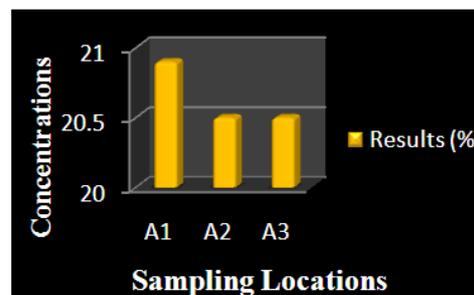


Figure 2. Comparison of O_2 Monitoring results of Ambient Air of incinerator

“Fig. 2” shows that the Oxygen (O_2) level was same at A2 and A3 of the incinerator.

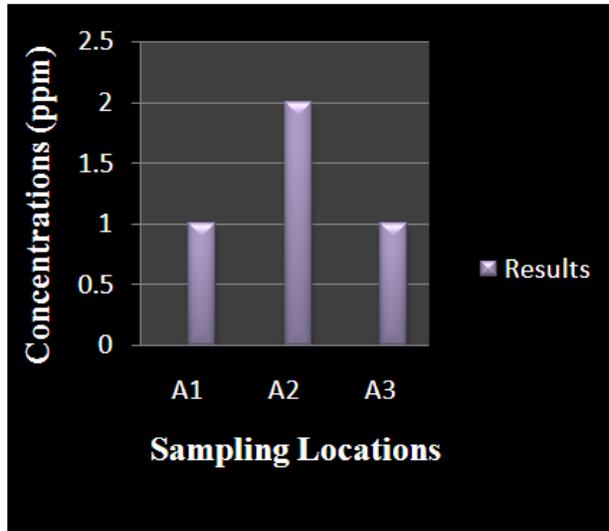


Figure 3. Comparison of VOCs Monitoring results of Ambient Air of incinerator

Volatile organic compounds (VOC_S) are the gases that result from solid and liquid waste. “Fig. 3” shows the comparison of VOC_S emissions at all three areas of the incinerator considered. The results revealed that the concentration of VOC_S were significantly higher in the area 2 whereas the VOC_S concentrations in the A1 and A3 were observed to be same i-e 1ppm .

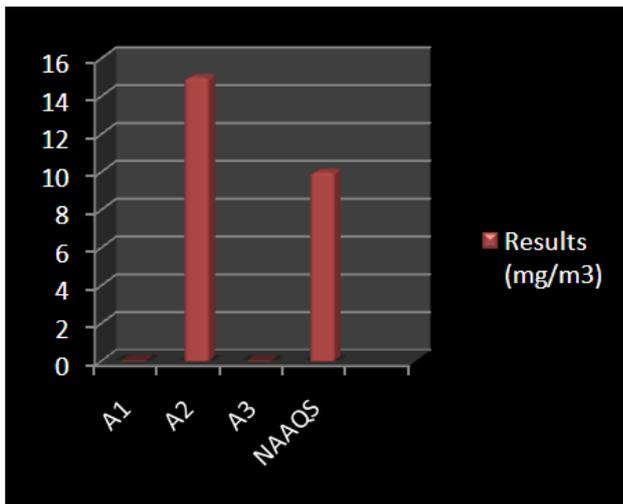


Figure 4. Comparison of CO Monitoring results of Ambient Air of incinerator with NAAQS

Carbon monoxide (CO) which is the toxic and poisonous gas may result from incomplete combustion of fossil fuels, was also monitored for ambient air quality. The results of CO monitoring represented in the “Fig. 4” shows that the concentration of CO emissions in A2 were highest whereas no CO emissions were witnessed at A1 and A3. Emissions at A2 were also not complying with National Ambient Air Quality Standards [22].

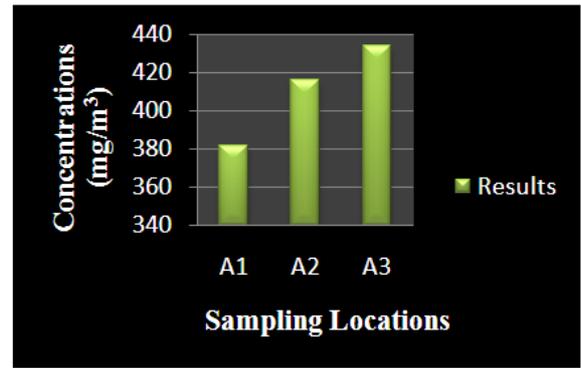


Figure 5. Comparison of CO₂ Monitoring results of Ambient Air of incinerator

CO₂ concentration was also monitored in ambient air quality. “Fig. 5” shows that the emission concentration of CO₂ at the main gate of the incinerator (A3) was significantly higher than emissions from the right (A1) and left side (A2) of the incinerator.

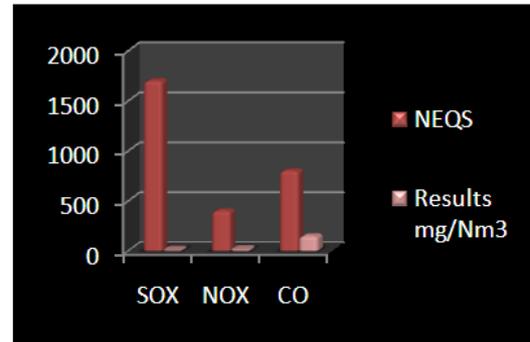


Figure 6. Comparison of SO_x, NO_x and CO monitoring results of stack emissions of incinerator with NEQS

For the purpose of stack emissions SO_x, NO_x and CO were monitored with the help of flue gas analyzer. “Fig. 6” shows that the concentration of CO in the stack was higher as compared to the concentrations of SO_x and NO_x [22].

VOC_s were also monitored in stack emissions. “Table 2” shows the concentration of VOC_s in the stack emissions. They were observed to be very low in amount. All selected parameters studied for stack emissions showed that they were under compliance with their respective standards.

Fly and Bottom ash are the solid output of incineration process. They contain significant amount of heavy metals. “Table. 3” shows that the amounts of heavy metals (Cd, Pb and Cr) in bottom ash were below the detectable limits (BDL), whereas heavy metals Cd, and Pb in Fly ash were also below the detectable limits except chromium which was 1.96 mg/kg.

4. Conclusion and Recommendations

The ambient air quality was monitored at three different sides of the incinerator. The results showed that the emissions at left side of the incinerator and main gate of the

incinerator were significantly higher than the emissions at right side of the incinerator. Stack emissions monitoring results revealed that the concentration of carbon monoxide was higher than the concentration of SOX and NOX and VOCS. The analysis of heavy metals (Cd, Cr and Pb) in bottom ash revealed that their concentration was below the detectable limits. The examination of heavy metals (Cd, Cr and Pb) in fly ash confirmed that the Pb and Cd were below the detectable limits whereas the concentration of Cr was 1.96 mg/kg.

Instead of incinerating massive quantities of organic wastes, it should be converted into compost or biofertilizers after necessary amendments.

Health and safety guidelines should be followed and personal protective equipments should be used by all the staff and visitors of the incinerator plant when it is under operation.

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