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CO-INCINERATION OF TEXTILE ETP SLUDGE IN CAPTIVE POWER HOUSE BOILER

Gautam S.P.[1], Bundela P. S.[2*], Jain R.K.[3], Padmanabhan V.[4]

[1]*Central Pollution Control Board, New Delhi, India*
[2]*Regional Office, Madhya Pradesh Pollution Control Board, Vijay Nagar Jabalpur, India*
[3]*Madhya Pradesh Pollution Control Board, Bhopal, India*
[4]*Raymond, Private Limited, Chhindwara, India*

Abstract

The ETP Sludge generated by Raymond Textile Ltd. Boregaon District – Chhindwara India is Co-incinerated in the Captive Power House Boiler in irreversible and environmental sound manner without influencing emissions on partial replacement of traditial fuel. Co-incineration benefits upgrade waste management, reduce environmental impacts, improver the industrial sector's competitiveness decreases largely the cost of waste management of ETP sludge. The analysis results of the stack parameters revealed that the emission values are well below the standards set by Central Pollution Control Board for the common Hazardous Waste Incinerations. The Captive Power House perforce requires high temperature in the boiler around 1000^{0}C. Such high temperature conditions ensure no noxious emission during the co-incineration of the waste materials.

Keywords: Hazardous waste, emissions, waste management, ETP sludge

Introduction

To meet the increase power demand in textile industry, Power plants are considering constantly increasing competitive pressures, the most important aim of each power generating unit is to generate the power in an energy efficient way (Lin *et al*., 2010).

Boiler operations have traditionally been fired by coal but hazardous waste as alternative fuels offer the joint benefits of overall CO2 reduction by avoiding incineration without utilizing its energy content and lower production costs. The fact that the energy costs have a considerable influence on large part of the production costs (about one third of the cost) leads many manufacturers to reduce consumption of conventional sources of energy in favor of alternative fuels. In other words, alternate fuels also offer conservation of traditional fuels. The hazardous wastes of defined characteristics can be utilized as alternate fuel in Boiler Operations i.e. "co-processing of hazardous wastes in Power plant Boiler operations" and is a proven, legally acceptable and environmentally safe procedure for destruction of hazardous wastes (Gautam *et al*., 2009a; Gautam *et al*., 2009b).

Raymond Limited is a leading wool & wool-blended fabrics manufacturer with a capacity of 38 million meters, Raymond commands over 60% market share in worsted suiting in India and ranks amongst the first three fully integrated manufacturers of worsted suiting in the world. And Raymond limited is the only company in the world to have a diverse product range of nearly 20,000 design and colors of suiting fabric to suit every age, occasion and style and spread its business over 55 countries including USA, Canada, Europe, Japan and the Middle East (Pearson *et al*., 2003).

Raymond produces high-value pure-wool, wool-blended and premium polyester viscose worsted suiting in addition to half a million blankets and shawls. Its strong in-house skills for research & development have always resulted in path breaking new products raising the standard of the Indian textile industry (Reddy *et al*., 2002).

Raymond limited Textile Division-Chhindwara the plant is at a distance of 57 kms. From Nagpur and 70 kms. From Chhindwara on Nagpur- Chhindwara road. The 100 acre plot stands as a pioneer in the socio-economic development of this region. is situated at Boregaon Industrial Growth Center, which became operational in April 1991.A composite plant manufacturing high quality, up market fabric in polyester-wool and polyester-viscose blends. It also has a subsidiary unit manufacturing furnishing fabrics. Unit has achieved 95.9% capacity utilization in the year 2001-02 which is considered very high in the Textile sector. The company's flourishing presence in this region is a tribute to the cooperation of the people here. The success has promoted other projects in this region and improved the quality of life in general. This all round growth is an ongoing process at Raymond (Haprton and Baity, 1941).

* Corresponding Author, *Email*: psbundela@hotmail.com, Tel.: +91-0761-4042780 Fax: +91-0761-4042780

Details of the production, process parameters, amount of coal and waste mix co -incinerated during the trial run have been recorded by Raymond limited as per the format suggested by CPCB. The parameters monitored and the frequency of sampling recommended by CPCB is given in Table- 2.

Table 1. Schedule of trial run

Particulars	*Duration*	Fuel Used
Phase-1	1 Day (02/12/2009)	Normal fuels (pre study blank)
Phase-2	1 Day (03/12/2009)	Normal fuels+ ETP sludge waste
Phase-3	1 Day (04/12/2009)	Normal fuels (post study blank)

Table 2. Recommendation parameters and frequency

Parameters	Frequency of sampling
Particulate matter (PM)	3 sample per day
Carbon dioxide (CO_2)	3 sample per day
Carbon monoxide (CO)	3 sample per day
Sulphur Dioxide SO_2)	3 sample per day
Hydrogen Chloride (HCl)	3 sample per day
Oxides of Nitrogen (NOx)	3 sample per day
Ammonia (NH_3)	3 sample per day
Total Organic carbon (TOC)	1 sample per day
Hydrogen Fluoride (HF)	3 sample per day
Volatile organic compounds (VOC)	1 sample per day
Poly-aromatic Hydrocarbons (PHC)	1 sample per day
Metals	3 sample per day
Dioxins & Furans	1 sample per day

Table 3. 24-Hourly daily sampling programme

Parameters	*0600-1400 Hrs*	*1400-2200 hrs*	2200-0600 Hrs
Particulate matter (PM)	√	√	√
Carbon dioxide (CO_2)	√	√	√
Carbon monoxide (CO)	√	√	√
Sulphur Dioxide SO_2)	√	√	√
Hydrogen Chloride (HCl)	√	√	√
Oxides of Nitrogen (NOx)	√	√	√
Ammonia (NH_3)	√	√	√
Total Organic carbon (TOC)	√	X	X
Hydrogen Fluoride (HF)	√	√	√
Volatile organic compounds (VOC)	√	X	X
Poly-aromatic Hydrocarbons (PHC)	√	X	X
Metals	√	√	√
Dioxins & Furans	√	X	X

(√- Done, X- Not done)

Scope of Study

Raymond limited has taken the initiative to conduct the trial run for co-incineration of ETP sludge waste. The scope of the emissions monitoring and material testing during study is detailed below. Trial run was carried out in three distinct phases as described in Table-1.

Table 4. Details of other materials analyzed

Parameters to be analyzed	No. of samples
ETP Volatile organic carbon (VOC), semi Volatile organic carbon (SVOCs) and Total petroleum Hydrocarbons (TPH) Proximate, Ultimate, Cl, F, Metals(Cd, Ti, Hg, Sb, As, Pb, Cr, Co, Cu, Mn, Ni, V, Zn, Se, Sn, Fe) poly chloro Biphenyl (PCBs), organo chlorine compound, TCLP, test,	1
Current Fuel-Imported coal Proximate analysis, ultimate analysis, calorific value, Metals (Cd, Ti, Hg, Sb, As, Pb, Cr, Co, Cu, Mn, Ni, V, Zn, Se, Sn,), PCB	3
Fly ash and Bottom ash Chemical characterization, TCLP test	3
Ambient Air Quality For TSPM, RPM, SO_2, NOx at 3 locations (one in up-wind and two in down wind direction) for hrs average throughout the trial period	9

Table 5. ETP Sludge-proximate & ultimate analysis

Parameters	*UOM*	ETP Sludge
Proximate analysis		
Moisture content	%	12.8
Ash Content	%	31.3
Volatile matter	%	48.8
Fixed carbon	%	7.1
Ultimate analysis (on received basis)		
Carbon	%	37.52
Hydrogen	%	10.87
Nitrogen	%	11.93
Sulphur	%	0.32
Oxygen	%	37.26
Gross Calorific value	k.cal/kg	27.18
Chlorine as Cl	%	0.02
Fluoride as F	mg/kg	13.78

Table 6. ETP Sludge-Metal

Parameters	*UOM*	ETP sludge
Cadmium as Cd	mg/kg	<0.1
Chromium as Cr	mg/kg	0.93
Copper as Cu	mg/kg	15.31
Cobalt as Co	mg/kg	20.17
Manganese as Mn	mg/kg	16.82
Nickel as Ni	mg/kg	0.29
Lead as Pb	mg/kg	<0.1
Zinc as Zn	mg/kg	5.97
Arsenic as As	mg/kg	0.19
Mercury as Hg	mg/kg	<0.1
Antimony as Sb	mg/kg	0.52
Vanadium as V	mg/kg	0.23
Thallium as Ti	mg/kg	<0.1
Tin as Sn	mg/kg	0.76

Test Method: USEPA method SW-846, 7000 series BDL: <0.1 mg/kg

Table 7. ETP sludge-TCLP TEST

Parameters	*UOM*	ETP sludge
Cadmium as Cd	mg/kg	<0.01
Chromium as Cr	mg/kg	<0.01
Copper as Cu	mg/kg	<0.1
Iron	mg/kg	<0.1
Cobalt as Co	mg/kg	0.06
Manganese as Mn	mg/kg	<0.1
Nickel as Ni	mg/kg	0.29
Lead as Pb	mg/kg	<0.01

Zinc as Zn	mg/kg	<0.1
Arsenic as As	mg/kg	<0.01
Mercury as Hg	mg/kg	<0.01
Selenium as Se	mg/kg	0.02
Antimony as Sb	mg/kg	<0.1
Vanadium as V	mg/kg	<0.1
Thallium as Ti	mg/kg	<0.1
Tin as Sn	mg/kg	<0.1

Test Method: ASTM D-5233-92

Table 8. Coal-Proximate and ultimate analysis

Parameters	*UOM*	ETP sludge
Proximate analysis		
Moisture content	%	3.25
Ash Content	%	12.31
Volatile matter	%	32.92
Fixed carbon	%	51.52
Ultimate analysis (on received basis)		
Mineral matter	%	5.49
Carbon	%	64.30
Hydrogen	%	4.82
Nitrogen	%	1.42
Sulphur	%	1.48
Oxygen	%	22.49
Gross Calorific value	k.cal/kg	5888
Net calorific value	k.cal/kg	5633.4

Based on the recommended frequency of monitoring, a 24 hourly daily sampling plan has been drawn to sample the flue gas emissions. The sampling plan is given in Table-3.

It is also proposed to analyze the ETP sludge waste and coal samples to know the contribution of both the fuel and fuel mix to emission of above mentioned pollutants. The various parameters that were analyzed are given in the Table- 4.

Details of Hazardous Waste

Raymond limited is using the ETP sludge, The hazardous waste generated from its own effluent treatment plant. The major effluents from Raymond limited, Chhindwara unit are dyes and detergents from Dyeing and finishing section of the composite mill. The unit has an efficient Effluent Treatment Plant designed to tree about 4000 m^3 effluents per day.

The effluent mixed with PAC (coagulated) flows to the clariflocculator for the separation of solids. The process of settling of solids is enhanced by the flocculator paddles. The solids thus settled in the bottom are collated at the centre of the tank by mechanical scrapper and disposed off on sludge drying beds. The size of each sludge drying bed is 18.5 X 18.5 X 0.6 mtr. Sludge holding capacity of each drying bed is 102 MT. the clear liquid over flows into the launder and flows to the aeration tank for biological treatment (Balasubramarian, *et al*., 2006).

Table 9. Coal-Metals

Parameters	*UOM*	ETP sludge
Cadmium as Cd	mg/kg	0.9
Chromium as Cr	mg/kg	33.2
Copper as Cu	mg/kg	29.1
Iron	mg/kg	26.50
Cobalt as Co	mg/kg	3.1
Manganese as Mn	mg/kg	6.2
Nickel as Ni	mg/kg	45.3
Lead as Pb	mg/kg	25.4
Zinc as Zn	mg/kg	21.9
Arsenic as As	mg/kg	0.09
Mercury as Hg	mg/kg	0.06
Selenium as Se	mg/kg	<0.1
Antimony as Sb	mg/kg	0.5
Vanadium as V	mg/kg	9.5
Thallium as Ti	mg/kg	<0.1
Tin as Sn	mg/kg	4.9

Chlorine as Cl	%	0.3
Fluoride as F	mg/kg	2.24
Total Organic carbon	%	24.8

ETP Sludge Disposal Method

The disposal of dryed sludge comes under hazardous category hence is sent to Madhya Pradesh waste management project, Pithampur (a MPPCB approved waste disposal facility). The Dryed ETP sludge is packed in HDPE bags, weighed and recorded in prescribed format. Workmen handling the waste are provided with appropriate nose masks, gumboots, hand gloves and goggles to ensure their safety (Santoleri, 1985).

Sampling, Analytical Methods and Quality Control

Sampling and analytical methods as per USEPA the accuracy of test results adopted for sampling and analysis.

Material Testing

Analysis of Coal, Fly ash and ETP Sludge

Chemical composition of the coal and ETP sludge will greatly influence the quality of the flue gas emissions from boiler stack. Samples of coal, ETP sludge and fly ash are collected during the trial run as per CPCB guidelines. Quality of materials such as ETP Sludge, coal, fly ash and bottom ash is given in Table.5-12.

Ambient air quality has been studied at three locations continuously throughout trial run period by installing respirable dust samplers at three locations representing one upwind direction and other two were in down wind direction. The ambient air quality levels are given in Table-13

Results and Discussion

The parameter wise concentration trends observed during the entire trial run is discussed below in table 14.

Particulate matter

The concentration of particulate Matter (mg/Nm^3) varied from 35.0 to 37.0 during pre Trial and 32.0 to 40.0 during co-incineration of ETP Sludge waste. During post trial period, the values observed between 35.0-42.0 mg /Nm^3. The concentration of PM is depicted in Fig. 1. It is evident from the data that there is no significant variation in particulate content in emissions during three phases of trial run (Stehlick, 2008).

Table 10. Chemical characterization of fly ash

Parameters	*UOM*	*02/12/09*	*03/12/09*	04/12/09
Cadmium as Cd	mg/kg	2.5	2.2	2.1
Chromium as Cr	mg/kg	102.3	112.4	110.2
Copper as Cu	mg/kg	102.8	98.6	101.9
Cobalt as Co	mg/kg	7.8	5.6	5.2
Manganese as Mn	mg/kg	185.3	186.2	182.3
Nickel as Ni	mg/kg	128.4	156	152.3
Lead as Pb	mg/kg	83.4	88.4	87.5
Zinc as Zn	mg/kg	73.5	72.6	56.3
Arsenic as As	mg/kg	0	0	0.09
Mercury as Hg	mg/kg	0.09	0	0.09
Selenium as Se	mg/kg	2.5	2.2	2.1
Antimony as Sb	mg/kg	0.5	0.2	0.2
Vanadium as V	mg/kg	20.9	20.9	25.6
Thallium as Ti	mg/kg	<0.1	<0.1	<0.1
Tin as Sn	mg/kg	9.3	8.8	11.2
Total Organic carbon	%	0.2	0.3	0.2
Loss on ignition	%	1.02	0.98	1.01

Table 11. Chemical characterization of Bottom ash

Parameters	*UOM*	*02/12/09*	*03/12/09*	04/12/09
Cadmium as Cd	mg/kg	3.2	3.5	2.4
Chromium as Cr	mg/kg	40.8	50.2	50.2
Copper as Cu	mg/kg	24.7	25.6	22.5
Cobalt as Co	mg/kg	0	0.1	0
Manganese as Mn	mg/kg	550.2	550.2	550.2
Nickel as Ni	mg/kg	88.2	112	65.5
Lead as Pb	mg/kg	54.1	54.1	44.8
Zinc as Zn	mg/kg	117.3	107.2	117.3
Arsenic as As	mg/kg	0.8	0.8	0.8
Mercury as Hg	mg/kg	0	0.08	0
Selenium as Se	mg/kg	<0.1	<0.1	<0.1
Antimony as Sb	mg/kg	0.2	0.1	0.1
Vanadium as V	mg/kg	10.1	10.1	8.9
Thallium as Ti	mg/kg	<0.1	<0.1	<0.1
Tin as Sn	mg/kg	<0.1	<0.1	<0.1
Total Organic carbon	%	0.1	0.1	0.1
Loss on ignition	%	0.09	0.08	0.08

Sulphur dioxide

The concentration of Sulphur Dioxide (mg/Nm^3) found to be less than below detection limit of 3.2 during entire study period (Kikuchi 2001).

Oxides of nitrogen

The concentration of Oxides of Nitrogen varied from 227.5 to 451.0 mg/Nm^3 during pre Trial; 309.5 to 381.3 mg/Nm^3 during co-incineration of ETP Sludge; and 334.2 – 382.1 mg/Nm^3 during post Trial of the study (Garg *et al*., 2001b; Svobodo, *et al*., 2006). The concentration of Oxides of Nitrogen is depicted in Fig. –2.

Table 12. TCLP test results of fly ash and bottom ash

Parameters	*UOM*	*Fly ash*	Bottom Ash
Cadmium as Cd	mg/kg	<0.1	<0.1
Chromium as Cr	mg/kg	<0.1	<0.1
Copper as Cu	mg/kg	<0.1	<0.1
Cobalt as Co	mg/kg	<0.1	<0.1
Manganese as Mn	mg/kg	<0.1	0.2
Nickel as Ni	mg/kg	<0.1	<0.1
Lead as Pb	mg/kg	<0.1	<0.1
Zinc as Zn	mg/kg	0.1	<0.1
Arsenic as As	mg/kg	<0.1	<0.1
Mercury as Hg	mg/kg	<0.1	<0.1
Selenium as Se	mg/kg	<0.1	<0.1
Antimony as Sb	mg/kg	<0.1	<0.1
Vanadium as V	mg/kg	<0.1	<0.1
Thallium as Ti	mg/kg	<0.1	<0.1
Tin as Sn	mg/kg	<0.1	<0.1

Test Method: ASTM D-5233-92

Table 13. Ambient air quality levels

Water shop (Up wind)				
Date	RPM	SPM	SO_2	NOx
02-12-09	38	110	20.2	25.6
03-12-09	35	135	21.1	28.4
04-12-09	42	128	20.8	27.2
VIP Guest house (down wind)				
02-12-09	48	15	19.8	26.1
03-12-09	55	162	22.3	29.3
04-12-09	51	157	21.5	25.4

Suruchi (down wind)				
02-12-09	53	138	24.1	30.2
03-12-09	55	142	23.3	31.5
04-12-09	58	156	20.5	28.7

All value is expressed in µg/m.

Carbon monoxide (CO)

Carbon Monoxide concentrations are given Fig – 3. In general Carbon Monoxide content in stack emission reveals the state of combustion of fuels as its concentration is dependent on the oxidation of carbon content of the feed. CO is considered to be the product of incomplete combustion. Carbon monoxide varied between 237.5-470 mg/Nm^3 during co-incineration of ETP Sludge; and 386.0 - 427.0 mg/Nm^3 during post Trial period of the study (Morre *et al*., 1975; Parash *et al*., 2005.

Hydrogen chloride (HCl)

Hydrogen chloride emissions varied from 20.2 to 23.4 mg/Nm^3 during use of pre trial; 24.8 to 26.5 mg/Nm^3 during co-incineration of ETP Sludge and during post trial the values were found to be between 21.3 – 25.1 mg/Nm^3. The HCl emission levels during the trial run are shown in Fig. – 4.

Table 14. Summery of average values of emissions during trial run of ETP sludge Stack height: 60 m, Stack Diameter: 2.0m, Stack Duct area: 3.14 m^2

Parameters	UOM	Incinerator Emission Limit	Pre Trial		Trial with ETP Sludge		Post Trial	
			Average	Range	Average	Range	Average	Range
Flue gas temperature	°C	-	112	110-114	115	113-118	112	111-114
Velocity	m/sec	-	8.0	7.9-8.1	9.0	8.9-9.1	8.8	8.8
Volumetric flow rate	Nm^3/sec	-	19.3	19.2-19.4	28.3	28.0-28.5	27.7	27.6-27.8
Particulate matter	mg/Nm^3	50	36	35-37	36	32-40	38.3	35-42
Sulphur dioxide	mg/Nm^3	200	<3.2	<3.2	<3.2	<3.2	<3.2	<3.2
Oxide of nitrogen	mg/Nm^3	400	375.8	227.5-451	363.5	309.55-399.75	357.2	334.2-382.1
Total Hydrocarbons	mg/Nm^3	NA	BDL	BDL	BDL	BDL	BDL	BDL
Carbon monoxide	mg/Nm^3	100	329.5	281-470	365.7	316.0-425.0	403	386-427
Hydrogen Chloride as HCl	mg/Nm^3	50	22.1	20.2-23.4	25.5	24.8-26.5	22.8	21.3-25.1
Hydrogen Fluoride as HF	mg/Nm^3	4	1.49	1.15-1.85	1.83	1.44-2.21	1.61	1.45-1.87
Total volatile organic compound	µg/Nm^3	NA	BDL	BDL	BDL	BDL	BDL	BDL
Total Organic Carbon	mg/Nm^3	20	4.2	4.2	4.9	4.9	4.5	4.5
Poly nuclear aromatic hydrocarbons	µg/Nm^3	NA	BDL	BDL	BDL	BDL	BDL	BDL
Mercury	mg/Nm^3	0.05	0.004	0.004	0.006	0.006	0.004	0.004
Cd+Ti	mg/Nm^3	0.05	0.002	0.002	0.02	0.02	0.022	0.022
Total Metals (Cu ,Co, Cd, Ti, Hg, Sb, As, Pb, Cr, Mn, Ni, V, Zn, Se, Sn, Fe)	mg/Nm^3	0.5	0.4	0.4	0.28	0.28	0.25	0.25
Total Dioxins and Furans	µg/Nm^3	0.1	0.000	0.000	0.000	0.000	0.000	0.000
Cyanide as CN	mg/Nm^3	NA	0.01	0.01	0.01	0.01	0.01	0.01

Fig. 1. Variation of Particulate Matter during Trial Run of ETP Sludge

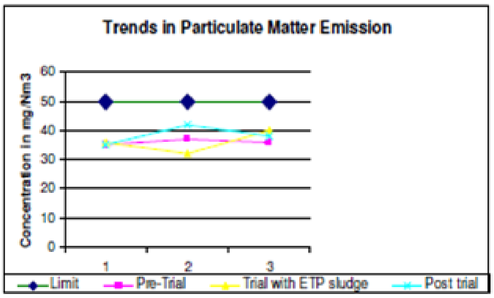


Fig. 2. Variation of Oxides of Nitrogen during Trial Run of ETP Sludge

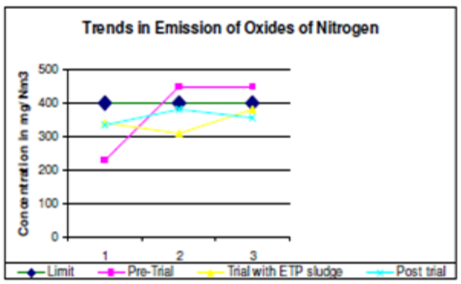


Fig. 3. Variation of carbon monoxide during trial run of ETP sludge

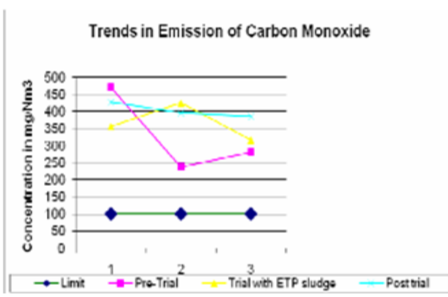
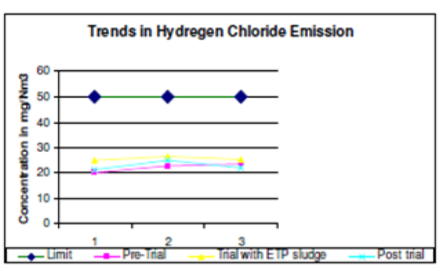


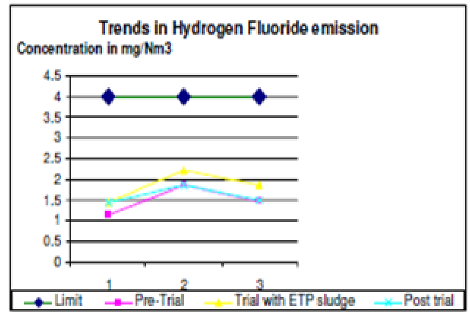
Fig. 4. Variation of Hydrogen Chloride during Trial Run of ETP Sludge



Hydrogen Fluoride (HF)

Hydrogen Fluoride emissions varied from 1.15 to 1.85 mg/Nm3 during use of pre trial; 1.44 to 2.21 mg/Nm3 during co-incineration of ETP Sludge and during post trial the values were found to be between 1.45 – 1.87 mg/Nm3. The HF emission levels during the trial run are shown in Fig.–5.

Fig.5. Variation of Hydrogen Fluoride during Trial Run of ETP Sludge



Total organic Carbon (TOC)

The concentration of Total Organic Carbon (TOC) was 4.2 mg/Nm3 during pre trial and 4.9 during co-incineration of ETP Sludge. The concentration of Total Organic Carbon (TOC) levels were at 4.5 mg/Nm3.

Volatile Organic Compounds (VOC) and Polynuclear Aromatic Hydrocarbons (PAH)

Volatile Organic Compounds (VOCs) and Polynuclear Aromatic Hydrocarbons were found to below detectable limits during entire study period.

Cadmium & Thallium

The maximum emissions concentrations for cadmium & thallium were found to be 0.01 mg/Nm3 during pre trial, 0.02 mg/Nm3 during co-incineration of ETP sludge, and 0.02 mg/Nm3 during post trial of the study.

Total metals

Maximum emission concentration total metals other than mercury, cadmium and thallium were found to be 0.3 mg/Nm3 during pre trial, 0.15 mg/Nm3 during co-incineration of ETP Sludge, 0.12 mg/Nm3 during post trial of the study.

Cyanide

Cyanide levels were found to 0.01 mg/Nm3 throughout the trial period.

Total Dioxins & Furans

The concentrations of Total Dioxins & Furans during Pre trial, during co-incineration of ETP Sludge waste and during post trial study were found to be below the detection limit.

Conclusion

The average and range of concentrations of various parameters sampled during pre co-incineration and post co-incineration periods with coal and during trial with co-incineration of ETP Sludge waste along with coal in Boiler.

The general observations of emission during the trial co-incineration study are

- The particulate emissions were always less than 50 mg/Nm3;
- Sulphur Dioxide emissions were observed to be less than below detectable limit i.e. 3.2 mg/Nm3;
- Oxides of Nitrogen emissions, which are much depended on the temperature, were found to be slightly higher during the co-incineration period than when coal is used;
- There is an increase in HF emission during co-incineration period whereas the HCL emissions showed the decreasing trend;
- No volatile organics and PAH were generated during the entire trial period;
- Dioxins & Furans were less than 0.012 ng TEQ/Nm3 all the times; and Though Heavy metals and Mercury were found to be emitted from the stack, the concentrations were less than 0.02 mg/Nm3 for Cd+Tl, less than 0.02 mg/Nm3 for mercury and less than 0.03 mg/Nm3 for all other metals.
- Ambient air quality was found to be normal representing the industrial activities.

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