
ENVIRONMENTAL IMPACT ASSESSMENT OF COAL FIRED THERMAL POWER STATIONS**K.S.V. Nambi, S. Sadasivan*, B.S. Negi, V. Meenakshy****Environmental Assessment Division
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SUMMARY

The coal fly ash samples collected from various thermal power plants along with one lignite ash sample were size separated into < 25 µm size. These fine fractions were analysed for various elements such as As, Ca, Ce, Co, Cr, Cu, Eu, Fe, Hf, K, La, Lu, Mn, Na, Ni, Pb, Rb, Se, Si, Sb, Sc, Sm, Sr, Ti, V, Yb and Zn using energy dispersive X-ray fluorescence (EDXRF) and instrumental neutron activation analysis (INAA) methods. It was found that the concentrations of rare earth elements (REE), Ca, Co, Fe, Na and Zn are higher in lignite ash by a factor of 4 to 10, but Cr, Mn, Pb, Rb, Sb, Se, Si and Ti are lower by a factor of 2 to 15 except Rb for which it is 200. The factor analysis of element concentrations of the fine coal ash samples shows that the REE - Ce, Eu, La, Lu, Sm and Yb are all well correlated among themselves and not associated with earth crust elements like Ca, Si, Ti, K and Rb. The trace elements like As, Co, Cr, Ni and Sb are well correlated among themselves whereas Pb, Mn and Zn are associated with Si. Calcium and Sr are well correlated as their chemical behaviour is identical. Copper comes out in a unique and separate factor with high loading.

The two-step maximum leachability test at total L/S = 100 was carried out on all the bulk fly ash samples. While the elemental concentrations were determined for all the residues the same in the extracts were determined only for four samples. The element concentrations in the fly ash extracts ranged from 0.001 to 12.45% of their concentrations in the fly ash. 12.45% and 8.21% leaching were observed for Sb and Co in a ESP ash (basic) and a stack ash (acidic) sample respectively. In general, Sb was seen to be leached substantially in all the samples. The individual elemental concentrations in the

extracts were found to be much less in comparison with the maximum allowable concentrations for marine discharge.

1. INTRODUCTION

In India at present, 65% of the total energy is generated by using non-coking, high ash coals in pulverized form. It is projected that by the year 2000, over 300 million tones of coal will be consumed each year to meet the country's energy requirements [1]. The total ash produced from its use is estimated to be approximately 90 Million tones per year assuming an average of 30% ash content in Indian coals. Mobilisation of various toxic elements into the environment from large quantities of fly ash (nearly 70% of the coal ash) is due to its reuse and dispersion. A study of elemental concentration in the fly ash and their removal by leaching due to rain and ground water, is therefore important.

Elements and their compounds which volatilise partially or completely at the prevailing temperatures of combustion (1500°C) recondense on the surface of the ash particles as the temperature drops on the cooler parts of the plant. Thus there is a partitioning of the volatile elements in fly ash. The shape of the fly ash particles is nearly spherical and consequently a large surface area is available for trace metal bonding on to the surface of these particles. Surface area (per gram) is inversely related to the particle size. The smaller fly ash particles have more concentration of the volatile elements and their concentration will also be in proportion to the volatility of the element [2].

The fly ash deposits on land are leached by rain or other water bodies to release various toxic elements. Knowledge of the amount of water soluble constituents of the fly ash is important as it gives an estimate of availability of metals to the biological systems. The leachability of elements from the fly ash particles depends on the nature of fly ash - acidic or basic, the position of these elements in ash particles, the nature of compounds in which the elements are present (oxides, silicates or sulphates), ash to solution ratio and length of extraction time [3,4].

2. SAMPLE PREPARATION AND ANALYSIS

The fly ash samples were collected from various thermal power stations in the

country, the details of which are given in Table 1. The samples were sieved into $< 25 \mu\text{m}$ size fraction and analysed for their elemental contents using energy dispersive X-ray fluorescence (EDXRF) and instrumental neutron activation method. For EDXRF 500 mg of the ash was mixed with 500 mg of cellulose powder and the mixture was pressed into one inch diameter pellets using a 20 tonne hydraulic press. The results were obtained in two steps - using a Fe-55 excitation source for Si, K, Ca, Ti, V and an X-ray tube with Mo foil as secondary target for Cr, Mn, Fe, Ni, Cu, Zn, Pb, Rb, Se, As and Sr. The K fluorescent X-rays (L X-rays for Pb) were detected by a X-ray spectrometer consisting of a 0.9 cc Si(Li) detector coupled to a multichannel pulse height analyser. The concentrations were evaluated by comparing the peak counts of X-rays of the elements of fly ash standard supplied by the Institute of Radioecology and Applied Nuclear Techniques (IRANT) of Czechoslovakia. Some of the combined peaks were resolved by empirical methods using the ratios of K and K intensities.

For INAA analysis small quantities of the fly ash (50 - 100 mg) were packed into polythene envelopes and irradiated in a swimming pool type of reactor having a neutron flux of $10^{12} \text{ n}\cdot\text{cm}^{-2}\cdot\text{s}^{-1}$ along with fly ash standard for 6 hours. The elements Sm, Lu, Yb, As, Na, K and La were assessed after a cooling time of 4 - 5 days and Ce, Cr, Hf, Sb, Sc, Fe, Zn, Co and Eu after a cooling time of 30 - 40 days. The details of analysis procedures have been described elsewhere [5,6].

The fly ash samples were leached in water at pH 4.0 by shaking 10g of the samples for 24 hours. This acidity is also required in order to simulate the effects of neutralisation of residue by rain water. We have adopted the two step maximum leachability test prescribed by Van der Sloot et al. [7] first with a liquid to solid ratio (L/S) of 20 and subsequently with L/S of 80 resulting in a total L/S ratio of 100. This also gives an indication of the behaviour of the material when dumped into a large volume of water [7]. The analysis procedure for residues were same as for the fly ash samples.

For the analysis of water extracts 150 ml of first extract and 400 ml second extract were separately reduced to small volumes and transferred carefully to clean polythene sheets and dried under infrared lamp. The polythene sheets were carefully packed in polythene covers and analysed by INAA method.

Air particulate samples were collected on pre-weighed glass fibre for total suspended particulate matter (TSPM) assessment and Whatman-541 filter papers for

elemental concentrations by EDXRF [8], using high volume samplers at a height of 2-3 meters above ground level at five locations around a coal fired power plant. Typically sampling was done for a period of about 2 h at a flow rate of $55 \text{ m}^3 \text{ min}^{-1}$ to give a dust load of 1 mg cm^{-2} .

3. RESULTS AND DISCUSSION

3.1. Concentration levels in < 25 μm fine size fly ash:

The concentrations of elements in fine (< 25 μm) coal fly ash samples along with one lignite ash sample are presented in Fig. 1. All the elements except Ti, Se, and V are evaluated with an accuracy of less than 6% . The evaluation of Ti and Se is within 12% and for V it is 28% [6]. The ash content of Indian coals varies from 30 to 45 percent whereas the ash content of lignite (brown coal) is about 7 percent. The concentrations of REE, Ca, Co, Fe, Na and Zn are higher in lignite ash by a factor of 4, 10, 5, 4, and 7 respectively, but Cr, Mn, Pb, Rb, Sb, Se, Si and Ti are lower by a factor of 2, 9, 15, 200, 10, 10, 5 and 2 respectively. In comparison with the concentrations in the bulk fly ash samples (Table 2) the concentrations of As, Cu, Rb, Se, Si and Sc are higher in the finer fraction of coal ash. This is in agreement with the observation made by other workers [3,9] regarding As, Cu and Se. The concentration of As in the fine fraction of lignite ash (high Ca content) was found to be same as in the bulk fly ash [6]. The volatility of arsenic depends on the calcium content of the coal [11]. Arsenic is mostly retained as arsenate or arsenite in high Ca coals and is not volatilised at the prevailing temperatures in the furnace.

The elemental concentrations in the fine fraction were subjected to factor analysis (a statistical method of interpreting data) to see the associations of various elements. The commercially available software, 'FACTOR' was used for the factor analysis. Table 3 presents the matrix of factor loadings for various elements. Elements having all positive or all negative loadings in one factor are taken to be correlated with each other. The higher the values of loadings, the better the correlations. During combustion the elements having similar physico-chemical properties would behave in a similar way and hence are associated. An element appearing in two factors gives an indication of its association with two different groups of elements because of its presence in different oxidation states [12]. The results of the factor analysis show that the REE are all well correlated among

themselves and they are not associated with the earth crust elements like Ca, K, Rb, Si and Ti. The trace elements like As, Co, Cr, Ni and Sb are all well correlated among themselves whereas Pb, Mn and Zn are associated with Si. Calcium and Sr are well correlated as expected from their identical chemical behaviour. The unique behaviour of Cu is seen from its presence in a separate factor with high factor loading. This is because Cu which occurs as Cu_2O is having a boiling point of 1800°C . This temperature is intermediate between the highly volatile elements (As, Cr, Ni) on one side ($< 800^\circ\text{C}$) and highly refractory elements (REE) on the other side ($> 2400^\circ\text{C}$) [9].

3.2. Leaching of bulk fly ash:

The concentrations of elements observed in bulk fly ash samples and their residues (leached fly ash) are given in Table 4 and 5 respectively. Out of the 12 fly ash samples subjected for leaching, three samples 14F, 18F and 20F are of acidic nature and others are alkaline including 28F-a lignite ash.

The element concentrations in the leachates (water extracts) of four typical fly ash samples at two different liquid to solid (L/S) ratios are given in Table 6. In acidic stack ash (sample 14F) Co is found to be leached by 8.21%. As regards Sb, except 8F alkaline sample, both acidic 14F and other alkaline ashes have shown leachability to about 3.5%. The 8F sample has shown significantly large leachability. A comparative statement of the leaching results available from recent literature is presented in Table 7. Regarding leachability of Sb, the only reported value in literature is 2.0% for a neutral fly ash sample leached at a L/S ratio of 5. The higher values in the range of 3.4 to 12.45% obtained by us is perhaps due to the acidic and alkaline nature of the samples and a higher L/S ratio of 100.

According to Natusch et al. [13] as quoted by Page et al. [2] elements can be broadly categorised with three degrees of leachability:

Matrix Elements:	Fe, Si, Ba, Ca and Mg with low extractability,
Core Elements:	Na and K with intermediate extractability,
Surface Elements:	Cd, Co, Mn, P, Ti and Zn with substantial extractability.

In our study results are available for Fe, Na and Zn respectively from low, intermediate and substantial extractability groups classified above and the leached rates

observed have been 0.02 to 0.04%, 0.15 to 0.36% and 0.74 to 1.97% respectively. The graded classification is indeed matching.

3.3. Air quality survey near a power plant

A preliminary study carried out around a thermal power station shows 5 to 10 fold increase in elemental concentrations in air particulates as compared to a low dust load area. These values are given in Table 8. The concentrations of various elements at the different distances indicate a predominantly NW plume followed next in priority by an eastward deposition. However it is to be noted that the air sampling was not done simultaneously at all the locations. The study was carried out over a period of 7 days and each sampling duration was about 2 h. The values for Pb and TSPM are found to be less than the predicted ambient air quality standards of the world.

4. CONCLUDING REMARKS

For the environmental impact assessment of coal fired power plants it is necessary to do a more detailed analysis of aerosols, stack effluents with particular reference to Pb and Hg, soil and vegetation around thermal power plant. The leaching of size separated fly ash samples for speciation studies and studying the structure of fly ash particles using X-ray diffraction techniques will also be included in the plan.

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Table 1
Details of Fly ash samples

Sample No.	Type of ash	Power Plant Location	pH of 1st extract
1F	ESP ash	Nashik, Maharashtra.	9.4
4F	ESP ash	Chandrapur, Maharashtra.	9.25
6F	ESP ash	Koradi, Maharashtra.	7.56
7F	ESP ash	Paras, Maharashtra.	9.64
8F	ESP ash	Parli, Maharashtra.	8.04
14F	Stack ash	Badarpur, Delhi.	4.71
14E	ESP ash	Badarpur, Delhi.	8.33
18F	ESP ash	Bokaro, Bihar.	4.20
20F	Bottom of stack	Bhatinda, Punjab.	4.76
23E	ESP ash	Gandhinagar, Gujarat.	9.80
27E	ESP ash	Tuticorin, Tamil Nadu.	9.80
28F	ESP lignite ash	Neyveli, Tamil Nadu.	11.40

* Extracted with water at pH 4.0 at L/S=20

Table 2
Elemental concentrations in bulk and fine flyash

Element	Minimum Conc.	Maximum Conc.	Arith. Mean	Arith. Std Deviation	Lignite ash
As (14)	3.46 3.10	14.1 30.9	6.62 9.05	3.40 7.08	12.6 11.1
Ca (17)	0.54 0.48	13.4 3.00	2.37 1.20	3.74 0.72	8.77 11.7
Ce (14)	151 157	371 339	240 205	61.5 47.6	786 627
Co (14)	18.9 13.5	51.7 56.2	28.2 27.3	11.2 12.2	299 327
Cr (14)	123 115	223 221	170 145	32.1 28.7	139 76.2
Cu (18)	20.0 56.0	139 221	67.7 107	37.4 44.6	<MDL 231
Eu (14)	1.93 1.79	3.07 4.01	2.51 2.41	0.42 0.59	14.6 15.0
Fe (14)	2.56 1.88	15.1 9.22	4.70 4.08	3.54 2.24	14.9 20.3
Hf (14)	9.04 9.78	17.7 24.3	14.0 14.00	4.48 4.14	18.9 38.9
K (18)	0.42 0.46	1.72 4.41	0.94 1.18	0.41 0.97	<MDL <MDL
La (14)	90.3 89.5	146 178	119 109	16.7 24.4	332 452
Lu (14)	0.47 0.63	1.05 1.52	0.76 0.83	0.19 0.22	2.59 3.12
Na (14)	600 213	2800 2850	1300 1170	600 874	2400 4528
Pb (18)	33.3 11.0	153 87.0	75.5 40.9	46.7 23.0	130 17.3
Rb (18)	2.16 39.0	78.9 138	32.6 89.2	17.3 34.0	41.0 3.20
Sb (12)	0.49 0.46	1.59 2.23	1.08 1.06	0.37 0.53	<MDL 1.50
Sc (14)	19.0 21.1	34.1 43.8	27.5 35.9	4.70 6.51	29.4 31.0

1. Ca, Fe, K, Si and Ti are in percent and the others are in ppm.
2. For each element the rows are for bulk and < 25 um respectively.
3. The numbers in the parenthesis denote the number of samples.

Table 2. (Contd.)

Element	Minimum Conc.	Maximum Conc.	Arith. Mean	Arith. Std Deviation	Lignite ash
Se (12)	2.0	100	27.0	30.0	<MDL
	10.0	147	48.2	37.6	<MDL
Si (18)	5.20	38.1	27.8	9.40	21.7
	29.9	47.3	37.5	5.00	6.80
Sm (14)	14.0	21.8	17.9	2.60	63.2
	13.3	29.4	15.9	4.23	87.1
Sr (18)	82.8	841	450	280	2062
	90.2	537	239	111	1300
Ti (18)	0.40	1.24	0.98	0.27	0.34
	0.81	1.50	1.13	0.19	0.56
V (18)	91.8	161	138	27.0	92.0
	91.0	193	127	56.4	111
Yb (14)	5.80	18.3	10.2	4.79	12.7
	5.27	11.5	7.13	1.74	24.6
Zn (14)	92.1	183	141	41.5	628
	59.4	193	127	41.1	870

1. Ca, Fe, K, Si and Ti are in percent and the others are in ppm.
2. For each element the rows are for bulk and < 25 um respectively.
3. The nos. in the parenthesis denote the no. of samples.

Table 3
Factor loadings for elements in fine size of flyash

Elements	F1	F2	F3	F4	F5
As		0.80			
Ca					0.89
Ce	0.91				
Co		0.80			
Cr		0.85			
Cu			0.62		
Eu	0.82				
Fe		0.81			
Hf		0.87			
K	-0.87				
La	0.93				
Lu	0.84				
Mn				0.60	
Na		0.73			
Ni		0.86			
Pb	-0.51			0.61	
Rb	-0.69				
Sb		0.80			
Sc	0.90				
Se	-0.79				
Si				0.92	
Sm	0.94				
Sr					0.73
Ti	-0.88				
V	-0.82				
Yb	0.81				
Zn				0.88	

Factor Loadings $\leq \pm 0.50$ are omitted.

Table 4
Concentrations of various elements in bulk flyash samples

	1F	4F	6F	7F	8F	14F*	14E	18F*	20F*	23E	27E
As	3.40	-	5.40	3.40	14.07	8.99	5.48	7.04	9.55	5.10	3.72
Ca	1.15	1.63	0.82	2.31	2.52	13.48	0.93	0.54	0.83	0.87	0.94
Ce	151	-	226	190	214	257	275	371	188	273	257
Co	18.9	-	21.2	40.6	51.7	21.9	19.6	22.5	23.8	38.0	24.8
Cr	132	-	156	123	211	175	145	184	178	223	177
Cu	28.2	78.9	42.7	37.9	112.0	20.0	92.9	86.1	139.0	46.0	60.6
Eu	1.93	-	2.42	1.93	2.95	2.68	2.47	2.35	2.28	3.07	3.02
Fe	3.54	3.05	3.54	3.67	3.30	15.06	3.62	4.04	6.16	2.56	3.46
Hf	11.3	-	14.7	13.2	9.0	10.9	12.0	24.1	10.4	17.7	16.3
K	0.56	0.42	0.75	0.53	0.51	1.16	1.16	1.18	1.12	1.72	1.29
La	90	-	134	108	126	146	137	110	107	120	114
Lu	0.47	-	0.70	0.70	0.64	1.05	0.76	0.73	0.61	0.89	1.04
Na	0.12	-	0.11	0.28	0.15	0.06	0.11	0.10	0.11	0.09	0.16
Pb	58.4	102	39.0	153	167	79.2	69.5	47.2	45.9	36.0	33.3
Rb	40.7	43.7	78.9	45.9	70.1	2.16	26.0	19.1	20.8	32.8	38.4
Sb	0.49	-	0.88	0.55	1.06	1.59	1.23	1.15	0.96	1.45	1.42
Sc	19.0	-	28.8	21.5	34.1	31.9	26.6	27.6	24.6	30.1	31.0
Si	28.3	29.7	37.1	25.5	18.4	5.20	25.1	31.8	34.4	38.1	32.2
Sm	15.0	-	21.8	17.2	20.2	21.6	17.5	16.6	14.0	17.9	17.0
Sr	82.8	310	177	331	551	379	907	608	841	832	740
Ti	0.84	1.03	1.11	0.78	0.91	0.40	1.14	1.17	1.20	1.24	1.16
V	91.8	134	185	104	155	114	148	130	148	161	149
Yb	9.8	-	17.1	8.4	15.2	18.3	8.0	7.6	6.1	6.1	5.8
Zn	205	-	157	148	182	183	92	105	117	92	124

* Acidic flyash

Ca, Fe, K, Na, Si and Ti are in percent, others are in ppm.

Table 5
Concentrations of various elements in the residue of flyash samples

	1F	4F	6F	7F	8F	14F*	14E	18F*	20F*	23E	27E	28F
As	3.40	-	3.36	3.40	14.70	9.14	2.84	7.89	12.10	3.40	1.98	10.85
Ca	0.85	1.50	0.79	2.21	2.82	0.59	0.86	0.46	0.62	0.76	1.02	8.79
Ce	118	-	220	226	320	272	236	188	283	255	275	647
Co	17.0	-	23.2	47.6	74.6	23.2	19.7	21.5	21.4	36.0	24.5	231
Cr	108	-	162	158	332	207	120	170	135	278	201	140
Cu	54.7	55.8	57.4	20.6	107	96.7	101	41.3	175	56.9	82.9	20.0
Eu	1.19	-	2.42	2.83	4.57	2.94	2.37	2.27	1.90	3.11	2.96	13.0
Fe	5.11	2.93	3.35	3.72	3.70	3.55	3.66	4.12	6.17	2.60	3.59	14.62
Hf	8.8	-	13.7	14.5	12.4	11.3	10.8	16.6	8.4	15.7	15.4	12.2
K	0.46	0.49	0.75	0.53	0.79	1.16	1.41	0.99	1.00	1.68	1.45	<MDL
La	68	-	125	130	173	160	150	110	91	122	123	269
Lu	0.44	-	0.74	0.72	1.01	1.42	0.91	0.68	0.48	1.02	0.92	2.02
Na	0.11	-	0.09	0.33	0.19	0.07	0.11	0.09	0.07	0.08	0.17	0.12
Pb	108	51.1	22.0	162	344	317	76.9	43.7	34.5	22.7	<MDL	136
Rb	31.9	45.1	73.5	44.0	60.1	23.3	29.0	19.6	19.7	32.2	44.0	19.5
Sb	0.26	-	0.92	0.65	1.38	1.77	1.34	1.02	0.79	1.44	1.56	<MDL
Sc	14.6	-	27.7	27.5	46.8	35.7	25.8	27.8	21.0	29.5	32.1	23.3
Si	16.7	29.9	31.3	24.1	29.9	30.0	35.8	39.2	39.0	40.3	30.0	13.6
Sm	11.2	-	19.7	20.5	28.9	23.8	19.8	16.5	12.9	17.4	18.0	49.9
Sr	56.6	316	167	333	476	205	996	705	857	851	841	2046
Ti	0.62	1.08	1.03	0.76	1.17	1.48	1.18	1.16	1.34	1.25	1.16	0.33
V	98	175	149	101	146	223	170	167	161	174	114	90
Yb	7.7	-	12.2	13.7	10.6	11.2	9.4	7.0	6.1	5.3	5.4	12.5
Zn	136	-	145	250	251	188	63	81	84	161	54	480

* Acidic flyash

Ca, Fe, K, Na, Si and Ti are in percent, others are in ppm.

Table 6

Concentration of a few elements in the extracts from typical flyash samples at two liquid to solid (L/S) ratios

Flyash No.	14F				8F			
Ele.	Ash (mg/kg)	L1 (ug/l)	L2 (ug/l)	% Leached (Total)	Ash (mg/kg)	L1 (ug/l)	L2 (ug/l)	% Leached (Total)
As	5.63	-	-	-	40.1	1.22	0.80	0.22
Ce	257.0	41.0	0.42	0.33	214	0.38	0.31	0.02
Co	21.9	89.3	0.16	8.21	52.0	1.64	0.24	0.10
Cr	175.0	23.9	1.08	0.32	211.0	169.0	5.05	1.79
Eu	2.68	3.26	0.03	2.52	2.95	<0.03	<0.01	0.05
Fe	150600	598.0	188.0	0.02	33000	310	91.5	0.04
Na	610.0	-	-	-	1480	57.2	20.5	0.19
Sb	1.59	1.35	0.36	3.52	1.06	4.08	0.63	12.45
Sc	31.9	4.60	0.28	0.36	34.1	0.33	0.07	0.04
Tb	1.40	0.24	0.03	0.51	1.67	0.08	<0.01	0.14
Th	42.1	1.35	0.05	0.07	27.8	0.16	0.06	0.03
Zn	183.0	38.9	35.4	1.97	171.0	42.0	12.8	1.09
Flyash No.	7F				6F			
As	25.5	0.15	0.029	0.02	28.2	0.77	0.13	0.09
Ce	190.0	<0.03	<0.01	0.001	226	<0.03	0.06	0.002
Co	40.6	0.04	0.07	0.016	21.2	0.36	0.31	0.15
Cr	123.0	6.65	<0.01	0.11	156.0	17.2	0.70	0.26
Eu	1.93	<0.03	<0.01	0.07	2.42	<0.03	<0.01	0.06
Fe	36700	100	22.2	0.01	44400	116	43.4	0.01
Na	2830	65.2	35.7	0.15	1090	62.4	33.1	0.36
Sb	0.55	0.60	0.08	3.34	0.87	0.76	0.18	3.40
Sc	21.5	0.02	0.03	0.01	21.7	0.03	0.22	0.08
Tb	0.74	0.04	<0.01	0.22	1.99	0.04	<0.01	0.08
Th	26.2	0.12	<0.01	0.01	31.7	0.06	<0.01	0.01
Zn	148.0	20.0	8.60	0.74	157.0	7.85	21.4	1.19

L1 and L2 denote extracts at L/S=20 and L/S=80 respectively.

Table 7
Percentage leached in water of trace elements
from flyashes reported by various workers

Element	Roy etal 1984 ¹		Sloot etal 1984 ²	This study 1991 ³	
	Acidic	Basic	Neutral	Acidic	Basic
Fe	0.07-0.17	<0.001		0.02	0.04
Na	-	0.4-0.9	2.0	-	0.15 - 0.36
As	-	-	0.5	-	0.02 - 0.22
Sb	-	-	2.0	3.52	3.40 - 12.45
Cr	-	-	1.0	0.32	0.11 - 1.79
Zn	1.7-6.5	0.005-5.0	0.05	1.97	0.74 - 1.09

1. L/S = 5 and stirred for 3 minutes 3 times a week for 140days.
2. L/S = 5 and stirred for 24h.
3. L/S = 100 and stirred continuously for 8h for 3 days.

Table 8

Concentration Levels ($\mu\text{g}/\text{m}^3$) of Various Elements in Air
Particulates collected near a Thermal Power Plant at Nasik

Sampling Location	0.5km E	0.4km NW	2km W	1.5km SW	Reference Sample*
Ca	2.29	6.56	4.33	3.61	0.60
Ti	<0.03	0.149	0.404	0.028	0.06
V	<0.02	<0.02	0.018	<0.02	<0.02
Fe	2.43	3.95	2.97	2.91	0.95
Ni	0.31	<0.05	0.078	0.17	0.026
Cu	0.54	0.36	0.106	0.118	0.05
Zn	0.435	0.882	0.118	0.107	0.12
Pb [@]	0.88	0.102	0.295	0.278	0.08
TSPM [@]	130.0	133.0	187.0	71.0	50.0

* Concentrations at Bangalore (a low dust load city), India.

@ Actual air quality standards in various countries range from 0.7 to 10 $\mu\text{g m}^{-3}$ for Pb and 100 to 750 $\mu\text{g m}^{-3}$ for TSPM.

- Plant Details 1: Average Power - 390 Mw (4 Units)
 2: Coal Consumption- 8724 Tons/Day
 3: Stack Height- 90 Metres
 4: Particulate Emission- 1.818 gm/m^3
 5: Quantity of gas emitted- 3150201 m^3/hr

Table 9
Enrichment Factors in Leached Flyash Residues for Various
Elements with respect to Titanium

Ele.	Flyash Sample No											
	1F	4F	6F	7F	9F	14F*	14E	18F*	20F*	23E	27E	28F
As	1.00	-	0.62	1.00	1.05	1.02	0.52	1.12	1.27	0.67	0.51	0.86
Ca	0.74	0.92	0.96	0.96	1.12	0.04	0.93	0.86	0.74	0.88	1.10	1.00
Ce	0.78	-	0.97	1.19	1.50	1.06	0.86	0.51	1.51	0.93	1.07	0.82
Co	0.90	-	1.09	1.17	1.45	1.06	1.00	0.96	0.90	0.95	1.00	0.77
Cr	0.81	-	1.04	1.28	1.57	1.18	0.83	0.93	0.76	0.96	1.13	1.00
Cu	1.94	0.71	1.34	0.54	0.95	1.30	1.09	0.46	1.26	1.24	1.37	-
Eu	0.61	-	0.93	1.47	1.52	1.10	0.95	0.97	0.83	1.00	1.00	0.90
Fe	1.43	0.96	0.95	1.01	1.12	0.23	1.02	1.02	1.00	1.02	1.03	0.93
Hf	0.77	-	0.93	1.10	1.37	1.63	0.90	0.69	0.81	0.89	0.94	0.64
K	0.82	1.18	0.99	1.01	1.56	1.00	1.22	0.85	0.88	0.98	1.12	1.00
La	0.75	-	0.93	1.21	1.33	1.10	1.09	1.01	0.86	1.10	1.08	0.81
Lu	0.92	-	1.05	1.03	1.57	1.35	1.18	0.94	0.80	1.13	0.88	0.78
Na	0.89	-	0.87	1.16	1.27	1.13	1.02	0.90	0.65	0.85	1.06	0.51
Pb	1.85	0.50	0.56	1.06	-	4.00	1.11	1.35	1.06	1.02	0.08	2.80
Rb	0.78	1.03	0.93	0.96	0.86	2.87	1.12	1.03	0.95	0.98	1.15	0.48
Sb	0.54	-	1.05	1.19	1.30	1.11	1.10	0.89	0.81	1.00	1.13	0.00
Sc	0.76	-	0.96	1.29	1.46	1.12	0.97	1.00	0.85	0.98	1.04	0.79
Si	0.59	1.00	0.85	0.95	1.62	5.73	1.43	1.23	1.13	1.06	0.93	0.62
Sm	0.74	-	0.90	1.19	1.46	1.10	1.13	1.00	0.92	0.97	1.06	0.79
Sr	0.68	1.02	0.94	1.00	0.86	0.54	1.10	1.16	1.02	1.02	1.14	0.99
Ti	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
V	1.07	1.30	0.80	0.96	0.94	1.96	1.14	1.28	1.08	1.08	0.76	0.98
Yb	0.78	-	0.71	1.63	0.66	0.61	1.17	0.87	1.00	0.86	0.93	0.98
Zn	0.66	-	0.92	1.69	1.38	0.97	0.68	0.76	0.72	1.74	0.44	0.76

* Acidic flyash