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Study of Leachability characteristics of fly ash and its effect on soil and ground water contamination

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Abstract

In the present study the leachability characteristics of fly ash and its effect on soil and ground water contamination. During the course of study it was found that despite the presence of the only trace amount of heavy metal in coal and coal ash, these material have the potential to accumulate in soil and increase in concentration by food chain biomagnification.

Key words: *Thermal power plant, fly ash, leachate*

Introduction

The use of coal for electricity generation was resulted in increasing environmental problems associated with gaseous and particulate emissions from coal fired power plants. Ash management is one of the key aspects of environmental management in coal fired thermal power stations. The ash production in thermal power plant result from the combustion of coal , consisting roughly 20% bottom ash and 80% fly ash. India is trying to expand the electric power generation capacity, as current generation is seriously below peak demand. About 110million tones of coal consumed in these power stations during a year produce about 30-40 million tones of fly ash i.e. at the rate of one lakhs per day. Only about 10% is utilized in the manufacture of bricks and cement. For the disposal of rest, nearly 28000 hectares of land has already been converted into ash dumps. Chemical constitutents of fly ash mainly depend on the chemical composition of the coal. Fly ash is the finer size particle.(Patil *et al*. 1991)

Leachate contamination may severely pollute neighboring ground and surface waters. The chemical quality of land fill leachate differs greatly from one landfill to another and fluctuates seasonally within individual landfill.Leachate composition is waste and site specific depending on waste type, landfill age, amount of infiltering water. Thus land disposal of fly ash creates the potential for ground water pollution via the migration of heavy metals from the fly ash. The disposal ponds are in interaction with surface and ground water systems and there is a risk of contamination of these water systems. Study of physico-chemical characteristics of fly ash, its trace metal contents and their leaching behavior are very important requirement for environmentally safe disposal management strategy. (Wasay SA, 1992)

Study Area

Ground water sampling site was identified during the site survey done at TPS. Panki thermal power station located between Kalpi road and G.T. road. Anpara TPS is located at the Anpara distt. Sonebhadra(U.P.), situated at longitude of 82º 48'E and the latitude of 24º 12'. The height above sea level is 275meters. Fly ash sample were collected from both the TPS and analyzed for parameters. At Panki TPS three samples were collected at the nearby area of ash pond. At Anpara TPS two samples were collected from the existing sources at nearby area of ash pond where one sample was collected about 3km. away from the ash pond.

Experimental Procedure

Fly ash sample were collected from both TPS and were analyzed for the parameters particle size, pH, Conductivity, Magnesium, Sodium, Potassium, Total chromium, Copper, Iron ,Lead ,Nickel, Silica, Zinc, Manganese, Aluminium, Mercury, Arsenic, Phosphorus.

Leachability Studies

Evaluation of ground water pollution potential require the condition of testing protocols to determine constituent concentrations in produce leachates. The leachability test was performed at different pH and contact time using standard TCLP (Toxicity characteristic leaching procedure) test of EPA. Alternately, batch test and column test were also conducted in order to evaluate the extent of dissolution of fly ash contents in the leachates.

These methods provide useful information as to the degree of leachability of many major and trace elements.(APHA, 1998)

TCLP Test

The TCLP test is used in a generic manner for the prediction of leaching trends of wastes. TCLP test is appropriate for the screening of fly ash for potential environmental impact.(USEPA Method 1311)

Batch Test

Batch test was conducted using 100g of fly ash with one liter of D.W for both the TPS maintaining liquid solid ratio of 1:10 for making fly ash slurry i.e. being disposed to the ash pond for 1 to10 days at 150 RPM in order to stimulate the actual condition . After the desired contact time , the sample was filtered and analyzed in accordance with the standard Method for water and waste water analysis APHA(1998).

Column Test

Glass columns of 90cm. height and 6cm. diameter was used to study the influence of flow rate on water quality obtained through leaching of fly ash. The column was filled with fly ash and D.W. and having pH-6.5 and 7.5 was allowed to pass through the fly ash column continuously , keeping the head constant leachates of sample were collected at regular intervals of 24hrs.

Each column is leached with approximately 230mL/day using ash of both analysed for metals sulphate, pH, Alkalinity, Hardness, Calcium, Magnesium, Chloride and Conductivity.(APHA, 1998)

Results and Discussion

The analysis of fly ash and Panki TPS and Anpara TPS was conducted in the laboratory. When compared with each other, It was observed that all values of the parameters analysed are high in Panki TPS ash compared to the fly ash of Anpara TPS (Table 2).

Characteristics of Ground water of Panki TPS

The ground water table encountered at the depth 7.5-9.2m depth from the GL during the period of the field exploration in Nov-2002 adjacent to Panki TPS.

Characteristics of ground water of Anpara TPS

The ground water table encountered at the depth 7.5-9.2m depth from the GL during the period of the field exploration in Nov-2002 adjacent to Anpara TPS.

Observation of Batch Test

If compared with each other it is seen that in case of water of pH 6.5 the total quantity of conductivity, Alkalinity,Chloride, Hardness, Ca, SO_4, SiO_2, Mn, Zn, Pb released are more compared to the water of 7.5 where as the total quantity of fluoride , Iron , Cu, Na,Al released when pH of 7.5 water was used. In terms of toxicity of heavy metals use in the fly ash of Panki TPS it is inferred that 6.5 pH water released comparatively more toxic metals compared to the water of 7.5 pH.

Observation of column test

The concentration of conductivity, Fe, SiO_2, Zn, Cu, Al, and SO_4 showed maximum values in the pH of 6.5. Whereas at pH 7.5 concentration of Alkalinity, Cl, Hardness, Mg, Ca, F, Cr^{+6}, Mn, Pb and Na were found to be more.The variation of release of various substances may be due to the resultant pH available at contact time. Variation of concentration of metal ions exhibit maximum absorbency at a specific pH.

It is possible that some of the heavy metals stripped from fly ash would be reprecipitate within the pile along leachate flow path, particularly if the leachate encountered higher pH material prior to just collection of leachates.

Comparison of fly ash of Panki TPS and Anpara TPS

The experimental results of leachates of both the TPS as indicated in table -7 & 8 reveals that with reference to total release potential of both the fly ash varies with the different metals nonmetals which could be due to the solubility behavior which is a function of particle size characteristic of fly ash.

As depicted from the table -5,6,7 and 8 at pH 7.5 concentration F, Cu, Al and Na indicated elevated concentration in the leachate of both the samples irrespective of variation in the fly ash characteristic. Whereas at the pH 6.5 the increased values of Cl, Ca, Sio_4, Zn, and Pb was recorded.

It is also possible that some of the heavy metals stripped from fly ash would reprecipitate with in the pile along leachate flowpaths, particularly if the leachate encountered higher pH materials prior to just collection. The data indicated that the potential for heavy striping from fly ash if an alkaline excess within these disposal zones is not maintained over the long term.

Findings and Recommendations

The variation in the concentration of various substances in the leachate may be due to differences in the particle size distribution of the fly ash,Smaller particles have a greater surface area related to their volume thus tending to become enriched in absorbed volatile elements. The relative distribution of trace element on the surface and in the internal matrix of fly ash particle has important environmental implication. Surface deposited metals may be easily mobilized in leaching waters, while metals in the silica metals are released only after periods extended weathering.

Both the power plants burning coals from these states produced alkaline flyash. Preliminary investigations have shown that the physical and chemical properties of fly ash and its alkaline nature. Different species of metal ion exhibit maximum absorbance at a specific pH. At some point of time it was observed that there is a change in resultant pH and increase in metals content in the water column due to the unloading of fly ash particles. pH is one of the main control of the solubility of metal is also closely related to the surface crystalinity. For some trace metals, the relationship between pH and solubility in an intricate process. The observations obtained suggests that some of the metals are released by dissimilar forms at the beginning and at the end of the experiment.

Thus, despite the presence of the only "trace" amount of heavy metals in coal and coal ash, these material have the potential to accumulate in soil and increase in concentration by food chain biomagnification it is important to use bioassays to evaluate toxicity.

The result indicates that if pH of water 7.5 is used for making ash slurry the ash in contact with eluting media increases the resultant pH of leachate after about 15 days if the sub soil pH is alkaline the leachate percolating down to meet ground water may increase the pH of the ground water.(WHO, 1993)

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Table-1 TCLP test for ash samples of Anpara and Panki TPS

Parameters	Unit	Conditions	
		Panki	Anpara
pH	-	5.1	5.2
Conductivity	Mmhos/cm	3.46	3.45
Chloride	mg/L	29.9	54.9
Hardness	mg/L	244	152
Magnesium	mg/L	45.7	28.4
Sulphate	mg/L	40	10
Fluoride	mg/L	0.843	0.299
Copper	mg/L	0.098	0.124
Chromium hexavalent	mg/L	0.06	0.07
Silica	mg/L	7.528	3.386
Maganese	mg/L	0.344	0.111
Zinc	mg/L	0.352	0.32
Iron	mg/L	1.05	2.93
Lead	mg/L	0.75	0.09
Sodium	mg/L	197	209
Potassium	mg/L	12.7	3.8

Table-2: Comparision of fly ash of Panki and Anpara

Parameters	Unit	Values obtained	
		Panki TPS	Anpara TPS
pH		7.9	7.6
Conductivity	Mmhos/cm.	0.112	0.062
Magnesium	mg/L	1200	425
Sodium	mg/L	1400	680
Potassium	mg/L	5300	4200
Total Chromium	mg/L	51.0	28.0
Copper	mg/L	37.0	30.0
Iron	mg/L	15000	14800
Lead	mg/L	52.0	47.0
Nickel	mg/L	35.0	30.0
Silica	mg/L	70.0	62.0
Zinc	mg/L	84.0	82.0
Fluoride	mg/L	412	500
Maganese	mg/L	139	110.0
Phosphorus	mg/L	712	680
WHC	%	58.1	27.5
Porocity	%	53.0	29.2

Table 3: Physico-Chemical characteristic of ground water quality of TPS during the post monsoon

Parameters	Obtained values			Desirable limit	Permissible limit
	Near township	Near ash pond	100m away from the pond		
pH	7.4	8.0	6.9	6.5-8.5	NR
Conductivity	0.70	1.20	0.97	-	-
Alkalinity	350	380	400	200	600
Hardness	135	190	200	300	600
Calcium	45	69	44	75	200
Magnesium	18	42	40	-	-
Sulphate	10.0	60.0	50.0	200	400
Chloride	5.8	25.0	21.0	250	1000
Copper	ND	0.03	0.01	0.05	1.5
Chromium+6	ND	0.02	0.01	0.05	NR
Maganese	0.05	0.10	0.08	0.1	0.3
Zinc	0.04	0.12	0.10	5.0	15.0
Iron	0.12	0.20	0.15	0.3	1.0
Nickel	ND	ND	ND	-	-
Lead	0.02	0.03	0.04	0.05	NR
Arsenic	ND	ND	ND	0.05	NR
Cadmium	ND	ND	ND	0.01	NR
Fluoride	0.44	0.43	0.583	1.0	1.5
Total Dissolved Solid	600	689	733	500	2000

Table 4: Physico-chemical characteristic of ground water quality of TPS during the post monsoon

Parameters	Obtained values			Desirable limit	Permissible limit
	HP Near Ash pond	Near village Anpara	Junction on way of Anpara		
pH	7.9	7.8	8.3	6.5-8.5	NR
Conductivity	0.133	0.092	0.450	-	-
Alkalinity	76	52	272	200	600
Hardness	88	68	176	300	600
Calcium	30.1	40	62	75	200
Magnesium	10	38.0	42	-	-
Sulphate	86	78	80	200	400
Chloride	4.5	2.5	10.5	250	1000
Copper	30	0.05	0.22	0.05	1.5
Chromium+6	0.08	0.03	0.24	0.05	NR
Maganese	0.07	0.01	ND	0.1	0.3
Zinc	0.22	0.1	0.035	5.0	15
Iron	0.115	0.40	0.01	0.3	1.0
Nickel	0.01	0.01	0.01	-	-
Lead	0.02	0.01	0.01	0.05	NR
Arsenic	ND	ND	ND	0.05	NR
Cadmium	ND	ND	ND	0.01	NR
Fluoride	0.710	0.613	0.643	1.0	1.5
T.D.S.	152	88	471	500	2000

Table-5 Analytical results of leachates test of Panki TPS

Duration	pH	Conductivity	Alkainity	Cl	Hardness	Mg	Ca	SO_4	F
1st	7.3	0.28	32	13.9	92	17.3	20.4	55	1.00
2nd	7.5	0.30	36	15.9	94	18.6	22.8	40	1.06
3rd	7.6	0.23	44	16.9	108	21.6	19.2	60	1.00
4th	7.3	0.23	44	12.9	104	20.2	20.8	50	0.96
5th	7.3	0.27	48	6.99	100	18.4	24.1	60	1.52
6th	7.3	0.28	48	4.99	104	18.2	28.9	64	1.63
7th	7.4	0.27	52	3.99	100	20.8	14.4	60	1.50
8th	7.6	0.27	56	3.99	100	20.8	14.4	56	1.88
9th	7.5	0.28	56	3.99	100	20.0	17.6	45	1.49
10th	7.5	0.27	54	3.0	92	20.0	17.0	44	1.34

Duration	Fe	Cr^{+6}	Sio2	Cu	Zn	Pb	Na	Mn	Al
1st	0.77	0.08	4.029	0.04	0.37	ND	17.0	0.16	0.54
2nd	0.68	0.08	40729	0.02	0.23	ND	20.8	0.076	0.54
3rd	0.66	0.08	5.221	0.04	0.23	ND	21.8	0.062	0.56
4th	0.65	0.06	5.864	0.03	0.21	0.01	20.4	0.033	0.57
5th	0.57	0.05	8.474	0.02	0.09	0.01	20.3	0.005	0.59
6th	0.45	0.08	9.288	0.004	0.006	0.02	20.2	0.005	0.68
7th	0.34	0.03	9.401	0.003	0.003	0.03	2.25	0.004	0.71
8th	0.32	0.04	10.29	0.002	0.002	0.04	2.3	0.001	0.71
9th	0.30	0.04	10.44	0.001	ND	0.04	2.0	ND	0.72
10th	0.29	0.04	10.40	ND	ND	0.05	2.0	ND	0.72

Note: All values are in mg/gm of fly ash except pH and conductivity in μmhos/cm

Table-6Analytical results of leachates test of Anpara TPS

Duration									
	pH	Conductivity	Alkainity	Cl	Hardness	Mg	Ca	SO_4	F
1st	7.6	0.11	36	19.9	80	17.1	9.62	20	0.09
2nd	7.3	0.14	36	18.9	72	15.5	8.02	35	0.17
3rd	7.3	0.18	38	17.9	68	14.5	8.02	40	0.26
4th	7.2	0.19	40	16.9	68	13.4	12.8	45	0.28
5th	7.5	0.19	44	12.9	64	12.4	12.8	45	0.45
6th	7.6	0.20	48	8.9	64	12.1	14.4	46	0.48
7th	7.8	0.16	52	7.9	60	11.5	12.8	25	0.74
8th	7.7	0.14	52	7.7	60	12.2	9.62	15	1.34
9th	7.5	0.11	51	6.9	56	11.3	9.62	13	1.38
10th	7.5	0.12	51	6.6	54	11.0	9.5	13	1.37

Duration									
	Fe	Cr^{+6}	Sio_2	Cu	Zn	Pb	Na	Mn	Al
1st	0.46	0.06	0.26	1.31	0.321	1.2	40.1	0.132	3.43
2nd	0.49	0.08	0.45	0.02	0.152	1.0	27.8	0.041	1.25
3rd	0.37	0.06	0.47	0.03	0.132	1.3	4.3	0.088	0.35
4th	0.31	0.07	1.00	0.02	0.120	1.2	4.4	0.070	0.49
5th	0.34	0.04	5.62	0.01	0.089	0.080	3.6	0.005	0.59
6th	0.36	0.06	6.60	0.008	0.049	0.049	1.9	0.006	0.77
7th	0.47	0.02	6.52	0.004	0.032	0.039	1.7	0.005	0.98
8th	0.74	0.05	6.69	0.001	0.027	0.041	1.7	0.004	1.19
9th	0.78	0.01	7.07	ND	0.020	0.040	1.6	0.004	1.0
10th	0.77	0.01	7.0	ND	0.010	0.039	1.5	0.003	0.79

Note: All values are in mg/gm of fly ash except pH and conductivity in μmhos/cm

Table-7 Quantification of substances released from fly ash of Panki TPS at different pH during 20 days contact period

Condition	Parameters							
pH of deionised water	Conductivity	Alkalinity	Cl	Hardness	Mg	Ca	SO_4	F
6.5	3.034	914	256.42	1432	257.42	372.48	313	22.49
7.5	3.81	738	221.92	1130	230.55	214.54	235.38	33.69

Condition	Parameters								
pH of deionised water	Fe	Cr+6	Sio_4	Mn	Zn	Cu	Pb	Na	Al
6.5	12.95	1.32	91.981	0.183	1.955	2.98	6.02	26.25	18.74
7.5	15.21	1.24	71.578	0.003	0.499	5.34	0.182	370.58	30.83

Table-8 Quantification of substances released from fly ash of Anpara TPS at different pH during 20 days contact period

Condition	Parameters							
pH of deionised water	Conductivity	Alkalinity	Cl	Hardness	Mg	Ca	So_4	F
6.5	1.926	371	204.6	456	89.47	87.04	79	7.11
7.5	2.205	580	201.9	650	139.44	73.86	57.5	14.31

Condition	Parameters								
pH of deionised water	Fe	Cr+6	Sio_4	Mn	Zn	Cu	Pb	Na	Al
6.5	15.7	0.42	46.08	0.11	0.764	0.070	0.298	12.84	11.67
7.5	4.73	0.64	31.34	2.12	0.22	2.01	0.054	74.89	26.88