Risk assessment of fly ash effluent and surrounding water of Parichha Thermal Power Plant Jhansi

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Abstract

Water quality is of vital concern, directly links with human health. Increased human population on this planet requires various industries to fulfil their need, which causes huge amount of by-products. Industrial waste disposal method is one of the major routes of polluting the various water bodies because of disturbing the physico-chemical and microbial parameters of potable water. In order to balance the socio-economic development and its impact on environment, the analysis of effluents of industriesbefore and after treatment as well as surrounding water bodies are required to be monitored. For the same, the Parichha Thermal Power Plant (PTPP) effluents and the surrounding water are analysed for the various physico-chemical parameters as well as micro, rare earthand radioactive elements byusing ICP-MS, UV-vis spectrophotometry and FAAS. The results obtained of these samples have been compared with the WHO standards to specify the quality of water. Among the total 37 detected elements, some elements are found in soluble form in all samples within limit. Besides this, toxic elements and radioactive elements, U and Th are absent in all samples. This study concluded that the potable water around thePTPP is safe from harmful effects with satisfactory physico-chemical and biochemical framework.

Key words-Fly ash effluent, Ash-slurry water, Rare earth element, Physico-chemical parameters, ICP-MS.

1.Introduction

Water is a ubiquitous substance essential for all living organisms. It is the most abundantly present material on earth which provides a medium for life. This “Adam’s ale” is required in almost every sphere of man’s activity, directly or indirectly. Water pollution may be referred to as a state of deviation from the pure form with its normal function, if there is a deflection of water quality index[1,2]. It may get polluted due to conducted[4-7]. Management of fly ash is problematic when its generation has the introduction of outer source like fly ash (solid waste) and industrial effluent (liquid waste). Fly ash is a by-product of combustion of coal in thermal power plants. For the purpose of generating electricity, the PTPP uses bituminous coal, which is obtained from the Bharat Coalfield Company Ltd. and the Northern Coalfield Ltd. It contains Fe_2O_3, Al_2O_3, and SiO_3[3].Several studies on fly ash from various thermal power stations have been increased from 40 in 1994-95 to 112 million tonnes in 2004-05 and it will be more than

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150 million tonnes per year in coming years, in India[1].Its disposal practice has increased several environmental problems due to leachate of dissolved constituents of fly ash(Fig.1).Some of which are radioactive and causes radiological health hazards more than causing nuclear waste[2,8-10]. Lithium is an essential trace element. A Japanese study suggests its intake increases human life span[4]. Sr is chemically similar to Ca. Its presence in bones steers to disorder the blood cell formation and responsible for anaemia. The ^{137}Cs isotope of caesium is major responsible for radioactive pollution[4]. Haematological damage and interference with heme synthesis are the biochemical effects of Pb in living organisms[1, 8]. Organic compounds of Hg, (methyl mercury and dimethyl mercury) are extremely toxic which can cause liver damage as well as cancer[1,11]. In this research study surrounding water quality of the PTPP is subjected to judge for its impact due to fly ash wet disposal method. Here for the first time the water chemical content is quantified in terms of unconventional elements like La, Ce, Pr, Nd, Sm, Eu, Gd, Dy, Tm, Yb, Lu and two elements of actinides series Th and U, along with those parameters which influence aquatic chemistry.

2. Experimental and Method

2.1 Study area

Parichha Thermal Power Plant (PTPP) is situated on NH-25 on the northern bank of Betwa River in Jhansi. Jhansi district is situated 24’ 11” N to 25’ 57” N latitude and 78’ 10” E to 79’ 23”E longitude in the semi-arid region of the country.

Fig. 1 Ash slurry

2.2 Sampling

In order to analyze the physico-chemical properties and elemental concentrations, a total of four samples have been collected in triplicate in July 2018 in as following manners-

(a) Control water sample collected from Betwa River (S-1).
(b) Ash-slurry water sample (S-2).
(c) Treated effluents before disposal in river ((S-3).
(d) Ground water near PTPP Jhansi ccollected from hand pump (S-4).

2.3 Methodology

pH measurement has been performed by Elico pH meter. Electric conductivity (EC) and total dissolved solid (TDS) content have been measured by Systronics Conductivity and TDS meter model no. 302, respectively. Acidity, alkalinity, hardness, dissolve oxygen (DO) content, biological oxygen demand (BOD)[12] and calcium content have been measured titrametrically[13]. Boron is measured by UV-visible spectrophotometer[14]. Fe has been measured by AAS model no. 2022[15. The rest of the elements have been detected by ICP-MS model no. oa-TOFMS 8000R[16].

3. Results and Discussion

Physico-chemical parameters of all four samples (Table 1) have been recorded between21-24°C temperatures. Temperature of potable water has an influence on its taste and it is also important for calculating the solubility of CO_2 and O_2, carbonate and bicarbonate equilibrium[13]. Temperature limits the saturation ranges of solids and gasses dissolved in it[14]. S-1 and S-4 are found in normal odour due to their potable quality while S-2 and S-3 smell unpleasantly. Here pH of all samples is found more than 7.5 except control water. Itshigher range is measured in S-2 collected from ash-slurry. It is indicating that the fly ash is responsible for alkaline nature of S-2.pH affects the chemical form and impacts of many chemical substances in water. Coagulation and flocculation, important mechanism used for purification of waste water, depends on pH, besides this, the size of coagulated particles and density of flocculent ultimately affect the rate of settling out[17]. EC have been observed between 0.35- 0.48 Siemens. The presence of metal ions in water is responsible for conductivity. TDS which indicates the amount of dissolved metal, salts and minerals in water, has been found to be in highest concentration in S-2 go to with correlation that higher alkalinity, higher pH[17]. Turbidity is higher in S-2 after treatment, which is decreases in S-3. Higher range of alkalinity is noticed in S-2. Some inorganic pollutants like As, Cd, NO_3^-, PO_4^-, fertilizers and heavy metal may also be responsible for increasing alkalinity of water. Hardness range in all samples is noticed under the standard range. Ca is found in decreasing order from S-1 to S-3. It is an important nutrient and is found within the standard range of potable water. DO and BOD are important biological parameters of water, which are also responsible for changing the composition and quality of water[18].Both of them are found in suitable range. Fe is measured by AAS techniques, which rely upon an atomic absorption process. Lower concentration of Fe is determined in S-1, 3 and 4 while S-2 is revealing its higher range. In our previous study, the Xrd results also deduced the presence of Femineral phases in fly ash which may be responsible for this higher range[5].Boron is used as micronutrient, for plant growth and its mobility in water is greatest at pH more than 7.5. Previous studies reveal presence of boron salts in fly ash but in this study, a minute amount of soluble boron is detected[12,19]. Arsenic content is present in S-2 and S-3 and similar findings of arsenic in ash slurry water were reported in previous studies as well[6, 20,21].

A total of 37 elements, including rare earth elements are analysed through ICP-MS (Table 2, Fig. 2). Trace of Li in ground water suggests its suitability against suicidal effects and mood disorder[4]. Mg concentration is exceeding the WHO standard value, but the hardness of water is acceptable and might be compensated by calcium content.Cs is completely absent in all samples. Barium is not an essential nutrient. All soluble salts of Ba are considered toxic but in this study, its concentration is below the toxic level. Ga is observed only in S-2. Ge and Pb are found to be absent in all samples. Ti and V both are found in all samples with their top range in S-2. Humans can ingest 0.8 mg/day of titanium[22] while intake of 1.8 mg/day of V is not harmful for human, animal and plants[23]. Traces of Ni are present in S-1, S-2 and S-3 while it is absent in S-4.1.0 mg/day of Ni is safe for human beings while more than it may cause carcinogenicity and toxicity[7]. None of the studied Lanthanides are present in none of the samples[3].Ce (IV) and Ga (III) are present only in S-2 but their absence in other samples might be because of a capability of forming polymeric species with OH^- and finally precipitate[17].

Table 1. Physico-chemical properties of water sample

	S-1 (Control water)	S-2 (Ash slurry water)	S-3 (Treated effluents)	S-4 (Ground water)	WHO Standard range for potable water [24]	WHO Standard range for waste water [25]
Temperature	22.4	24.2	23.5	21.0	20-25	
Colour	Colourless	Greyish	Greyish white	colourless	Colourless	
Odour	Normal	Unpleasant	Unpleasant	Normal	Normal Agreeable	
pH	7.24	8.18	7.8	7.6	6.5-8.5	6.5-8.5
EC	0.40	0.48	0.38	0.35	-	-
TDS (ppm)	36	48.4 ppm	25.4 ppm	22 ppm	300-600 ppm	1500
Turbidity (NTU)	0.42	1.27	0.87	0.55	1.0 NTU	
Alkalinity (mg/L)	220	324	284	250	200-600	
Hardness(mg/L)	220	280	320	280	300	
Ca (ppm)	110	100	140	160	60-120	230
Dissolve oxygen DO (ml/L)	8.2	3.8	7.1	0.8	10-14 mg/L	-
BOD (mg/L)	4.6	1.6	2.4	0.9	5.0 mg/L	30
Fe (ppm)	0.120	0.74	0.101	0.120	0.3	0.5
B (ppm)	0.037	0.047	0.031	0.085	2.4	1.0
As (ppm)	0.00	0.03	0.01	0.00	0.05	0.1

Table 2. Total elements analysed by ICPMS in water samples.

Elements	S-1 Control water (mg/L)	S-2 Ash slurry water (mg/L)	S-3 Treated effluent (mg/L)	S-4 Ground water (mg/L)	Standard range (mg/L)
^{3}Li	0.025	0.060	-	0.11	
^{24}Mg	7.2	9.1	10.2	59.0	30
^{48}Ti	0.112	0.435	0.145	0.075	0.1
^{51}V	0.002	0.048	0.005	0.022	
^{55}Mn	-	-	-	-	0.1
^{59}Co	-	-	-	-	
^{60}Ni	0.005	0.012	0.007	-	0.2
^{65}Cu	-	-	-	-	0.05
^{66}Zn	-	-	-	-	5.0
^{69}Ga	-	0.035	-	-	
^{74}Ge	-	-	-	-	
^{88}Sr	0.250	0.300	0.340	0.800	4
^{89}Y	-	-	-	-	
^{90}Zr	-	-	-	-	
^{102}Ru	-	-	-	-	
^{103}Rh	-	-	-	-	

^{106}Pd	-	-	-	-	
^{133}Cs	-	-	-	-	
^{138}Ba	**0.034**	**0.480**	**0.032**	**0.015**	**2.0**
^{139}La	-	-	-	-	
^{140}Ce	-	**0.005**	-	-	
^{141}Pr	-	-	-	-	
^{142}Nd	-	-	-	-	
^{152}Sm	-	-	-	-	
^{153}Eu	-	-	-	-	
^{158}Gd	-	-	-	-	
^{164}Dy	-	-	-	-	
^{169}Tm	-	-	-	-	
^{174}Yb	-	-	-	-	
^{180}Hf	-	-	-	-	
^{175}Lu	-	-	-	-	
^{195}Pt	-	-	-	-	
^{197}Au	-	-	-	-	
^{202}Hg	-	-	-	-	**0.001**
^{232}Th	-	-	-	-	
^{208}Pb	-	-	-	-	
^{238}U	-	-	-	**Not detectable**	

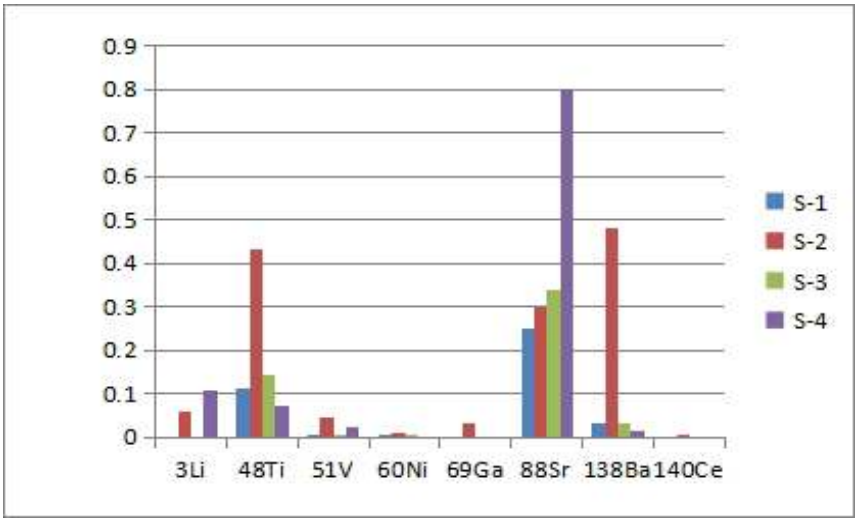

Fig. 2 Concentration of dissolved elements in samples.

5.Conclusion

Water is the effective media for the transfer and transport of waste material. Pollutants released into the water may get distributed in soil and air as well. The transfer of pollutant from one medium to another may be bulk transfer and interfacial transfer. By process of adsorption, vaporisation; the nature and properties of pollutant, their concentration, solubility, vapour pressure plays an important part in interfacial transfer.

With increased emphasis on the need to monitor and manage the fly ash, it can be concluded that, in case of the water sample collected in the vicinity of PTPP:

a) Concentrations of lithium, barium, magnesium, vanadium, nickel, and titanium are found to be in very minute range in all samples. So, there is no harmful effect on water

quality through fly ash with respect to these elements.

b) Gallium and Cerium are seen only in S-2 This indicates that the Ga and Ce present in fly ash get bound with the inorganic compound used in ash slurry treatment.

c) The effluent of PTPP does not exert any radiological effect on surroundings water bodies.

d) There is no risk of toxic elements (As, Hg, Hf, Pb and Zr) in the surrounding water bodies but accumulation of Ce and As are a matter of further study.

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References

[1] Singh S, Gond D P, Pal A, Tewary B K, and Sinha A, Performance of several crops Grown in Fly ash Amended Soil" World of coal ash (WOCA) Conference (2011).

[2] Yadav S, and Gupta M, Evaluation of water quality index by using physicochemical parameter from ground water of Jhansi India. International Journal of Recent ScientificResearch,7(8),(2016), 12747-12749.

[3] Srivastava A, Yadav S, Srivastava S, Saha A, Deb S B, Speciation Of Some Selected Elements In Fly Ash Of Parichha Thermal Power Plant. Jhansi For Potential, Ecological, Radiological And Health Effects,Carpathian journal of Earth and Environmental science, 16 (2),(2021) 287-292.

[4] Taek R K, Effects of rare earth elements on the environment and human health: A literature review. Toxicology and environmental health sciences, 8(3),(2016)189-200.

[5] Srivastava A, Yadav S, and Srivastava S, The validation approach for quantifying Fly ash of the Parichha Thermal Power Plant, Jhansi, uses the spectral technique for its potential use in various fields, Solid Fuel Chemistry, 6 (55)(2021) 450-457.

[6] Pandey V C, Singh J S, Singh R P, Arsenic Hazards in coal Fly ash and its fate in Indian Scenario". Resources, Conservation and Recycling,(2011) 819-835.

[7] Ahamad M S, and Ashraf M, Essential roles and hazardous effect of nickel in plants. Reviews of Environmental Contamination and Toxicology, 14,(2011) 125-167.

[8] Habib A, Basuki T, Miyashita S, Bakelesi W, Nakashima S, Techato K, Khan R, Majilis A B K, andPhoungthong K, Assessment of natural radioactivity in coals and coal combustion residues from a coal-based thermoelectric plant in Bangladesh: implications for radiological health hazard. Environmental Monitoring andAssessment, (2019)http://link.springer.com/article/10.1007/s10661-018-7160-y.

[9] Hvistendahl M, Coal ash is more radioactive than nuclear waste. Scientific American,(2007) 99.

[10] Gabbard A,Coal Combustion: Nuclear Resource or Danger? Emissions from burning coal include uranium and other nuclear materials–potential hazardous andresource.(1993) 26.http://www.ornl.gov/ORNLReview/rev26-34/text/coalmain/html.

[11] Asthana D K, and Asthana M, Environment: Problems and Solutions, S. Chand & Company limited, New Delhi. ISBN: 81-219-1654-2, (2006) .

[12] Kaul S N, and Gautam A, Water and waste water analysis, Daya Publishing house, Delhi(2002).

[13] Paul B N, Chanda S, Das S, Singh P, Pandey B K, and Giri A S, Mineral assay in Atomic Absorption Spectroscopy, The beats of natural sciences,1**,**(2014) 1-18.

[14] San S, Kyi K W, and Naing K, Spectrometric determination of Boron in Environmental Water samples. (2001)Proc. Of M.A.A.S.MM070069.

[15] Annem S, Determination of Iron Content in water,Capstone project, (2014) 6-7.

[16] Saha A, Deb S B, and Saxena M K, Determination of trace impurities in advanced metallic nuclear fuels by inductively coupled plasma time-of-flight mass spectrometry (ICP-ToF-MS). Journal of Analytical Atom Spectrum,31,(2016) 1480-1489.

[17] Manahanan S E, (2001) Environmental Chemistry, Lewis Publication, Sixth Edition.(2001) 61.

[18] Edet A, Nganje T N, Akor A J, and Ekwere A S, Groundwater chemistry and quality of Nigeria: A status review. Afri. J. Environ. Sci. Tech. 5(13),(2011) 1152-1169.

[19] Rathinasabapathy S, Santosh M S, and Ashokan M, Significance of Boron Nitride in Composites and Its Applications.Recent Advances in Boron-containing Material. DOI: 105772/intechopen.81557 (2018).

[20] Yadav S, Gaur A, Srivastava A, and Yadav S, Monitoring of Arsenic contents in water

bodies of Bundelkhand region (India). International journal of environmental science,7(1),(2016) 62-69.

[21] Fulekar M H, and Dave J M, Arsenic content in fly ash and its relationship with physico-chemical characteristics of ash effluents. Asian Environment,6 (5),(1985) 35-38.

[22] Emsley J,Titanium. Nature building blocks, an A-Z guide to the elements. Oxford. England. UK.(2001) Press ISBN 978-0-19-850340-8.

[23] Rodriguez R, Arredondo I M, and Rodriguez I, Geological differentiation of ground water threshold concentration of Arsenic, Vanadium and Fluorine in EI Bajioguanajuatense, Mexico. Geofisica International, 55 (1),(2016) 5-15.

[24] Indian standard specification for drinking water IS: 10500.

[25] WHO, A compendium of standards for waste water reuse in the Eastern Mediterranean Region.(2006).