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Groundwater Quality Assessment around Ash Pond of Parichha Thermal Power Plant, Jhansi, India

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Abstract: Groundwater contamination around the ash pond of a thermal power plant is the major problem related to groundwater contamination by wet method of ash disposal. The influence of ash disposal from thermal power plant on groundwater quality was assessed in terms of physicochemical properties (pH, EC, TDS, Cl^-, Hardness, Ca^{2+}, Mg^{2+} and SO_4^{2-}) and trace elements (Fe and Pb). The study area was selected around the ash disposal site of Parichha Thermal Power Plant, Jhansi. The obtained results were compared with the BIS guidelines for drinking water quality. All the parameters were found to be exceeding the permissible limits prescribed by BIS at site 1 while on other sites only few parameters were exceeding the limit. Lead and iron concentration in all groundwater samples was higher than permissible limits prescribed by BIS for groundwater.

Key words: Ash pond, bore well, groundwater, trace elements.

Introduction

Groundwater is being considered as a dependable source of uncontaminated water (Karunakaran et al., 2009). But nowadays it has however been realized that this source of water is in serious danger of being contaminated as any liquid that finds its way into the ground can eventually enter the groundwater supply (Bagchi, 2004). Although, the soil and other materials do naturally purify most of the water as it strains through an aquifer, some harmful materials are allowed to pass through (Monroe, 2001). The quality of ground water is affected by the characteristics of the media through which the water passes on its way to groundwater zone of saturation (Ragi and Alagbe, 1997). Trace elements present in fly ash, have a tendency to leach out and contaminate the environment, especially surface and groundwater (Prasad and Mondal, 2008).

When large quantities of ash accumulate for longer period of time in the disposal sites, hazardous substances are likely to be released by leaching, percolate through the soil layers and eventually reach the groundwater (Figure 1) (Mandal and Sengupta, 2005). The present study was carried out to estimate the groundwater contamination due to ash disposal of Parichha Thermal Power Station in terms of their physicochemical parameters and some trace elements that can affect human health.

Materials and Methods

Description of Study Area and Sampling Stations

Parichha thermal power plant is situated on the bank of Betwa River at Parichha in Jhansi district of Bundelkhand region of state Uttar Pradesh, India. The study area lies in the plateau of central India and is

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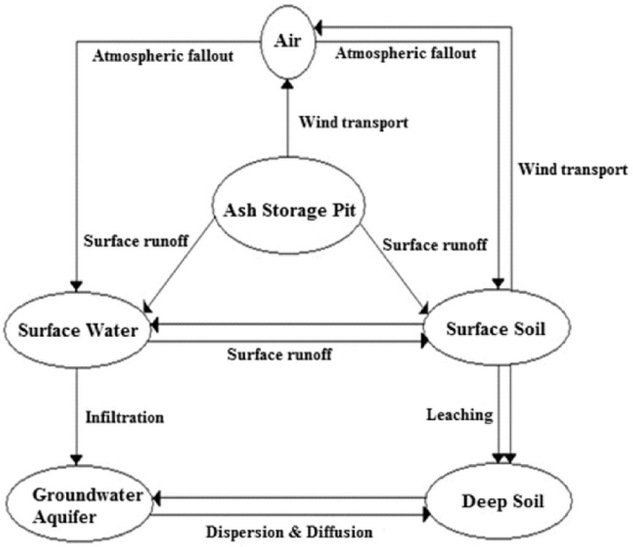

Figure 1: Schematic representation of air, water and soil pollution due to ash disposal.

dominated by rocky relief and minerals underneath the soil. The ash pond is neither lined nor it is used for transportation purpose. The scope of study area comprises four sampling sites (S_1-S_4) located within the range of 5 km of the ash disposal site (Figure 2) and a reference site (S_0) as a control site at a distance of 15 km from Parichha Thermal Power Plant (Jhansi), India. The ash pond of thermal power plant is located at an average elevation of 207.26 m and four sampling sites S_1 at 204.83 m, S_2 at 201.17 m, S_3 at 200.25 m, S_4 at 202.39 m and reference site S_0 at 200.56 m. These sampling sites (S_1-S_4) are also located near Betwa river in which the ash pond decant is being disposed. The elevation of river is 196.29 m.

Sample Collection

Groundwater samples were collected from bore wells by using area sampling method from the four non-overlapping areas around the ash pond and one from the

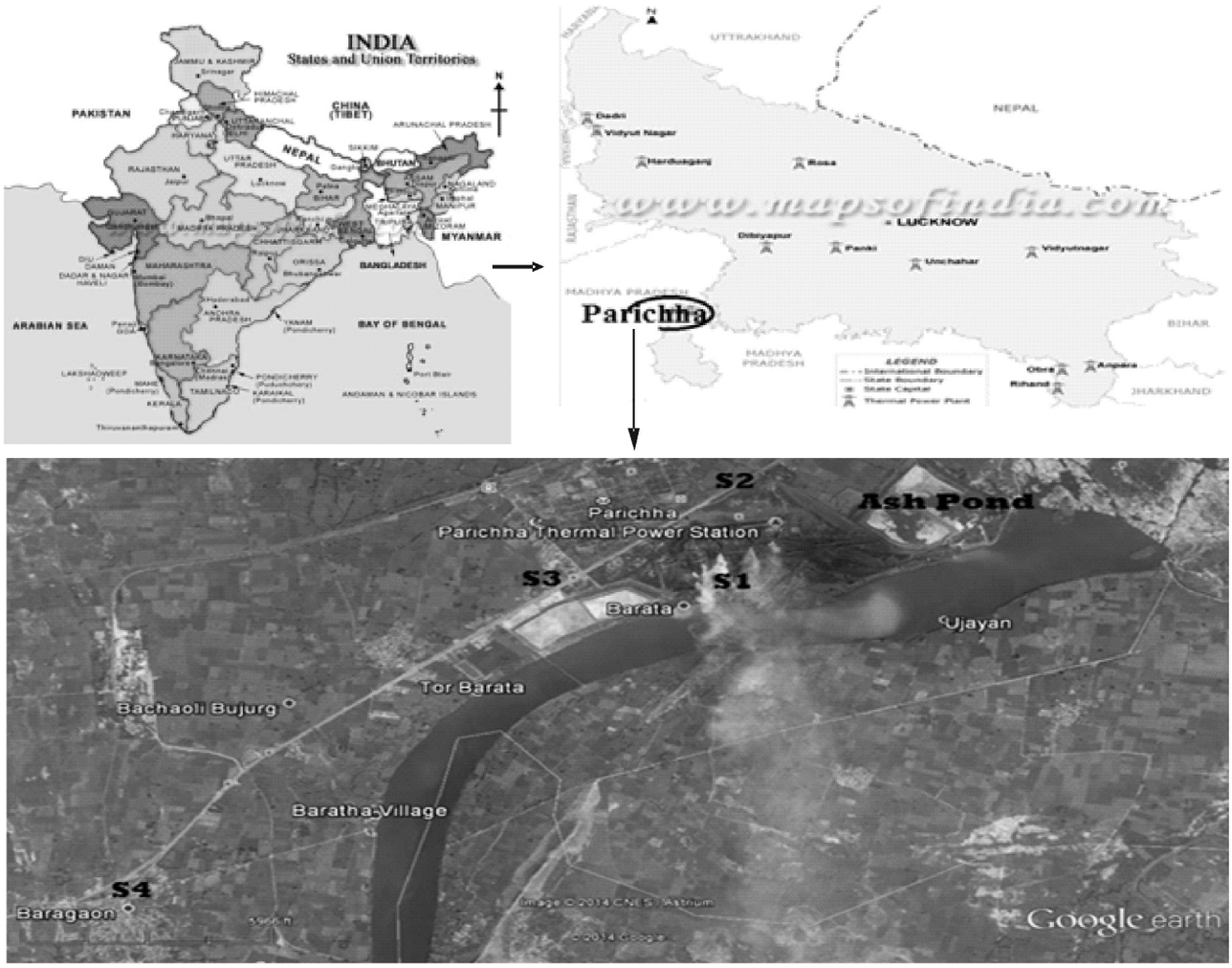

Figure 2: Map of sampling sites around ash disposal site of Parichha Thermal Power Plant.

reference site as a control site. The depth of all the bore wells lies in the range of 18 to 21 m. A total number of fifteen samples; single sample from each bore well (Grab sampling) was taken from all five sites (four study sites S_1-S_4 and one reference site S_0) in the months of May, September and June in year 2012. Water samples for the analysis of trace elements were preserved at site by adding 3 mL of HNO_3 per litre of sample.

Analytical Techniques

Water samples were analysed in terms of physicochemical parameters: pH, EC (Electrical Conductivity), TDS (Total Dissolved Solids), chlorides, hardness, calcium, magnesium, sulphate and trace elements (iron and lead). Physicochemical analysis of water was carried out as per 'standard methods' (APHA, 2005). pH, EC, TDS were measured at the sampling site by using water analyzing kit (ISO 9001-2000). Trace elements were determined with atomic absorption spectrophotometer (AAS). Simple linear correlation analysis has been carried out to determine the correlation value between tested parameters. The results obtained from the analysis are being compared with the BIS standards.

Results and Discussion

The results obtained from the analysis of various groundwater samples in terms of their physicochemical parameters are summarized in Table 1. Correlation matrix among various physicochemical parameters has been evaluated and values for the same are given in Table 2. Perusal from the data given in Table 2 shows the positive correlation of all parameters with each other. The summarized results of various physicochemical parameters from Table 1 can be discussed as:

pH

pH is a term used universally to express the intensity of the acid or alkaline condition of a solution. The average value of pH for groundwater sample was 8.40±0.44 at S_1, 8.35±0.15 at S_2, 8.30±0.09 at S_3, 8.33±0.15 at S_4 and at reference site S_0 it was 7.39±0.28. The highest value of pH was observed as 8.9 at S_1 which is exceeding the acceptance limit of BIS, prescribed as 6.5-8.5.

Electrical Conductivity

Electrical conductivity is a direct function of total dissolved solids in water (Harilal et al., 2004). The electrical conductivity of groundwater sample was 4.78±0.57 mS/cm at S_1, 1.00±0.10 mS/cm at S_2, 1.34±0.49 mS/cm at S_3, 1.64±0.49 mS/cm at S_4 and 0.47±0.06 mS/cm at reference site S_0. Electrical conductivity of water is a good indicator of pollution as most of the soluble pollutants exist as ions in water (Ravichandran and Jayaprakash, 2011). The maximum value of EC was found at S_1 as 5.41 mS/cm. According to BIS the prescribed value of EC is 1.4 mS/cm. The EC value of groundwater samples is compared with BIS standard and is found to be exceeding the limit at S_1.

TDS

Total Dissolved Solid is a measure of the combined content of all inorganic and organic substances contained in a liquid in molecular, ionized or micro granular suspended form (Saravanakumar and Kumar, 2011) and it is an indicator of polluted water. In perspectives of BIS standards, collected groundwater samples showed concentration of TDS beyond permissible limit prescribed for drinking water of 500 mg/L barring the reference site. An average value of TDS in groundwater samples was recorded as 3096.67±468.76 mg/L at S_1, 605.00±74.67 mg/L at S_2, 703.33±23.69 mg/L at S_3, 873.33±60.28 mg/L at S_4 and 409±26.51 mg/L at S_0 reference site. The maximum value of TDS was observed at S_1 as 3630 mg/L.

Chloride

The average value of chloride concentration in groundwater sample was 412.73±51.05 mg/L at S_1, 45.83±4.14 mg/L at S_2, 129.90±47.79 mg/L at S_3, 185.35±53.96 mg/L at S_4 and 34.4±4.62 mg/L at S_0. The maximum concentration of chloride is found as 470.23 mg/L at S_1. Chloride usually occurs as NaCl, $CaCl_2$ and $MgCl_2$ in widely varying concentrations, in all natural waters. These forms of Cl^- enter into water by solvent action of water salts present in the soil, from polluting material (Shaikh and Mandre, 2009). Chloride concentration above 250 mg/L as prescribed limit by BIS imparts an unacceptable taste. Perusal from the data as summarized in Table 1 indicates the values of chloride concentration below the permissible limits prescribed by BIS except at S_1 which was beyond the acceptable limit.

Hardness

Carbonates and chlorides of calcium and magnesium are mainly responsible for the hardness of water. It is the measure of the capacity of water to precipitate soap. As per the results tabulated in Table 1, the average value of hardness in groundwater sample was 1005.49±372.61 mg/L at S_1, 182.01±46.46 mg/L at S_2, 223.78±97.22 mg/L at S_3, 255.72±60.51 mg/L at S_4

Table 1: Physicochemical characteristics of groundwater around ash disposal site of Parichha Thermal Power Plant

Parameters	*Site 1 (S_1)*			*Site 2 (S_2)*			*Site 3 (S_3)*			*Site 4 (S_4)*			*Reference site (S_0)*		
	Range	*Mean*	*Std dev*	*Range*	*Mean*	*Std dev*	*Range*	*Mean*	*Std dev*	*Range*	*Mean*	*Std dev*	*Range*	*Mean*	*Std dev*
pH	8.1-8.9	8.40	0.44	8.2-8.5	8.35	0.15	8.2-8.4	8.30	0.09	8.2-8.5	8.33	0.15	7.1-7.6	7.39	0.28
EC (mS/cm)	4.31-5.41	4.78	0.57	0.92-1.11	1.00	0.10	1.01-1.9	1.34	0.49	1.29-2.2	1.64	0.49	0.41-0.52	0.47	0.06
TDS (mg/L)	2750-3630	3096.67	468.76	550-690	605.00	74.67	685-730	703.33	23.63	810-930	873.33	60.28	382-435	409.00	26.51
Chloride (mg/L)	372.75-470.23	412.73	51.05	42.6-50.5	45.83	4.14	101.18-185.07	129.90	47.79	149.10-247.36	185.35	53.96	30.5-39.5	34.40	4.62
Hardness (mg/L)	771.18-1435.16	1005.49	372.61	133.8-226.5	182.01	46.46	124.23-318.5	223.78	97.22	204.53-322.50	255.72	60.51	98-112	105.67	7.09
Calcium (mg/L)	408.82-592.23	477.07	100.30	64.13-120.00	84.09	31.16	54.11-135.00	93.10	40.52	48.09-70.50	56.23	12.40	35-46	40.33	5.51
Magnesium (mg/L)	362.37-842.93	528.19	272.70	65.66-121.60	97.92	28.94	34.05-183.50	130.68	83.81	154.43-252.00	199.49	49.21	63-66	65.00	1.73
Sulphate (mg/L)	210-240	223.33	15.28	22-220	109.00	101.16	9-100	56.33	45.61	17-110	70.67	48.13	8-45	22.67	19.66
Iron (mg/L)	1.72-1.99	1.84	0.14	0.48-0.50	0.49	0.01	1.21-1.27	1.24	0.03	1.24-1.25	1.24	0.01	0.31-0.32	0.31	0.01
Lead (mg/L)	0.43-0.48	0.45	0.03	0.38-0.41	0.39	0.02	0.32-0.38	0.34	0.03	0.32-0.35	0.33	0.02	0.11-0.12	0.11	0.01

Table 2: Correlation matrix for different groundwater quality parameters

Parameters	*pH*	*EC*	*TDS*	*Chloride*	*Hardness*	*Calcium*	*Magnesium*	*Sulphate*	*Iron*	*Lead*
pH	1.000									
EC	0.831	1.000								
TDS	0.857	0.998	1.000							
Chloride	0.722	0.975	0.960	1.000						
Hardness	0.852	0.997	0.998	0.956	1.000					
Calcium	0.856	0.977	0.987	0.910	0.990	1.000				
Magnesium	0.831	0.997	0.992	0.984	0.990	0.959	1.000			
Sulphate	0.968	0.913	0.936	0.806	0.936	0.953	0.899	1.000		
Iron	0.418	0.844	0.811	0.930	0.810	0.751	0.853	0.552	1.000	
Lead	0.930	0.801	0.836	0.649	0.841	0.892	0.772	0.968	0.372	1.000

and 105.6667±7.09 mg/L at S_0. The maximum value of total hardness is found at S_1 as 1435.16 mg/L. Though hardness is not harmful to health, it has been suspected to be playing some role in heart disease (Shahnawaz and Singh, 2009). Total hardness of all samples has been found to be below 500 mg/L as prescribed limits of BIS except at S_1.

Calcium

Results of analysis of calcium is summarized in Table 1 and the average value of calcium concentration in analysed groundwater samples was 477.07±100.30 mg/L at S_1, 84.09±31.16 mg/L at S_2, 93.10±40.52 mg/L at S_3, 56.23±12.40 mg/L at S_4 and 40.33±5.51 mg/L at S_0. The maximum concentration of calcium was observed at S_1 as 592.23 mg/L. In order of abundance it is the fifth element which is commonly present in all water bodies (Shahnawaz and Singh, 2009). The calcium concentration of all samples was within the permissible limit of 75 mg/L prescribed by BIS except at S_1.

Magnesium

In perspective of BIS standards for drinking water, collected groundwater samples showed magnesium concentration beyond the acceptable limit of 50 mg/L at all sites except reference site and the same is summarized in Table 1. The average value of magnesium concentration was 528.19±272.70 mg/L at S_1, 97.92±28.94 mg/L at S_2, 130.68±83.81 mg/L at S_3, 199.49±49.21 mg/L at S_4 and 65±1.73 mg/L at S_0. Magnesium tolerance by human body is lower than that of calcium. High concentration of magnesium in drinking water gives unpleasant taste to water (Shahnawaz and Singh, 2009). Although, at all sites magnesium concentration was exceeding the BIS limit the highest concentration was observed at S_1.

Sulphate

According to results presented in Table 1 the average concentration of sulphate was 223.33±15.28 mg/L at S_1, 109.00±101.16 mg/L at S_2, 56.33±45.61 mg/L at S_3, 70.67±48.13 mg/L at S_4 and 22.66±19.66 mg/L at S_0. The maximum value of sulphate concentration of 240 mg/L was found at S_1. Sulphate occurs naturally in water as a result of leaching from gypsum and other common minerals (Patil and Patil, 2010). Discharge of industrial waste tends to increase its concentration of sulphate (Murhekar, 2001). The sulphate concentration at all sites was less than 200 mg/L a permissible limit value prescribed by BIS except at S_1 as 210-240 mg/L and at S_2 as 220 mg/L.

Iron

The permissible limit as prescribed by BIS for iron concentration in drinking water is 0.30 mg/L. Perusal of the data given in Table 1 indicates that the concentration of iron was found to be higher than the prescribed limit at all sites except reference with an average value of 1.84±0.14 mg/L at S_1, 0.49±0.01 mg/L at S_2, 1.24±0.03 mg/L at S_3, 1.24±0.01 mg/L at S_4 and 0.31±0.01 mg/L at S_0. The maximum concentration of iron was 1.99 mg/L at S_1. Excess iron residual in water may cause taste and odour problem and result in red colouration of water (Adetuned et al., 2011).

Lead

The lead concentration in groundwater samples was 0.45±0.03 mg/L at S_1, 0.39±0.02 mg/L at S_2, 0.34±0.03 mg/L at S_3, 0.33±0.02 mg/L at S_4 and 0.11±0.01 mg/L

at S_0. This concentration was much higher than the permissible limit of 0.05 mg/L prescribed by BIS for the drinking water. Lead concentration was found to be maximum value of 0.48 mg/L at S_1. Lead poisoning symptoms usually develop with intestinal cramps, peripheral nerve paralysis, anemia and severe fatigue (Mishra et al., 2009).

Conclusion

The results indicated alkaline water with high pH, higher value of electrical conductivity, total dissolved solids and magnesium. However, the concentration of iron and lead at all sites was exceeding the permissible limits as prescribed by BIS for drinking water. Results also indicate S_1 as the most contaminated site although it is located at the bank of river. This is because river has least dilution effect on site 1 and that is due to the location of site elevation which is higher than that of the river elevation. Analysis of the obtained results and from the present study it can be concluded that S_1 is the most contaminated site around thermal power plant.

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