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Assessment of heavy metal pollution index for groundwater around Jharia coalfield region, India

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Abstract

Assessment of the seasonal variations of the groundwater with respect to heavy metals contamination. For this purpose, 29 groundwater samples were collected and analyzed for heavy metals such as cadmium, copper, iron, manganese, lead and zinc of Jharia coalfield region. In majority of the samples, the analyzed heavy metals are well within the desirable limits and water is potable for drinking purposes. However, concentration of the Fe and Mn exceeding the desirable limits in many groundwater samples in both the seasons. The HPI of groundwater was found 9.94 in pre-monsoon season and 5.24 in post-monsoon season. The HPI values of the samples within study area are found below the critical pollution index (100) in both the seasons, which shows that the groundwater was not polluted with respect of heavy metals.

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Introduction

Coal mining activity in India started decades back, since then the groundwater is getting affected with coal mining, leachates generated from large number of industrial waste and overburden dumps that are in abundance around the mining areas, may reach the groundwater and may adversely affect its quality (Khan *et al.* 2005; Mohammad *et al.* 2010). Groundwater contamination is one of the most important environmental problems in the present world where metal contamination has major concern due to its high toxicity even at low concentration (Marcovecchio *et al.* 2007; Momodu and Anyakora 2010). Heavy metals contamination in the groundwater is one of the major issues in many fast growing cities (Sundaray *et al.*, 2006; Akoto *et al.*, 2008; Ahmad *et al.*, 2010). Enhancement of heavy metals contamination of the groundwater is one of the serious environmental issues. Some of the heavy metals considered as micronutrients become detrimental to human health when their concentrations exceed the permissible level of drinking water (Prasanna *et al.* 2011). Rapid urbanization, especially in developing countries like India has affected the availability and the quality of the groundwater due to its overexploitation and improper waste disposal, especially in urban areas (Ramakrishnaiah et.al. 2009). The weathering of natural resources such as rocks bearing minerals is one of the major causes of heavy metal contamination in groundwater; anthropogenic sources include fertilizers, industrial effluent and leakage from service pipes. Heavy metals occur in the earth's crust and may get solubilised in ground water through natural processes. Moreover, groundwater can get contaminated with heavy metals from landfill leachates, seawage leachates from mine tailings, deep well disposals of liquid wastes, seepage from industrial waste lagoons or from industrial spills and leaks (Evanko and Dzombak, 1997). Usually in unaffected environments, the concentration of most of the metals is very low and is mostly derived from the mineralogy and the weathering (Karbassi *et al.*, 2008). Main anthropogenic sources of heavy metal contamination are mining, disposal of untreated and partially treated effluents contain toxic metals, as well as metal chelates from different industries and indiscriminate use of heavy metal-containing fertilizer and pesticides in agricultural fields (Hatje *et al.*, 1998; Amman *et al.*, 2002; Nouri *et al.*, 2006; Nouri *et al.*, 2008). However, public ignorance of environment and related considerations, lack of provisional basic social services, indiscriminate disposal of increasing anthropogenic wastes, unplanned application of agrochemicals, and discharges of improperly treated sewage/industrial effluents; result in excess accumulation of pollutants on the land surface and contamination of water resources (Tiwari *et al.* 2013; Singh *et al.* 2014). The studies carried out by various researchers on water quality by using different water quality indices across India, including Jharkhand (Giri *et al.* 2010; Giri *et al.* 2012; Singh *et al* 2013a, Prasad *et al.* 2014, Tiwari *et al.* 2014, Singh *et al.* 2014). Scarcity of clean and potable drinking water has emerged in recent years as one of the most serious developmental issues in many parts of West Bengal, Jharkhand, Orissa, Western Uttar Pradesh, Andhra Pradesh, Rajasthan and Punjab (Tiwari & Singh 2014). The present study aimed to investigate the groundwater quality status with respect to heavy metal concentrations in mining areas of Jharia coalfield. In the present study, six important heavy metals such as iron, manganese, lead, copper, cadmium, and zinc have been evaluated in 29 groundwater samples, obtained from different places of Jharia coalfield for post-monsoon and pre-monsoon seasons of the year 2013.

Materials and methods

Study area

A Jharia coalfield (JCF) area is one of the most important coal mining areas in India. It is roughly elliptical or sickles – shaped, located in Dhanbad district of Jharkhand lies between latitude 23°39/ N and 23°48/ N and longitudes 86°11/ E and 86°27/ E. It stretches from Chandanpura on the west to Sindri on the east. The main component of the natural drainage in JCF is the Damodar River. There are eight major streams, a few perennials and the rest intermittent, which drains the JCF from north to south to join the Damodar River. They are Tisra, Chatkari, Katri, Khudia, Jamuniya, Kumari and Bansjora etc. (Fig .1). Detail location with latitude and longitutide of sampling given in Table 1.

Table 1. Sampling location of Jharia coalfield.

S.No.	Location	Latitude	Longitude	Elevation
W1	Near Bararee Colliery	23°43'26"	86°24'35"	623
W2	Bhoolan Bararee	23°43'27"	86°24'36"	642
W3	Jealgora-7 No.	23°47'42"	86°19'40"	731
W4	Bhowrah South	23°40'41"	86°24'26"	526
W5	Digwadih Campus	23°41'46"	86°25'19"	552
W6	Bararee	23°43'25"	86°24'34"	622
W7	Bhagamor	23°47'37"	86°18'07"	599
W8	South Tisra	23°47'38"	86°19'08"	613
W9	Joyrampur	23°47'40"	86°19'20"	588
W10	Ghanudih 4-No	23°44'47"	86°26'14"	667
W11	Ghanudih 4-No	23°44'48"	86°26'25"	665
W12	Ghanudih 4-No	23°44'47"	86°26'24"	661
W13	Bera Colliery	23°46'06"	86°25'53"	656
W14	Chandmari Colliery	23°45'38"	86°25'15"	784
W15	Bengali Kothi	23°45'38"	86°25'15"	645
W16	Victory	23°45'50"	86°24'44"	690
W17	Goluckhdih	23°44'80"	86°26'33"	637
W18	Dobari	23°45'20"	86°25'57"	638
W19	Khas Kusunda	23°44'82"	86°26'37"	642
W20	East-Basseria	23°45'30"	86°26'41"	650
W21	Bhalgora	23°47'37"	86°18'07"	584
W22	Tetulmari Road	23°48'5.8"	86°20'07"	675
W23	Akashkinari	23°47'48"	86°16'11"	640
W24	Sonardih	23°46'37"	86°14'21"	794
W26	Phulawartar	23°46'37"	86°14'12"	690
W27	Loyabad	23°47'49"	86°16'13"	698
W28	Mooraidih	23°48'16"	86°13'59"	330
W29	Baghmara	23°47'37"	86°18'07"	590

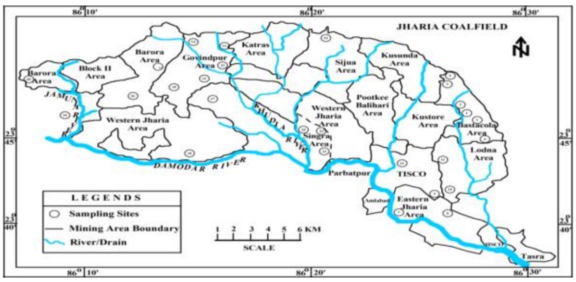

Fig. 1. Sampling sites in the study area.

Geology of the Jharia Coal field

Geology, the major feature is the great coal basin of this region with intervening areas of crystalline rocks. The ancient rock types of Dharwar and post Dharwar period from the basement rock which the lower-Gondwana group. The region is important for its large reserves of lower – gondwana coal distributed in these fields, these fields, the Jharia and chandrapura coalfield and the Barakar series, which extends into Raniganj coalfield in west Bengal. The main axis of the Jharia coalfield basin runs west-north –west – east-south-east and is petering gently towards west and can be seen by the dips of the Raniganj strata along the Jamunia River. (Fig .2)

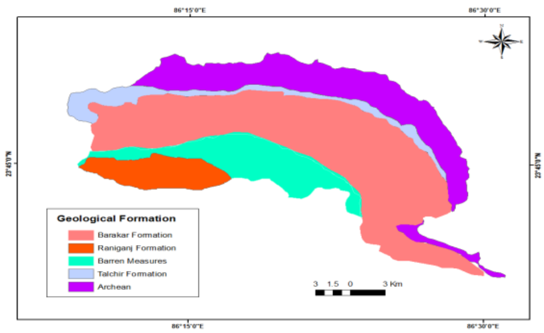

Fig. 2. Geology map of the Jharia coalfield.

Sampling and analysis

A systematic sampling was carried for the assessment of ground water quality of Jharia coal mining area.

Representative, 29 groundwater samples were collected from different mines of Lodna, Bastacolla, Sijua, Western Jharia, Block-II, Barora, and mining area of the study area (Fig 1). Sampling has been done for the month of May (summer) 2013 and December (winter) 2013 to get an idea of the seasonal variation of the heavy metal concentrations. All samples have been digested, concentrated and prepared for analysis by atomic absorption spectrophotometer (AAS) methods using model: M Series Thermo Fisher (Arnold *et al.* 1992). Analysis of these metals were performed by calibrating the instrument with different dilutions of standard solutions and analysis of Cu, Mn, Pb, Fe, Cd, Zn and Cr was performed at 324.7, 279.5, 217.0, 248.3, 228.8, 213.9 and 357.9 nm, respectively.

Heavy metal pollution index

Heavy metal pollution index (HPI) is a technique of rating that provides the composite influence of individual heavy metal on the overall quality of water. The rating is a value between zero and one, reflecting the relative importance of individual quality considerations and inversely proportional to the recommended standard (Si) for each parameter (Reza & Singh, 2010; Prasad and Kumari, 2008; Mohan, Natalia & Reddy, 1996). In the present formula, unit weightages (Wi) is taken as value inversely proportional to the recommended standard (Si) of the corresponding parameter. Iron, manganese, lead, copper chromium and zinc have been monitored for the model index application. The HPI model proposed is given by Mohan *et al.* (1996).

$$\mathrm{HPI} = \frac{\sum_{i=1}^{n} W_i\, Q_i}{\sum_{i=1}^{n} W_i} \quad (1)$$

Where, Q_i is the sub-index of the ith parameter. W_i is the unit weightage of ith parameter, and n is the number of parameters considered.

The sub index (Qi) of the parameter is calculated by Eq. (2)

$$Q_i = \sum_{i=1}^{n} \frac{\{M_i(-)I_i\}}{(S_i - I_i)} \quad (2)$$

Where M_i is the monitored value of heavy metal of ith parameter, I_i is the ideal value of the ith parameter and S_i is the standard value of the ith parameter. The sign (–) indicates numerical difference of the two values, ignoring the algebraic sign.

Result and discussion

The concentration of six heavy metals in groundwater of Jharia coalfield region such as Fe, Mn, Pb, Cu, Cd, and Zn of pre-monsoon seasons is listed in table 2 and post-monsoon season in table 3. The mean concentrations of Fe, Mn, Pb, Cu, Cd, , and Zn were 0.854, 0.033, 0.0056, 0.045, 0.00092, 0.092 mg/l, for pre-monsoon and for post-monsoon 0.663, 0.0231, 0.0053,0.049,0.00044 and 0.0676 mg/l which include total twenty nine groundwater sampling points for two seasons of the year. From the results, it has been observed that concentrations of heavy metals such as Cu, Pb, and Zn were well below the permissible limits of Indian drinking water standard (IS: 10500). The concentration of Mn and Fe has been found more than the highest desirable limit of drinking water standard at many places, in both the seasons. The concentration of Fe in summer has exceeded the highest desirable value of 0.3 mg/l at sampling points 4, 8, 9, 10 11, 12, 20.Excess iron is an endemic water quality problem in many party of India (Singh *et al* 2013b). Lowason 1993 reported that in Jharia coalfield mineral pyrite (FeS_2) found as a secondary mineral in the coal and associated sediment. It is observed high value of Fe due to weathering of pyrites (Lowason et., al 1993). Since the weightages (Wi) given to Fe and Mn is very less, in evaluation of HPI of groundwater, these parameters do not contribute much on HPI value. Heavy metals like Pb, Cd, and Cr have been given no relaxation in drinkingwater standard and they have been given high weightages (Wi) value in HPI calculation. Concentration of Cu and Zn has not been found at any sampling point in any season higher than the desirable limit of drinking water standard. The heavy metal pollution index is calculated for the season pre-monsoon is 9.94 and for the post-monsoon 5.25, which is well below the critical index value 100. This index value indicates that in general the groundwater is not contaminated with respect to the heavy metal pollution. The HPI calculated with mean concentration values of all metals including all sampling points of groundwater showing in table 4. Post-monsoon season showing good quality of groundwater in terms of heavy metal with compare to pre-monsoon season.

Table 2. Statistical parameter of Heavy metal (pre-monsoon).

SL.NO	Constituents	Min	Max	Mean	SD	SE
1	Fe(mg/L)	0.471	2.456	0.854	0.786	0.145
2	Cu(mg/L)	0.0012	0.01	0.005	0.003	0.0005
3	Mn(mg/L)	0.0023	0.0903	0.033	0.028	0.051
4	Zn(mg/L)	0.0015	1.124	0.092	0.0225	0.0041
5	Pb(mg/L)	0.00021	0.0124	0.0056	0.003	0.00057
6	cd(mg/L)	0.0001	0.024	0.00092	0.005	0.00092

Table 3. Statistical parameter of Heavy metal (post-monsoon).

SL.NO	Constituents	Min	Max	Mean	SD	SE
1	Fe(mg/L)	0.045	2.415	0.663	0.736	0.136
2	Cu(mg/L)	0.001	0.0312	0.004	0.006	0.0011
3	Mn(mg/L)	0.0023	0.087	0.023	0.19	0.035
4	Zn(mg/L)	0.006	0.43	0.068	0.110	0.020
5	Pb(mg/L)	0.0002	0.21	0.0053	0.005	0.00092
6	cd(mg/L)	0.0014	0.0093	0.00045	0.002	0.00037

Table 4. Calculation of Unit Weightages (Wi) and Standard Permissible Value (Si) based on the Indian Standards (IS: 10500, 1993).

Heavy metals	Mean Concentration(Vi) (ppm)		Highest Permitted values for water(Si) (ppm)	Unit weight age(Wi)	Sub index(Qi) (ppm)		Wi× Qi	
	Summer(s)	Winter (w)			S	W	S	W
Fe(mg/L)	0.854	0.663	1.0	0.0381	85.4	66.3	3.25	2.52
Cu(mg/L)	0.0049	0.0044	1.5	0.0253	0.32	0.29	0.0080	0.0007
Mn(mg/L)	0.033	0.023	0.3	0.1265	11.0	7.66	1.39	0.96
Zn(mg/L)	0.092	0.0676	15	0.0025	0.61	0.45	0.0015	0.0015
Pb(mg/L)	0.0056	0.0053	0.05	0.0758	11.12	10.6	0.842	0.803
cd(mg/L)	0.00092	0.0004	0.01	3.7939	9.2	4.5	34.90	17.07

Conclusion

In the present study, determine the heavy metals and groundwater quality of the Jharia coalfield for drinking and domestic uses. In majority of the samples, the analyzed heavy metals are well within the desirable limits and water is potable for drinking purposes. However, concentration of the Fe and Mn exceeding the desirable limits in many groundwater samples in both the seasons and required treatment before its utilization for drinking purposes. Overall HPI calculated based on the mean concentration of the heavy metals was found for pre-monsoon is 9.94 and for post-monsoon is 5.25 which below the critical index value 100; indicates that the selected groundwater sample is not contaminated with heavy metal pollution inspite of growth of mining and allied activities. Post-monsoon season showing good quality of groundwater in terms of heavy metal with compare to pre-monsoon season.

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Reference

Ahmad MK, Islam S, Rahman S, Haque MR, Islam MM. 2010. Heavy metals in water, sediment and some fishes of Buriganga River, Bangladesh. International Journal of Environmental Research **4(2),** 321-332.

Akoto O, Bruce TN, Darko G. 2008. Heavy metals pollution profiles in streams serving the Owabi reservoir. African Journal of Environmental Science and Technology **2(11),** 354-359.

Ammann AA, Michalke B, Schramel P. 2002. Speciation of heavy metals in environmental water by ion chromatography coupled to ICP-MS. Analytical and bioanalytical chemistry **372(3),** 448-452.

Dzombak DA, Morel FMM. 1997. Adsorption of Inorganic Pollutants in Aquatic Systems. Journal of Hydraulic Engineering **113,** 430-475.

Giri S, Mahato MK, Singh G, Jha VN. 2012. Risk assessment due to intake of heavy metals through the ingestion of groundwater around two proposed uranium mining areas in Jharkhand, India. Environmental monitoring and assessment **184(3),** 1351-1358.

Giri S, Singh G, Gupta SK, Jha VN, Tripathi RM. 2010. An Evaluation of Metal Contamination in Surface and Groundwater around a Proposed Uranium Mining Site, Jharkhand, India. Mine Water and the Environment **29(3),** 225-234.

Hatje V, Bidone ED, Maddock JL. 1998. Estimation of the natural and anthropogenic components of heavy metal fluxes in fresh water Sinos river, Rio Grande do Sul state, South Brazil. Environmental Technology **19(5),** 483-487.

Karbassi AR, Nouri J, Ayaz GO. 2007. Flocculation of trace metals during mixing of Talar river water with Caspian Seawater. International Journal of Environmental Research **1(1),** 66-73.

Khan S, Cao Q, Zheng YM, Huang YZ, Zhu YG. 2005. Health risks of heavy metals in contaminated soils and food crops irrigated with wastewater in Beijing, China. Environmental Pollution **152,** 686–692.

Marcovecchio JE, Botte SE, Freije RH. 2007. Heavy Metals, Major Metals, Trace Elements. In: Handbook of Water Analysis. L.M. Nollet, (Ed.). 2nd Edn. London: CRC Press, pp: 275-311.

Mohammad Mehdi Heydari, Ali Abasi, Seyed Mohammad Rohani, Seyed Mohammad Ali Hosseini. 2010. Correlation Study and Regression Analysis of Drinking Water Quality in Kashan City, Iran. Middle-East Journal of Scientific Research **13(9),** 1238- 1244.

Mohan SV, Nithila P, Reddy SJ. 1996. Estimation of heavy metal in drinking water and development of heavy metal pollution index. Journal of Environmental Science & Health Part A **31(2),** 283-289.

Momodu MA, Anyakora CA. 2010 Heavy Metal Contamination of Ground Water: The Surulere Case Study. Research Journal Environmental and Earth Sciences **2(1),** 39 -43.

Nouri J, Mahvi AH, Babaei A, Ahmadpour E. 2006. Regional pattern distribution of groundwater fluoride in the Shush aquifer of Khuzestan County Iran Fluoride. Fluoride. **39(4),** 321-325.

Nouri J, Mahvi AH, Jahed GR, Babaei AA. 2008. Regional distribution pattern of groundwater heavy metals resulting from agricultural activities. Environmental Geology **55(6),** 1337-1343 .

Peeler KA, Opsahl SP, Chanton JP. 2006. Tracking anthropogenic inputs using caffeine, indicator bacteria, and nutrients in rural freshwater and urban marine system. Environmental science & technology **40,** 7616–7622.

Prasad B, Kumari P, Bano S, Kumari S. 2014. Ground water quality evaluation near mining areaand development of heavy metal pollution index. Applied Water Science **4,** 11–17.

Prasad B, Mondal KK. 2008. The impact of filling an abandoned open cast mine with fly ash on groundwater quality: a case study. Mine Water and the Environment **27,** 40–45.

Prasanna MV, Praveena SM, Chidambaram S, Nagarajan R, Elayaraja A. 2011. Evaluation of water quality pollution indices for heavy metal contamination monitoring: a case study from Curtin Lake, Miri City, East Malaysia. Environmental Earth Science. doi:10.1007/ s12665-012-1639-6.

Singh AK, Raj Beenu, Tiwari AK, Mahato MK, 2013b. Evaluation of hydrogeochemical processes and groundwater quality in the Jhansi district of Bundelkhand region, India, Environmental Earth Science **70(3),** 1225-1247.

Singh P, Tiwari AK, Singh PK. 2014. Assessment of Groundwater Quality of Ranchi Township Area, Jharkhand, India by Using Water Quality Index Method. International Journal of ChemTech Research **7(01),** 73-79.

Singh P, Tiwari AK, Singh PK. 2014. Hydrochemical characteristic and Quality Assessment of Groundwater of Ranchi Township Area, Jharkhand, India. Current World Environment **9(3),** 804-813.

Singh PK, Tiwari AK, Mahato MK. 2013a. Qualitative Assessment of Surface Water of West Bokaro Coalfield, Jharkhand by Using Water Quality Index Method. International Journal of ChemTech Research **5(5),** 2351-2356.

Sundaray SK. 2009. Application of multivariate statistical techniques in hydro-geochemical studies-a case study: BrahmaniKoel River (India). Environmental monitoring and assessment **164 (1-4),** 297-310.

Tiwari AK, Singh AK. 2014. Hydrogeochemical investigation and groundwater quality assessment of Pratapgarh district, Uttar Pradesh. Journal of the Geological Society of India **83(3),** 329-343.

Tiwari AK, Singh PK, Mahato MK. 2013. Chemistry of Groundwater and Their Adverse Effects on Human Health: A Review. Indian Journal of Health and Wellbeing **4(4),** 923-92.

Tiwari AK, Singh PK, Mahato MK. 2014. GIS-Based Evaluation of Water Quality Index of Groundwater Resources in west Bokaro Coalfield, India. Current World Environment **9(3),** 843-850.