Qualitative Evaluation of the Damodar River water flowing over the Coal mines and Industrial area

Apurba Ratan Ghosh and Ruma Banerjee

Department of Environmental Science, The University of Burdwan, Burdwan 713104, West Bengal

Abstract- The water quality parameters of the river Damodar flowing across the coal mines and industrial area was carried out in order to evaluate its suitability of irrigation application. Damodar River basin is the repository of 46% coal reserves in India and is one of the richest mineralized zones of the country with a high growth of mining and industrial development, demographic and urban growth extending over a large area of Jharkhand and West Bengal. The present study deals with the in depth investigation on spatio-temporal variations in chemical constituents, the distribution pattern of lead, manganese and iron and qualitative evaluation of the river water flowing across the coal mines and industrial areas. The results showed the pronounced temporal and spatial variations of river-water chemistry contaminated with mines and industrial effluents, viz., the mean concentration (mg/l) of heavy metals was in the order of Fe (0.536)> Mn (0.036) >Pb (0.019). The significant levels of electrical conductivity, sulphate and chloride in the river water were observed in the study area. The phenomenal combination of coal mining and allied activities can be related with the acceptability as well as suitability of its agricultural uses.

***Index Terms*-** Damodar River, physicochemical parameters, heavy metals, irrigation

I. INTRODUCTION

Coal mines and industrial effluents contain substantial amount of toxic chemical constituents; their long term and continuous discharge into the water body results in elevated concentrations in water and sediment. Rivers are highly heterogeneous at different spatial scales. Spatial and temporal variability in water chemistry in river are directly related to different factors like the natural processes and anthropogenic activities. River water quality is affected by a wide range of natural influences *viz*., geological, hydrological, and climatic factors (Bartram and Balance, 1996). On the other hand, various anthropogenic activities are also providing the major factors in determining the quality of the surface water through atmospheric pollution, agrochemicals, effluent discharges and land use. Natural processes influencing water quality include precipitation, weathering of rocks, and sediment transport, whereas anthropogenic activities include urban development and industrialization in the catchment area. According to Ouyang *et al*., 2006 the characterization of seasonal changes in water quality due to natural or anthropogenic inputs is an important aspect to study. Various rivers are facing the problem of contamination as well as (Sundaray *et al*., 2006; Chandra *et al*., 2006) and other parts of the world (Kakulu and Osibanjo, 1992; Cameron, 1996; Pennington *et al*., 2001; Adamiec and Helios-Rybicka, 2002; Kistemann *et al*., 2002; Ajibade, 2004; Parlak *et al*., 2006; Kannel *et al*., 2007; Yidana *et al*., 2008; Zheng *et al*., 2008).

Damodar river serves for a variety of purposes including drinking, agriculture and industry. The freshwater is a finite resource and essential for agriculture (Fattal *et al*., 1988; Fernandez-Alvarez *et al*., 1991; Thornburn *et al*., 2003). Usually, the concentration and composition of dissolved constituents in water determines its quality for irrigation usage. The degree of adverse effects on soil health and crop productivity is mainly related to the chemical composition of irrigation water. Increasing exploitation of water resources in the catchment area is responsible for much of pollution load (Güler *et al*., 2002; Pandey, 2006). The discharged effluent from industrial, municipal, or agricultural activities incorporating toxic substances into aquatic environment creating a problem of water pollution rendering water no longer fit for drinking, agriculture, and aquatic life (Fent, 2004; Bailey *et al*., 2005; Qadir *et al*., 2007).

II. MATERIALS AND METHODS

Description of the study area

Present investigation was carried out on river Damodar which originates near Chandwa village, Palamau district, on the Chota Nagpur Plateau in the Jharkhand state in eastern India, and flows through the cities Ramgarh, Bokaro, Dhanbad, Asansol, Durgapur, Bardwan and Hawrah, before ultimately joining the lower Ganga (Hooghly estuary) at Shayampur, 55 km downstream of Hawrah. Damodar is totally a rain fed river, during the monsoon months about 82% of the total annual precipitation flows through the river. Physicochemical parameters along with some heavy metals were assessed in three seasons (premonsoon, monsoon and postmonsoon season) in Barakar and Damodar river water in seven sampling stations (SSI-SSVII) designated as BRS (Barakar river site), PDR (Purbanchal), RGDR (Ramghat), DDRS (Dihika), HDR (Hirapur), MDR (Mejhiaghat) and DBDR (Durgapur Barrage). Water samples were collected from river Barakar (SS I) and river Damodar (SS II-VII) and each sampling station further divide into substations. The material used and methods followed during the course of studies are mentioned below.

Samples and sampling

The sampling and preservation of river water samples were carried out as per APHA (1998) guidelines. The samples were collected in 1L high-density polyethylene bottles prewashed with nitric acid and rinsed three to four times with the water sample before filling them to the required capacity. The unfiltered river water samples for total metal analysis were preserved using ultra pure nitric acid to lower the pH to <2.0 to prevent the precipitation of metals, and freeze for further physicochemical analysis. The samples thus preserved and brought to the laboratory for heavy metal analysis. Water pH, electrical conductivity (EC) was measured in the field immediately after the collection of the samples using pH and conductivity meters.

Physicochemical analysis

Water samples from river Barakar and Damodar were analyzed for pH, electrical conductivity (EC), sulphates (SO_4^{2-}), nitrates (NO_3^-), phosphates (PO_4^{3-}), chloride (Cl^-), manganese (Mn), lead (Pb), iron (Fe), sodium (Na^+), potassium (K^+) according to standard methods (APHA, 1998). In the laboratory, water samples were filtered through 0.45 millipore filter to separate the suspended sediments. Nitrate, iron and phosphate content were determined spectrophotometrically. Sulphate content was determined by $BaCl_2$ method. Na and K were measured by flame photometric method. The solution obtained after digestion were analyzed for heavy metals by AAS (GBC, Avanta). The results obtained from study are compared with the recommendation of IS irrigation standards (IS 11624: 1986) set by the Bureau of Indian Standards (BIS) and the FAO Standards for agricultural application (Pescod, 1992).

III. Results and Discussion

In this study, physicochemical characteristics of river water (Table I and II) are compared with the IS irrigation standards (IS 11624: 1986) as follows:

pH value ranged from 7.7 (MDR2) to 8.9 mg l^{-1} (RGDR2) during premonsoon, 7.5 (BRS2) to 8.6 mg l^{-1} (HDR2) during monsoon and 7.7 (HDR3) to 8.8 mg l^{-1} (BRS1) during postmonsoon seasons with a moderate range of fluctuations at different locations (Table I). pH in the water samples exceeds the FAO Standards (6.5 - 8) for agricultural application but within the recommended IS irrigation standards (5.5 - 9.0). The electrical conductivity indicates the dissolved materials in water and its values ranged from 190 (BRS3) to 470 mg l^{-1} (HDR4), 100 (MDR2&BRS2) to 540 mg l^{-1} (DDRS), 140 (HDR3) to 650 mg l^{-1} (DDRS) during premonsoon, monsoon and postmonsoon seasons respectively showing a wide range of fluctuations at different locations (Table I). Generally, conductance depends on the number of ions present in water. In the premonsoon season, the total volume of water decreases, as a result the conductivity increases. Electrical conductance values for the premonsoon season are higher than that for the monsoon. The electrical conductivity in the analyzed river was within the recommended FAO Standards (750-2000 µScm^{-1}) for agricultural application.

Phosphorus is an essential, limiting nutrient in freshwater ecosystems and its values ranged from 0.03 (HDR2) to 1.1 mg l^{-1} (MDR2) in premonsoon, 0.01 (BRS1) to 0.35 mg l^{-1} (HDR1) in monsoon and 0.01 (BRS2 and MDR1) to 0.42 mg l^{-1} (DBDR2) in postmonsoon times depicting a wide range of fluctuations at different locations (Table I). Chloride ion, the environmental contaminant, ranged from 2.18 (DBDR2) to 42.68 mg l^{-1} (HDR2) during premonsoon, 2.54 (PDR1) to 24.32 mg l^{-1} (DDRS) in monsoon and 7.32 (BRS1) to 31.24 mg l^{-1} (HDR4) during postmonsoon seasons with a wide range of fluctuations at different locations (Table I). Chloride is not absorbed by the soil but readily moves with the soil water. The concentrations of chloride in the river water are within the recommended IS irrigation standards (600 mg l^{-1}) (IS 11624: 1986) and FAO Standards (1100 mg l^{-1}) for agricultural application.

Nitrate is the indicative of organic pollution and its values ranged from 0.14 (MDR2) to 4.39 mg l^{-1} (PDR1) during premonsoon, 0.19 (MDR3) to 2.99 mg l^{-1} (DDRS) during monsoon and 0.09 (HDR3) to 2.89 mg l^{-1} (DDRS) during postmonsoon periods with a wide range of fluctuations at different locations (Table I). Nitrate, the most highly oxidized form of nitrogen compounds is commonly present in surface waters because it is formed as the end product of the aerobic decomposition of organic nitrogenous matter. The concentrations of nitrate in the river were within the recommended IS irrigation standards (18 mg l^{-1}) *i.e.*, (IS 11624: 1986). Sulphate in natural water body show the pollution status and anthropogenic load of it and here the values ranged from 10.83 (BRS1 and HDR4) to 89.67 mg l^{-1} (DDRS) during premonsoon, 7.35 (MDR3) to 79.28 mg l^{-1} (DDRSRS5) during monsoon and 7.25 (BRS2) to 81.92 mg l^{-1} (DDRS) during postmonsoon seasons with a wide range of fluctuations at different locations (Table I). The concentrations of sulphate in the river are within the recommended range of IS irrigation standards (1000 mg l^{-1}) and FAO Standards (1000 mg l^{-1}) for agricultural purposes. Sodium is considered as an important parameter determining the suitability of water for irrigation and its values ranged from 5.5 (BRS1) to 27.8 mg l^{-1} (DBDR2) during premonsoon, 6.52 (MDR4) to 28.3 mg l^{-1} (RGDR1) during monsoon and 8.24 (BRS2) to 25.0 mg l^{-1} (HDR1) during postmonsoon periods (Table I). High concentration of sodium is undesirable in water, sealing the pores of the soil and making it impermeable to flow of water. Potassium in nature occurs only as ionic salt and its values ranged from 1.2 (BRS2) to 13.6 mg l^{-1} (RGDR2), 1.1 (PDR1) to 7.22 mg l^{-1} (DDRS) and 1.32 (DBDR1) to 8.21 mg l^{-1} (HDR1) during premonsoon, monsoon and postmonsoon respectively disclosing a wide range of fluctuations at different locations (Table I).

Considerable amounts of manganese in natural waters have some harmful effects; here its values ranged from 0.011 (HDR2) to 0.205 mg l^{-1} (PDR1) during premonsoon, 0.007 (DBDR3) to 0.135 mg l^{-1} (HDR4) during monsoon and 0.008 (BRS3 and DBDR1) to 0.096 mg l^{-1} (MDR3) during postmonsoon seasons. Manganese in the river exceeds the FAO Standards (0.2 mg l^{-1}) for agricultural application and within the recommended IS irrigation standards (2.0 mg l^{-1}) (IS 11624: 1986). Lead is an extremely pervasive and toxic environmental contaminant in water; and its values ranged from 0.00 (BRS2 and PDR1) to 0.071 mg l^{-1} (HDR4), 0.00 (BRS3 and MDR1, 2, 3 and DBDR1) to 0.092 mg l^{-1} (DDRS) and 0.00 (BRS2,3, PDR2, RGDR1, MDR1,2,3 and DBDR1) to 0.092 mg l^{-1} (DDRS) during premonsoon, monsoon and postmonsoon respectively. The concentrations of lead (Pb) in the river are within the recommended FAO Standards (5.0 mg l^{-1}) for agricultural application. Iron is the most abundant metal in nature and its values ranged from 0.042 (HDR3) to 2.787 mg l^{-1} (DDRS) during premonsoon, 0.12 (RGDR2) to 1.52 mg l^{-1} (DDRS) during monsoon and 0.052 (MDR4 and DBDR2) to 3.55 mg l^{-1} (DDRS) during postmonsoon sampling periods depicting a wide range of fluctuations at different locations (Table II). Iron in the river exceeds the recommended IS irrigation standards (3.0 mg l^{-1}) (IS 11624: 1986) and within the recommended FAO Standards (5.0 mg l^{-1}) for agricultural utilization.

IV. CONCLUSION

The study reveals that there is a considerable variation in the concentration of heavy metals in water samples. These variations may be due to the change in the input of coal mines and industrial wastes being added to river. The study depicts that water quality of the river was influenced by the seasons. Water analysis indicates the presence of heavy metal pollutants and the concentration of metals in the study area is in the order of Fe> Mn>Pb. The results of the present study would indicate a remarkable increase of iron concentration at Dihika of the river Damodar due to the increased loading of the indiscriminate and long-term disposal of effluents from IISCO (Indian Iron and Steel Company) discharge. The coal mines had contributed to increase electrical conductivity, chloride and sulphate concentration in the river water. The results infer that in general, except some areas the water could be considered quite acceptable for irrigation purpose to some extent. At some of the places where the water is higher the permissible limit and doubtful category needs especial attention and better management.

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AUTHORS

First Author – Apurba Ratan Ghosh, Department of Environmental Science, The University of Burdwan, Burdwan 713104, West Bengal
Second Author – Ruma Banerjee, Department of Environmental Science, The University of Burdwan, Burdwan 713104, West Bengal, Email: banenvs@gmail.com

Table 1.1 Physico-Chemical characteristics of the Damodar River water

Parameter	pH			EC			PO_4^{3-}			SO_4^{2-}			NO_3^-			Cl^-			Na^+			K^+		
Standard 1	5.5 - 9.0			—			—			1000			18			600			—			—		
Standard 2	6.5 - 8			750 -2000			—			1000			—			1100			—			—		
SMPLE CODE	a	b	c	a	b	c	a	b	c	a	b	c	a	b	c	a	b	c	a	b	c	a	b	c
BRS1	8.1	7.9	8.8	260	200	210	0.08	0.01	0.04	10.83	10.24	16.56	2.76	0.46	1.35	41.36	7.32	7.32	5.5	10.5	10.24	3.4	2.5	4.10
BRS2	8.4	7.5	7.9	230	100	170	0.07	0.09	0.01	12.21	11.51	7.25	0.87	0.26	0.43	4.9	4.26	8.24	6.3	8.45	8.24	1.2	2.4	1.60
BRS3	8.2	7.6	7.8	190	120	170	0.08	0.02	0.03	18.11	7.69	10.57	4.19	0.63	0.76	7.8	11.25	12.32	6.7	7.25	9.42	4.5	4.5	2.50
PDR1	8.5	8.0	7.9	350	260	254	0.07	0.02	0.2	60.92	32.62	41.65	4.39	0.95	0.54	22.0	2.54	18.22	8.7	8.25	9.32	2.5	1.1	6.20
PDR2	8.6	7.8	8.0	220	140	190	0.07	0.15	0.16	47.72	9.65	28.35	0.72	0.83	0.76	24.04	6.32	17.25	8.1	8.35	16.32	5.4	2.5	1.35
RGDR1	8.4	8.4	8.1	250	180	210	0.04	0.08	0.09	38.87	21.65	22.98	0.53	0.95	0.94	11.54	9.32	21.32	6.8	28.3	22.35	5.6	4.25	5.21
RGDR2	8.9	7.6	7.9	220	140	210	0.14	0.06	0.08	42.92	25.36	31.54	0.95	0.63	0.54	10.45	10.32	10.22	10.4	12.5	18.2	13.6	4.32	1.45
DDRS	8.3	8.1	7.9	300	540	650	0.51	0.14	0.09	89.67	79.28	81.92	2.37	2.99	2.89	25.46	24.32	18.35	26.6	9.32	20.25	6.1	7.22	4.00
HRDR1	8.3	7.9	7.8	220	170	210	0.06	0.35	0.14	41.32	15.25	31.55	0.67	0.44	0.98	17.25	5.32	16.32	9.4	19.4	25.0	9.8	1.32	8.21
HRDR2	8.6	8.6	8.1	230	170	200	0.03	0.19	0.04	32.03	9.40	12.53	0.61	0.75	0.74	42.68	8.24	14.32	10.5	14	19.32	4.1	3.32	7.32
HRDR3	7.8	8.1	7.7	250	150	140	0.05	0.06	0.09	21.13	32.56	26.30	0.53	0.35	0.09	9.26	10.25	15.32	17.6	7.89	14.23	11.2	2.21	8.00
HRDR4	8.2	8.2	8.0	470	270	200	0.14	0.13	0.08	10.83	18.25	22.65	0.49	1.6	0.54	26.34	9.34	31.24	21.6	16.5	14.26	6.5	1.32	2.98
MDR1	7.9	7.9	7.9	300	190	210	0.08	0.02	0.01	26.60	12.50	38.36	0.90	0.28	0.76	11.0	9.21	9.32	16.4	22.6	18.25	10.5	3.32	4.32
MDR2	7.7	8	7.8	230	100	180	1.1	0.04	0.02	35.07	8.35	21.50	0.14	0.34	0.35	22.0	5.24	14.32	17.8	19.5	12.35	5.2	2.21	5.21
MDR3	7.8	7.8	7.8	210	150	180	0.09	0.07	0.08	28.00	7.35	11.64	0.29	0.19	0.43	12.02	8.54	9.32	24.4	10.2	20.3	4.5	4.21	2.31
MDR4	8.3	8.1	8.3	240	190	200	0.09	0.16	0.02	43.87	9.45	18.36	0.38	0.26	0.49	18.16	10.32	10.52	18.5	6.52	18.5	4.8	2.9	6.33
DBDR1	8.1	8.0	8.0	250	250	190	0.12	0.08	0.04	24.59	12.3	11.31	0.46	0.39	0.43	10.25	9.32	12.32	18.3	10.3	19.25	5.3	4.4	1.32
DBDR2	8.2	7.8	7.9	250	200	230	0.11	0.06	0.42	19.81	22.35	12.35	1.29	0.38	0.38	2.18	12.24	10.24	27.8	10.3	10.2	8.5	3.9	5.32
DBDR3	7.9	7.7	7.9	230	180	200	0.13	0.07	0.16	40.75	8.43	11.45	0.21	0.23	0.25	12.25	3.54	9.24	16.3	14.3	21.3	4.9	3.1	4.25
Min	7.7	7.5	7.7	190	100	140	0.03	0.01	0.01	10.83	7.35	7.25	0.14	0.19	0.09	2.18	2.54	7.32	5.5	6.52	8.24	1.2	1.1	1.32
Max	8.9	8.6	8.8	470	540	650	1.1	0.35	0.42	89.67	79.28	81.92	4.39	2.9	2.89	42.68	24.32	31.24	27.8	28.3	25	13.6	7.22	8.21
Mean	8.22	7.95	7.97	257.9	195	221	0.16	0.09	0.09	33.96	18.64	24.15	1.19	0.67	0.72	17.42	8.80	13.99	14.6	12.9	16.17	6.19	3.21	4.31
SEM	0.07	0.06	0.06	14.5	22.1	24.5	0.06	0.02	0.02	4.414	3.844	3.93	0.29	0.15	0.14	2.549	1.06	1.32	1.65	1.36	1.157	0.73	0.33	0.51
SD	0.31	0.27	0.24	63.21	96.5	107	0.25	0.08	0.1	19.24	16.76	17.17	1.28	0.65	0.6	11.11	4.63	5.754	7.19	5.93	5.042	3.16	1.46	2.24

Units: dissolved ions, mg l^{-1}, EC, µScm $^{-1}$
a premonsoon, b monsoon, c postmonsoon season
Standard 1: Indian standards - IS 11624: 1986,
Standard 2: FAO irrigation standards (Pescod, 1992)

Table II Heavy metal analysis of the river water samples

Parameter	Mn			Pb			Fe		
Standard 1	2.0			–			3.0		
Standard 2	0.2			5.0			5.0		
Sample code	a	b	c	a	b	c	a	b	c
BRS1	0.015	0.021	0.018	0.012	0.006	0.026	0.942	0.986	0.490
BRS2	0.014	0.024	0.013	0.000	0.002	0.000	0.516	0.752	0.196
BRS3	0.031	0.024	0.008	0.006	0.000	0.000	0.65	0.655	0.175
PDR1	0.205	0.015	0.025	0.000	0.002	0.002	0.848	0.421	0.745
PDR2	0.024	0.013	0.038	0.006	0.009	0.000	0.558	0.260	0.235
RGDR1	0.034	0.008	0.024	0.009	0.010	0.000	1.871	0.321	0.142
RGDR2	0.043	0.008	0.014	0.044	0.002	0.026	0.564	0.120	0.255
DDRS	0.029	0.024	0.014	0.006	0.092	0.092	2.787	1.520	3.550
HRDR1	0.018	0.013	0.023	0.012	0.087	0.009	0.148	0.215	0.641
HRDR2	0.011	0.095	0.005	0.057	0.019	0.019	0.253	0.120	0.421
HRDR3	0.163	0.025	0.009	0.007	0.010	0.001	0.042	0.422	0.985
HRDR4	0.169	0.135	0.016	0.071	0.050	0.050	0.763	0.632	0.175
MDR1	0.020	0.028	0.009	0.021	0.000	0.000	0.432	0.320	0.451
MDR2	0.022	0.017	0.033	0.046	0.000	0.000	1.311	0.196	1.421
MDR3	0.050	0.043	0.096	0.052	0.000	0.000	0.516	0.250	0.631
MDR4	0.027	0.077	0.005	0.008	0.002	0.002	0.19	0.421	0.052
DBDR1	0.034	0.024	0.008	0.039	0.000	0.000	0.764	0.422	0.198
DBDR2	0.024	0.021	0.034	0.014	0.004	0.004	0.469	0.142	0.052
DBDR3	0.020	0.007	0.023	0.006	0.002	0.087	0.785	0.245	0.352
Min	0.011	0.007	0.008	0.000	0.000	0.000	0.042	0.120	0.052
Max	0.205	0.135	0.096	0.071	0.092	0.092	2.787	1.520	3.550
Mean	0.050	0.033	0.027	0.022	0.018	0.019	0.758	0.443	0.588
SEM	0.013	0.008	0.005	0.005	0.007	0.007	0.149	0.080	0.183
SD	0.059	0.034	0.021	0.022	0.029	0.029	0.648	0.348	0.797

Units: mg $l^{-1,}$ a premonsoon, b monsoon, c postmonsoon season
Standard 1 Indian standards - IS 11624: 1986,
Standard 2 FAO irrigation standards (Pescod, 1992)