Evaluation of ecological characteristics of river Damodar Adjacent to Asansol Industrial Complex, West Bengal (India)

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ABSTRACT

The present study deals with the characterisation of Damodar river water and the status of distribution and environmental implications of metals in the river adjacent to Asansol industrial zone. The pH was found in the alkaline range (7.6-8.8), while conductance was obtained in the range of 180 - 530 µS/cm. The results of different parameters of Damodar river water are varied and displayed as 112.0 to 367.6 mg/l (TDS), 0.01 to 1.84 mg/l (PO$_4^{3-}$), 0.00 to 3.21 mg/l (NO$_3$), 6.36 mg/l to 19.32 mg/l (Na$^+$), 1.25 to 10.32 mg/l (K$^+$) and 7.46 to 49.84 mg/l (SO$_4^{2-}$), 0.14 to 1.214 mg/l (Fe), 0.0 to 0.095 mg/l (Pb), 1.610 to 8.91 mg/l (DO), 0.378 to 4.856 mg/l (BOD) and 7.22 to 32.56 mg/l (Cl$^-$). In general the concentration of metals in the river water in the study area is low but there is an elevated concentration of Pb and Cd found in some water samples drain off from the industrial activities. The results are generally showing a negative impact of the discharged effluents on the receiving part of river and suggest for a regular and continuous monitoring program.

Keywords: Damodar river, Ecological characteristics, Water quality, Metals.

1. Introduction

Quality of river water has become a critical issue in Damodar river basin areas where there is an intense industrial activity resulted into scarcity of noble uses of river water in this region so a water quality monitoring program is an utmost necessary for protection of freshwater resources. The river Damodar plays an important role in human development and is most important natural potential sources of industrial and irrigation water usages. Industrial effluents contain an appreciable amount of metals from their long term and continuous discharge into the water body describing elevated metal concentrations in aqueous environment. Low amounts of surface active contaminants can cause disturbance in the ecological equilibrium due to their toxic impacts on aquatic plants and animals (Gerlache et al., 1996). Contamination of metals in aquatic environments has been a major environmental threat due to its toxicity, abundance and persistence in nature, and subsequent accumulation in aquatic habitats (Sin et al., 2001). Introduction of large quantities of nutrients, mainly nitrogen and phosphorus to river waters can cause eutrophication problems (Jarrie et al., 1998; House and Denison, 1998; Hejzlar et al., 1996) which in turn deteriorate the quality of surface water due to contamination (Bukit, 1995; Drocl and Zagorc, 2002; Ekholm et al., 2000).

In fresh water systems, heavy metals have high potential for causing pollution and their residues in contaminated habitats may accumulate in microorganisms, aquatic flora and fauna, which in turn, may enter into the human food chain (Cook et al., 1990; Radojevic et al., 1996)
al., 1999; Loska and Wiechula, 2003). The pollution of water bodies reduces their quality and becomes stressful to aquatic biota (Gagné et al., 2002; van der Oost et al., 2003). Natural surface water bodies, such as rivers, lakes, reservoirs, and other impounding structures are major sources of raw water which is used for the community water supply after necessary treatment. Discharge of wastewater along with associated toxic compounds into aquatic systems represents an ongoing environmental problem due to their possible impacts on communities in the receiving river and poses a serious threat on biological communities (Bartsch, 1948; Hynes, 1960; Rörig et al., 2007). The heavy metal, lead (Pb) has no known physiological activity, but they are detrimental beyond a certain limit (Marschner, 1995; Bruins, et al., 2000) and affects haeme synthesis, causing anemia, kidney damage, and elevations in blood pressure when across the broad range of blood lead (Pb) levels (USEPA, 1990). The present work attempts to characterize the river water and the status of heavy metal distribution as well as incursion in the microenvironment of the river Damodar near Asansol industrial area.

2. Materials and Method

2.1 Collection of samples

Water samples were collected from river Damodar, a tributary of holy river Ganga in three replicates from different stations din three replicated uring premonsoon, monsoon and postmonsoon seasons near Asansol industrial area, Burdwan, West Bengal, India. Criteria for selection of sampling stations were based on the locations of industrial belt and land use pattern to quantify heavy metal concentration in the river water along with other ecological parameters. Electrical conductivity (EC) and pH values were measured in the field using a portable conductivity and pH meter. Grab samples of river water were taken at a depth of 6 cm below the surface in triplicate and mixed to get a composite sample for each spot. The samples for heavy metals were acidified with high-purity HNO₃ and then stored at approximately 4°C before analysis.

2.2 Laboratory methods

The collected samples were filtered (Whatman no. 42) and preserved with 6N of HNO₃ for further analysis. The various physicochemical attributes of water samples such as pH, Electrical Conductivity (EC), Total Dissolved Solids (TDS), Chloride (Cl⁻), Nitrate (NO₃⁻), Sulphate (SO₄²⁻), Phosphate (PO₄³⁻) and heavy metals like cadmium (Cd), iron (Fe), manganese (Mn), and lead (Pb) were analyzed following the standard procedure of APHA (1998). Concentration of heavy metals in water samples was determined with an atomic absorption spectrometer (GBC-Avanta).

3. Results and Discussion

Descriptive statistics of the analyzed chemical components of river Damodar are presented in Table 1–3. Any alteration in water pH is accompanied by the change in other physicochemical parameters; its values range from 7.6 (S2) to 8.8 (S7) during premonsoon; 7.7 (S3, S6, S7), 8.4 (S1) during monsoon and 7.6 (S4) to 7.9 in most of the sampling sites during postmonsoon sampling. The electrical conductivity is indicator of the amount of materials dissolved in water, which qualitatively reflects the status of inorganic pollutants; and its values range from 220 µS/cm (S4) to 530 µS/cm (S2) during premonsoon(Table 1); 180 µS/cm (S3) to 210 µS/cm (S6) during monsoon (Table 2) sampling and 200 µS/cm (S1, S4) to 280 µS/cm (S3, S6) during postmonsoon (Table 3) showing a wide range of
fluctuations at different locations. High Electrical conductivity in some areas indicates a larger quantity of dissolved mineral salts, thereby making it unsuitable for drinking purpose. Total dissolved solids (TDS) indicates the general nature of water quality or salinity; and its values range from 132.4 mg/l (S4) to 367.6 mg/l (S2) during premonsoon (Table 1); 112 mg/l (S4) to 152 mg/l (S6) during monsoon (Table 2) and 121 mg/l (S6) to 175 mg/l (S3) during postmonsoon (Table 3) depicting with a wide range of fluctuations at different locations. High Total dissolved solids (TDS) in some areas are observed due to drain off effluents discharged by industrial process.

**Table 1: Descriptive statistical analysis of various physicochemical parameters of river Damodar (premonsoon)**

| Sites | pH  | EC  | TDS  | DO  | BOD | Pb  | Fe  |
|-------|-----|-----|------|-----|-----|-----|-----|
| S1    | 8.7 | 320 | 212.5| 5.637| 2.386| 0.002| 0.414|
| S2    | 7.6 | 530 | 367.6| 7.216| 4.856| 0.007| 1.214|
| S3    | 8.2 | 410 | 257.4| 5.675| 1.216| 0.017| 0.67 |
| S4    | 7.8 | 220 | 132.4| 7.65 | 3.972| 0.027| 0.656|
| S5    | 8.6 | 310 | 215.8| 5.675| 3.243| 0.0  | 0.245|
| S6    | 8.5 | 440 | 257.6| 4.026| 2.019| 0.007| 0.896|
| S7    | 8.8 | 310 | 210.5| 3.648| 1.656| 0.001| 0.479|
| Min   | 7.6 | 220 | 132.4| 3.648| 1.216| 0.0  | 0.245|
| Max   | 8.8 | 530 | 367.6| 7.65 | 4.856| 0.027| 1.214|
| Ave   | 8.31| 362.86| 236.26| 5.647| 2.764| 0.009| 0.653|
| SE±   | 0.18| 44.98| 31.52| 0.558| 0.546| 0.004| 0.141|

**Table 1: Continued**

| Sites | PO₄³⁻ | NO₃⁻ | Na⁺ | K⁺ | Cl⁻ | SO₄²⁻ |
|-------|-------|------|-----|----|-----|-------|
| S1    | 0.95  | 3.21 | 19.32| 4.51| 29.56| 22.11 |
| S2    | 1.84  | 1.45 | 11.35| 2.21| 32.56| 49.84 |
| S3    | 0.84  | 2.05 | 17.6 | 6.5 | 18.32| 32.21 |
| S4    | 0.06  | 1.46 | 11.32| 2.5 | 14.2 | 28.32 |
| S5    | 0.88  | 2.89 | 14.32| 5.51| 21.56| 21.71 |
| S6    | 1.42  | 0.98 | 17.35| 6.21| 26.85| 42.14 |
| S7    | 0.95  | 2.75 | 17.32| 4.99| 22.23| 26.75 |
| Min   | 0.06  | 0.98 | 11.32| 2.21| 14.2 | 21.71 |
| Max   | 1.84  | 3.21 | 19.32| 6.5 | 32.56| 49.84 |
| Ave   | 0.99  | 2.11 | 15.51| 4.63| 23.61| 31.87 |
| SD±   | 0.6   | 0.88 | 3.41 | 1.85| 7.02 | 11.27 |
| SE±   | 0.25  | 0.36 | 1.39 | 0.76| 2.87 | 4.6  |

Generally high levels of phosphorous increase the growth of aquatic vegetation in water bodies as well as and increase the oxygen demand. Phosphorus is a key nutrient element responsible for the eutrophication of freshwater system. Phosphate is always indicative of eutrophy; and its values range from 0.06 mg/l (S4) to 1.84 mg/l (S2) during premonsoon season; 0.01 mg/l (S7) to 0.24 mg/l (S6) during monsoon and 0.04 mg/l (S1,S4,S7) to 0.84 mg/l (S6) during postmonsoon with a wide range of fluctuations at different locations. Sulphate concentration in the study area ranges from 21.71 mg/l (S5) to 49.84 mg/l (S2) during premonsoon; 9.74 mg/l (S5) to 36.53 mg/l (S2) during monsoon and 7.46 mg/l (S7) to 29.52 mg/l (S4) during postmonsoon showing a wide range of fluctuations at different locations. The concentration of nitrate in the Damodar river ranges from 0.98 (S6) to 3.21
mg/l (S1) during premonsoon, 0.00 (S4) to 2.25 (S2) mg/l during monsoon, 0.14 (S3) to 1.55 mg/l (S5) during postmonsoon. High levels of nitrate in the downstream of the study area indicate pollution from livestock wastes, fertilizers, landfills and nonpoint sources of pollution, such as runoff from vast areas under agricultural practices.

Table 2: Descriptive statistical analysis of various physicochemical parameters of river Damodar (monsoon)

| Sites | pH   | EC   | TDS   | DO     | BOD   | Pb     | Fe     |
|-------|------|------|-------|--------|-------|--------|--------|
| S1    | 8.4  | 190  | 119.5 | 6.845  | 1.988 | 0.0027 | 0.154  |
| S2    | 7.9  | 210  | 145   | 1.61   | 1.975 | 0.0    | 0.253  |
| S3    | 7.7  | 180  | 118.6 | 6.845  | 1.578 | 0.0    | 0.592  |
| S4    | 8    | 190  | 112   | 6.845  | 0.764 | 0.0    | 0.347  |
| S5    | 7.8  | 190  | 119.5 | 6.442  | 0.451 | 0.003  | 0.154  |
| S6    | 7.7  | 210  | 152   | 4.026  | 0.764 | 0.0    | 0.253  |
| S7    | 7.7  | 190  | 119.5 | 7.297  | 0.58  | 0.0    | 0.14   |
| Min   | 7.7  | 180  | 112   | 1.61   | 0.451 | 0.0    | 0.14   |
| Max   | 8.4  | 210  | 152   | 7.297  | 1.988 | 0.003  | 0.592  |
| Ave   | 7.89 | 194.29 | 126.59 | 5.702 | 1.157 | 0.0    | 0.27   |
| SD±   | 0.25 | 11.34 | 15.34 | 2.172  | 0.668 | 0.0    | 0.16   |
| SE±   | 0.1  | 4.29  | 5.8   | 0.887  | 0.252 | 0.0    | 0.06   |

The sodium concentration in the study area ranges from 11.32 (S4) to 19.32 mg/l (S1) during premonsoon, 6.36 (S3) to 14 (S2) mg/l during monsoon, 8.32 (S2, S6) to 18.44 mg/l (S5) during postmonsoon. The potassium concentration in the study area ranged from 2.21 (S2) to 6.5 mg/L (S3) during premonsoon, 1.25 (S1) to 6.32 (S2) mg/l during monsoon, 2.45 (S7) to 10.32 mg/l (S4) during postmonsoon. Iron is the most abundant metal in nature because it is one of the most common elements in the earth’s crust. Iron concentration in the study area ranges from 0.245 (S5) to 1.214 mg/l (S2) during premonsoon, 0.14 (S7) to 0.592 (S3) mg/l during monsoon, 0.234 (S3) to 1.125 mg/l (S7) during postmonsoon. Lead (Pb) concentration in the study area ranges from 0.0 (S5) to 0.027 mg/l (S4) during premonsoon, 0.0 in most of the monitoring stations, to 0.003 (S5) mg/l during monsoon, 0.008 (S4) to 0.095 mg/l (S2) during postmonsoon.
Table 3: Descriptive statistical analysis of various physicochemical parameters of river Damodar (postmonsoon)

| Sites | pH  | EC  | TDS  | DO   | BOD  | Pb   | Fe   |
|-------|-----|-----|------|------|------|------|------|
| S1    | 7.9 | 200 | 121.5| 7.297| 1.621| 0.042| 1.125|
| S2    | 7.8 | 270 | 161  | 6.845| 3.629| 0.095| 0.49 |
| S3    | 7.9 | 280 | 175.5| 7.702| 0.405| 0.008| 0.234|
| S4    | 7.6 | 200 | 129.9| 8.91 | 1.408| 0.008| 0.66 |
| S5    | 7.9 | 220 | 131.5| 8.1  | 2.315| 0.022| 0.896|
| S6    | 7.8 | 280 | 171  | 6.89 | 0.405| 0.045| 0.49 |
| S7    | 7.9 | 200 | 121.5| 5.234| 0.378| 0.008| 1.125|
| Min   | 7.6 | 200 | 121.5| 5.234| 0.378| 0.008| 0.234|
| Max   | 7.9 | 280 | 175.5| 8.91 | 3.629| 0.095| 1.125|
| Ave   | 7.83| 235.71 | 144.55| 7.282| 1.451| 0.036| 0.71 |
| SD±   | 0.11| 39.09 | 23.71 | 1.156| 1.215| 0.029| 0.34 |
| SE±   | 0.04| 14.77 | 8.965 | 0.437| 0.459| 0.011| 0.12 |

Table 3: Continued

| Sites | PO₄³⁻ | NO₃⁻ | Na⁺ | K⁺ | Cl⁻ | SO₄²⁻ |
|-------|-------|------|-----|----|-----|-------|
| S1    | 0.04  | 1.35 | 8.54| 2.9| 7.92 | 8.25  |
| S2    | 0.05  | 0.74 | 8.32| 2.65| 24.32| 10.45 |
| S3    | 0.05  | 0.14 | 12.45| 4.21| 14.32| 11.45 |
| S4    | 0.04  | 0.75 | 12.2| 10.32| 17.3 | 29.52 |
| S5    | 0.08  | 1.55 | 18.44| 2.9 | 17.92| 10.17 |
| S6    | 0.84  | 1.44 | 8.32| 4.57| 18.76| 19.33 |
| S7    | 0.04  | 1.29 | 8.54| 2.45| 7.22 | 7.46  |
| Min   | 0.04  | 0.14 | 8.32| 2.45| 7.22 | 7.46  |
| Max   | 0.84  | 1.55 | 18.44| 10.32| 24.32| 29.52 |
| Ave   | 0.16  | 1.03 | 10.97| 4.28| 15.39| 13.8  |
| SD±   | 0.29  | 0.51 | 3.77| 2.78| 6.12 | 7.94  |
| SE±   | 0.11  | 0.19 | 1.42| 1.05| 2.31 | 3     |

Dissolved oxygen is the pulse of water body and is also one of the most important parameters for maintaining the quality of water. It depends on a number of physical, chemical, biological and microbiological processes and its deficiency directly affects the natural balance of aquatic ecosystem. The values of dissolved oxygen also show lateral, spatial and seasonal variations depending on industrial, human and thermal activity. In the study area, the DO content ranges from 3.648 (S6), to 7.650 (S4) mg/l during premonsoon, 1.610 (S2) to 7.297 mg/l (S7) during monsoon, 5.234 (S6) to 8.91 mg/l (S4) during postmonsoon. In the present study, the lowest values of dissolved oxygen (DO) are observed in premonsoon season and highest values in postmonsoon season. The high DO values in postmonsoon are possibly due to low water temperature and considerable growth of algae, which release appreciable amount of oxygen as a result of photosynthetic activities. The deficiency of DO content during premonsoon might be due to active utilization in bacterial decomposition of organic matter. High level of DO in sampling sites of the river indicates a rapid aerobic oxidation of biological substances. In the study area the BOD content ranges from 1.216 (S3) to 4.856 mg/l (S2) during premonsoon, 0.451 (S5), to 1.988 (S1) mg/l during monsoon, 0.378 (S7) to 3.629 mg/l (S2) during postmonsoon. Low BOD in postmonsoon was mainly due to higher...
algal productivity, along with increased solubility of oxygen at low temperatures, while premonsoon maxima resulted from the rapid utilization of oxygen at higher temperatures (Chetana and Somashekhar 1997). Direct discharge of untreated domestic and industrial waste in the study zone is responsible for the high organic pollution, and lead to very high BOD.

Statistical calculation carried out in terms of linear regression model with fitted line plot diagram between phosphate and nitrate concentration (mg/l) showing $R^2$ value 10.1% (Fig. 1.1) i.e. lowly correlated and pH and Conductivity ($\mu$S/cm) showing R2 value 14.8 %. (Fig.1.2). Linear regression relationship between the mean values of sodium versus potassium ion (mg/l) of premonsoon, monsoon and postmonsoon seasons depict the R2 value 23.3 % (Fig. 1.3) and the linear relation between the mean values of iron versus lead (mg/l) of premonsoon, monsoon and postmonsoon seasons representing the $R^2$ value 63.3% (Fig. 1.4). The mean values of BOD (mg/l) and DO (mg/l) shows the $R^2$ value 0.1% (Fig. 1.5) indicating a moderate relation between the two variables.

![Regression Plot](image)

**Figure 1.1**: Regression equation between the mean values of nitrate versus phosphate
Figure 1.2: Regression equation between the mean values of pH versus electrical conductivity

Regression Plot

\[ pH = 0.42765 - 0.0015821 \times EC \]

\[ s = 0.201027 \quad R^2 = 14.8 \% \quad R^2(\text{adj}) = 0.0 \% \]

Figure 1.3: Regression equation between the mean values of sodium versus potassium ion

Regression Plot

\[ \text{Sodium} = 14.7759 - 0.604770 \times \text{Potassium} \]

\[ s = 1.18973 \quad R^2 = 23.3 \% \quad R^2(\text{adj}) = 8.9 \% \]
4. Conclusion

The result of the study zone showed a negative impact of the discharged industrial effluents on the receiving site of the river and asks for a regular and consistent monitoring to ensure best management practices. Present study reveals that there is a considerable variation in the concentration of heavy metals in different spots of river water. The variations may be due to...
the change in the input of industrial waste being added to river. BOD values in some areas indicate serious organic load in the riverine system, which may adversely affect the water quality and biodiversity. A trend of BOD level in downstream river sites, indicating the self-purifying capacity of the riverine ecosystem is acting. Human activities at the basin scale have been increasingly recognized as major threats to the ecological equilibrium of river Damodar.

5. References

1. APHA (American Public Health Association), (1998). Standard Methods for the Examination of Water and Waste Water, APHA Washington, 20th edition.

2. Bartsch A.F., 1948, Biological aspects of stream pollution. Sewage Works Journal, 20, pp 292–302.

3. Bruins M.R., Kapil S., and Oehme F.W., 2000, Microbial resistance to metals in the environment, Ecotoxicology and Environmental Safety, 45, pp 198-207.

4. Bukit N.T., 1995, Water quality conservation for the Citarum river in west Java, Water Science and Technology, 31, pp 1–10.

5. Cook J.A., Andrew S.M., and Johnson M.S., 1990, Lead, zinc, cadmium and fluorspar tailings, Water, Air, & Soil Pollution, 51, pp 43–54.

6. Drolc A., and Zagorc K.J., 2002, Estimation of sources of total phosphorus in a river basin and assessment of alternatives for river pollution reduction, Environment International, 28, pp 393–400.

7. Ekholm P., Kallio K., Salo S., Pietilainen O.P., Rekolainen S., Laine Y., and Joukola M, 2000, Relationship between catchment characteristics and nutrient concentrations in an agricultural river system, Water Research, 34, pp 3709–3716.

8. Gagné F., Blaise C., Aoyama I., Luo R., Gagnon C., and Couillard Y., 2002, Biomarker study of a municipal effluent dispersion plume in two species of freshwater mussels, Environmental Toxicology, 17, pp 149–59.

9. Gerlache M., Kauffmann J.M., Quarin G., Vire J.C., Bryant G.A., and Talbot J.M., 1996, Electrochemical analysis of surfactants: an overview, Talanta, 43, pp 507–519.

10. Hejzlar J., Vyhnalek V., Kopacek J., and Duras J., 1996, Sources and transport of phosphorus in the Ultava river basin. Water Science and Technology, 33, pp 137–144.

11. House W., and Denison F., 1998, Phosphorus dynamics in a lowland river, Water Research, 32, pp 1819–1830.

12. H.B.N. Hynes., (1960), The Biology of Polluted Waters. Liverpool University Press, 103-108.
13. Jarrie H., Whitton B., and Neal C., 1998, Nitrogen and phosphorus in east coast British rivers Speciation sources and biological significance, Science of the Total Environment, 210, pp 79–109.

14. Loska K., and Wiechula D., 2003, Application of principal component analysis of source of heavy metal contamination in surface sediments from the Rybnik Reservoir, Chemosphere, 57, pp 723–733.

15. H. Marschner, (1995), Mineral nutrition of higher plants, Academic Press, London.

16. M. Radojevic, N. Vladimir, (1999). Practical environmental analysis. UK: Paston Prepress Ltd, 8-16.

17. Rörig L.R., Tundisi J.G., Schettini C.A.F., Pereira-Filho J.A., Menezes J.T., Almeida T.C.M., Urban S.R., Radetski C.M., Sperb R.C., Stramosk C.A., Macedo R.S., Castro-Silva M.A., and Perez J.A.A., 2007, From a water resource to a point pollution source: the daily journey of a coastal urban stream, Brazilian Journal of Biology, 67, pp 597–609.

18. Sin S.N., Chua H., Lo W., Ng L.M., 2001, Assessment of heavy metal cations in sediments of Shing Mun river, Hong Kong1, Environment International, 26, pp 297–301.

19. U.S. Environmental Protection Agency., (1990), National Primary and Secondary Drinking Water Regulations: Synthetic Organic Chemicals and Inorganic Chemicals and Microorganisms. Federal Register, 50, pp 46937–47022.

20. van der Oost R., Beber J., and Vermeulen N.P.E., 2003, Fish bioaccumulation and biomarkers in environmental risk assessment: a review, Environmental Toxicology and Pharmacology, 13, pp 57–149.