

# Hydrochemical Variations in Dissolved Trace Metals of Surface Water Sources in the Jia-Bharali River Basin, India

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**Abstract**—The present study has been undertaken to establish the spatial and seasonal variation patterns in the surface water quality of the Jia- Bharali river basin, Assam, India with respect to the concentrations of dissolved trace metals (As, Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb and Zn). The monitoring was done during wet and dry seasons for a period of 3 years from three types of sources – ponds, rivers and streams on both banks of the Jia - Bharali River. The surface water has As content (0.10 – 6.18 µg/L). 20.1 % of the samples in the rainy season and 34.4 % in the dry season show Cd content higher than the desirable limit of 0.005 mg/L. 54.4 % of the surface water samples also have Pb above the permissible limit of 0.05 mg/L during the rainy season while in the dry season, 85.8% surface water sources show Pb above the limit. Similarly, 60.1 % water samples during the wet season and 80.1 % water samples during the dry season show Ni content above the permissible limit of 0.02 mg/L. Zn content of the surface water sources are however very low throughout the year. The results are correlated to the dominant geological features, local environmental setting, and differences in water utilization by the people, variations in runoff volume, etc.

**Index Terms** – Surface water quality; Jia Bharali river basin; Brahmaputra plain; Trace metals

## I. INTRODUCTION

The river Jia Bharali is one of the major south flowing tributaries of the river Brahmaputra with a major part of its catchment within Arunachal Himalaya. The Jia Bharali is a highly dynamic braided river, often changing its course and in the process, making large tracts of agricultural land non-productive by depositing layers of sand. Surface waters are most susceptible to pollution as runoffs and wastewaters find their easy entry. Anthropogenic influences such as urban, industrial and agricultural activities increasing exploitation of water resources as well as natural processes, such as precipitation inputs, erosion, weathering of crustal materials, etc., degrade surface waters often making their use hazardous for drinking, industrial, agricultural, and other uses ([1], [2]). It is commonly accepted that the concentrations of trace metals in surface water, which are available to aquatic organisms, are lower than the total concentrations of those metals [3]. The biological response is very often proportional to the labile metal concentrations [4], which are therefore usually regarded as bio available metal concentrations.

The people in the Jia-Bharali river basin seldom use the surface water for drinking, but they use it for various other household purposes including irrigation of crops, rearing of poultry and fish, etc. The surface water quality of the basin is thus intimately connected with public health and is very important for sustaining aquatic life in the area. The present study assesses the seasonal and temporal variability of surface water quality with respect to the trace metal content in the Jia Bharali river basin and estimates their susceptibilities to changes on the ground.

## II. MATERIALS AND METHOD

### A. Study area

The Jia Bharali river catchment area is bounded by longitudes 92° 00' - 93°25'E and latitudes 26° 39' - 28°00' N (Fig. 1). In Arunachal Pradesh, the river is known as Kameng and enters the plains just to the north of Bhalukpung (92°65'E:27°01'N) and got its name as Jia Bharali (Jia meaning alive in local language). A large flood plain of a meandering river system can be identified adjacent to the present channel as a distinct geomorphic entity towards west. It is dotted with numerous meander scars, remnant channels, misfit streams, inactive floodplains and natural levee. The region has extensive tea-plantations on the higher topographic surfaces and paddy fields generally occupying the topographic lows. The northern portion along the foothills of Arunachal Himalaya is made up of Reserve Forests (e.g. Chariduar, Balipara Reserve forests) and sparsely populated forest-villages. The region abounds in biodiversity with evergreen and deciduous trees of many types. The recorded maximum and minimum annual discharge of the Jia- Bharali River at the gauging station N.T. Road Crossing [5] is 9,939 cumec and 53 cumec respectively. The average annual suspended sediment load of the river recorded at this gauging site was 2,143 ha-m [5]. The climate of the study area is sub-tropical in nature with hot and humid summer, (average temperature 29° C), heavy monsoon rain (May to September) followed by inundation of almost the entire area, dry autumn and cold winter (November to February, average temperature 16° C). The Jia-Bharali River basin experiences 4 to 5 major floods annually during the monsoon periods

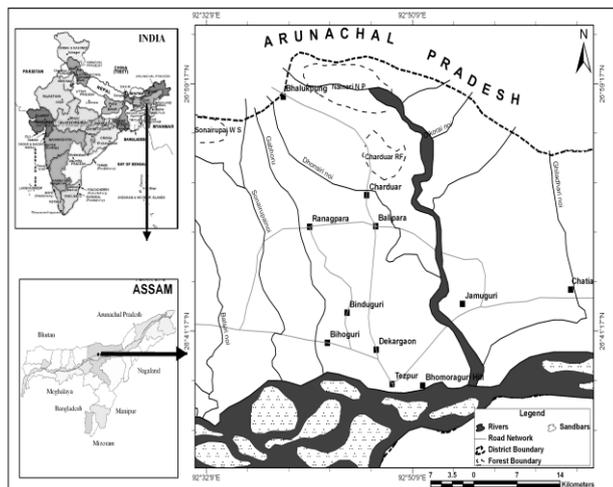


Figure 1: Location map of the study area

### B. Water sampling and chemical analysis

Water samples from 35 sources consisting of streams, rivers, and public ponds spread over the entire area of the Jia Bharali river basin were collected from pre-selected locations (Fig. 2) twice a year (monsoon and post-monsoon) for a three year period from 2008 to 2010. Standard methods [6] were followed in collection, storage and analysis of the water samples.

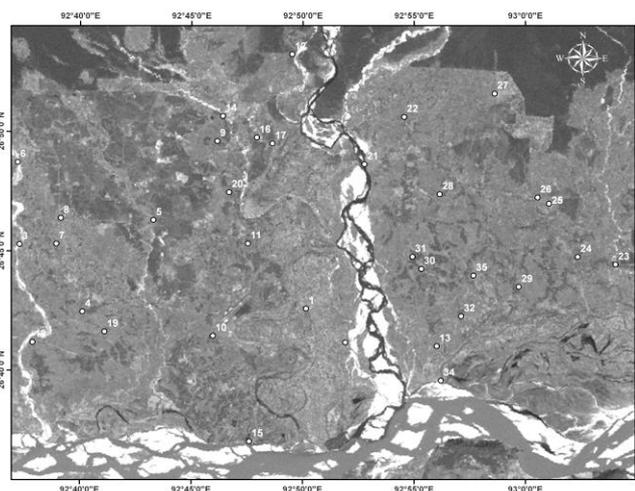


Figure 2: Surface water sampling in the study area.

The metals were estimated in the sample solution by aspirating the sample solution directly into the appropriate flame in an Atomic Absorption Spectrometer (Varian SpectrAA 220) following standard acid digestion technique. Arsenic was estimated by hydride generation atomic absorption spectrometry (HGAAS) using Varian VGA-77 vapour generation assembly.

### III. RESULTS AND DISCUSSION

Since most of the water sources are being used by the people for domestic purposes (including cooking and in some cases for drinking), the results have been compared with WHO guidelines for drinking water quality to assess their suitability for consumption. Basic statistics of the water quality data with respect to minimum, maximum, and mean values along with standard deviation are given in Tables 1 and 2.

The results can be discussed as follows:

Table 1: Trace metal compositions of the surface water sources. (BDL: Below detection limit, SD standard deviation; As  $\mu\text{g/L}$ ; all other parameters in  $\text{mg/L}$ )

Trace metals	Wet Season				
	Min	Max	Mean	SD	Min
As	BDL	2.95	0.78	0.79	BDL
Cd	BDL	0.012	0.003	0.003	BDL
Co	BDL	0.059	0.018	0.014	BDL
Cu	BDL	0.13	0.04	0.04	BDL
Cr	0.01	0.14	0.07	0.03	0.03
Fe	0.16	1.11	0.43	0.29	0.24
Mn	BDL	0.13	0.04	0.03	BDL
Ni	BDL	0.10	0.04	0.03	BDL
Pb	BDL	0.14	0.06	0.04	BDL
Zn	BDL	0.07	0.02	0.02	BDL

Table 2: Trace metal compositions of the surface water sources. (BDL: Below detection limit, SD standard deviation; As  $\mu\text{g/L}$ ; all other parameters in  $\text{mg/L}$ )

Trace Metals	Dry season				
	Min	Min	Max	Mean	SD
As	BDL	BDL	6.18	2.32	1.42
Cd	BDL	BDL	0.035	0.008	0.009
Co	BDL	BDL	0.094	0.040	0.027
Cu	BDL	BDL	0.18	0.10	0.04
Cr	0.01	0.03	0.29	0.13	0.06
Fe	0.16	0.24	2.90	0.81	0.56
Mn	BDL	BDL	0.16	0.08	0.04
Ni	BDL	BDL	0.15	0.07	0.04
Pb	BDL	BDL	0.25	0.11	0.06
Zn	BDL	BDL	0.11	0.04	0.03

#### A. Arsenic (As)

In the present study, arsenic concentration of the surface water samples was in the range of BDL to 2.95  $\mu\text{g/L}$  (wet seasons) and from BDL to 6.18  $\mu\text{g/L}$  in the dry seasons. All of the values are below the recommended maximum permissible limit of drinking water standards (0.01  $\text{mg/L}$  or 10  $\mu\text{g/L}$ , [7]). The values are distributed in the ranges as shown in Table 2:

Range	% of surface water sources	
	Wet Season	Dry Season
BDL	22.9	2.7
< 1.0 $\mu\text{g/L}$	42.8	17.2
1.0 – 10.0	34.3	80.1
> 10 $\mu\text{g/L}$	NIL	NIL
Total	100	100

Arsenic commonly occurs in the form of the oxyanions, arsenite and arsenate, in natural waters. The form and concentration of arsenic species are usually determined by pH, the redox potential, and such other factors that control the speciation and the mobility of arsenic in the environment. It has already been shown that the surface water sources of the present study are considerably rich in Fe and this may be one reason for low values of total arsenic in the water samples. Inorganic arsenic (III) species are highly toxic, and various diseases, including lung cancer, liver cancer, renal cancer, and

skin cancer or perturbations of the respiratory, gastrointestinal, cardiovascular, nervous [8].

#### B. Cadmium (Cd)

Cadmium is a biologically nonessential teratogen, carcinogen, and probable mutagen usually present in water as a result of discharges from human activities [9]. Cd content of the surface water sources varied from BDL to 0.012 mg/L (mean 0.003 mg/L) in the wet seasons and from BDL to 0.035 mg/L (mean 0.008 mg/L) in the dry seasons. Since industrial activities are virtually absent in the study area, the most likely sources of Cd must have been lithological or application of fertilizers in the catchment. There is, however, a high concentration of cadmium in the studied surface water sources with 20.1 % of the samples in the rainy season and 34.4 % in the dry season having cadmium content higher than the desirable limit of 0.005 mg/L [10]. However, in the dry seasons, 28.6 % sources and in the wet seasons, 37.2 % of the surface water sources had Cadmium below the detection limit. The distribution of Cd in the surface water is relatively consistent throughout the study area, implying that it could have been derived from non-point sources such as agricultural runoff.

#### C. Cobalt (Co)

The cobalt contents of the surface water sources in the study area are in the ranges of BDL to 0.059 mg/L with a mean value of 0.018 mg/L in the wet seasons and from BDL to 0.094 mg/L with a mean value of 0.040 mg/L in the dry seasons. Most of the surface water sources show enrichment of the Co content. Also, the dry season Co content is higher than that of the wet season. 25.8 % sources (mainly river) in the wet season and 11.5 % sources in the dry season show cobalt content below the detection limit. Cobalt did not show any systematic variation so far as spatial distribution is concerned.

#### D. Copper (Cu)

Copper content of the surface water samples in the present study is in the ranges of BDL to 0.13 mg/L (mean 0.04 mg/L) in the wet seasons and BDL to 0.18 mg/L (mean 0.10 mg/L) in the dry seasons. The average copper concentration of the water samples is far below the desirable value of 2 mg/L [7]. However, the dry seasons show more copper content. 91.5 % of the surface water sources have higher Cu concentration in the dry season than in the wet season. It is observed that the river water samples have lower Cu content than the pond water samples for both the wet and dry seasons. Application of organic or mineral fertilizers, other crop protection products, sewage sludge, etc. [11] may add Cu. Though copper is not a cumulative systemic poison, large dose (>100 mg) of Copper are harmful to humans and might cause central nervous system disorder, failure of pigmentation of hair and adverse effects on Fe-metabolism that results in liver damage [12].

#### E. Chromium (Cr)

High doses of chromium cause liver and kidney damage [13]. It exists in both +3 and +6 oxidation states with the latter being more stable and more toxic. Cr (VI) is also the more mobile form in the soil environment than the trivalent form [14]. Cr (III) is considered as an essential trace element for the maintenance of an effective glucose, lipid and protein metabolism in mammals. On the other hand, Cr (VI) is toxic for biological systems. In the present work, the total Cr concentration (both Cr (III) and Cr (VI)) varied from low to

sufficiently high values, i.e. in the range of 0.03 – 0.29 mg/L in the dry seasons and 0.01 – 0.14 mg/L in the wet seasons. However, 94.4 % of the surface water sources show more Cr concentration in the dry season. Thus, Cr characteristics of the studied aquifers can be presented as,

Range	Number of surface water sources	
	Wet Season	Dry Season
BDL	NIL	NIL
≤ 0.05	11	3
0.051 – 0.11	20	9
> 0.11	4	23
Total	35	35

Reference [10] has suggested a maximum permissible value of 0.05 mg/L for Cr in drinking water and most of the sources in the studied area have Cr exceeding this value. So, it is clear that most of the surface water sources of the study area had high Cr content in both the wet and the dry seasons. Chromium may enter water from various industrial processes through discharge of effluents, but this could be ruled out in the present study area because of almost complete absence of industry.

#### F. Iron (Fe)

Iron in surface water is generally present in the ferric state. The concentration of iron in well aerated water is seldom high, but under reducing conditions, which may exist in some ground water, lakes or reservoirs and in the absence of sulfide and carbonate, high concentration of soluble ferrous iron may be found. The other reasons for the high concentration of this element may be the removal of dissolved oxygen by organic matter leading to reduced conditions. Iron dissolution in surface water increases further due to bacteriological degradation of organic matter under reducing conditions that lead to the formation of various humic and fulvic compounds ([15], [16]). In the present work, iron contents (considering average values) varied from 0.16 to 1.11 mg/L in the wet seasons and 0.24 to 2.90 mg/L in the dry seasons with most sources exceeding WHO [7] limit (0.3 mg/L) for drinking water. Fe, along with Mn, can affect the organoleptic quality of water as well as coloration of the water thus initiating sedimentation in the system. The iron content varies from location to location depending on the soil characteristics and it can be summarized as:

Range	Number of surface water sources	
	Wet Season	Dry Season
< 0.3 mg/L	19	2
0.3 – 1.5 mg/L	16	30
1.5 – 3.0 mg/L	NIL	3
Total	35	35

It is obvious that in the wet season 54.4% surface water sources have Fe content below the maximum permissible limit while in the dry season, Fe content increases to well above this limit for 94.4% surface water sources, mainly due to the reduction in

water volume. 85.8% sources in the dry seasons and 45.8% sources in the wet seasons show Fe content in the range of 0.3 – 1.5 mg/L.

#### G. Manganese (Mn)

The surface water samples of the study area show Mn content in the range of BDL – 0.13 mg/L (mean 0.04 mg/L) in the wet seasons and BDL – 0.16 mg/L (mean 0.08 mg/L) in the dry seasons. Obviously dilution by rain water lowers the Mn-content in the wet season. Only 8.6 % of the samples in the wet seasons and 34.3 % samples in the dry seasons have Mn above the permissible limit of 0.1 mg/L [10]. 80.1 % of the surface water sources in the study area have higher Mn-content in the dry seasons than in the wet seasons. In nature, manganese oxides are widely dispersed in various forms of discrete particles, coatings, nodules, micro-nodular deposits, thin layers on mineral surfaces, or interspersed in clay minerals ([17], [18]). These oxides tend to be deposited at the redox front which may occur near the water table and also at places along the ground-water flow path owing to changes in vertical and horizontal permeability.

Under favourable conditions of water circulation pattern and/or chemical composition, manganese salts can be redissolved [19]. Higher levels of manganese sometimes found in freely flowing river-water and are usually associated with industrial pollution [7].

#### H. Nickel (Ni)

Sources of nickel in water include contamination from municipal sewage sludge, wastewater from sewage treatment plants, and surface water near landfill sites. Anthropogenic sources include combustion of fuel or waste released from industries [20]. In this work, Ni contents spread from BDL to 0.10 mg/L (mean 0.04 mg/L) in the wet seasons and from BDL to 0.15 mg/L (mean 0.07 mg/L) in the dry seasons. 60.1 % water samples during the wet season and 80.1 % water samples during the dry season show Ni content above the permissible limit of 0.02 mg/L [10]. River water sources have been found to have Ni content in the range of BDL – 0.06 mg/L in the wet seasons and from 0.02 – 0.11 mg/L in the dry seasons. 91.5 % sources have comparatively higher nickel concentrations in the dry season than in the wet season.

#### I. Lead (Pb)

Lead is a cumulative poison to humans. Its major effects are impairment of hemoglobin and porphyrin synthesis [6]. Lead solubility is controlled principally by  $PbCO_3$  and low-alkalinity while low-pH waters can have higher Pb concentrations [21]. Adsorption of Pb on organic and inorganic sediment surfaces (Hem 1976) may be the reason for the concentration of this toxic metal in the surface water. Long term exposure to lead or its salts (especially soluble salts or the strong oxidant  $PbO_2$ ) can affect the nervous system and kidneys adversely [13]. In this work, the concentration of Pb was in the range of BDL – 0.25 mg/L (mean 0.05 mg/L) in the dry seasons and BDL – 0.14 mg/L (0.06 mg/L) in the wet seasons. Most of the values exceed the maximum permissible limit of 0.05 mg/L for drinking water [10]. However, almost all the surface water sources have higher Pb-content in the dry season than in the wet season. 54.4 % of the surface water samples have Pb above the permissible limit of 0.05 mg/L [10] during the rainy season while in the dry season, 85.8% of the surface water sources show Pb above the limit corresponding to the low pH of the sources. Long term exposure to lead or its salts (especially

soluble salts or the strong oxidant  $PbO_2$ ) can affect the nervous system and kidneys adversely [13].

#### G. Zinc (Zn)

Zinc shows a significant content in the surface waters from BDL – 0.07 mg/L (mean 0.02 mg/L) in the wet seasons and BDL – 0.11 mg/L (mean 0.04 mg/L) in the dry seasons. River water samples have low Zn content compared to that of pond water sources ranging from BDL – 0.05 mg/L in both the wet and the dry seasons. However, even the highest values of Zn measured in this work are far below the guideline value of 3 mg/L [7]. During the wet season, Zn concentration came down slightly due to the effect of dilution by runoff water infiltration. Occurrence of these low concentrations of Zn in the surface water might be indicative of leaching of this element through percolation into the surface water from the overlying soil.

## IV. CONCLUSIONS

The hydrochemical analyses showed the distribution characteristics of trace element concentrations of the surface water sources in the Jia-Bharali river basin are the result of combined influence of natural conditions, i.e., geological and human activity. Though human activities have not yet caused serious degradation of surface water quality, some trace metal concentrations have profoundly exceeded the related standards. Dissolved metal concentrations of all water samples are below or close to the maximum permitted concentration for drinking water, except for Fe, Pb, Cd and Cr. The higher values of these metals in the surface water sources of the basin imply additional inputs from unusual geochemical enrichment, which in turn may be attributed to the geological sources coupled with anthropogenic inputs from the catchments.

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