Available online at www.scholarsresearchlibrary.com

Scholars Research Library

Archives of Applied Science Research, 2012, 4 (2):1169-1174
(http://scholarsresearchlibrary.com/archive.html)

ISSN 0975-508X
CODEN (USA) AASRC9

Physico-chemical studies on surface water quality in the Jia-Bharali River Basin, North Brahmaputra Plain, India

Nayan J. Khound*[a], Parag Phukon[b] and Krishna G. Bhattacharyya[a]

[a]*Department of Chemistry, Gauhati University, Guwahati*
[b]*Department of Geological Sciences, Gauhati University, Guwahati*

ABSTRACT

The lower catchment of Jia Bharali river basin and adjoining areas defined by the Arunachal Himalaya towards north, Brahmaputra river towards south, Jia Gabharu river and Ghiladhari river towards west and east respectively, is characterized by a network of foothills fed rivers and numerous static water bodies linked to fluvial activities. The surface water regime is primarily monsoon dependent, although the trunk channels receive significant contribution from ground water during lean season. This study presents a comprehensive assessment of surface water quality of the area based on analysis of six datasets representing thirty five point sources and three consecutive years (2008 – 2010). The physico- chemical parameters show variable spatial and temporal relationships. The major ion contents show the trend Ca>Na>Mg>K while anion composition follow the trend $HCO_3>Cl>SO_4>>PO_4>NO_3$ *in both the wet and the dry season. With respect to the physico – chemical parameters, the surface water sources of the Jia- Bharali catchment and adjoining area are found to be suitable for domestic, agricultural and industrial use.*

Keywords: Surface water quality, Jia-Bharali river basin, Brahmaputra plain.

INTRODUCTION

The Jia Bharali river catchment area is bounded by longitudes 92° 00′ - 93°25′E and latitudes 26° 39′ - 28°00′ N. The Jia Bharali, one of the major tributaries of the river Brahmaputra, flows down from the lower Himalayas in Arunachal Pradesh in the northeastern India and runs through the middle of Sonitpur district of Assam (India) for about 66 km before meeting the Brahmaputra at Tezpur (92°53′53″ E: 26°39′15″ N). The river known as Kameng in Arunachal Pradesh flows orthogonal to the Himalayan thrust pattern and deflects along the Tipi Thrust in north and foothills fault in the south respectively, before debouching into the foreland at Bhalukpung (92° 65′E: 27° 01′N) where it takes the name of Jia Bharali. The region has extensive tea-plantations and paddy fields. The northern portion is made up of Reserve Forests and sparsely populated forest-villages. The region abounds in biodiversity with evergreen and deciduous trees of many types.

The average annual suspended sediment load of the river recorded at this gauging site was 2,143 ha-m [2]. The climate of the study area is sub-tropical in nature with hot and humid summer, followed by dry autumn and cold winter (November to February). South west monsoon (June- September) brings most of the precipitation that show increasing trend from south to north (~ 1500 cm> 3000 cm). The trunk channels of Jia-Bharali, Jia Gabharu, Ghiladhari and Dipota together with their network of foothills fed channels and numerous static water bodies linked to fluvial activities, from the surface water regime of the study area. These water bodies are extensively used as source of domestic water supply apart from the ubiquitous dug wells. Irrigation use of the surface water is however very minimal. The area lacks significant industries and large scale commercial farming. However elevated grounds

---

are extensively used for tea cultivation. As such the significant human intervention contributing towards surface water quality may be the chemicals used in these tea gardens.

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]. Spatial and temporal variability of surface water sources may be affected by hydrologic inputs in the form of precipitation, direct overland flow, subsurface flow through shallow soils, drainage from shallow and deep aquifers and in stream processes such as dilution, release and adsorption of metals from sediments, etc.

The Jia-Bharali river basin is one of the most developed regions in the north Brahmaputra plain, and it has been observed in the recent years that intensive agriculture, urbanization, development of small industries in the basin have become important factors in rapid deterioration of the water quality of almost all surface water bodies in the basin. The present study assesses the seasonal and temporal variability of surface water quality in the Jia Bharali river basin and estimates their susceptibilities to changes on the ground.

MATERIALS AND METHODS

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 twice a year (monsoon and post-monsoon) for a three year period from 2008 to 2010, (Fig. 1) 1 L polyethylene containers, pre-cleaned with 10 % reagent grade nitric acid, followed by rinsing three times with deionised water and thoroughly dried in a fume hood were used for sample collection. Standard methods [3] were followed in collection, storage and analysis of the water samples. Na and K were determined with a flame photometer (Elico CL 361), the anions, sulphate, phosphate and nitrate with UV-visible spectrophotometer (Hitachi 3210), total dissolved solids (TDS) by evaporation method, total hardness, Ca, Mg, chloride and bicarbonate by titrimetric method.

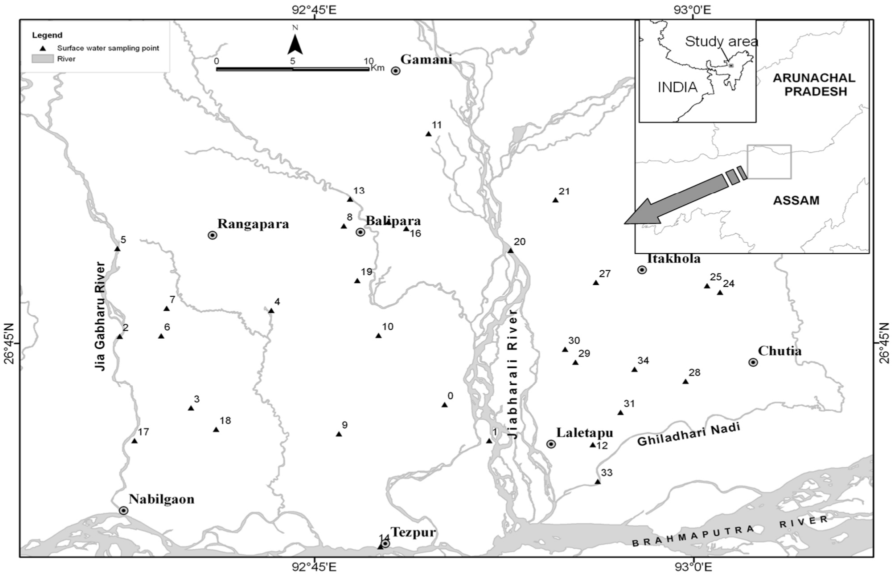


Fig. 1 The locations for surface water sampling in the study area.

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 Table 1. The results can be discussed as follows:

The surface water sources were found to experience the temperature of 22^o – 27^oC in the wet seasons and 17^o – 23^oC in the dry seasons. The surface water samples differ by about 10ºC with respect to temperatures of the wet seasons and the dry seasons and the temperature change is very similar in all the locations. In the dry seasons, the river water sources showed lower water temperature (17 – 20) when compared to the wet season water temperatures. The temperature differential is likely to play an important role in governing species diversity because fish, insects, zooplankton, phytoplankton, and other aquatic species all have a preferred living and breeding temperature range.

Table 1. Physico-chemical characteristics of the surface water sources. (BDL: Below detection limit, SD standard deviation and all other parameters in mg/L).

parameter	Wet season				Dry season			
	Min	Max	Mean	SD	Min	Max	Mean	SD
pH	6.1	7.4	6.7	0.3	6.3	8.0	6.8	0.4
TDS	55	130	86	19	70	170	102	25
Hardness	29	112	55	17	35	153	77	26
Ca	2.2	26.3	6.4	4.7	3.6	24.6	9.9	4.5
Mg	0.8	9.1	3.4	2.4	1.6	11.2	5.3	2.8
Na	3.5	11.2	5.5	1.7	4.3	13.8	6.6	1.4
K	0.8	5.1	2.6	1.1	1.5	6.2	2.7	0.8
HCO_3^{2-} alkalinity	18	39	25	6	28	54	38	7
Cl-	5.9	25.3	10.9	4.0	9.8	28.7	15.5	4.9
SO_4^{2-}	1.8	14.2	6.5	3.2	3.4	24.4	9.8	4.2
NO_3^-	BDL	1.23	0.17	0.32	BDL	0.43	0.04	0.09
PO_4^{3-}	BDL	1.48	0.11	0.23	BDL	1.14	0.09	0.24

The surface water samples were found slightly alkaline in nature (except a few sources) during both the seasons with the averages being in the range of 6.1 to 7.4 in the wet seasons and from 6.3 to 8.0 in the dry seasons. The water is thus suitable for irrigation purposes with respect to pH, i.e. there is no alkalinity hazard. With respect to the classification of the surface water sources, it was observed that the river waters have pH from 6.7 – 8.0 and the ponds 6.2 – 7.8 for both the seasons. In the wet seasons, a few of the surface water sources showed acidic characteristics (pH < 7.0) in comparison to those of the dry seasons. It is known that due to the presence of carbonate (CO_3^{2-}) and bicarbonate (HCO_3^-) ions in solution, the pH of most natural water lies between 6.5 – 8.5, but values lower than the minimum limit may be due to the presence of dissolved carbon dioxide and organic acids (fulvic and humic acids), derived from the decay and subsequent leaching of plant materials [4]. This may also be related to the basin characteristics, particularly the wide distribution of lateritic soil whose pH is always acidic [5]. As the study area is surrounded by extensive agricultural fields, the low pH could be related to the use of acid producing fertilizers like ammonium sulphates and super phosphates of lime [6].

The TDS varied from a minimum of 55 mg/L to a maximum of 130 mg/L with a mean value of 86 mg/L in the wet seasons and from a minimum of 70 to a maximum of 170 mg/L with a mean value of 103 mg/L in the dry seasons. The values are generally higher in the dry seasons due mainly to reduction in water volume. When TDS > 1000 mg/L [7], the water is likely to have objectionable tastes; however, no water sample in the present work, had TDS ≥ 1000 mg/L. Total dissolved solids represent the amount of soluble inorganic substances in the water [8] and originates from natural sources, sewage, urban runoff, industrial wastewater and chemicals used in the water treatment process. Majority of the sources (79.9 % in the wet season and 57.2 % in the dry season) have TDS < 100 mg/L in both the wet and dry seasons.

The total hardness of the surface water is dependent on the presence of Ca and Mg contents that enter the water bodies through residues of soaps, detergents and parent bed rock materials made up of Ca, Mg and other metal ions [9], [10]. The average total hardness values of the surface water samples varied from 29 – 112 mg/L with a mean value of 56 mg/L in the wet seasons and 35 – 153 mg/L with a mean value of 77 mg/L in the dry seasons. Using Durfer and Backer [11] classification, the surface water bodies in the study area could be categorized as shown in the Table 2.

Table 2. Durfer and Backer classification of Hardness

Class	Hardness as CaCO3 (mg/L)	% surface water sources	
		Wet Season	Dry Season
Soft	0 – 60	79.9	28.6
Moderately Hard	61 – 120	20.1	65.7
Hard	121 – 180	NIL	5.7
Very Hard	> 180	NIL	NIL
	Total	100	100

It is seen that 5.7 % of the surface water sources are in 'very hard' class during the dry seasons and majority of the surface water bodies are in soft category in the wet seasons (obviously due to dilution). As much as 65.7 % of the sources are under moderately hard category in the dry seasons. It is found that all surface water bodies has hardness ($CaCO_3$/L) well below the WHO [7] permissible limit of 500 mg/L.

Calcium and magnesium have wide variations in values. The average values are Ca: 2.2 – 26.3 mg/L and 3.6 – 28.9 mg/L; Mg: 0.8 – 9.1 mg/L and 1.6 – 11.2 mg/L in the wet and the dry seasons respectively. Except two ponds (30 and 33), all the other sources has higher values of calcium in the dry season than those in the wet season. None of the values exceed the guideline value of 75 mg/L [12]. Out of 35 surface water bodies analysed, 5.7 % of the sources have higher magnesium content in the wet season and the remaining 94.3 % of the water samples show higher values in the dry season. In both the rainy and dry seasons, all the water samples have Mg below the guideline value of 30 mg/L [12].

Sodium contents were in the range of 3.5 – 11.2 mg/L in the wet seasons and 4.3 – 13.8 mg/L in the dry seasons while potassium contents were from 0.8 – 5.1 mg/L in the wet seasons and 1.5 – 6.2 mg/L in the dry seasons. It is found that 85.8 % of the surface water samples show higher values of sodium in the dry season than in the wet season. As in the case of Na, 77.3 % of the surface water bodies showed more potassium content in the dry season than in the wet season. Only 2.8 % (one) sources in the wet season and 5.7 % sources in the dry season were found to have potassium content above 5 mg/L. Sodium is found in association with high concentration of chloride resulting in salinity while potassium is a component of potash fertilizers and animal waste. The natural sources of potassium in water are the minerals of local igneous rocks such as feldspars (orthoclase and microcline), mica and sedimentary rocks as well as silicate and clay minerals [13].

From the above analysis, it is seen that the major ion contents of the surface water sources follow the trend, Ca > Na > Mg > K, in both the wet and the dry seasons.

Bicarbonate content (as $CaCO_3$) of the surface water samples varied from 18 – 39 mg/L in the wet seasons and 28 – 54 mg/L in the dry seasons. No carbonate (CO_3-) alkalinity could be found as dissolved carbonates raise the pH to more than 8.3 and in the present study; the surfacewater pH was lower than this value [14]. The total alkalinity is therefore almost entirely due to the presence of bicarbonate, which was found at slightly higher levels in the post-monsoon period indicating that some contribution might have come from the carbonate weathering process due to heavy downpour in the catchment.

Chloride in this work shows a wide range of values from 5.9 – 25.3 mg/L with a mean value of 10.9 mg/L in the wet seasons and from 9.8 – 28.7 mg/L with a mean value of 15.5 mg/L in the dry seasons. 91.5 % of the surface water sources have higher chloride content in the dry seasons than those of the wet seasons. High concentration of chloride makes water unpalatable and unfit for drinking and livestock watering. However, all the surface water sources show Cl values below the permissible limit of 200 mg/L [15] which can be attributed to (i) the rate of percolation of agricultural and domestic wastes to the surface water bodies (the area is not industrial) is low and (ii) the contributions from the geological formations of the area is not much significant preventing the sources from excessive chloride accumulation [16].

Sulfate enters surface waters from groundwater, the oxidation of sulfide minerals during chemical weathering, atmospheric deposition from acid rain, human and animal waste, farming, and industrial processing and manufacturing [17]. The sulphate contents of the basin in the present study are much below the permissible limit for drinking water (400 mg/L, [7]) with the values ranging from 1.8 to 14.2 mg/L in the wet seasons and 3.4 to 28.4 mg/L in the dry seasons. The variation of sulphate concentration in both the seasons is thus very wide. In as many as 85.8 % of the surface water sources, the sulphate content is higher in the wet season than in the dry season.

The surface water of the investigated area contains only small amounts of nitrate from BDL to 1.23 mg/L in the wet and BDL to 0.43 mg/L in the dry seasons (Maximum permissible limit 50 mg/L as nitrate for drinking water, [15]. Smaller values of nitrate in the study area indicate that the nitrifying bacteria are not much active due to the presence of anaerobic conditions (the area having a water cover for most of the time) for the large part of the year. The nitrate concentration varies seasonally and generally it is observed that nitrate concentrations of the surface water sources are more in the wet season because of nitrate-rich runoff. In 79.9 % of the water samples, nitrate concentration is higher in the wet season while the rest 20.1 % show higher values in the dry season. Nitrate is one of the most frequently introduced pollutants into surface water systems and is being implicated for diseases like hypertension, cancer and birth defects [18]. In the present study area however the nitrate concentration is too small to warrant special attention.

The phosphate contents in this work are from BDL to 1.48 mg/L in the wet seasons and from BDL to 1.14 mg/L in the dry seasons. In 88.5 % of the surface water samples, phosphate concentration is higher in the wet season than the dry season. The presence of vast paddy cultivation in the study area suggest that agricultural runoff is the probable source for this concentration. Easy solubility is also responsible for phosphates finding their way into water from animal waste, runoff from agricultural land due to fertilizer use, and detergent-filled domestic wastewater [19].

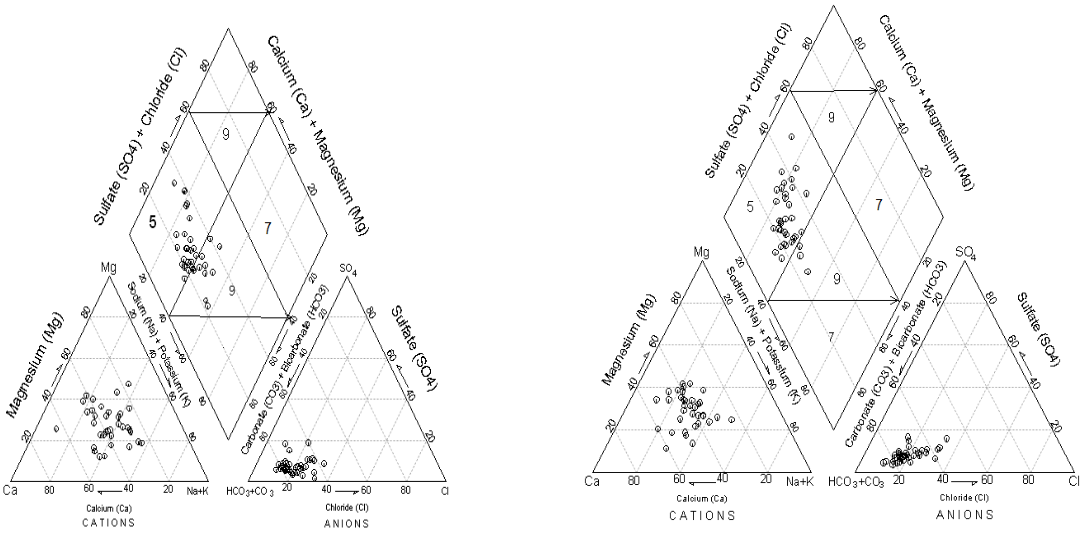
Thus, the anion composition of the surface water samples is dominated by bicarbonate, chloride and sulphate (in that order) with almost insignificant contribution from phosphate and nitrate, the order being HCO3 > Cl > SO_4 >>> PO_4 > NO_3 in both the wet and the dry seasons.

Piper Classification

In the present study, Piper trilinear diagram [20] constructed (Fig. 2) on the basis of the experimental results shows that the surface water samples can be grouped into two types as shown in the Table 3.

Table 3. Piper Classification of surface water sources

Piper Area	Water type	Number of surface water sources	
		Wet season	Dry season
5	Alkaline earth and weak acid are dominating	26	32
9	No cation anion pair exceeds 50 %	9	3
	Total	35	35



(a) (b)

Fig. 2 Piper diagrams of the surface water sources in (a) the wet and (b) the dry season.

The classification reveals the preponderance of alkaline earths (Ca, Mg) and weak acids (HCO_3) over alkalis (Na, K) and strong acids (SO_4, Cl) in the surface water of the majority of sites of the study area, thereby indicating calcium and magnesium bicarbonate type of water. The second group of the remaining 9 sites of the surface water samples in the rainy season and 3 sites in the dry season shows no dominant type of water class (no one cation-anion pair exceeds 50 percent).

CONCLUSION

This study shows that the surface water sources in and around Jia Bharali lower catchment are characterized by physic chemical parameters well within the WHO prescribed limit for drinking water. As such the water sources may be used safely for both domestic and industrial uses as well as for irrigation. Spatio - temporal variability of the physico - chemical parameters from this study may be used as future baseline data to monitor and manage any changes with changing land use.

Acknowledgements

The present work has been undertaken under the National Programme on "Science of Shallow Subsurface Studies" of the Department of Science and Technology, New Delhi, Government of India.

REFERENCES

[1] Simeonova, V., Stratis, J. A., Samara, C., Zachariadis, G., Voutsa, D., Anthemidis, A., *Water Research*, **2003,** 37, 4119–4124.
[2] Jain, S. K., Agarwal, P. K., & Singh, V. P. *Dordrecht, The Netherlands: Springer*, **2007**, (13-978-1-4020-5180-7, e-book).
[3] APHA, AWWA (American Public Health Association), Standard methods for the examination of water and wastewater, *American Public Health Association*, **1998**, Washington D.C.
[4] Garcia M. G., Hidalgo Del V. M., Blesa M. A. *Hydrogeology J*., **2001**, 9, pp 597 – 610.
[5]CESS:, Resource Atlas of Kerala, *Centre for Earth Science Studies*, **1984** ,Thiruvananthapuram, Kerala.
[6] Raghunath, R. Sreedhara Murthy, T. R. and Raghavan, B. R.:, *Pollu. Res*., **2001** 20(3), 413–418.
[7] WHO Guidelines for drinking water quality. Health criteria and other supporting information, WHO Publ., **1984**, vol 2, Geneva, 335 p.
[8] Harley S., *Water quality testing*, **2002**, Agriculture and agri-food Canada.
[9] Nanda, S. P., *Environmental management plan (EMP) for Bhubaneswar, India*, **2005**, Retrieved on Aug. 22, 2006 from http:// www.orissa.gov.in/forest&environment/pdf/Chap_8.pdf
[10] Jain, C. K. & Sharma, M. K., *Indian Journal of Environmental Health*, **2002**, 42(4), 159–163.
[11] Durfor C. N. and Becker E., *US Geol Sur. Water Supply Paper*, **1964**, 1812, pp364.
[12] IS (Indian Standard) - Packaged drinking water (other than packaged natural mineral water) – Specification (First Revision) 14543**: 2004**.
[13] Howari, F. M., & Banat, K. M., *Journal of Hydrology and Hydromechanics*, **2002**, 50(1), 50.
[14] Narain, S. and Rajeev Chauhan. *Poll. Res*., **2000**, 19(3), 351– 364.
[15] WHO, *Guidelines for drinking-water quality* (Vol. 1, 3rd ed.), **2004**, Geneva: World Health Organization.
[16] Mariappan, P., Yegnaraman, V. and Vasudeva, T., *Poll. Res*., **2000**, 19(2), 225–229.
[17] Souligny EA, Davidson JD, Martin TD, Mcinnish MB, Schultz BS, Wilson CG, Wood JL, Hollabaugh CL, Sulfate content of surface waters of West Georgia: variations with land usage and flow characteristics of streams in Carroll and Heard Counties, Georgia. *The Geological Society of America annual meeting*, **2001**, Paper no: 151–0
[18] Spalding R.F & Exner M.E., *J Environ Qua.* **1993**, 22, pp 392– 402
[19] Anda, J., Shear, H., Maniak, U. and Riedel, G.,. *Lakes & Reservoirs: Research and Management*, **2001**, 6, 313–321.
[20] Piper A. M., *Transactions— American Geophysical Union*, **1994**, 25, 914–928.