

Seasonal variation of heavy metals in three major water bodies of Guwahati City, Assam, India

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(Received 8 May, 2021; Accepted 27 June, 2021)

ABSTRACT

Heavy metals are reported as endocrine disruptors that cause adverse health hazards. Heavy metals are being passed into the aquatic ecosystem through natural and anthropogenic sources such as geological weathering and atmospheric deposition, discharge of municipal, industrial and agricultural runoff. As a result, the water quality of aquatic ecosystem is deteriorating. Deepor Beel, Borsola Beel and Bharalu River are the largest notable water bodies of Guwahati City which is facing threat due to industrialization and urbanization. In this context, the present study aims at investigating the presence and seasonal variation of heavy metals (As, Cd, Cr, Cu, Pb, Hg and Ni) in water of these water bodies. The water samples were analyzed using Inductively Coupled Plasma-Optical Emission Spectrophotometer (ICP-OES; Thermo Scientific iCAP-7000 series). The present study revealed the presence of heavy metals in Deepor Beel, Borsola Beel and Bharalu River. Concentrations of heavy metals were recorded to be higher during monsoon season as compared to winter season.

Key words: Aquatic ecosystem, Heavy metals, Seasonal, Water bodies, Urbanization.

Introduction

Heavy metal pollution in aquatic environment is one of the major global challenges as they are non-biodegradable, persistent in nature, toxic at very low concentration and bioaccumulate causing health hazards to aquatic inhabitants that also affects other organisms and ultimately human through food chain (Jayakumar *et al.*, 2008; WHO, 2008). Heavy metals are naturally occurring elements having high density of $>5 \text{ g/cm}^3$ and atomic number greater than 20 excluding alkaline earth elements, alkali metals, lanthanides and actinides (Kopp and Kroner, 1972; Jarup, 2003; Celik and Kunene, 2021). The natural sources of heavy metals are soil leaching and chemical weathering of minerals. The anthropogenic sources of heavy metals in aquatic ecosystem are municipal sewage, industrial effluents, road runoff,

agricultural runoff, urban storm, mining of coal and ore, landfill and atmospheric sources (Biney *et al.*, 1994; Zarazua *et al.*, 2006).

Guwahati is a major metropolitan city and known as the Gateway of the entire North East India. It is located within $26.13^\circ \text{ N } 91.77^\circ \text{ E}$ at the southern bank of the river Brahmaputra and the foothills of the region. Guwahati is experiencing a drastic change and rapid urbanization as it is a central place for business, tourism, health and education. As a result Guwahati's aquatic system and their inhabitant species are facing a threat. The Deepor Beel, Borsola Beel and Bharalu River which are the notable water bodies of the Guwahati city that provided drinking water to native people, shelter to a large number of biodiversity. But nowadays, they have become highly polluted due to dumping of municipal, industrial and household wastes. The

objective of the present study was to determine the presence of heavy metals As, Cd, Cr, Cu, Pb, Hg and Ni in the water of these water bodies so that the government can take necessary action to protect the water bodies from heavy metal pollution.

Materials and Methods

Study area

Deepor Beel

Deepor Beel is the only Ramsar site of Assam. It is situated in Kamrup district at the southern bank of Brahmaputra River between the coordinates of $26^{\circ} 7' 3.70''\text{N}$ to $91^{\circ} 38' 57.67''\text{E}$ and 10 km away from Guwahati city. Deepor Beel is a large and permanent fresh water lake which serves as the largest storage basin of storm water. The beel provides shelter to a large number of biodiversity. Deepor Beel is designated as bird sanctuary because of its water fowl diversity. The natural topography of the beel is such that the rain water carries all the city's wastes including municipal, household and industrial wastes to the beel. The agricultural runoff containing fertilizers and pesticides is also being passed to the beel from the nearby agricultural fields. Chemical and solid wastes from the garbage dumping cen-

tre near the beel are also discharged into the water. As a result of which the water quality of the beel is gradually degraded causing threat to its inhabitants (Saikia, 2005).

Borsola Beel

Borsola Beel is a notable wetland of Guwahati city located within $26^{\circ}10'19.52''\text{N}$ to $91^{\circ}44'42.47''\text{E}$ near Paltan Bazar area. It once harbored a large number of aquatic biodiversity. Of late, due to the discharge of effluents with untreated industrial and municipal wastes and garbage dumping, the pollution level of the beel has become very high (Islam *et al.*, 2015).

Bharalu River

Bharalu River is a tributary of River Brahmaputra and flows through the heart of the Guwahati city having site coordinates $26^{\circ}10'5.22''\text{N}$ and $91^{\circ}45'22.77''\text{E}$. Once it provided drinking water to the inhabitants of the city but now the river has turned into a segment of drainage system due to the lack of proper management of waste disposal (Roy, 2011).

Sampling Sites

Anthropogenic activities are one of the major sources of heavy metal pollution in aquatic ecosys-

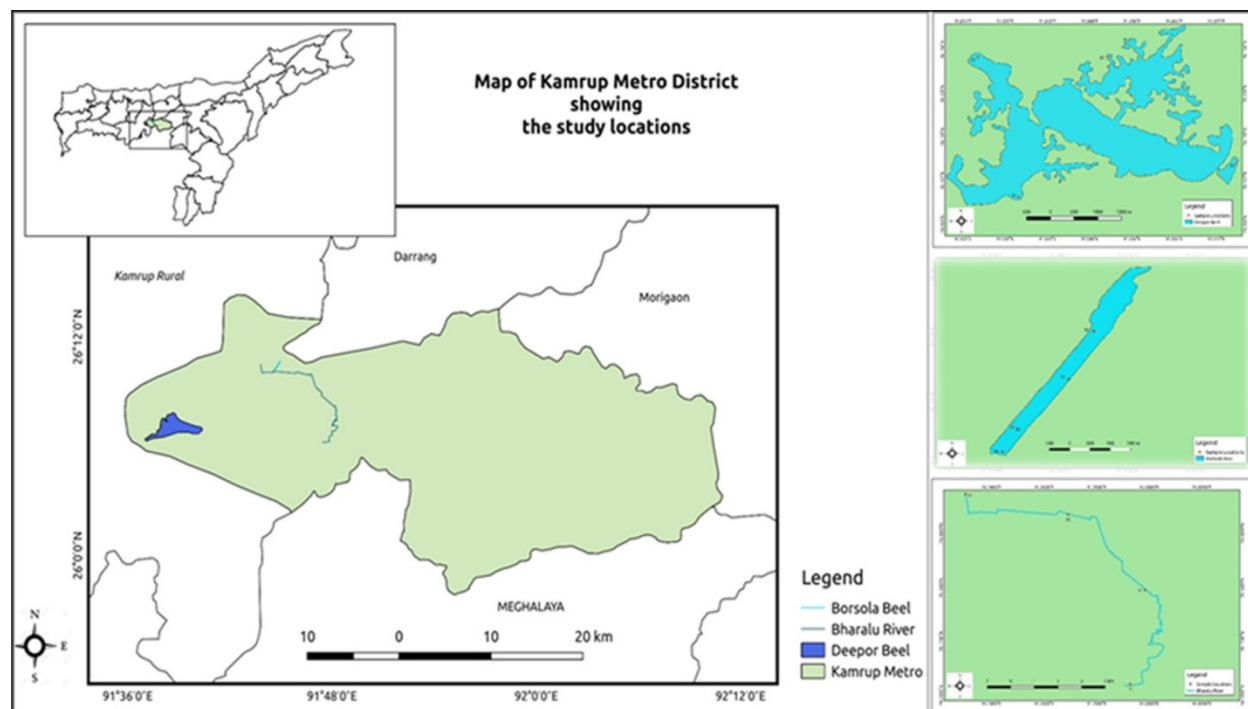


Fig. 1. Map showing the different sampling sites of Deepor Beel, Borsola Beel and Bharalu River of Guwahati City.

tem. Depending on the intensity and mode of human activities in the three water bodies, different sampling sites were selected. Deepor Beel has a large catchment area and different sites receive effluents from different anthropogenic sources i.e. from residential, roadside, municipal garbage dump and agricultural area. Borsola Beel and Bharalu River flow through the heart of Guwahati city and all sites of these two water bodies receive same kind of effluent i.e. municipal, industrial as well as road runoff.

Detection of heavy metals in water samples

Sample preparation

To estimate the concentrations of As, Cd, Cr, Cu, Pb, Hg and Ni in water bodies, water samples were collected from different selected sites of Deepor Beel, Borsola Beel and Bharalu River during winter and monsoon seasons. Water samples were collected

during winter and monsoon seasons (2019). Samples were collected in 500 ml glass reagent bottles which were properly soaked in dilute nitric acid and rinsed using distilled water before collection. Prior to filling, the bottles were washed with the beel water. Sub surface samples were collected in the bottles and sealed tightly. Three samples were collected from each sampling site.

Acid digestion of samples

Preliminary acid digestion and extract preparation are necessary for the sample analysis. Acid digestion helps in removing the suspended organic matter. Digestion of water samples were done by following the standard protocol (APHA, 1998; Tribedi and Goel, 1984; US Environmental Protection Agency, 1991). The collected water samples were acidified using 60% HCl (Merck, Darmstadt, Germany) to make $\text{pH} \leq 2$. Then, 5 ml of concentrated nitric acid was added to 50 ml of each acidified sample and

Table 1. Description of sampling sites of Deepor Beel, Borsola Beel and Bharalu River

Study Area	MSL	Sampling sites	Geographic location	Description
Deepor Beel	152 ft	S ₁	26° 8'26.02"N and 91°39'58.03"E	Located near GMC garbage dump, Boragaon Area
		S ₂	26° 8'4.73"N and 91°39'4.76"E	Located near AEC campus, towards the north and northwest side of the beel where residential complexes are situated adjacent to the beel.
		S ₃	26° 8'10.26"N and 91°36'35.81"E	This site is located to the North side of the beel near the national highway in Dharapur-Khanamukh area.
		S ₄	26° 6'28.21"N and 91°38'6.07"E	Located near agricultural area between south and south-west side of the beel. Agricultural runoff directly enters into the beel through small irrigation pools.
Borsola Beel	180 ft	S ₁	26°10'31.40"N and 91°44'50.83"E	Located near Beelpar area.
		S ₂	26°10'22.88"N and 91°44'46.87"E	Located near Rehabari Area.
		S ₃	26°10'15.15"N and 91°44'37.87"E	Located near Chatribari area.
		S ₄	26°10'10.81"N and 91°44'34.91"E	Located near sluice gate, Chatribari area.
Bharalu River	178 ft	S ₁	26°6'22.91"N and 91°47'16.58"E	Located near Basistha area (Up stream of Bharalu river).
		S ₂	26°10'30.19"N and 91°43'46.94"E	Located near Down town hospital area
		S ₃	26°10'1.04"N and 91°46'8.70"E	Near Bora Service area
		S ₄	26°10'29.9"N and 91°43'47.2"E	Located near Bharalumukh area (the confluent zone of Brahmaputra and Bharalu, downstream).

heated in beaker on a hot plate to reduce the volume to 15-20 ml. The temperature of the hot plate should not exceed 160°C. The contents were then transferred to a 100 ml volumetric flask and diluted with de-ionized water and the volume was adjusted to 50 ml. The digested samples were then filtered through whatman filter paper.

Analysis of samples

The digested water samples were analyzed using Inductively Coupled Plasma-Optical Emission Spectrophotometer (ICP-OES; Thermo Scientific iCAP-7000 series). The obtained concentration levels of heavy metals were compared with the permissible limits (FAO/WHO, 2014) of heavy metals in water.

Statistical analysis

All results were expressed as Mean \pm SEM (Standard Error of Mean) using MS Office Excel 2007. The difference among winter and monsoon seasons was analyzed using one-way ANOVA analysis (SPSS V 16.0). The difference was considered the levels of significance at $p < 0.05$. Map was prepared using QGIS 3.2.

Results

The seasonal variation of concentrations of heavy metals As, Cd, Cr, Cu, Pb, Hg and Ni in water of different selected sites of Deepor Beel, Borsola Beel and Bharalu River is presented in Figure 2, 3 and 4. The mean concentrations of heavy metals in Deepor

Beel, Borsola Beel and Bharalu River are shown in Table 2.

The present study has revealed that concentrations of most of the heavy metal were above the permissible limits of WHO/FAO (2014) except a few heavy metals. In Deepor Beel, during both winter and monsoon seasons in site S_1 , S_2 and S_4 , the concentrations of Cd were recorded to be higher than the other heavy metals while concentrations of Pb were found to be higher than the other heavy metals in S_3 . In Borsola Beel and Bharalu River, concentrations of Pb were recorded to be higher in all of the four sites S_1 , S_2 , S_3 and S_4 during winter and monsoon seasons.

As seen in Table 2, the mean concentrations of As, Cd, Cr, Cu, Pb, Hg and Ni were found to be higher during monsoon season as compared to winter season in the three water bodies. In Deepor Beel, mean concentration of Cd was higher in Deepor Beel during both winter (0.057 mg/l) and monsoon (0.085 mg/l) seasons whereas in Borsola Beel, the mean concentration of Pb was found to be higher in both winter (0.065 mg/l) and monsoon (0.079 mg/l) seasons and also in Bharalu River Pb mean concentration was recorded to be higher during both winter (0.043 mg/l) and monsoon (0.064 mg/l) seasons.

Discussion

In the present study, occurrence of heavy metals was observed in all three study areas. In Deepor Beel, the estimation of heavy metals at different sites revealed that Cd was the most abundant heavy

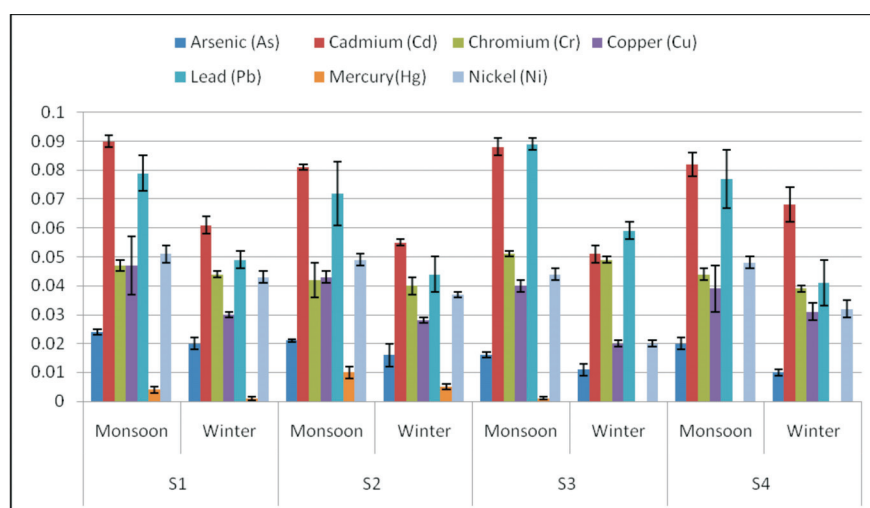


Fig. 2. Concentrations of heavy metals in the water samples of four sites (S_1 , S_2 , S_3 , S_4) of Deepor Beel, Assam during winter and monsoon seasons (all values are expressed in Mean \pm SEM).

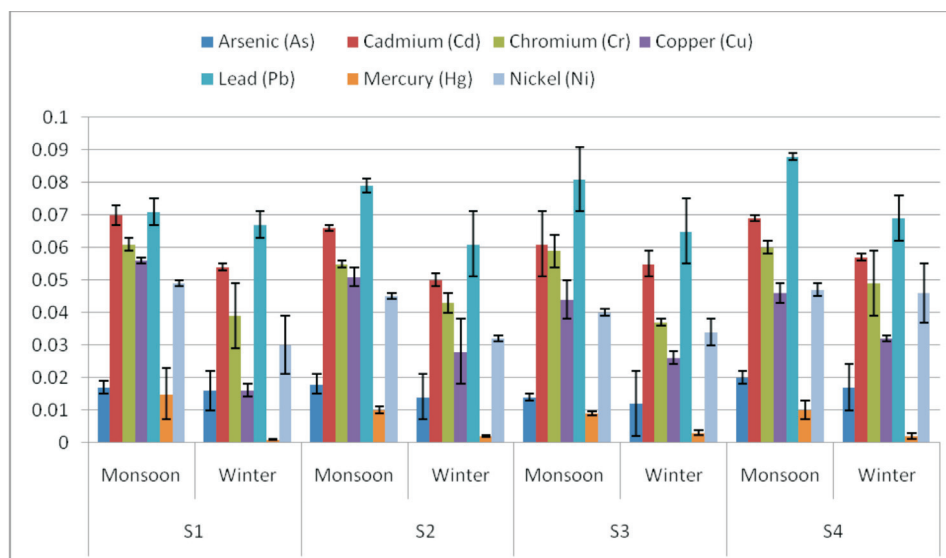


Fig. 3. Concentrations of heavy metals in the water samples of four sites (S_1, S_2, S_3, S_4) of Borsola Beel, Assam during winter and monsoon seasons (all values are expressed in Mean \pm SEM).

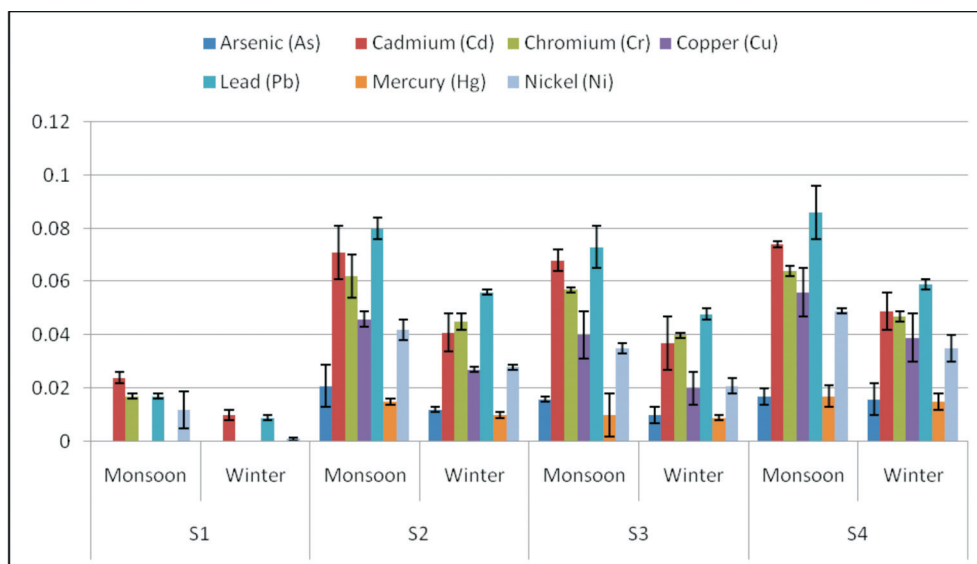


Fig. 4. Concentrations of heavy metals in the water samples of four sites (S_1, S_2, S_3, S_4) of Bharalu River, Assam during winter and monsoon seasons (all values are expressed in Mean \pm SEM).

metal at site S_1, S_2, S_4 during both winter and monsoon seasons. S_1 is located near Guwahati municipal garbage dump. The higher concentrations of heavy metals in this side may be due to the flow of toxic leachate from the garbage dump to the ground water and surface water of Deepor Beel. Gohain and Bordoloi (2013) reported presence of high concentrations of trace metals (Cd, Mn, Cu, Ni and Zn) in water of Deepor Beel near garbage dump. In S_2 , Pb concentration was observed to be higher than other heavy metals. The national highway passing near

this site might be the one cause of higher concentration Pb in the site. Pb was reported to be emitted from the automobile exhaust by combustion of petroleum fuels (Lenntech, 2004). The residential runoff and agricultural runoff are releasing continuously into the water near site S_2 and S_4 . The presence of heavy metals in these sources may also contribute to the increased concentrations of heavy metals in water of Deepor Beel.

In all sites i.e. S_1, S_2, S_3 and S_4 of Borsola Beel and Bharalu River, Pb was the most abundant heavy

Table 2. Mean concentrations levels of heavy metals in three water bodies (Deepor Beel, Borsola Beel and Bharalu River) during winter and monsoon seasons (all values are expressed in Mean \pm SEM). Superscript (*) shows statistical significance ($P < 0.05$) and represents significance difference of monsoon season with winter season.

Heavy metals (mg/l)	Deepor Beel		Borsola Beel		Bharalu River		Permissible limit (FAO/WHO, 2014; mg/l)
	Winter	Monsoon	Winter	Monsoon	Winter	Monsoon	
Arsenic (As)	0.014 \pm 0.002	0.020 \pm 0.001	0.014 \pm 0.001	0.017 \pm 0.001	0.009 \pm 0.001	0.013 \pm 0.004	0.01
Cadmium (Cd)	0.057 \pm 0.003	0.085 \pm 0.002*	0.054 \pm 0.001	0.066 \pm 0.002	0.034 \pm 0.008	0.059 \pm 0.001*	0.003
Chromium (Cr)	0.043 \pm 0.002	0.046 \pm 0.001	0.042 \pm 0.002	0.058 \pm 0.001	0.033 \pm 0.004	0.050 \pm 0.003	0.05
Copper (Cu)	0.027 \pm 0.002	0.042 \pm 0.001*	0.025 \pm 0.003	0.049 \pm 0.002*	0.021 \pm 0.007	0.035 \pm 0.006	1.00
Lead (Pb)	0.048 \pm 0.003	0.079 \pm 0.003*	0.065 \pm 0.001	0.079 \pm 0.003	0.043 \pm 0.002	0.064 \pm 0.01	0.01
Mercury (Hg)	0.001 \pm 0.0004	0.003 \pm 0.002	0.002 \pm 0.0004	0.011 \pm 0.001	0.008 \pm 0.0001	0.010 \pm 0.003	0.001
Nickel (Ni)	0.033 \pm 0.004	0.048 \pm 0.001	0.035 \pm 0.003	0.045 \pm 0.001	0.021 \pm 0.007	0.034 \pm 0.008	0.05

metal followed by other heavy metals. This may be due to the flowing of these water bodies through the heart of Guwahati city passing near the city roads and receiving all the city's wastes. Fernandez *et al.* (2007), Geagea *et al.* (2007), Suzuki *et al.* (2009) and Ogbonna and Okezie (2011) reported emission of Pb, Cd, Zn, Ni and Cr from road dust and heavy traffic on roads. In Bharalu River, S₁ was observed in less polluted state as compared to other sites. The site is free from anthropogenic activities to certain extent as this site is upstream of the river. The low levels of heavy metal concentrations in S₁ may be due to flowing water from upstream to downstream. Pandey and Singh (2017) reported lower concentrations of heavy metals in upstream as compared to downstream of Ganga River. In the current study, concentrations of all the heavy metals in the three water bodies were observed to be higher in monsoon season as compared to winter season. It might be due to the heavy rainfall in monsoon season that increases the surface run off (Hashim *et al.*, 2014) which carries the entire city's wastes containing heavy metals to the water of these water bodies.

Deepor Beel, Borsola Beel and Bharalu River are interconnected and received city's wastes which are ultimately released into Brahmaputra River. At present Guwahati city has no separate sewerage network. The sewage is discharged into Bharalu River coming through Borsola Beel. Therefore, the waste water enters into Deepor Beel through the channels of Bharalu River. The presence of heavy metals was reported in drains discharged into Bharalu River that resulted from untreated effluents (NMCG, 2020). Cd, Pb, Ni, Cu and other elements were reported in Chandmari drain and Rehabari drain that discharged into Borsola Beel (PCBA,

2019). Kakati *et al.*, (1990) reported the presence of higher concentration of As, Cd, Fe, Mg, Cu, Na, Hg, Zn, Pb and Cr in water samples of twenty different sites including municipal drains, public ponds, rivers, beels and tube-wells of Greater Guwahati. Polluted water with different toxic substances including heavy metals affects not only the fish, amphibians, birds and other animals but also the human through food chain. Polluted water is not suitable for drinking, agriculture and recreation.

Heavy metals are essential for living organism but they become toxic when they are present above the permissible limits while some heavy metals such as cadmium, lead, arsenic and mercury do not have any known biological role and are toxic even at very low concentrations (Jenni, 2011). The present study distinctly depicted that the three water bodies i.e. Deepor Beel, Borsola Beel and Bharalu River of Guwahati City are highly polluted due to heavy metals and it has become unsuitable for its biota. It can also affect other organisms and human being adversely through food chain. The present study will make people aware about the urgent need of proper step and initiative to protect the water bodies from heavy metal pollution.

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