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Presence of Toxic Heavy Metals in Hill Water Bodies of Arunachal Pradesh, India – A Health Implication to the Indigenous Population

Amar Deep Soren[1*], Balam Bayor[2] and Akash Ekke[2]

[1]PG and Research Department of Zoology, B. Borooah College, Guwahati - 781007, Assam, India; amar4deep@gmail.com
[2]PG and Research Department of Zoology, Bishop Heber College, Tiruchirappalli - 620017, Tamil Nadu, India

Abstract

Water bodies in hilly areas are considered the cleanest in India. They are also sites for household and recreation activities. On the contrary, they are disposal sites for household and toxic industrial wastes. This study evaluates the physio-chemical parameters and the toxic heavy metal content in two water bodies of Itanagar, the capital city of the Himalayan state of Arunachal Pradesh. Physio-chemical parameters were evaluated using standard procedures and toxic heavy metal contents were analyzed using Inductively coupled plasma optical emission spectroscopy. The study revealed high dissolved oxygen contents in both water bodies. Other parameters such as alkalinity, carbon dioxide, phosphate, chloride, and nitrate contents were found to be within the permissible limits. However, lead and arsenic were found in trace amounts but below the permissible limits in both water bodies. Cadmium was exactly within the permissible limit whereas, antimony was found to exceed the permissible limit (0.010ppm). Also, chromium (0.070±0.002 ppm) in Ganga Lake and nickel (0.086±0.011 ppm) in Poma River were found to be above the permissible limits. The presence of toxic metals in these natural hilly areas is alarming and can be attributed to increasing anthropogenic activities. Adequate measures and precautions to prevent such contamination activities should be undertaken.

Keywords: Contamination, Ganga Lake, Metal, Poma River, Water Quality

1. Introduction

With the growth in population and economic development, water scarcity has become a serious threat worldwide[1]. Contamination of water bodies has been occurring rapidly resulting in serious damage in recent years[2]. Pollution of water bodies is more severe and critical in South Asian countries such as Nepal, India, Pakistan, and Bangladesh particularly in urban localities due to huge amounts of waste discharged by various urban activities. In India, pollution is a serious problem where more than 70% of the surface water resources and groundwater reserves are contaminated by biological, organic, and inorganic pollutants[3].

Physio-chemical parameters such as pH, specific conductivity, dissolved oxygen, carbon dioxide, phosphate, nitrate, and chloride contents have been evaluated by several authors to assess water quality. Contamination of water sources can be due to various salts such as chloride, phosphate, nitrate, and toxic heavy metals. Also, contamination of groundwater and surface water with chlorine has become a cause of concern in many regions across the world[4]. A study conducted by Huo *et al.*, evaluated the chloride, Total Dissolved Solids (TDS), calcium, total hardness, magnesium, nitrate, Chemical Oxygen Demand (COD), Dissolved Oxygen (DO), and Biological Oxygen Demand (BOD) of groundwater in China. The study revealed that although calcium, magnesium, nitrate, and other parameters were found to be under the permissible limits, chlorine was found to exceed the permissible limit[5]. Similarly, a study in India on the water quality of the Kosi River in the state of Uttar Pradesh revealed a high amount of chlorine (88ppm) which was attributed to natural contamination and pollutants. The workers also concluded that the water was highly contaminated and unfit for drinking, domestic and irrigation purposes[3].

Water bodies can also be contaminated by toxic heavy metals coming from both natural activities such as volcanoes, and rock breakdown as well as anthropogenic activities such as mineral extraction, mining, and industrial and agricultural practices[6]. Consumption of such contaminated water can lead to serious health complications. A study conducted in the

**Author for correspondence*

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Narmada River in India revealed high levels of toxic heavy metals such as chromium, arsenic and lead[7]. Another similar study in South India assessed the metal contents of ground water revealing safe metal limits[8]. Similar studies in other water bodies of Arunachal Pradesh such as Kameng river[9], Siang river[10], and groundwater of Itanagar[11] have also been carried out. All these studies have raised caution about the increasing contamination level of these water bodies. Such studies are necessary to warrant the safety of water bodies particularly used for drinking and other household purposes.

Water bodies in cities are also sites for waste disposal. The capital city of the Himalayan state of Arunachal Pradesh, Itanagar is flanked by two water bodies namely, Ganga Lake and Poma River. Since they are sites for recreational activities and are also used as a drinking water source, this study was undertaken to evaluate their water quality and the content of toxic heavy metals. This study analyzed the pH, specific conductivity, alkalinity, chloride, phosphate, nitrate, dissolved oxygen, carbon dioxide and toxic heavy metal contents, namely, Arsenic (As), Cadmium (Cd), Lead (Pb), Manganese (Mn), Cobalt (Co), Copper (Cu), Zinc (Zn), Silver (Ag), Chromium (Cr), Nickel (Ni), Antimony (Sb), and Thallium (Tl).

2. Materials and Methods

2.1 Study Area

Two water bodies in the city of Itanagar were selected for the study, namely, Ganga Lake (Figure 1) and Poma River (Figure 2). They are located in the western part of Itanagar and are used as sites for recreation, washing vehicles, fishing, bathing, agriculture and household purposes. These water bodies receive industrial runoff and sewage coming from the city. Water samples from these water bodies were collected from 10 sites downstream during February and March to avoid the monsoons which could cause a change in the actual results. The samples were brought to the Department of Zoology, B. Borooah College to carry out further assessments.

2.2 Experimental Procedure

2.2.1 Physio-chemical Parameters

The physio-chemical parameters were assessed following the standard procedures[12] and the results were compared with the World Health Organization (WHO) and the Bureau of Indian Standards (BIS) permissible values[13,14]. The pH was estimated using a pH meter and specific conductivity was evaluated using a specific conductivity meter. All chemicals and reagents used in the study were of analytical grade.

2.2.2 Heavy Metal Content

Water samples were digested using an acid digestion method employing nitric acid (HNO_3) and hydrochloric acid (HCl). The toxic heavy metal contents were analyzed using Inductively Coupled Plasma-Optical Emission Spectrometry (ICP-OES) and were then compared with the WHO permissible limits[15].

2.3 Statistical Analysis

All the experiments were performed in triplicates and the data were generated using OriginPro v8. All data are represented as mean ± Standard Error of the Mean (SEM).

Figure 1. Poma River.

Figure 2. Ganga Lake.

Table 1. Physico-chemical parameters of the studied water bodies

Parameter	Ganga lake	Poma river	WHO	BIS
Dissolved oxygen	94.06±0.011	78.2±0.115	4-6	6
Carbon dioxide	6.06±0.066	4±0.057	-	-
Alkalinity	22±0.577	38±0.577	-	200
Phosphate	0.083±0.001	0.251±8.819	-	-
Chloride	33.62±0.314	25.64±0.321	250	250
Nitrate	0.4±0.057	2.8±0.115	50	45
pH	6.49±0.001	7.47±0.001	6.5-9.5	6.5-8.5
Specific conductivity	39±0.001	58±0.001	-	-

Data is represented as mean ± standard error of the mean. All parameters are expressed in mg/L except for pH and specific conductance.

3. Results

3.1 Physio-Chemical Parameters

Analysis of dissolved oxygen revealed very high contents in both the water bodies. Ganga Lake showed a higher value of 94.06±0.011 mg/L compared to 78.2±0.115 mg/L of Poma River. On the contrary, Poma River showed higher contents of phosphate and nitrate (0.251±8.819 mg/L and 2.8±0.115 mg/L, respectively), whereas Ganga Lake showed lower contents (0.083±0.001 mg/L and 0.4±0.057 mg/L, respectively). The chlorine content was found to be higher (33.62±0.314 mg/L) in Ganga Lake compared to Poma River (25.64±0.321 mg/L). The pH and specific conductivity of the Poma River (7.47 and 58, respectively) were higher than that of Ganga Lake (6.49 and 39, respectively). Higher content of dissolved carbon dioxide was observed in Ganga Lake (6.06±0.066 mg/L) compared to Poma River (4±0.057 mg/L). All the examined parameters were found to be within the permissible safe limits of WHO and BIS. The observed values are represented in Table 1.

3.2 Metal Contents

Toxic heavy metals such as As, Cd and Pb were detected in both the water bodies, however, they were found to be below the permissible limits of WHO and BIS. Cd was found to be exactly within the permissible limit of 0.003 ppm in both the water bodies and Cr was found to be above the permissible limit in Ganga Lake (0.070±0.002 ppm). Other evaluated metals such as Ni, Cu, Mn, Zn, Sb, Tl, Ag and Co were found in trace amounts and were below the permissible limits. The metal contents of both the water bodies are listed in Table 2.

Table 2. Metal contents of the studied water bodies

Metal	Ganga lake	Poma river	WHO	BIS
Arsenic (As)	0.006±0.001	0.003±0.001	0.01	0.05
Cadmium (Cd)	0.003±0.002	0.003±0.001	0.003	0.01
Lead (Pb)	0.003±0.01	0.009±0.001	0.01	0.05
Chromium (Cr)	0.070±0.002	0.034±0.002	0.05	0.05
Nickel (Ni)	0.058±0.01	0.086±0.011	0.07	-
Copper (Cu)	0.017±0.002	0.123±0.001	2	0.5
Manganese (Mn)	0.186±0.021	0.026±0.002	-	0.1-0.3
Zinc (Zn)	0.181±0.02	0.139±0.01	-	5-15
Antimony (Sb)	0.010±0.002	0.010±0.022	0.02	-
Thallium (Tl)	0.005±0.012	0.005±0.001	-	-
Silver (Ag)	0.234±0.000	0.268±0.001	-	-
Cobalt (Co)	0.003±0.002	0.005±0.002	-	-

Data is represented as mean ± standard error of the mean. All values are expressed in ppm.

4. Discussion

Water bodies of hilly regions, which includes the North-east India of which Arunachal Pradesh is a part, are claimed to be the cleanest water bodies in India. With the increasing population and anthropogenic activities, the reliability of these claims seems doubtful. Assessment of the physio-chemical parameters is necessary to ascertain such claims which ultimately determine the water quality. Determination of pH helps in assessing the corrosive nature of water[12]. In this study, both the water bodies showed almost a neutral pH, indicating that the water can be used for drinking and other domestic purposes. Also, knowing the specific conductance is necessary since it correlates with other parameters such as temperature, alkalinity, hardness, chlorine concentration, chemical oxygen demand and total solids[12]. Specific conductivity is usually twice the hardness of unsoftened water[13]. Likewise, carbon dioxide is a byproduct of all aquatic environments and its estimation is a measure of net ecosystem metabolism[16]. Also, alkalinity assists in measuring the carbonate (CO_3^{2-}) and bicarbonate (HCO_3^-) ions present in water bodies. The main sources of natural alkalinity are rocks containing carbonate, bicarbonate, and hydroxide. Similarly, the assessment of the chloride content in water bodies is an important parameter to assess water quality. The sources of chlorine include fertilizers and animal wastes. Likewise, sulphates are brought from surface runoff. Phosphorus, which is an essential nutrient is naturally present in soil and water in both inorganic and organic forms[17]. A similar study carried out by Yadav and Kumar in the Kosi River in India showed that the nitrate and phosphate contents were in the range of 4.7-4.8 ppm and 3.3-6.7 ppm respectively, which were within the permissible limits. Also, all the other studied parameters were found to be within the permissible limits[3]. Likewise, this study also showed similar results where all the assessed physio-chemical parameters were found to be within the permissible limits of WHO and BIS.

Water bodies are also known to harbour toxic heavy metals which have been described as systemic toxicants because of their ability to induce multiple organ dysfunctions even at low levels[18]. Pollution of aquatic ecosystems with heavy metals can lead to environmental problems and adverse health impacts[6]. Thomas *et al.*, assessed the water sources in Nigeria and showed that the water bodies contain high levels of Pb, Cd, As and Hg. Also, the residents who had consumed water from the studied sources showed high heavy metal, urea, HCO_3^-, chloride, sodium, Kidney Injury Molecule-1, ALP, Gamma-Glutamyl Transpeptidase (GGT), Aspartate Aminotransferase (AST), Alanine Aminotransferase (ALT), Total Bilirubin (TB) and Conjugated Bilirubin (CB) and lower total protein and albumin in their blood[15]. Another similar study by Alfaifi *et al.*, revealed that As, Mn, Cr, Ni, Se, and Zn were found to be above the permissible limits in the groundwater of Saudi Arabia. Likewise, this study also revealed the presence of toxic heavy metals in trace amounts[19]. Similar results were also reported in a study on the Kameng River of Arunachal Pradesh where high amounts of Cd, Pb, Zn, and Mn were reported. These high contents were attributed to weathering, dissolution and mineralization of rocks[9]. A study on the Siang River reported the presence of various metals in high amounts resulting from excessive use of fertilizers and pesticides[10]. Another study in Itanagar which analysed groundwater samples reported Cr contamination that was three times higher than the WHO recommended values[11]. Cr is considered a group 1 carcinogen by the IARC[20] and is known to cause lung, liver, kidney, and skin damage and internal haemorrhage[21] whereas, As is known to be lethal[11]. Likewise, Pb is known to damage the nervous system extensively and can also damage the kidneys and cause death[22]. Such water bodies harbouring these metals cannot be used for drinking or other domestic purposes.

5. Conclusion

Water bodies in natural hilly areas can be contaminated. The notion that water bodies in hilly areas are free of contamination is not true. Hence, their quality assessments seem necessary. Although most of the studied parameters were found to be within the permissible safe limits of WHO and BIS, it is only a matter of time before these contents might increase if proper measures to prevent or control contamination and anthropogenic activities are not undertaken.

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7. Authors' Contribution

ADS conceptualised and supervised the study and wrote the first draft. AE and BB collected water samples and carried out the analysis. All the authors read and approved the final manuscript.

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