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Present Status of Heavy Metals in Lake Nainital, India

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Abstract

To evaluate heavy metal pollution status of the Lake Nainital, an eutrophic lake, situated in the Central West Himalayan region at 29°24′ N latitude, 79°28′ E longitude and an altitude of 1935 m above mean sea level, the assessment of heavy metals in the lake water was made from September 2016 to February 2017 using Atomic Absorption Spectrophotometer (AAS). Three sites *viz*., S_1 (Aeration centre at thandi sadak), S_2 (Platform near the Naina Devi Temple) and S_3 (Boat stand near bus stand) were selected and fortnightly sampling for assessing the concentration of six selected heavy metals (Lead, Cadmium, Arsenic, Zinc, Copper and Manganese) was made. The range and average concentration of heavy metals in water of Lake Nainital was observed as Zn: 0.013- 0.051 (0.029 mg L^{-1}), Pb: 0.137- 0.629 (0.346 mg L^{-1}), Cu: 0.0- 0.263(0.113 mg L^{-1}), Mn: 0.0- 1.314 (0.361 mg L^{-1}), Cd: 0.0- 0.012 (0.007 mg L^{-1}) and As: 0.0- 0.004 (0.001 mg L^{-1}). Three water quality pollution indices namely Heavy metal Pollution Index (HPI), Heavy metal Evaluation Index (HEI) and Degree of Contamination (C_d) were used to evaluate the present status of selected heavy metals. The average value of heavy metal pollution index of different metals (Zn: 0.005, Pb: 6.438, Cu: 0.066, Mn: 1.642, Cd: 0.610 and As: 0.205) show that the water of Lake Nainital is slightly affected with Mn and seriously affected with Pb pollution. Though the average value of HEI (1.448) and C_d (0.447) suggests low heavy metal pollution in the Lake Nainital, higher lead pollution is case of concern.

Keywords: Risk assessment, Lead, Cadmium, Pollution status, Pollution indices

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Introduction

Water quality is one of the most vital concerns for the mankind as well as for aquatic organisms as it is directly linked with their welfare. The aquatic environment with its water quality is considered as the main factor controlling the state of health and diseases in both cultured and wild fishes. As the freshwater is an important and scarce resource and lakes have its major proportion in inland area, therefore it is important to assess the quality of water in lake from time to time.

The undesirable human activities and unscientific utilization of resources from the lakes have caused adverse environmental changes which leads to environmental degradation thereby threatening the biodiversity sustained in it. Human activities like disposing large quantities of sewage in the lake are definitely causing a detrimental effect on the lake water quality (Singh et al., 2002). Contamination of water in Lake Nainital is caused by dumping of waste material into the lake. Due to dumping of large quantity of waste material in the Lake Nainital, earlier it was categorized as eutrophic lake. To resolve the problem occurring due to eutrophication (Fish mortality, wide variation in physico-chemical parameters and imbalance in trophic level organisms), artificial aeration and biomanipulation (phase wise partial removal of uneconomical fishes and stocking of eco friendly fishes for balancing trophic level structure) works have been done (Mishra et al., 2017) for seven years (2007 to 2014). Though the water quality condition of the lake is up to the mark now and the stocked fishes are surviving well but this lake is not used for fish culture and harvesting as rehabilitation of golden mahseer, an endangered sport fish, is going on. Heavy metals (including both essential and non-essential elements) have a particular significance in eco-toxicology. They are highly persistent and potentially toxic to the aquatic organisms as well as humans. The monitoring of heavy metal concentrations in aquatic ecosystems is usually done by measuring their concentration in water (Ebrahimpour & Mushrifah, 2008; Joshi et al., 2020). These are considered as the serious environmental pollutants because of their high toxicity, abundance and ease of accumulation by various organisms (Malik et al., 2014). Their applications in industrial, domestic, agricultural, medical and technological fields have led to their wide distribution in the environment, raising concerns over their potential effects on ecosystem as well as human health. Heavy metals have tendency to get concentrated from one trophic level to other trophic level in the food chain. As the food chain gets disturbed, the entire aquatic ecosystem gets destroyed by the metal toxicity.

The objective of this study was to determine the concentrations of Zinc (Zn), Lead (Pb), Copper (Cu), Manganese (Mn), Cadmium (Cd), and Arsenic (As); evaluate their effect on water quality and to estimate the extent of metal pollution in water of Lake Nainital- a tourist hub in Uttarakhand. Though the heavy metals get accumulated in trophic level organisms with hierarchical manner, their concentration in fish is not mentioned here as the Lake fish is not harvested for human consumption.

Material and Methods

The present experiment was conducted from September 2016 to February 2017 in Lake Nainital, a 48 ha natural kidney shaped, tectonic, warm monomictic lake (Sharma, 2014). The water samples were collected fortnightly from three selected sites *viz.*, S_1 (Aeration centre at thandi sadak), S_2 (Platform near the Naina Devi Temple) and S_3 (Boat stand near bus stand) (Fig. 1). The water samples were thoroughly filtered through cellulose nitrate filter paper to eliminate suspended solids and stored in plastic bottles after adding 1 ml concentrated nitric acid as preservative (AOAC, 1990). Heavy metal analysis has been done using Atomic Absorption Spectrophotometer (Thermo Scientific iCE 3000 Series) following AOAC standard operational method.

To assess the water quality of Lake Nainital in terms of heavy metals, 3 indices namely Heavy metal Pollution Index (HPI), Heavy metal Evaluation Index (HEI) and Degree of Contamination (C_d) were calculated.

Heavy metal Pollution Index (HPI) (Caerio et al., 2005):

$$HPI = \frac{(Ci/Si)^2_{max} + (Ci/Si)^2_{min}}{2} \quad \text{..........................(1)}$$

Where,

C_i is the reported concentration of each element and

S_i is the standard permissible value for the element.

The Heavy metal Pollution Index (HPI) is categorized into six classes presented in the Table 1.

Heavy metal Evaluation Index (HEI) (Edet & Offiong, 2002):

$$HEI = \sum_{i=1}^{n} \frac{H_c}{H_{mac}} \quad \text{................................(2)}$$

Where,

H_c is the monitored value and

H_{max} is the maximum admissible concentration

Degree of Contamination (CD) (Backman et al. 1997):

$$C_d = \sum_{i=1}^{n} C_{fi} \quad \text{..(3)}$$

Where,

$$C_{fi} = \frac{C_{Ai}}{C_{Ni}} - 1$$

Where,

C_{fi} represent contamination factor

C_{Ai} represent analytical value and

C_{Ni} upper permissible concentration of the i^{th} component

The statistical analysis has also been done to identify the relationship between various heavy metals in the water samples by using Pearson's correlation matrix with the help of SPSS software.

Results and Discussion

The concentration of selected heavy metals observed during investigation period from water of Lake Nainital and values of different heavy metal indices are depicted in Tables 1 to 4.

Zinc is an essential trace element found in natural environment in the form of salts or organic complexes. Its concentration varied from 0.013 to 0.051 mg L^{-1} throughout the study period. The mean concentration of Zinc at site S_1, S_2 and S_3 was recorded as 0.025 mg L^{-1}, 0.030 mg L^{-1} and

0.034 mg L^{-1}, respectively. Probable sources of Zn in Lake water may be erosion of minerals, burning of waste material, fertilizers, galvanised pipes, paints, *etc*. Agro-chemical run-off from the catchment area of the water body may also result in metal contamination (Keith & Plowes, 1997; Richards & Baker, 1992).

Lead is a highly toxic metal even at very low concentrations (Odum 1971; Freedman, 1995) and its exposure can produce a wide range of adverse effects in humans and other organisms. During the investigation period, its concentration varied from 0.137 to 0.629 mg L^{-1}. The mean concentration of Lead at site S_1, S_2 and S_3 was recorded as 0.245 mg L^{-1}, 0.389 mg L^{-1} and 0.405 mg L^{-1}, respectively. Lead is a non-essential element and is among the most toxic pollutant and is frequently encountered (Cecchi et al., 2008; Grover et al., 2010; Shahid et al., 2011). The high concentration of Pb may be attributed to mixing in lake during winters, dissolution of painting material from available boats, old galvanized pipelines, addition of vermilion from temple washings, domestic sewage discharge, dissolution of Pb containing rocks, burning of Pb containing fuels, *etc*.

Copper is considered as an essential element however, at high concentrations, it can cause severe health problems in organisms (Turnland, 1988). Its concentration ranged from 0.00 to 0.263 mg L^{-1} during the study period. The mean concentration at site S_1, S_2 and S_3 was recorded as 0.081 mg L^{-1}, 0.104 mg L^{-1} and 0.153 mg L^{-1}, respectively. The natural input of copper into aquatic environment is from erosion of mineralized rock whereas the anthropogenic inputs include industrial effluents, paints, *etc*. Elmaci et al. (2007) reported that industrial and domestic discharge results in higher concentration of Zn and Cu.

Manganese is ubiquitous in the environment and its distribution in aquatic systems is determined by the chemical characteristics of the oxidation states of the metal and the physical, chemical, and biological characteristics of the environment (Balistrieri et al., 1992). During the research period, its concentration varied from 0.00 to 1.314 mg L^{-1}. The mean concentration at site S_1, S_2 and S_3 was recorded as 0.233 mg L^{-1}, 0.426 mg L^{-1} and 0.423 mg L^{-1}, respectively. The anaerobic environment in deeper layers of lake (reduction of particulate Manganese oxides), Mn bearing minerals, municipal wastewater discharges, sewage sludge, leaching and combustion of fossil fuels, and to a much lesser extent, emissions from the combustion of fuel additives may be the possible sources of Manganese in the lake water.

Cadmium is non-essential element which is toxic even at low concentrations. It is retained for very long time in organisms after bioaccumulation (Larison et al., 2000). During the investigation period, its concentration varied from 0.00 to 0.012 mg L^{-1}. The mean concentration at site S_1, S_2 and S_3 was recorded as 0.005 mg L^{-1}, 0.007 mg L^{-1} and 0.008 mg L^{-1}, respectively. The possible reasons for the increased concentration of Cadmium include erosion of natural deposits, discharge of municipal wastes, corrosion of galvanized pipes, washings of dyes, paints of boats, etc.

Arsenic is a prevalent element that is detected at low concentrations in virtually all environmental matrices. Throughout the present investigation, its concentration varied from 0.00 to 0.004 mg L^{-1}. The mean concentration at site S_1, S_2 and S_3 was recorded as 0.001 mg L^{-1}, 0.001 mg L^{-1} and 0.002 mg L^{-1}, respectively. Possible reasons for the concentration of As in lake water may be erosion of rocks and minerals, paints, drugs, dyes, soaps, *etc*. The agricultural use of pesticides and herbicides also contributes to the higher level of the metal (Gecol et al., 2004; Zaw & Emett, 2002; Niazi et al., 2012).

The correlation coefficient among selected heavy metals has been calculated and depicted in table 3. The correlation matrix analysis is important as it helps in understanding the level of relationship between the described factors in terms of strong, average and no relationship. It is clear from the correlation table that Lead has strong positive correlation (values of correlation coefficient between 0.7 and +1) with Manganese and Cadmium which may be due to the presence of some common sources of these heavy metals in the lake whereas Copper and Cadmium have strong negative correlation (values of correlation coefficient between -0.7 and -1) between them.

The Heavy metal Pollution Index (HPI) of all the heavy metals has been calculated individually and the values are depicted in table 4. The results indicate that the water of Lake Nainital is slightly affected with Mn and seriously affected with Pb pollution.

By following the approach of Edet & Offiong (2002), the proposed Heavy metal Evaluation Index (HEI) criteria for the samples are as follows: low (HEI < 10), medium (HEI = 10-20) and high (HEI > 20). The average value of HEI obtained during the study period was 1.448. The present level of HEI shows that the water quality of Lake Nainital with respect to heavy metal content falls within low pollution zone.

The degree of contamination (C_d) was used as a reference to estimate the extent of metal pollution (Al-Ami et al., 1987). C_d may be grouped into three categories as follows: low (C_d < 1), medium (C_d = 1-3) and high (C_d > 3). The range and mean values of C_d were 0.09-5.92 and 0.447. The value of contamination index is below 1, suggesting that water of study site falls within low pollution zone.

The study reveals that the water of Lake Nainital exhibits low concentration of heavy metals like Zn, Cu, Mn, Cd and As whereas concentration of Pb was little high. The low values of Heavy metal Evaluation Index (HEI) and Contamination Index (C_d) show that water quality of lake is at low contamination level and Heavy metal Pollution Index (HPI) on the other hand shows that the water is slightly affected with Mn and seriously affected with Pb contamination. The study concludes that the high concentration of Pb in water of Lake Nainital should be looked upon as a serious issue and summons immediate attention for the conservation of existing biodiversity and well being of human population using water of the lake.

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