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Heavy Metal Pollution and Bioaccumulation in Mansagar lake

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ABSTRACT

The present research work was carried out for assessing the physicochemical parameters and heavy metal pollutioninMansagar lake water. Waterand fish samples were collected continuously over 12 months from January to December 2022 in triplets from designated locations inside the lake. The sampling and testing process was kept strictly according to the procedures of IS and APHA standards.The physico-chemical parameters observed were then compared to the allowable limits in accordance with the standards of the National Plan for Conservation of Aquatic Ecosystem (NPCA), which is run by the Indian government's Ministry of Environment, Forests, and Climate Change. It was discovered that while certain parameters were within the range, others were over the allowable limits. The heavy metal concentration was also found higher in some sites, The bioaccumulation of heavy metals was also recorded in some fish species. It certainly indicates that the lake is getting polluted day by day and the possible reasons may be continuous growth of population resulting into rapid industrialization and disposal of waste in the water body.

Key words: Jalmahal lake, Physico-Chemical Parameters, Dissolved oxygen, Heavy metals

Introduction

The globe, including India, is now experiencing a freshwater crisis in this century. The irony is immense: out of the water that covers 70% of the planet, just 2.5 percent can be used for fresh water. With the discharge of waste water in freshwater sources like lakes and rivers, the freshwater issue is getting worse every day.." Water is a complex element of the environment that possesses unique physical, chemical, and biological properties that are necessary for life. It is home to a wide variety of highly diverse aquatic organisms, and it is currently at a critical stage in their evolution (Gandotra et al., 2017; Verma and Pandey, 2013).Heavy metals include iron, manganese, nickel, lead, and zinc (Fe, Mn, Ni, Pb, and Zn) make up 80% of the waste water. In addition, nonmetallic pollutants such organic pollutants, hazardous compounds, and solutions have a negative impact on the quality of the water. Other effects, such as an increase in biological oxygen requirement and excessive TDS in drinking water, are caused by the declining water quality. More life is lost annually as a result of this quickly growing problem of contaminated water supplies than via conflict and violence. We were all aware that just 1% of water could be classified as freshwater overall. While many affluent nations may not have many issues with access to clean drinking water, nations like India are facing severe challenges because of their dense populations and scarce water supplies. It takes life" would be a good way to sum up the impacts of water contamination. Numerous surveys indicate the annual toll that water contamination causes in fatalities. People who live in areas with fewer amenities are especially vulnerable since they could be surrounded by contaminated streams, dirty industry, and dangerous water sources. The underlying cause of several illnesses, including cholera, typhoid, dengue, malaria, and many more, is water-borne pathogens including viruses and bacteria [Vashishth *et al* 2019]. The spread of these illnesses is aided by urban garbage discharge and inadequate sewage treatment, even in large cities. Every year, a large number of individuals in our nation contract pneumonia, an illness that spreads across the entire nation and is brought on by drinking contaminated water. In the meantime, these difficulties are growing daily as a result of the addition of dangerous metallic trash to drinking water sources [Gupta *et al* 2017], which is creating serious health problems like cancer and brain damage.

Literature review

Numerous studies on the water quality of various lakes, including Jaipur's Mansagar Lake, have been conducted Chaudhary(2021) (Amarnath Misra, 2020) Singh (2022) Yang Liu (2007) LoucifKarim (2008) Singh (2022) Vasistha Prachi (2020),Nidhi *et al (*2024) .The aquatic ecosystem has been directly disturbed by the fast population growth and increased anthropogenic and industrial activities in recent decades, which have led to a rise in heavy metal pollution in the water (Velez & Montoro 1998; Kaur 2008). Urbanisation, marine sand mining, industrial growth, and other human-caused activities are all contributing to the rise in metals (Gumgum et al., 1994; Velez & Montoro 1998; Kaur 2008; Baki et al., 2018). Due to industrial and agricultural activities upstream on rivers all water bodies acquire a significant amount of trace metals (Usero et al. 2005).Typically, these metals are found in trace amounts in freshwater and marine ecosystems (M. Pragnya 2020) through volcanic eruptions and rock weathering, but their levels have been rising as a result of some anthropogenic activities like increased urbanisation, agriculture, mining, andindustrialisation, as well as wastewater treatment facilities. (Garcia-Montelongo et al., 1994; Kalay and Canli 2000; Duffus 2002; Jordao et al., 2002; Demirak et al., 2006; Maier et al., 2014; Dhanakumar et al., 2015; Garcia et al., 2015). In addition to these human activities, improper enforcement of environmental standards has resulted in rising pollution levels (FAO, 1992). Because of its harmful effects on living things, heavy metal pollution has become a global problem (Mac Farlane and Burchett, 2000). Heavymetal buildup in various aquatic systems has been often recorded, despite the requirement for preventative measures prior to discharge into aquatic environments (Iqbal et al., 2017; Achary et al., 2017; Jinadasa et al., 2018; Shokr et al., 2019).

Heavy Metals

Metals can be categorized into two types essential and non-essential, essential metals such as copper, cobalt, zinc, iron, molybdenum, manganese, selenium, nickel, and magnesium play an important role in various physiological and biochemical functions in the body and deficiency of these essential metals may cause malnourishment and other health problems (WHO/FAO/IAEA, 1996). But even essential elements have a threshold limit for an organism and causes toxic effect if consumed in large amount. (Bryan, 1976; Alloway and Ayres, 1993; Fernandes et al., 2008). Whereas metals such as mercury, arsenic, cadmium, lead, have no essential role in living Both essential and non-essential metals can be classified. Essential metals, including copper,cobalt, zinc, iron, molybdenum, manganese, selenium, nickel, and magnesium, are vital for many physiological and biochemical processes in the body, and their deficiency can lead to malnourishment and other health issues (WHO/FAO/IAEA, 1996). However, even necessary components have a limit and can be harmful if taken in excess by an organism.(Fernandes et al. (2008); Alloway and Ayres (1993); Bryan (1976). However, even if they are present in trace amounts, metals like lead, cadmium, arsenic, and mercury have detrimental consequences while having no necessary function in living things. but they cause harmful effects even though they are present in minute quantities (Eisler, 1985; Munoz-Olivas and Camara, 2001; Järup, 2003; Fernandes et al., 2008). Environmental heavy metals not Metal bioaccumulation in freshwater and marine environments: M. Pragnya only builds up in organisms, but when its concentration rises, it can move from one trophic level to another (Svobodova et al. 2004). Consuming fish tainted with hazardous metals over an extended period of time has a number of negative impacts on all living things, including human health (Eisler 1985, Järup 2003).

Prior to using any water for household, industrial, agricultural, or drinking reasons, it is imperative to test its purity. Water quality needs to be determined using certain physiochemical and biological parameters. The water includes certain pollutants, which can be suspended or solved, bacterial or microbial, etc. The amount of these impurities can be determined by evaluating physical characteristics such as temperature, pH, turbidity, and TDS, as well as chemical parameters such as BOD, COD, dissolved oxygen, and hardness [Spellman *et al* 2017]. These tests ultimately determine the water quality of any given source.

Because of their strong ties to their surroundings, fish are essential to assessing the condition of a body of water. There is a possibility that the bioaccumulation of metals in freshwater and marine ecosystems will be contaminated as a result ofindustrialisation and urbanisation. Rapid industrialisation and urbanisationresult from its advantageous position and easy access. There are several private companies growing around the city in addition to significant public-sector ones. However, the water bodies in and around this cityisusually contaminated as a result of uncontrolled expansion and tourism activities. Local vendors and tourists throw the waste in this water body along with the sorrounding discharge channels andfishes absorb these causing bio-accumulation. It allows these contaminants to enter human bodies. Therefore, it is crucial to investigate how bio-accumulationin fishes occur and how they do the same in people.Because they take in pollutants from the surrounding water more quickly than their systems can eliminate them, aquatic species are frequently the targets of bioaccumulation.

Research Methodology

Study Area

The Jal Mahal palace is situated on Man Sagar Lake, which is home to the following fish species: common carp, mirror carp, grass carp, silver carp, rohu, catla, and maggal. Numerous fish, insect, microbe, and aquatic plant species previously called the lake home. But according to a 2017 assessment, the lake has turned poisonous and unfit for human habitation. High concentrations of germs, dissolved oxygen, and human waste were noted in the paper.

Figure 1 Mansagar Lake(Source: www.pexel.com)

Collection of Samples-Some designated locations within the lake were used to gather the samples. Water samples were collected 0.5m below the water surface in sterilized and rinsed plastic bottle.

Analysed parameters:

pH, Temperature, Electrical conductivity, Salinity readings were taken on the spot followed by DO, BOD, TDS, Chlorides, Total hardness, Alkalinity, and heavy metals were analyzed using standard procedures as given in table-1.

Analysis method

The pH and EC were measured by using portable meters. The concentration of magnesium, calcium, hardness, nitrate and salinity was estimated by volumetric methods and the results are compared with BIS standards. From each location three different Fish species have been selected to represent the various feeding habits: Numerous fish, insect, microbe, and aquatic plant species previously called the lake home. But according to a 2017 assessment, the lake has turned poisonous and unfit for aquatic habitation. High concentrations of germs, dissolved oxygen, and human waste were noted in the paper.

Table 1 and Table 2 below shows the protocols followed for the testing of different parameters and their permissible limits.

Parameter	Method
Acidity	APHA (21st Ed.) Method
Alkalinity	IS 3025 (Part 23): 2019
BOD (3 Day @ 270 C)	IS 3025 (Part 44): 2019
Calcium Hardness	IS 3025 (Part 40): 2019
Cd	IS 3025 (Part 65): 2017
Chloride (as Cl)	IS 3025 (Part 32): 2019
COD	IS 3025 (Part 58): 2017
Dissolved Oxygen	IS 3025 (Part 38): 2019
Fluoride (as F)	IS 3025 (Part 60): 2019
Magnesium Hardness	IS 3025 (Part 46): 2019
Nitrate (as NO3)	IS 3025 (Part 34): 2019
Pb	IS 3025 (Part 65): 2017
pH	IS 3025 (Part 11): 2017
Temperature	In-house Method
Total Dissolved Solids	IS 3025 (Part 16): 2017
Total Hardness (as CaCO3)	IS 3025 (Part 21): 2019
Turbidity	IS 3025 (Part 10): 2017
Zn	IS 3025 (Part 65): 2017

Table 1: Protocols followed

Physicochemical parameters	**Permissible values**
Bicarbonate (mg/L)	200
Calcium (mg/L)	75
Chloride (mg/L)	250
Fluoride (mg/L)	1
Magnesium (mg/L)	30
Nitrate (mg/L)	45
pH	7.2
Sulphate (mg/L)	200
Total dissolved solids (mg/L)	500
Total Hardness (as $CaCo_3$) (mg/L)	200

Table 2: Desirable and permissible limits of parameters

Duration of study

Water sampling was done during February 2022 to December 2022. A thorough analysis of the physico-chemical parameters was designed and carried out based on 12 months of testing and sampling Procedures. The IS and APHA guidelines were followed in the sampling and testing of the lake water. Table 3 shows

Parameters	**Sample 1**	**Sample 2**	**Sample 3**	**Sample 4**
pH	7.71	7.82	7.75	8.52
EC(us/cm)	1840	1860	1610	1643
Turbidity(NTU)	21	16.0	9.2	8.5
COD(mg/l)	100	80.0	85	100
BOD(mg/l)	19.0	15.0	18	19
DO(mg/l)	6.8	6.6	6.5	6.6
TSS(mg/l)	24.0	19.0	22.0	23
TDS(mg/l)	952	968	969	954
TH(mg/l)	316.80	316.80	318.9	318.80
Na(mg/l)	174.25	173.55	177.66	176.80
K(mg/l)	22.20	22.05	22.06	22.05
Mg(mg/l)	52.27	57.02	55.02	56.0

Table 3-Physico-chemical parameters of lake water during January 2022-december 2022

Name of the test	Method	unit
Zinc(Zn)	IS 3025(Part 65) 2014	Mg/l
Cadmium(Cd)	IS 3025(Part 65) 2014	Mg/l
Lead(Pb)	IS 3025(Part 65) 2014	Mg/l
Nickel(Ni)	IS 3025(Part 65) 2014	Mg/l

Table 4 protocols followed

Heavy metal	Sample 1	Sample 2	Sample 3	Sample 4	Unit
Zinc(Zn)	BLQ(LOQ)0.005	BLQ(LOQ)0.005	BLQ(LOQ)0.005	BLQ(LOQ)0.005	Mg/l
Cadmium(Cd)	BLQ(LOQ)0.001	BLQ(LOQ)0.001	BLQ(LOQ)0.001	BLQ(LOQ)0.001	Mg/l
Lead(Pb)	BLQ(LOQ)0.005	BLQ(LOQ)0.005	BLQ(LOQ)0.005	BLQ(LOQ)0.005	Mg/l
Nickel(Ni)	BLQ(LOQ)0.005	BLQ(LOQ)0.005	BLQ(LOQ)0.005	BLQ(LOQ)0.005	Mg/l

Table 5 Heavy metal concentration in lake water

Materials and methods

Fish Sample collection

A total of 4 different fish samples were selected and specimens of each fish species were collected from two ecosystems in 2022 during pre-monsoon (March), monsoon (September), and post-monsoon (December) seasons with similar morphological characters as given in table-5 and the tissue samples were analyzed using ICP-MS.

Sample preparation for water:

Water samples were acidified by adding 5ml of supra pure nitric acid (HNO_3) and then heated at 70⁰C until the solution becomes transparent (APHA 2005). The solution was allowed to cool and then filtered using 0.45µm micropore filter paper. The solutions were then kept for analysis for
the determination of heavy metals in water for the 12months and their concentration assessed(mg/l).

Digestion of the fish sample:

Fish samples were collected and were washed with distilled water and kept in an ice box and then brought to the laboratory. Samples were measured (length, breadth and weigh) after getting it to room temperature and dissected with stainless steel knife and kept in a freezer at -4̊c. All the laboratory equipment were washed thoroughly and then soaked in a 2% nitric acid and rinsed with double distilled water prior to experimentation to avoid contamination. Five grams of the homogenized spineless muscle tissue of each fish was taken into a beaker and then 7ml of supra pure HNO_3 (65% v/v) and 3ml of H_2O_2 (30% v/v) 3 ml (1:3 ratio) were added to it (Durali et al., 2010; APHA 2005) and covered it using watch glass and kept it overnight The mixture was placed on thermostatically controlled hot plate maintained at 70̊c for 45 minutes. The clear solution was cooled down and filtered through waltz men filter paper and make up to 25 ml using double distilled water(APHA 2014)
The concentration of heavy metals was measured using Inductively Coupled Plasma Mass Spectrometry (ICP-MS - Agilent 7700 series USA) (Table-6) results are expressed in µg/g per wet weight. All the digested samples and blank were run parallelly using standard solution acid mixture.

Results and discussions

S.No.	Scientific name	Common name	Feeding habit	length	weight
1	Lobeo Rohita	Rohu	Surface feeder,filamentous algae and sand	0.5m	2-4 kgs
2	CatlaCatla	Catla	Surface feeder,zooplanktons	3.5 m	2-5 kgs
3	LuciobarbusEsocinus	Mangar	Zooplanktons and small fishes,insects	2.3 m	1-2kgs

Table-5 Characteristics of the examined fish species

S.No.		Cu	Zn	Pb	Mn
1	Lobeo Rohita	1.88 µg/g	59.89 µg/g	3.08 µg/g	1.02 µg/g
2	CatlaCatla	2.97µg/g	42.87 µg/g	1.00 µg/g	0.86 µg/g
3	LuciobarbusEsocinus	2.93µg/g	48.30 µg/g	1.92 µg/g	1.94 µg/g

Table-6 Concentrations of Heavy Metals in some organs of Fish species collected from Study Area

conclusion

The values of the physicochemical parameters are ecological indicators of the pollution levels of any water body so it is most important to study the physicochemical parameters to understand the dynamics of heavy metal interactions in relation to the organisms andthe tendency of the pollution .It is widely established that the pH of the water affects both trace metal and micronutrient availability (Kirkham, 2006). Alkalinity is a measure of the quantity of carbonate in water, which indicates how well the water can support algal development and balance the acidity of the soil (Manahan, 1994). The quantity of trace metals in a solution can be determined by measuring the dissolved solids (EC). Therefore, while researching any interactions in water bodies, physiochemical investigations are required.Through a comparison of the evaluated lake water parameters with the NPCA requirements, it is evident that the pH level of MansagarLake which is in the range of 7.71 to 8.52 is moderately suitable. Whereas dissolved oxygen has been shown suitable for usage in categories B, C, and D of water, with a range of 3.6 – 5.8 mg/L.According to the NPCA criteria, BOD which is in the range of 15.0 to 19.2 is not appropriate for any category.(Nidhi *et al*2024).It is evident that the PH value is maximum in the month of May, June and November. In rest of the months the pH value is within the permissible limits. Monthly variations in COD and BOD and DO levels which again are very important parameters as far as water quality is concerned. It can be seen that the BOD levels are high and the DO level is very low during the month of August. During this study it was also observed that the BOD level was much higher than the permissible limit in all the months. The variation in other parameters is shown in Table-3 and we can observe the undulating values throughout the year. The present analysis clearly indicates that the lake water is not meeting the desirable criteria of clean water and is polluted. It is important to first treat this water before any kind of usage. The COD values are also above permissible limits in the lake water which shows presence of industrial effluents in lake water. In summary, this means that, in accordance with NPCA standards the quality of lake water is currently unsuitable for any kind of uses.The heavy metal concentration in the fish species was also above the suitable criteria and some organs were also found effected .

Through a comparison of the evaluated lake water parameters with the NPCA requirements, it is evident that the pH level of Mansagar Lake which is in the range of 7.71 to 8.52 is moderately suitable. Whereas dissolved oxygen has been shown suitable for usage in categories B, C, and D of water, with a range of 3.6 – 5.8 mg/L. According to the NPCA criteria, BOD which is in the range of 15.0 to 19.2 is not appropriate for any category. In summary, this means that, in accordance with NPCA standards the quality of lake water is currently unsuitable for any kind of uses.

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