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Research article

Assesment of sediment pollution in Koradi Lake under the influence of industrial and thermal power activities

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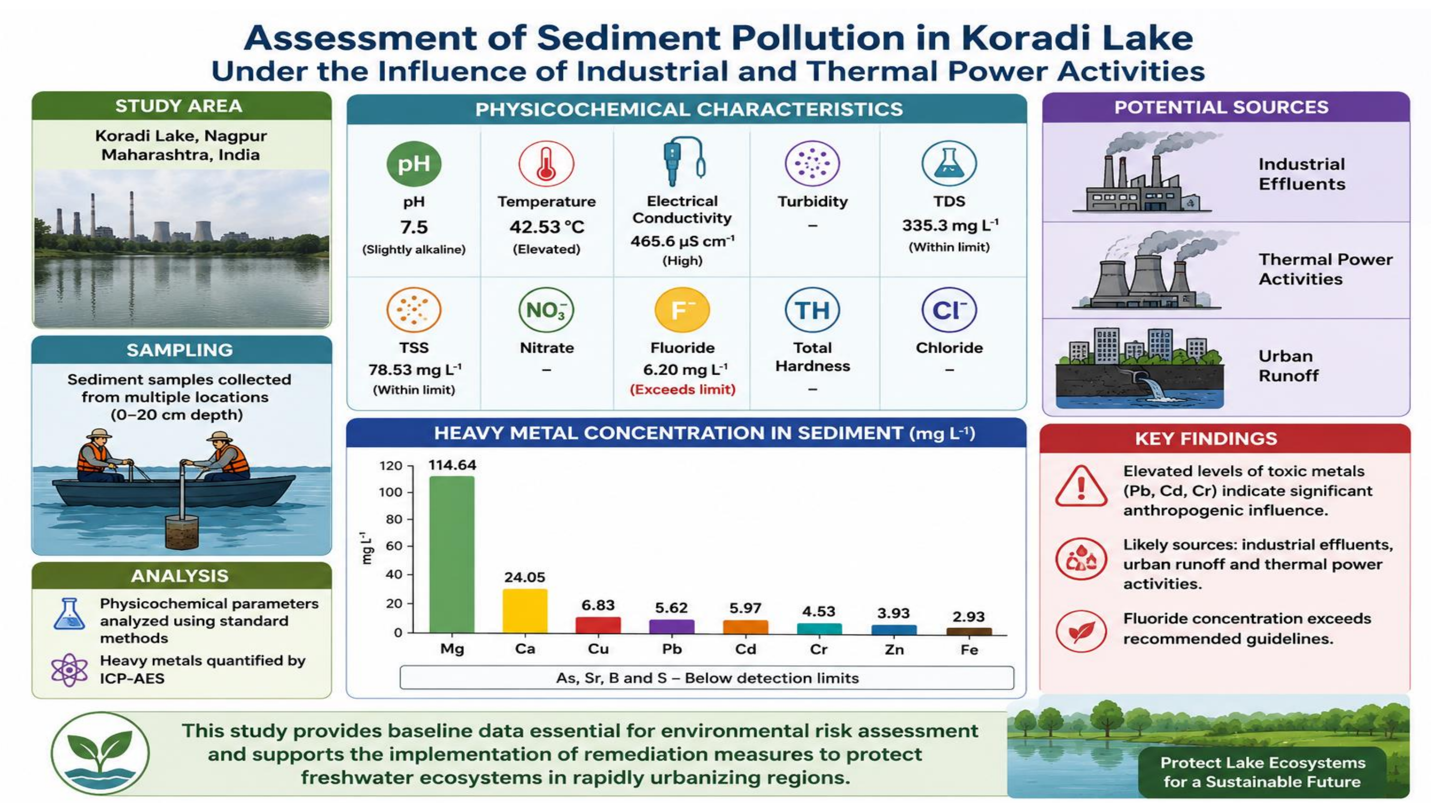
ABSTRACT

The present study evaluates the physicochemical characteristics and heavy metal concentrations of lake sediments collected from Koradi Lake in the Nagpur environment of Maharashtra, India, an area influenced by urbanization, industrial activities and thermal power generation. Sediment samples were collected from multiple locations at a depth of 0-20 cm and analyzed using standard protocols. Physicochemical parameters, including pH, temperature, electrical conductivity, turbidity, total dissolved solids (TDS), total suspended solids (TSS), nitrate, fluoride, total hardness and chloride, were determined using established analytical methods.



Heavy metal concentrations were quantified using inductively coupled plasmaatomic emission spectrometry (ICP-AES).The sediment samples exhibited slightly alkaline pH (7.5), elevated temperature (42.53 °C), and relatively high electrical conductivity (465.6 µS cm^{-1}), indicating enhanced ionic content. TDS (335.3 mg L^{-1}) and TSS (78.53 mg L^{-1}) values were within permissible limits, whereas fluoride concentration (6.20 mg L^{-1}) exceeded recommended guidelines. Heavy metal analysis revealed notable concentrations of magnesium (114.64 mg L^{-1}), calcium (24.05 mg L^{-1}), copper (6.83 mg L^{-1}), lead (5.62 mg L^{-1}), cadmium (5.97 mg L^{-1}), chromium (4.53 mg L^{-1}), zinc (3.93 mg L^{-1}), and iron (2.93 mg L^{-1}), while arsenic, strontium, boron, and sulfur were below detection limits. The elevated levels of toxic metals such as Pb, Cd, and Cr suggest significant anthropogenic influence, likely originating from industrial effluents, urban runoff and nearby thermal power activities. This study provides baseline data essential for environmental risk assessment and supports the implementation of remediation measures to protect freshwater ecosystems in rapidly urbanizing regions.

Keywords: Heavy metals, Bioremediation, Lake sediment, Industrial waste.

INTRODUCTION

Freshwater ecosystems are among the most vital natural resources on Earth, providing drinking water, food, irrigation, industrial supply, recreation, and ecological services that sustain both human societies and natural biodiversity. Lakes, reservoirs, and wetlands play a particularly important role in regulating regional hydrology, maintaining nutrient cycling, supporting aquatic and terrestrial food webs, and acting as sinks for sediments and contaminants. However, rapid urbanization, industrialization, population growth, and unplanned land use changes have placed immense pressure on freshwater bodies worldwide, especially in developing countries. Among the various environmental compartments of aquatic systems, sediments act as both indicators and archives of environmental quality, reflecting long-term inputs of pollutants and natural geochemical processes. Consequently, the assessment of physicochemical characteristics and heavy metal concentrations in lake sediments has become a crucial component of environmental monitoring and management [1,2].

Sediments are dynamic matrices composed of mineral particles, organic matter, water, and associated biota. They function as both sinks and secondary sources of contaminants, particularly heavy metals and nutrients. Unlike water, which reflects short-term variations in environmental conditions, sediments integrate pollution signals over extended periods, making them reliable indicators of historical and ongoing contamination. Heavy metals introduced into aquatic environments through natural weathering processes or anthropogenic activities tend to accumulate in sediments due to their low solubility, high affinity for particulate matter, and tendency to form complexes with organic and inorganic ligands. Once deposited, these metals can persist for decades and may be remobilized under changing physicochemical conditions such as pH, redox potential and temperature, posing long-term risks to aquatic organisms and human health [3].

In recent decades, concern over sediment associated pollution has intensified due to the toxic, persistent, and bioaccumulative nature of heavy metals. Metals such as lead (Pb), cadmium (Cd), chromium (Cr), arsenic (As), and mercury (Hg) have no known biological function and can exert severe toxic effects even at low concentrations. Other metals, including copper (Cu), zinc (Zn), iron (Fe), manganese (Mn), calcium (Ca), magnesium (Mg), and potassium (K), are essential for biological processes but become harmful when their concentrations exceed physiological thresholds. The accumulation of heavy metals in sediments can adversely affect benthic organisms, disrupt microbial communities, reduce biodiversity, and enter the food chain through bioaccumulation and biomagnifications. Ultimately, these processes can threaten ecosystem stability and public health, particularly in regions where surface waters are used for domestic, agricultural, or recreational purposes.

Maharashtra, one of India's most industrialized states, contains numerous natural and artificial lakes that are integral to regional water supply, agriculture, and biodiversity conservation. Nagpur, located near the geographic center of India, is a major urban and industrial hub experiencing sustained population growth and infrastructural expansion [4,5]. The city is surrounded by several lakes that play important ecological and socio-economic roles. However, increasing anthropogenic activities in and around these water bodies have raised concerns regarding their environmental health. Industrial emissions, domestic sewage discharge, surface runoff from urban areas, religious activities, and thermal power generation are among the major contributors to pollution in the region [6]. As a result, systematic scientific investigations are required to evaluate the current status of sediment quality and associated environmental risks.

Physicochemical parameters such as pH, temperature, electrical conductivity, turbidity, total dissolved solids (TDS), total suspended solids (TSS), hardness, chloride, nitrate, fluoride, and dissolved oxygen strongly influence the chemical behaviour, mobility, and bioavailability of contaminants in aquatic systems. These parameters govern processes such as adsorption–desorption, precipitation–dissolution, ion exchange, and complexation, which in turn control the distribution of heavy metals between the water column and sediments. For instance, pH plays a central role in determining metal solubility and speciation; acidic conditions often enhance metal mobility, while alkaline conditions favor adsorption onto sediment particles. Temperature affects chemical reaction rates, microbial activity, and dissolved oxygen levels, thereby influencing nutrient cycling and metal transformation. Electrical conductivity serves as an indicator of ionic strength and salinity, reflecting the total concentration of dissolved ions in water and sediment pore spaces.

Turbidity, TDS, and TSS are critical indicators of particulate and dissolved matter in aquatic environments. High turbidity can reduce light penetration, impair photosynthesis, and alter primary productivity, while elevated TDS and TSS levels may indicate contamination from domestic or industrial sources. Nutrients such as nitrate and phosphate, although essential for aquatic productivity, can lead to eutrophication when present in excessive amounts, resulting in algal blooms, oxygen depletion, and ecosystem degradation. Fluoride and chloride, commonly derived from geological formations and anthropogenic inputs, also serve as important indicators of water–sediment interactions and potential health risks [7]. Together, these physicochemical parameters provide essential context for interpreting heavy metal concentrations and understanding the processes governing sediment quality.

Heavy metals in sediments originate from both natural and anthropogenic sources. Natural inputs include the weathering of parent rocks, volcanic activity, and atmospheric deposition of mineral dust. Anthropogenic sources are often dominant in urban and industrial regions and include effluent discharge from industries, thermal power plants, mining and smelting operations, vehicular emissions, sewage sludge application, agricultural runoff, and improper disposal of solid waste. In lake environments, metals released into the water column are rapidly scavenged by suspended particles and organic matter, eventually settling into sediments. The fine-grained fraction of sediments, particularly clay and silt, exhibits a high capacity for metal binding due to its large surface area and abundance of reactive sites.

Despite growing awareness of sediment pollution, many freshwater bodies in India remain insufficiently studied, particularly at the local and regional scales [9]. Site-specific investigations are essential because sediment characteristics and contamination levels vary widely depending on geology, hydrology, land use, and anthropogenic pressure. Koradi Lake, located near Nagpur, represents an ecologically and culturally significant water body influenced by nearby industrial and urban activities, including thermal power generation and religious tourism. The lake receives inputs from surface runoff, atmospheric deposition, and potentially untreated effluents, making it susceptible to sediment contamination. However, systematic data on the physicochemical properties and heavy metal content of its sediments remain limited.

The present study addresses this knowledge gap by conducting a detailed assessment of physicochemical parameters and heavy metal concentrations in lake sediments from the Nagpur environment of Maharashtra. By analyzing key water-sediment quality indicators and a broad spectrum of metals, this investigation aims to evaluate the extent of sediment contamination and identify potential environmental risks. The results provide baseline information for future monitoring, contribute to a better understanding of anthropogenic impacts on urban lake ecosystems, and support the development of effective management and remediation strategies.

MATERIALS AND METHODS

Sample collection

The sampling location were identified and the sample were collected in keeping a view of the geological structure and formation of the individual locations. To determine the individual activity concentration of the radionuclides a large number of sand and sediment sample were collected from different sampling location of the Nagpur environment of Maharashtra. The sample were collected in the month of December 2023 using standard procedures. For collecting the sand sample undisturbed surface areas were selected. About 1 m^2 area was marked, stones and pebbles on the surface are cleaned, and the sample up to the desired depth (0-20 cm) were collected for analysis. Within a distance of 50 meters, the sample were collected following the same procedure. The bulk sample was reduced by quartering process. The collected sample were mixed thoroughly for homogeneity and divided into four equal parts and one part was selected as the representative sample. About 2.5 kg of sample collected in a polythene bag and brought to the laboratory for further analysis.

Sample processing

The collected sample were carefully processed using standard procedures. The sample were cleaned and air-dried at room temperature in the open air. Then the sand sample were transferred to porcelain trays and dried in an oven at 110°C till a constant dry weight. The dried sample were sieved through a standard mesh of 250 µm grain size. About 300 gm of each sample was taken in an airtight cylindrical polyethylene plastic container and sealed with adhesive tapes.

Physico chemical parameters measurement

The physico-chemical parameters of the sediment sample from the Nagpur environment identified and average values were recorded during the investigation. The important physico-chemical parameters such as pH, temperature, electrical conductivity, turbidity, total dissolved solids, total suspended solids, nitrate, fluorides, total hardness, total chloride of the collected sample were measured following standard methods and techniques.

pH

The pH is the measure of concentration of hydrogen ions and the scale of intensity of active acidity or alkalinity of water, soil, sand or any other substance in the aqueous system. During the process of sample collection, a standard digital pH meter was utilized to measure the pH. About 20 gm of sand sample was taken in a 100 mL beaker and added 50 mL of distilled water and then the suspension was stirred for 5 times over a period of 30 minute to reach equilibrium. In the meantime, switch on the instrument, set the temperature knob to room temperature and set range selector to zero, also set the galvanometer to zero with zero knobs after 15 minutes. The pH meter was calibrated with phosphate buffer of known pH. It uses electrodes that are free from interference. At constant temperature, a pH change produces a corresponding change in the electrical property of the solution. This change was read by the electrode and the accuracy was the greatest in the middle pH ranges. Then washed the electrode with distilled water and dipped into the suspension and readings were noted.

Temperature

Thermometer was used to measure the temperature, on the spot at the time of sample collection.

Electrical conductivity (EC)

The electrical conductivity of the sand samples was measured using Systronics conductivity meter. It is based on the principle of Wheat-Stone Bridge in which an alternating current is used instead of direct current in order to eliminate the polarization of electrodes. The balance point is indicated by a magic eye. About 10gm of soil was taken in a beaker and 25 mL of distilled water was added to it. Then the suspension was stirred and left overnight to get a clear supernatant solution. Later on, instrument was used to stabilize for 15 minutes prior to recording reading. The conductivity cell was dipped into the supernatant solution and moved the pointer on the dial to get the maximum area in the shade in the magic eye. The reading on the solute bridge was noted and electrical conductivity of the sample was measured.

Turbidity

Turbidity was measured using turbido meter (Neohelo meter), It measured the scattered light at right angle of the path of incident light. The Nephelometer was set at 100 with 40NTU standards. In this case every division on the scale was equal to 0.4NTU turbidity.

Turbidity NTU = Nephelometer reading x 0.4 x dilution factor

Total dissolved solids

Filter paper was washed, dried and evaporated in a petri dish and weighed. Filtered 50 ml of sample was stirred and washed three times and the filtrate was transferred to an evaporating dish, cooled and weighed.

$$TDS/L = \frac{(A-B) \times 1000}{\text{Volume of sample}}$$

Total Suspended Solids

Place filtration apparatus with weighed filter in filter flask. Mix sample well and pour into a graduated cylinder to the selected volume. Apply suction to filter flask and seat filter with a small amount of distilled water. Pour selected volume into filtration apparatus. Draw sample through filter into filter flask. Rinse graduated cylinder into filtration apparatus with three successive 10 mL portions of distilled water, allowing complete drainage between each rinsing. Continue suction for three minutes after filtration of final rinse is completed. Dry filter in an oven at 103-105°C for at least 1 hour. Cool filter in desiccator to room temperature. When cool, weigh the filter and support.

Nitrate

Nitrate is the most highly oxidized form of nitrogen compounds commonly present in natural water, because it is the product of the aerobic decomposition of organic regions matter. The sample was coloured, and the colour was removed by adding 3 ml aluminium hydroxide. Nitrite from the sample was oxidized from NO_2 to NO_3 under acid condition using potassium permanganate. Chloride was also removed perpetually by using Mercuric Sulphate. Neutralized the classified sample and the pH was adjusted to 7.0. Adequate quantity of sample was taken in a beaker and it was evaporated to dryness on water bath. Dissolved the residue using 2 ml phenol disulphuric acid reagent 8-10 ml of 12 N potassium hydroxide was added, filtered and it was made to 100 ml. Prepared blank in the same way using distilled water instead of sample. The intensity of colour developed at 410 mm Record NO_3 as N in mg/l was read. Calibration curve rising suitable aliquots of standard nitrate solution in the range of 5-500 mg NO_3 was prepared.

Fluoride

The sample can be collected in a clean sample container prior to filtration. Filtered sample is placed into a sample bottle, after rinsing. Ensure sample bottle is prerinsed three times with filtered sample water (3 × 20 ml) before final collection. Filter sample through 0.45m pore diameter cellulose acetate (membrane) filter. Refrigerate at 1–4°C or freeze. Fill to below shoulder of bottle if freezing. Analyse within 1 month if sample is kept refrigerated at 1–4°C.

Total hardness

Hardness of water is due to the presence of calcium, magnesium and strontium in water and is determined by complex metric titration. Hardness is the total concentration of Ca and Mg in water. When EDTA (Ethylene Diamine Tetra Acetic acid) was added as a titrate Ca and Mg were complexed and the solutions turned blue.

To a portion of a sample 1-2ml of NH_4Cl – NH_4OH buffer to maintain the pH level above 10. The absence of a sharp end point, colour change in the titration means that indicators have deteriorated. One to two drops of the Enciohrome Black T indicator were added. EDTA solution was then added slowly with continuous stirring. At the end point, colour changed from wing red to blue.

The hardness of the sample was calculated from this formula.

$$\text{Hardness as Mg of } {}^{CaCO_3}/_{L} = \frac{(A \times B) \times 1000}{\text{Volume of sample}}$$

Were,

A =Volume of EDTA in ml,

B= mgs of $CaCO_3$ = 1 ml of EDTA

Total Organic Carbon (TOC)

Chloride

Chloride is an anion generally present in natural waters, the presence of which can be attributed to the dissolution of salt deposits discharge of effluents from chemical industries, oil well operations, sewage discharges and irrigation drainage. Chloride was determined in a neutral or slightly alkaline solution by titration method with standard silver nitrate, using potassium chromate as an indicator.

$$\text{Chloride mg /L} = \frac{(A-B) \times 35.45 \times 1000}{\text{Volume of sample}}$$

Metal Analysis

Concentrations of Barium (Ba), Calcium (Ca), Iron (Fe), Potassium (K), Magnesium (Mg), Copper (Cu), Manganese (Mn), Lead (Pb), Cadmium (Cd), Chromium (Cr), Sodium (Na), Strontium (Sr), Zinc (Zn), Boron (B), Sulphur (S), Phosphorous (P), Silicon (Si) and Arsenic (As) in the lake sediment samples were analysed using inductively coupled plasma atomic emission spectrometer (ICP-AES - Thermo Electron IRIS INTREPID II XSP DUO). The sediment samples must be preserved in the field by cooling to less than 4°C within four hours of sampling before ICP-OES analysis. One gram of finely powdered dried sediment was digested repeatedly with HF-$HClO_4$- HNO_3, suspended in 0.5 M HCl (25 ml) and analysed for heavy metals following the standard protocol. For sediment sample, a known volume was filtered and the filtrate was acidified using concentrated HCl. The dissolved metals were extracted using 2 % ammonium pyrrolidine dithio carbamate (APDC) in 10 ml of methyl Isobutyl ketone (MIBK) at pH 4.5 and brought back to aqueous layer by back-extraction with concentrated HNO_3 and made up to 20 ml with sterile de-ionized water. The extracts were analysed in the flame for trace metals. The analyses were done in triplicate. The concentration of metal in water and sediment is expressed as mg L^{-1} and mg kg^{-1}, respectively.

RESULTS

Study Area

A bioremediation study was conducted in Nagpur, a city located at the geographic center of India and recognized as an important birding destination since pre-independence times. Koradi, known for its thermal power station and the Mahalaxmi Devi Temple, which draws devotees to its doors throughout the year The Koradi lake, which has covered an area of 172.35 hectares, is located about 17 kilometers from Nagpur, at a latitude of 21°15'39"N and a longitude of 79°05'18"E. The study area was positioned in close proximity to the lake. Figure 1 depicts the location of Koradi Lake in Nagpur.

Figure 1: Sampling location- Aerial view of Koradi lake

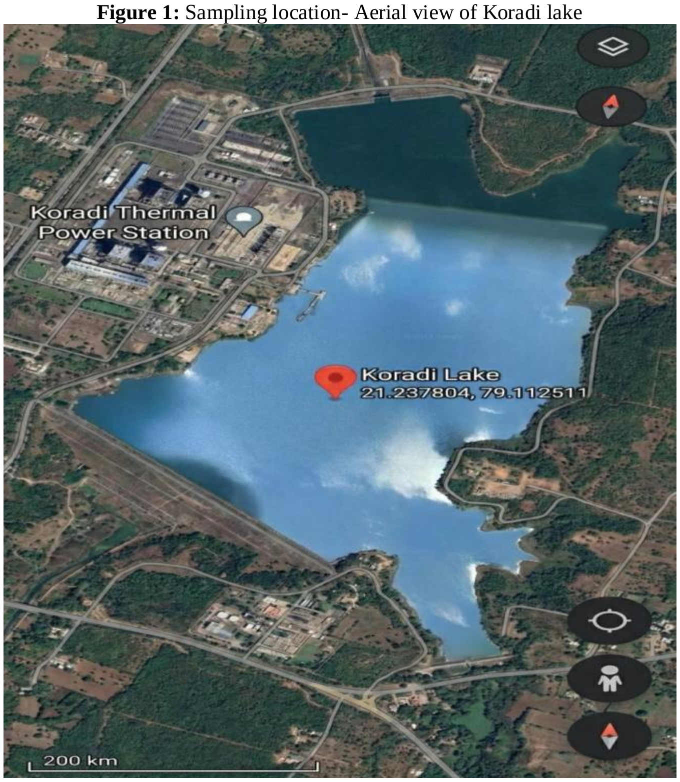


Figure 2: Sampling location- Koradi lake photo

Physicochemical characteristics of the collected sediment

Sediment sample was collected from Koradi lake, Nagpur environment of Maharashtra, India, at a depth of 20cm into sterile vials, with solid particles carefully avoided. The collected sediment sample immediately filtered via 0.45micron filters to remove particulates. The sediment samples were subsequently subjected to standard testing methods for comprehensive quality analysis.

The physicochemical properties considered included pH, temperature, electrical conductivity, turbidity, total dissolved solids, total suspended solids, nitrate, fluorides, total hardness, total chloride are the physical and chemical parameters are considered for water quality analysis. Dissolved oxygen is measured by chemical and electrochemical analysis method (Table 1).

Table 1: Physico-chemical parameters of Lake sediment samples

Parameters	Value of Lake sediment
pH	7.5 ± 0.04
Temperature (°C)	42.53 ± 0.41
Electrical Conductivity (us/cm, 25ºC)	465.6 ± 3.29
Turbidity (NTU)	10.07 ± 0.11
Total Dissolved Solids (mg/L)	335.3 ± 1.24
Total Suspended Solids (mg/L)	78.53 ± 0.41
Nitrate -N (mg/L)	2.63 ± 0.44
Fluorides (mg/L)	6.20 ± 0.01
Total Hardness (mg/L)	126.3 ± 0.69
Total Chloride (mg/L)	58.22 ± 0.016

pH

In the present investigation, the sediment samples were found to be slightly alkaline with a pH value of 7.5.

Temperature

In the present study, the sediment temperature of the lake was recorded at 42.53 °C, which is considerably higher than the typical average sediment temperature range of 23.05–28.07 °C.

Electrical conductivity (EC)

In the present study, the average electrical conductivity of the sediment samples collected from the selected site was 465.6 µS/cm at 25ºC.

Turbidity

Turbidity measures the concentration of suspended particles in water and is a key factor regulating photosynthetic activity within the water column. Although elevated turbidity is often associated with freshwater inflow or rainfall carrying sediments into a system, the measurement essentially indicates the degree to which water scatters and absorbs light. This scattering is usually caused by fine suspended or colloidal particles that settle very slowly. In this study, the turbidity of the sediment sample was recorded as 10.07 NTU.

Total Dissolved Solids

Total Dissolved Solids (TDS) are a important parameter for evaluating both the physical and biological processes involved in wastewater treatment and for determining overall water quality. TDS primarily consists of dissolved salts, specifically the carbonates, bicarbonates, chlorides, phosphates, and nitrates of elements such as calcium, magnesium, sodium, potassium, and manganese. Elevated TDS levels can make water unsuitable for drinking and irrigation. According to the Bureau of Indian Standards (BIS) the permissible limit for TDS in water is 1000 mg/L. In the present study, the sediment sample exhibited a TDS value of 335.3 mg/L, indicating that it falls well within the acceptable limit.

Total Suspended Solids (TSS)

In the present study, the sediment sample showed a TSS value of 78.53 mg/L, which is well below the recommended limit.

Nitrate (NO_3^-)

Nitrate (NO_3) is a primary limiting nutrient in many aquatic environments and plays a important role in regulating denitrification activity in aquatic sediment. However, elevated nitrate levels pose health risks, with concentrations above 10 mg/L considered unsafe for humans. Excess nitrate in water bodies often results from pollution sources such as runoff from fertilized agricultural fields, leakage from landfills or septic systems, wastewater discharge, animal feedlots, and municipal drainage. In the present study, the nitrate concentration was recorded at 0.

Fluorides

Fluoride (F^-) is one of the most electronegative and reactive elements found in the environment. Although the World Health Organization (WHO, 2004 recommends a maximum safe fluoride concentration of 1.5 mg/L in drinking water, the present study recorded a significantly elevated fluoride level of 6.20 mg/L in the sediment samples.

Total Hardness

Total Hardness is a water quality indicator, rather than a pollution parameter, and results from the presence of polyvalent metallic ions. Hard water contains elevated levels of dissolved minerals such as calcium, magnesium, and, in some cases, iron. he higher the concentration of these dissolved minerals, the greater the hardness of the water. Carbonate hardness (CH) refers to the portion of total hardness that is equal to the water's total alkalinity (the combined concentration of carbonates and bicarbonates), provided that total hardness is higher than total alkalinity. According to WHO standards, the acceptable limit for total hardness is 100 ppm. In the present study, the sediment sample exhibited a total hardness of 126.3 mg/L.

Total Chloride

Chlorides are salts formed through the chemical combination of a metal with chlorine. Chloride play a vital role in normal cellular processes in both plants and animals. In the current study, the sediment sample was found to contain a chloride concentration of 58.22mg/L.

Heavy metals

Heavy metal pollution is a harmful consequence of human activities and significantly degrades soil and water quality. The presence of heavy metals in lake ecosystems represents a significant and emerging environmental pollution threat. These metals are of particular concern due to their persistence and potential harmful effects on both the environment and human health. While some heavy metals are essential in trace amounts for living organisms, even slight increases above safe levelswhether due to natural processes or human activitiescan pose serious health risks. Elevated concentrations of these metals in water and sediments can disrupt ecosystems. Essential trace metals such as cobalt, copper, zinc, and manganese are necessary nutrients for humans and other organisms, but their levels above acceptable limits can be harmful. In contrast, metals like lead, mercury, arsenic, and cadmium have no known biological function, and even small amounts can be toxic. In the present study, sediment samples were analyzed for the concentrations of various heavy metals, including Barium (Ba), Calcium (Ca), Iron (Fe), Potassium (K), Magnesium (Mg), Copper (Cu), Manganese (Mn), Lead (Pb), Cadmium (Cd), Chromium (Cr), Sodium (Na), Strontium (Sr), Zinc (Zn), Boron (B), Sulfur (S), Phosphorus (P), Silicon (Si), and Arsenic (As) are presented in Table 2.

Table 2: Concentration of heavy metals in the Nagpur environment of Maharashtra

Metals	mg/L
Barium (Ba)	5.71
Calcium (Ca)	24.05
Iron (Fe)	2.93
Potassium (K)	1.34
Magnesium (Mg)	114.64
Copper (Cu)	6.83
Manganese (Mn)	0.308
Lead (Pb)	5.62
Cadmium (Cd)	5.97
Chromium (Cr)	4.53
Sodium (Na)	2.03
Strontium (Sr)	BDL
Zinc (Zn)	3.93
Boron (B)	BDL
Sulphur (S)	BDL
Phosphorous (P)	2.18
Silicon (Si)	1.84
Arsenic (As)	BDL

BDL- Below detection limit

Barium (Ba)

Barium is an alkaline earth metal commonly present in small to moderate amounts in the natural environment, including food and drinking water. Persistent barium compounds tend to accumulate in soil surfaces or in aquatic sediments. In the present study, barium was detected in the effluent samples at a concentration of 5.71 mg/L.

Calcium (Ca)

Calcium is commonly found in natural waters, primarily derived from the leaching of calcium-rich minerals such as limestone or from the mineralization of organic matter by bacteria. It plays a vital role in ecosystem function, influencing flora and contributing to metabolism and growth. The elevated calcium levels may be attributed to sewage input from the surrounding area. The generally accepted limit for calcium in water is 75 mg/L, while the maximum permissible limit is 200 mg/L. In the present study, calcium hardness in the effluent sample was measured at 24.05 ppm.

Iron (Fe)

Iron acts as a micronutrient in water when its concentration is below 0.3 mg/L, but higher levels can negatively impact water quality and pose risks to both aquatic life and human health. In the present study, iron was detected in lake sediment at a concentration of 2.93 mg/L. Such elevated iron levels may result from natural mineral deposits or from contamination due to nearby human activities, potentially affecting overall water quality and the health of aquatic ecosystems.

Potassium (K)

Potassium is the eighth most abundant element in the Earth's crust, with an estimated concentration of 1.84%. In global rivers, potassium primarily originates from the leaching of silicate minerals, with smaller contributions from sources such as evaporite minerals, fertilizers, rainfall, and the decomposition of terrestrial plants. Natural sources are generally considered more significant than anthropogenic inputs. In the present study, potassium was detected in the sediment samples at a concentration of 1.34 ppm.

Magnesium (Mg)

Magnesium is the seventh most abundant element in the Earth's crust, with an average concentration of 2.76%, and the Mg^{2+} ion is the second most abundant cation in natural waters after sodium. Magnesium plays a crucial role in limiting phytoplankton growth and is essential for chlorophyll synthesis. However, elevated magnesium levels in water can reduce its quality, impart an unpleasant taste, and render it unsuitable for domestic use. In the present study, magnesium concentration in lake sediment was found to be 114.64 mg/L. The generally accepted limit for magnesium in water is 50 mg/L, while the maximum permissible limit is 100 mg/L (ICMR, 1975).

Copper (Cu)

Copper is an essential element for human health in small amounts, but excessive exposure can cause adverse effects such as anemia, liver and kidney damage, and gastrointestinal irritation. In water, copper commonly originates from corrosion of copper pipes or from additives used to control algal growth. It is also crucial for plant growth, playing an important role in CO_2 assimilation and ATP synthesis. In the present study, copper was detected in lake sediment at a concentration of 6.83 mg/L. Elevated copper levels in these water bodies highlight the need for careful monitoring and potential remediation to protect both public health and aquatic ecosystems.

Manganese (Mn)

Manganese is an essential micronutrient for plant growth, playing a critical role in the formation of photosynthetic proteins and enzymes, as well as supporting the biosynthesis of growth substances. It is vital for plant development and metabolic functions within various cell compartments. Although manganese is necessary for normal cellular function, it can be toxic at high concentrations.

Elevated manganese levels can also increase water hardness, which may reduce the efficiency of water heaters, pumps, and pipe systems. Manganese enters water bodies through the erosion of sediments and rocks and can dissolve into the water. In the present study, manganese was detected at trace levels of 0.308 mg/L in lake sediment, whereas its average concentration in drinking water is around 4.0 µg/L.

Lead (Pb)

The determination of lead is an important parameter because it is toxic to aquatic organisms and can lead to mortality. The natural concentration of lead in lakes, rivers, and reservoirs worldwide is typically estimated to range from 1 to 10 ppm. Higher concentrations have occasionally been reported, primarily due to industrial contamination, although such occurrences are relatively rare because natural processes often regulate lead levels. In the present study, the lead concentration in lake sediment was found to be 5.62 mg/L.

Cadmium (Cd)

Cadmium is a trace element widely distributed in the Earth's crust, often occurring in small amounts within zinc ores. It is highly toxic to humans, animals, microorganisms, and plants. Although only a small portion of cadmium is absorbed by the body, it tends to accumulate in the bones and liver, and with chronic exposure, in the kidneys. Even low levels of cadmium can cause harmful effects, including damage to kidney arteries, and it has been linked to cases of foodborne poisoning. Cadmium can enter water systems through industrial discharges or the corrosion of galvanized pipes. In the present study, the cadmium concentration in the sediment sample was measured at 5.97 mg/L.

Chromium (Cr)

Most rocks and soils naturally contain small amounts of chromium, and due to its low solubility, chromium levels in water are typically low. However, there have been instances of water contamination, sometimes severe, caused by the discharge of effluents containing chromium compounds into rivers. In the present study, the chromium concentration in lake sediment was recorded at 4.53 mg/L.

Sodium (Na)

Elevated sodium concentrations can reduce biological diversity by causing osmotic stress and can also inhibit seed germination. In the present study, sodium was detected at a concentration of 2.03 mg/L in the sediment, representing the highest level among the analyzed elements.

Strontium (Sr)

Strontium is an important mineral for human bones and teeth and can enter the body through food, water, or inhalation. It behaves similarly to calcium in biological systems. In the present study, strontium levels in the sediment were found to be below the detection limit (BDL).

Zinc (Zn)

Zinc is an essential trace element for plants, and deficiency can result in delayed maturity and stunted growth. The environmental toxicity of zinc in water depends on the presence of other minerals. Excessive zinc exposure can cause vomiting, diarrhea, skin irritation, and anemia, and very high levels may damage the pancreas, liver, and kidneys, disrupt protein metabolism, and contribute to arteriosclerosis. In the present study, zinc was detected in sediment at a concentration of 3.93 mg/L.

Boron (B)

Boron is a trace mineral essential for plants, animals, and humans, playing a critical role in maintaining the structural and functional integrity of cell walls and membranes, supporting photosynthesis, cell division and elongation, as well as nitrogen and carbohydrate metabolism. In the present study, boron in the lake sediment was found to be below the detection limit (BDL).

Sulphur (S)

Sulphur (S) occurs in sediments in various forms, including sulfites, sulfates, sulfides, and as part of organic compounds. In the present study, sulphur in the sediment was found to be below the detection limit (BDL).

Phosphorous (P)

Phosphate is an essential nutrient for living organisms and is present in water bodies in both dissolved and particulate forms. Its primary sources include the weathering of phosphorus-bearing rocks, rainfall, cattle dung, and soil phosphates, typically occurring in small amounts in natural waters. Elevated phosphorus levels often indicate pollution in a water body. In the present study, the phosphorus content in lake sediment was measured at 2.18 mg/L.

Silicon (Si)

Silicon is a very important part of the earth's crust and comprising approximately 28% of its composition. It has been shown to mitigate the harmful effects of heavy metals in plants grown on contaminated soils. Silicon is the second most abundant element in soil, with concentrations typically ranging from 50 to 400 g Si per kg of soil. In the present study, silicon was detected in the sediment at a concentration of 1.84 mg/Long-term exposure to arsenic-contaminated water may cause a range of health issues, including conjunctivitis, hyperkeratosis, hyperpigmentation, cardiovascular disorders, disturbances in the peripheral vascular and nervous systems, skin cancer, gangrene, leucomelanosis, and non-pitting edema. In the present study, arsenic in the lake sediment was found to be below the detection limit (BDL).

CONCLUSION

The present investigation provides a comprehensive assessment of the physicochemical characteristics and heavy metal contamination of lake sediments from Koradi Lake in the Nagpur environment of Maharashtra, India. The study demonstrates that sediment quality is significantly influenced by both natural geochemical processes and anthropogenic activities associated with urbanization, industrial discharge, and thermal power generation in the surrounding region. Most physicochemical parameters, including total dissolved solids, total suspended solids, nitrate, hardness, and chloride, were within permissible limits; however, fluoride concentrations substantially exceeded recommended guidelines, indicating potential risks to aquatic organisms. The heavy metal analysis revealed considerable enrichment of magnesium, calcium, copper, iron, zinc, lead, cadmium, and chromium in the sediment samples, while arsenic, strontium, boron, and sulfur were below detection limits. Of particular concern are the elevated concentrations of toxic metals such as Pb, Cd, and Cr, which are known for their persistence and adverse ecological and human health impacts.

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Conflicts of interest

The authors declare no conflicts of interest.

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