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Original Research Article

Evaluating Heavy Metal Toxicity Risks and their Effect on Water Quality in Kelageri Lake, Dharwad District, Karnataka

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Abstract: Lakes are huge bodies of water located inland. India is a country that relies heavily on agriculture, and its lakes, rivers, and ponds are used for irrigation. Lakes provide important environmental, social, and economic roles. These include supplying drinking water, replenishing groundwater, absorbing floodwater, fostering biodiversity, and living. While the presence of heavy metals in water is vital for life, concentrations higher than those advised by national and international organizations can lead to physiological problems. The presence of heavy metals in water and sediment presents serious problems for aquaculture, agriculture, and freshwater ecosystems. Excess of these can come from both natural and man-made sources in the aquatic environment through a variety of processes and pathways. Due to their non-biodegradable nature, an accumulation of heavy metals in living organisms can be hazardous and carcinogenic. In this study, Kelageri Lake in the Dharwad district was evaluated in 2023 for the concentrations of many heavy metals (Fe, Cu, Mn, Pb, Cd, Ni, and Cr) as well as other physico-chemical characteristics. While heavy metals were analysed using an Atomic Adsorption Spectrometer (AAS), water quality data were gathered monthly. All heavy metal levels were below allowable limits, apart from Fe and Ni, which had greater values during the southwest monsoon. Mn, on the other hand, had a higher concentration during the northeast monsoon throughout the summer. The remaining physico-chemical parameters are also within the acceptable range. The lake is prolific, and the water is rather firm.

Keywords: Dharwad, Heavy metals. Kelegeri Lake, Water quality

Introduction

Lakes are vital resources for both human needs and aquatic animals, and any changes made to their physicochemical properties will have a significant impact on society and the environment. The active interactions among biological, chemical and physical processes are frequently quantitatively or qualitatively different from those on land or in the air because of the various boundaries that separate water and air from land. They provide as an example of a lentic ecosystem. However, compared to rivers and the ocean, material mobility in lakes is constrained. Sediments that enter lakes through inlets created by erosion in the catchment area gradually fill the lake bottoms. Lake biological activity is increased in lentic ecosystems due to the swift interaction between sediment and water (Chakrapani, 2002).

Lakes are important inland water resources that can help fulfil the growing demand for water. They are dynamic lentic ecosystems. All these activities, however, are dependent on the quality of the water, which is determined by the presence of a balanced environment with respect to its physical, chemical, and biological components (Yu *et al.,* 2010). The principal factors that alter the chemistry of water are mud, silt, and human activities like bathing and washing (Jeeji Bai *et al.,* 1999). Furthermore, the disposal of religious items into lakes also influences the quality of the water in the lakes (Dhote *et al.,* 2001).

In addition, lakes provide substantial economic benefits by giving water for agriculture, producing electricity, supplying food in the form of fish and aquatic products, and maintaining the biodiversity and general health of critical life support ecosystems (ILEC 2003). As a result, before using water, it must be carefully characterized physicochemically. The Kelageri Lake in Dharwad, Karnataka, India, was taken into consideration for the physico-chemical characterization of water in this work. For the locals and the animals that serve as feed, it serves as a natural watering source. Water from surface runoff reaches it. A significant portion of the lake's watershed is abundant with water lilies, Hydrilla, *Eichhornia crassipies*, and blue-green algal blooms. In the summer, the physico-chemical characteristics of Kelageri Lake's water quality were evaluated.

The use of the water for aquatic life and human consumption is severely limited due to its declining quality, and the dumping of solid waste has made matters worse. As a result, to take preventative action, periodic analysis of water quality monitoring is required. Ponds and lakes are becoming more and more contaminated daily because of individuals living close to water bodies not being aware of this. Serious environmental issues are caused when untreated water effluents from a variety of industries, residential and commercial sewage, agricultural wastewater, and animal and human waste are dumped directly into adjacent water bodies.

Human contamination and effluent discharges are two common ways that heavy metals enter aquatic bodies. Heavy metals from effluent discharge are typically not removed by aquatic ecosystems through natural processes. Certain heavy metals, such as arsenic, cadmium, copper, and mercury, build up in sediments and then remobilize to release them into water (Paul *et al.,* 2012). Then, in various forms, they ascend to the top of the food chain and eventually affect humans by producing severe acute and chronic illnesses. Through manual handling, food and absorption of air, heavy metals can enter humans, animals, and plants. Heavy metals have the power to stop. Further affect to health can result from the replication of deoxyribose nucleic acid (DNA) and subsequent cell division (Sharma *et al* 2014).

Even at low concentrations, the build-up of heavy metals has always caused stress, which might result in physiological circumstances that are irreversible (Jaishasnkar *et al* 2014). Analyzing the existence of several physicochemical characteristics and heavy metals like Iron, Copper, Manganese, Lead, Cadmium, Nickel and Chromium was the study's main goal of study.

Materials and methods

Study Area

The district of Dharwad spans 4263 km2, between the longitudes of 73°43' and 75°35' E and the latitudinal parallels of 15°02' and 15°51' N. The Kelageri Lake (Fig. 1 A, B and C) is situated in latitude 15° 272 N and longitude 15° 272 E. It was built in March 1911 by Sir M. Vishweshwaraiah. The lake's catchment area spans 6.36 square kilometres.

The study was conducted in the year 2023. The seasons and months were as follows, following the guidelines set forth by the Indian Meteorological Department: The seasons that follow are Winter (January-February), Pre-Monsoon (March-May),

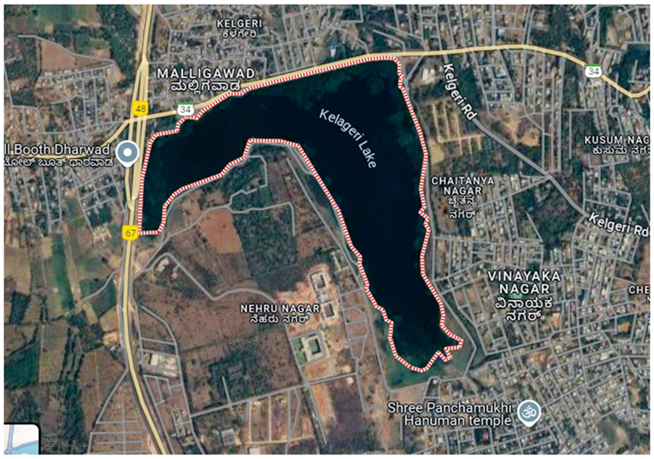

Fig. 1. Map showing location of Kelageri lake Dharwad, Karnataka.

Fig. 2. Sampling Sites of Kelageri Lake Dharwad, Karnataka.

Southwest Monsoon (June-September) and Post-Monsoon (October-December). Water samples are subjected to physico-chemical analysis in accordance with APHA (American Public Health Association) 2005 standard analytical techniques.

Sample collection

Every month in 2023, water samples from Kelageri Lake were taken and analyzed (Fig. 2). The current study involved gathering information on a few topics, including heavy metal detection and physiochemical characteristics.

Methodology

Every month in 2023, water samples from Kelageri Lake (Fig. 1) were collected using the composite surface water sampling method, and physico-chemical parameters such pH, DO, BOD, COD, alkalinity, hardness, TDS, TSS, and nitrate were analysed. To estimate the biochemical oxygen demand, winkelerization was carried out in separate 300 ml bottles and pH was measured on the spot. Dark-coloured ice boxes were used to carry the samples to the lab so they wouldn't be exposed to sunshine. Physico-chemical characteristics were examined in the samples using the Standard Procedures (APHA, 1998).

Atomic absorption spectrometry (AAS)

The AAS technique was used to analyze elements such as iron, copper, manganese, lead, cadmium, nickel and chromium. The AAS is a quantitative metal analysis procedure that can identify about seventy elements. This technique passes light through an atom cloud from a sample in a particular wavelength that is emitted by an element radiation source to determine the concentration of that element. Light from a hollow cathode lamp (HCL) energy source will be absorbed by atoms. The element concentration in the initial sample is thought to be measured by the decrease in light intensity that reaches the detector.

The components of a standard AA spectrometer were the sample container (atomizer) and the energy source (light). A quartz tube, a flame, or an electrodeless discharge lamp (EDL) are some examples of atomizers used in different AAS procedures. The radiation source is typically a hollow cathode lamp (HCL) or electrodeless discharge lamp (EDL). A photomultiplier tube is usually used as the detector, which transforms the light signal into an electrical signal proportional to the light intensity. The monochromator eliminates scattered light of other wavelengths by focusing the radiation through a variety of lenses and mirrors (Beaty and Kerber 1993).

Results

Physico-chemical Parameters

Water has featured such dissolved salts, buffers, nutrients, etc., and physicochemical analysis of the water provides a reliable indicator of the chemical quality of the aquatic system. Local factors determine the precise concentrations. Table 1 and Figure 3-7 provide fluctuations in the physico-chemical properties of Kelageri lakes and illustrate the seasonal variation of water quality indicators.

Temperature

The amount of heat in the water is measured by its temperature. The temperature of Kelageri Lake varied from 38.57°C to 40.4°C. The Post-monsoon (summer) saw the greatest temperatures, while the winterwas the lowest (Table 1).

pH

pH is a unit of measurement for the hydrogen ion activity or, more generally, the acidity of water. The pH range that was measured was 8.59 to 6.27 (Table 1).

Total Alkalinity

The water in Kelageri Lake has alkalinity readings ranging from 168.5 mg/L to 174.19 mg/L (Table 1) during the several seasons.

Table. 1. Seasonal Variation in water Quality parameters of Kelageri Lake.

Physicochemical Parameters	Winter	Pre-Monsoon(Summer)	Southwest Monsoon (Rainy)	Post Monsoon
Temperature	38.57±3.77	34.95±16.72	40.3±3.77	40.4±3.77
pH	8.59±0.03	7.25±0.27	12±3.74	6.27±0.30
Total alkalinity(mg/L)	168.5±3.59	170.43±3.86	172.17±3.77	174.19±3.77
Turbidity (NTU)	19.58±3.77	21.37±3.77	22.41±3.77	21.32±3.77
Total Suspended solids (mg/L)	29.43±3.86	31.44±3.65	33.41±3.52	37.36±3.48
Dissolved Oxygen (mg/L)	11.21±3.77	11.53±3.33	12.1±3.77	11.91±3.77
Biological Oxygen Demand (mg/L)	20.17±3.77	20.57±3.74	18.85±3.74	17.14±3.74
Chemical Oxygen Demand (mg/L)	39.66±3.39	41.53±3.34	43.39±3.38	45.17±3.77
Total Hardness as $CaCo_3$ (mg/L)	255.13±3.80	121.32±3.52	131.32±3.52	106.37±3.69
Nitrates(mg/L)	11.21±3.77	7.71±3.77	6.51±3.77	7.24±3.77

Values are Mean ± SD (n=5) (all values except temperature, pH and turbidity are in mg/L).

Table. 2. Seasonal Variation in Heavy Metals of Kelageri Lake.

Heavy Metals	Winter	Pre-Monsoon (Summer)	Southwest Monsoon (Rainy)	Post Monsoon
Iron	7.36±3.56	7.44±3.65	7.37±3.56	7.24±3.77
Copper	0.08±0.37	0.22±0.03	0.09±0.03	0.07±0.04
Manganese	7.37±3.69	7.36±3.56	7.36±3.56	7.44±3.65
Lead	20.32±3.52	0.31±0.03	17.27±3.57	14.44±3.65
Cadmium	0.37±0.28	7.08±3.77	7.24±3.77	6.94±3.77
Nickel	0.16±0.03	0.2±0.03	0.27±0.03	0.29±0.03
Chromium	0.16±0.03	0.27±0.37	0.28±0.03	0.53±0.47

Values are Mean ± SD (n=5) (all values are in mg/L)

Turbidity

Turbidity is a measurement of the murkiness of water, or the amount of light that can travel through it. Turbidity is the suspension of particles in water that obstructs light flow. The range for Kelageri Lake was 19.58 to 21.32 NTU (Table 1).

Total Suspended Solids (TSS)

The breakdown of algae, plants, and animals produces suspended solids, which can break apart into small organic particles and enter the water column (Murphy, 2007). Sedimentary materials also include chemical precipitates. Occasionally, suspended solids can settle out into sediment at the bottom of a body of water over several seasons. Seasonal variations in suspended solids were observed, with the post-monsoon (rainy) season recording the highest concentration of 37.36 mg/L and the winter season recording the lowest concentration of 29.43 mg/L (Table 1). Runoff flows are the cause of suspended solids; even in places where storm drains are present, these drains typically feed straight, unfiltered, to a nearby water source.

Dissolved Oxygen (DO)

The areas with a healthy aquatic life have higher levels of dissolved oxygen. The measured dissolved oxygen concentrations in Kelageri Lake varied from 11.21 mg/L to 11.91 mg/L (Table 1).

Biochemical Oxygen Demand (BOD)

BOD relates to the volume of oxygen that microorganisms consume to oxidize organic materials aerobically. The water in Kelageri Lake has BOD values ranging from 20.17 mg/L to 17.14 mg/L (Table 1).

Chemical Oxygen Demand (COD)

COD utilized as a measurement of organic pollution that takes phytoplankton growth into account. The water of Kelageri Lake has COD values ranging from 20.17 mg/L to 17.14 mg/L (Table 1).

Total Hardness

The multivalent metal ions that are produced when minerals dissolve in water are typically the cause of hardness in water. Kelageri Lake's water has concentrations of hardness ranging from 255.13 mg/L to 106.37 mg/L (Table 1).

Nitrates

In the current investigation, nitrate concentrations varied according to the season: 11.21 mg/l to 7.24 mg/l during the winter, 1.46 mg/l to 2.66 mg/l during the monsoon, and values below detectable limits during the summer.

Heavy metal analysis of Kelageri lake by Atomic Absorption Spectroscopy (AAS)

Iron

Among the elements that are most prevalent in rocks and soil is iron. Because of these decreasing conditions, water bodies typically have larger quantities of iron toward the bottom. When iron content exceeds 0.3 mg/l, it can discolour clothing and cutlery and make people throw up. The iron levels in the current study ranged from 7.36 to 7.24 mg/l (Table 2) and were determined to be within the BIS (0.3 mg/l) and WHO (0.1 mg/l) permitted limits.

Copper

The extremely low concentration of copper found in Kelageri Lake suggests that there isn't a substantial source of pollution; in contrast, Wang *et al.* (2009) found the highest value of 0.22 mg/l in the kelageri lake and linked it to farm runoff and domestic sewage inflow.

Manganese

The functioning of the enzyme's pyruvate carboxylases, dismutase, kinases, transferases, and hydrolases depends on manganese, a plentiful metal in the earth's crust that is present in 11 oxidative states (USEPA, 1994). Human activity is the primary source of manganese in soil, which erodes into surface waters in both dissolved and suspended forms (ATSDR, 2000). Manganese in drinking water is undesirable, however in certain cases, depending on the local conditions, concentrations under 0.05 mg/l are permissible. The concentration of manganese in the waters of Kelageri Lake varied from 7.37 to 7.44 mg/l (Table-2).

Lead

One of the dangerous heavy metals that is frequently found in the environment is lead. It is highly persistent in soils and has no discernible metabolic effect in either plants or animals. Lead tends to stay available over time and build up in the food chain. According to Trivedy and Goel 1984, lead is extremely poisonous and builds up in the body's muscles, brain, kidney, and bones. It causes harm to the urinary and digestive systems, which leads to neurological disorders and brain damage.Lead concentrations range from 20.32 to 14.44 mg/l (Table 2). This variation is caused by the absence of any wastewater flow into the lake.

Cadmium

Water in the study area had a cadmium range of 0.37 to 6.94 mg/L; it was greater in the early summer months of 2023 in the lake under study than it was in the winter (Table 2). This exceeded the Cadmium drinking water guidelines. However, the mean for aquatic bodies exposed to pollutant discharge was within the tolerance level.

Nickel

The weathering of ultramafic rocks in humid, tropical environments produces nickel laterite ores. Thus, tropical regions account for more than 70% of Ni laterite deposits, with South-East Asia and Melanesia (SEAM) hosting more than half of these locations. Five of the world's greatest Ni laterite deposits are found in New Caledonia and Indonesia alone. Notable deposits are also found in Papua New Guinea, Myanmar, and the Solomon Islands.

When compared to the winter season, the research area's water's nickel (Ni) concentration was highest in the early post monsoon of the analyzedKelagerilake, ranging from 0.16 to 0.29 mg/L (Table 2). This exceeded the recommended levels of drinking water for Ni. However, the mean for aquatic bodies exposed to pollutant discharge was within the tolerance level.

Chromium

Chromium (Cr) levels in Kelageri lake water ranging from 0.16 to 0.53 mg/L (Table 2), exceeding EPA and BIS drinking water guidelines as well as Food and Agriculture Organization

(FAO) irrigation standards. Furthermore, Cr exceeded the 2.0 ppm tolerance limit for contaminated water bodies (Nithya *et al* 2018). The range of the critical threshold is 5.00 ppm to 30.0 ppm. According to Onchoke and Sasu (2016), the crucial range is 20–100 ppm. This was lower than the background value of 32.0 ppm reported by Elias *et al.* (2018) and below the likely effect level (PEL) of 90.0 ppm.

Discussion

Temperature: As shallow water reacts swiftly to changes in atmospheric temperature, Welch, 1952 stated that samples taken from the shallow zone have direct connection to air temperature. In general, water temperature was found to be correlating with air temperature. Conversely, as stated by Desai 1995, the temperature of the water might vary depending on the time of year, the location, and the season.

pH: The south-west monsoon rainy season had the highest pH value, whereas the post monsoon season had the lowest pH value. The monsoon's low rating could be the result of precipitation dilution and noted a decrease in pH during the monsoon season (Shardendu and Ambasht, 1988). Summer time records for pH readings were at their highest. Higher pH values were also encountered in Jana's 1973 investigation during the pre-monsoon (summer).

Total Alkalinity: A pollutant is not alkalinity. All the compounds in water that are capable of "acid neutralizing" are measured in total. The alkalinity number gives an indication of the natural salts that are in the water (Gawas *et al.*, 2006).The post-monsoon season was when the alkalinity value was highest, and the winter season was when it was lowest. Solanki and Pandit 2006 suggest that variations in alkalinity are contingent upon carbonates and bicarbonates, as well as CO_2 concentrations. Alkalinity levels are within acceptable to marginal bounds.

Turbidity: The Southwest monsoon produced the highest value, while the winter season produced the lowest. According to Saxena *et al.* (1966), Ansari and Prakash (2000), and Solanki (2001), rainfall and surface runoff of water carrying a lot of silt from the surrounding area may be the cause of the maximum values of turbidity in the Southwest monsoon.

Total Suspended Solids: Suspended solids are not just an indicator of pollution but also a possible home for bacteria and protozoa. By adhering to the dispersed particles, these microbes facilitate their movement and shield them from hazardous chemicals. Temperature and dissolved oxygen are two more factors that are indirectly impacted by suspended particles. The stratification (layering) tends to stabilize because the surface water gets warmer due to the particle matter's increased heat absorption (Volunteers safeguarding Kentucky Waterways, 2014).

DO: During the Pre-monsoon (summer) the largest value of dissolved oxygen was measured, and the Southwest monsoon season, the lowest amount measured. Singh *et al.* (1991) state that low oxygen dissolves may be caused by poor oxygen solubility in water, which in turn affects the BOD. According to Vijayan (1991), dissolved oxygen measurement is a crucial component of all pollution investigations.

BOD: The Pre-Monsoon (summer) season yielded the largest values, while the monsoon season produced the lowest values. According to Sankar *et al.*, 2002, an increase in oxygen demand caused by the organic wastes thrown into the water may be the cause of increased BOD. According to the data, the lake's BOD concentration is higher than the recommended level of less than 3 mg/L.

COD: The Pre-Monsoon (summer) season recorded the lowest values, while the Monsoon season recorded the largest values. As per the 2014 Environmental Quality Standards (EQS) pertaining to water contaminants, any COD level below 1 mg/l is unrelated to human activity. When this is the case, waters can be used to preserve the ecosystem.

Total hardness: Summertime was when the largest value was recorded, and Southwest Manson season was when the minimum value was recorded. According to Udhaya Kumar *et al.* (2006), water becomes too hard due to an overabundance of calcium and magnesium.

Nitrates : Although nitrates are vital nutrients for plants, excessive nitrate intake can seriously harm the quality of water. Excessive nitrates can hasten eutrophication in conjunction with phosphorus, leading to notable increases in the growth of aquatic plants and alterations in the kinds of plants and animals inhabiting the stream. Increased nitrate concentrations could result from sewage and industrial effluents being dumped into the river. Nitrate is typically present in trace concentrations in uncontaminated natural water.

Iron: Jakir Hussain *et al.* 2017 noted similar things when investigating heavy metal poisoning in the Godavari River. Periodically, the mean iron value stayed at 0.01 mg/l throughout the seasons (Table 2). This contrasts with the results of Wasim *et al.* 2010, who found that the winter season in the Ganga River around Kolkata had the highest iron values. They attributed this to the dilution that occurs during the rainy season, which is followed by the formation of metal chelates during the winter. Iron concentrations were positively correlated with water's physico-chemical parameters, including total solids, total hardness, electrical conductivity, chloride, and biological oxygen demand; iron concentrations were negatively correlated with PH and chemical oxygen demand (Table 2).

Copper: Rarely found in natural waters, copper is a crucial trace element that is widely dispersed throughout the natural world. In aquatic environments, copper can be found in soluble, particulate, and colloidal forms. Copper is essential for metabolic pathways. The production of steel, mining, chemical weathering, farming practices, and sewage are some of the processes that release copper into natural waterways. Humans experiencing intermittent fever, hypertension, and coma due to copper concentrations over the BIS-established legal limit of 50 mg/l are at risk of developing cancer or mutations (Moore and Rama Moorthy 1984). Because it is a major component of both chlorophyll and cytochrome oxidase, copper is important for plant metabolism (Pande and Sharma 1998) and Dwivedi and Tiwari (1997) reported elevated copper concentrations in the water bodies under study. However, because there were no industrial effluents present in the current investigation, no such high Copper concentration was found. Copper's descriptive statistics are shown in Table 2.The copper contents in Table 2 of the current study did not vary with the season, in contrast to the summer maximum reported by Dwivedi and Tiwari (1997). The relative abundance of heavy metals is seen, where copper is the least abundant of all the heavy metals examined. Additionally, copper failed to show any significant positive or negative associations with the physico-chemical parameters.

Manganese: In contrast, Siong Fong Sim *et al.* (2016)found that the Manganese concentration in Sarawak Dam, Malaysia, was greater. Comparably, greater manganese concentrations from the Ganga River near Kolkota, ranging from 0.022 to 1.78 mg/l, were noted by Md. Wasim Aktar *et al.* (2010). Manganese remained high during rainy seasons and was at its lowest during summer and winter. This could be because of agricultural runoff, which is consistent with the findings of (Md. Wasim Aktar *et al.* 2010). Karl Pearson's correlation matrix, the concentration of manganese is directly influenced by physico-chemical parameters like PH, alkalinity, sulphate, phosphate, and sodium. Conversely, the concentration of manganese has a negative relationship with turbidity, dissolved solids, air and water temperature, biological oxygen demand, chemical oxygen demand, and magnesium.

Lead: In the current study, lead levels were varied in each of the three seasons. In contrast, high lead contents were reported during the winter and low lead contents during the pre-monsoon season by Smriti Dwivedi and Tiwari 1997, Solanki Hitesh and Pandit 2000, and Saeed Shanbehzadeh *et al.* 2014. In contrast to our results, Mohammad Ali *et al.* 2016 reported 9.85 mg/l of lead during the summer and, based on the USEPA (1999) toxicity reference value, concluded that the river's water was unsafe for cooking and drinking, which is not supported by our research. Table 2 clearly shows that the concentration of lead has a positive correlation to sodium and sulfurate at a substantial level, but negative relationships with air and water temperatures were noted. Contrary to our study, Jakir Hussain *et al.* (2017) found maximum lead concentrations from the Godavari River (7.41 mg/l), which are significantly higher than the permissible limit. Harvey *et al.* 2015 reported similar results from the Rupsha River and linked it to the release of agricultural and industrial effluents.

Cadmium: The slow rate of metabolism and high toxicity of cadmium (Cd) have led to its ranking as the eighth most hazardous substance in the Top 20 Hazardous Substances Priority List (ATSDR, 1999) among environmental pollutants (Zhang *et al*., 2020). Lakes are a significant supply of freshwater on a global scale, and the growth of industry, agriculture, and other human activities is making lead poisoning of waterbodies a growing concern (Gao *et al.,* 2016; Harikumar *et al.,* 2009). Freshwater ecosystems, drinking water sources, the food chain, and water quality are all seriously threatened by cadmium pollution in lakes.

It has been documented that sediments in waterbodies act as a source and a sink for lead (Cd). The mobility of Cd in sediments can be influenced by a few environmental parameters, including the redox state, pH, and concentrations of acid volatile sulfide (AVS), Fe, Mn, and dissolved organic matter (DOM) (Banks *et al.,* 2012; Du *et al.,* 2009). According to Ghavidel *et al.* (2018), a drop in pH can cause Cd to dissolve from the solid phase and raise the amount of dissolved Cd in sediments. Moreover, AVS can oxidize in aerobic environments, increasing the amount of labile Cd in surface sediments five times (De *et al.,* 2012). On the other hand, because of the sulfide, a drop in the redox state of the sediment can result in a decrease in dissolved Cd.

Nickel: In a similar vein, Ni has been detected in a wide range of plants, with non-edible wild plants having concentrations as high as 340 ppm. According to Jumbe and Nandini (2009), this falls into the crucial range of Ni levels in plants, which is between 10 and 50 ppm.

Lateritic ore extractions usually utilize open-cut mines due to their shallow nature, which produces a lot of potentially corrosive waste rock and tailings. These waste materials can travel downstream through surface and groundwater waterways, where they may solubilize and absorb Ni as well as co-occurring trace metals like cobalt and chromium, which can cause direct toxicity.

If laterites are not properly handled after being disturbed by mining, their fine-grained and dispersive nature can lead to an increase in water turbidity, which could influence the benthic biota and water column in both fresh and marine environments. Protecting these extraordinary settings is crucial because most of the world's diversity is found in the tropics, and several freshwater ecoregions within SEAM have been recognized as having very high biodiversity and endemism.

Chromium: Cr enters the circulatory system through the skin and lungs, where it is subsequently eliminated by the liver (Xiao *et al.* 2012). When trivalent Cr is reduced to tetravalent Cr, when ROS are created, oxidative damage results. According to Balakrishnan *et al.* 2013), this ROS contributes to hepatotoxicity, cardiotoxicity, gene toxicity, etc. High dosages of hexavalent Cr have been shown to cause liver damage (Xiao *et al*., 2012).

Cr progressively builds up in the cell's mitochondria and nucleus, where it alters DNA and regulates biological functions (Venter *et al.,* 2015). According to Tian *et al.* (2018), several histological analyses revealed nuclear pyknosis, central phlebectasia, and hepatocyte degeneration in Cr-infected groups.

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