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Integrated Study of Physico-Chemical Parameters and Heavy Metal Distribution in Freshwater Lakes of Chitradurga, Karnataka, India

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ABSTRACT:

Freshwater ecosystems in semi-arid regions of India are increasingly threatened by anthropogenic pressures, necessitating integrated assessments of water quality and heavy metal contamination. This study investigates the physicochemical parameters and heavy metal distribution across four lakes—Gonur, Mallapura, Matadahatti Kere, and Chandravalli—in Chitradurga, Karnataka, from July to December 2024. Systematic sampling and analysis were conducted to evaluate pH, total dissolved solids (TDS), electrical conductivity (EC), turbidity, alkalinity, hardness, and concentrations of key ions and nutrients. Concurrently, heavy metals including chromium (Cr), lead (Pb), copper (Cu), iron (Fe), nickel (Ni), and zinc (Zn) were quantified using Atomic Absorption Spectroscopy (AAS). Results revealed seasonal fluctuations in physicochemical parameters, with elevated TDS and EC during monsoon and pre-monsoon periods, attributed to agricultural runoff and reduced dilution. Alkalinity and hardness peaked in summer, indicating increased decomposition and mineralization. Notably, Mallapura Lake exhibited the highest levels of pollution, with TDS reaching 688 mg/L and EC exceeding 1200 µS/cm. Heavy metal concentrations varied across lakes, with Cr and Pb frequently surpassing permissible limits set by BIS and WHO, particularly in Mallapura and Gonur Lakes. Cu and Fe levels were elevated in all lakes, while Ni and Zn remained within acceptable thresholds. The presence of non-biodegradable metals in sediments and water poses significant ecological and public health risks, including bioaccumulation and biomagnification through aquatic food webs. Seasonal variations in metal concentrations suggest remobilization driven by changes in pH, redox potential, and microbial activity. The study underscores the urgent need for sediment remediation, community education, and policy interventions to mitigate contamination sources. By integrating physicochemical profiling with geospatial mapping and heavy metal analysis, this research provides a comprehensive environmental status of Chitradurga's lakes. The findings contribute to regional water quality databases and offer actionable insights for sustainable lake management, ecological restoration, and public health safeguarding in vulnerable freshwater habitats.

Introduction

The progressive deterioration of water quality has emerged as a critical environmental challenge, severely limiting its suitability for human consumption, agricultural use, and sustaining aquatic biodiversity. This degradation is largely driven by the indiscriminate dumping of solid waste, untreated industrial effluents, and domestic sewage into freshwater bodies, particularly in developing regions where regulatory enforcement is weak or absent. Studies have shown that illegal solid waste disposal near lakes and rivers significantly alters key physico-chemical parameters such as pH, dissolved oxygen, conductivity, and microbial load, thereby

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threatening both ecological integrity and public health (Bangani *et al.,* 2023). In India, for instance, only 37% of the total wastewater generated is treated, with the remainder discharged directly into natural water systems, often without meeting prescribed standards (NITI Aayog, 2022). Agricultural runoff rich in pesticides, fertilizers, and organic matter further compounds the issue, contributing to eutrophication and the proliferation of toxic algal blooms. The lack of community awareness and inadequate waste management infrastructure exacerbate these risks, leading to chronic contamination of lakes and ponds. Globally, the volume of untreated municipal wastewater is projected to increase by over 50% by 2050, underscoring the urgency of implementing robust water quality monitoring and sustainable remediation strategies (Tariq & Mushtaq, 2023). Without periodic assessments and targeted interventions, the unchecked pollution of surface water bodies will continue to pose severe ecological and socio-economic consequences.

Heavy metal contamination in aquatic ecosystems has emerged as a persistent and multifaceted environmental threat, primarily driven by industrial effluents, agricultural runoff, mining activities, and urban waste discharge. These metals including mercury (Hg), cadmium (Cd), copper (Cu), arsenic (As), lead (Pb), and chromium (Cr)—are non-biodegradable and tend to accumulate in sediments, where they undergo complex geochemical transformations. Over time, environmental disturbances such as changes in pH, redox potential, or microbial activity can trigger remobilization, releasing these toxicants back into the water column and increasing their bioavailability (Kumar & Singh, 2024).

Once mobilized, heavy metals infiltrate aquatic food webs, bioaccumulating in primary producers and biomagnifying through trophic levels, ultimately posing acute and chronic health risks to humans via consumption of contaminated water and aquatic organisms. Recent studies have documented significant concentrations of Cd, Pb, and Hg in fish tissues, correlating with histopathological alterations and oxidative stress markers (Venkadeshwaran *et al.,* 2025). These metals disrupt cellular homeostasis by generating reactive oxygen species (ROS), impairing mitochondrial function, and interfering with enzymatic pathways involved in DNA replication and cell division mechanisms linked to carcinogenesis, neurotoxicity, and reproductive dysfunction (Bangani *et al.,* 2023).

Exposure pathways include inhalation of contaminated aerosols, dermal absorption during recreational or occupational activities, and ingestion through drinking water or aquatic food sources. Alarmingly, even trace concentrations of heavy metals have been shown to exceed safe thresholds for non-carcinogenic and carcinogenic risks, particularly in vulnerable populations such as children and pregnant women (Tariq & Mushtaq, 2023). These findings underscore the urgent need for continuous monitoring, sediment remediation, and public health interventions to mitigate the long-term ecological and biomedical consequences of heavy metal pollution.

This study aims to conduct a comprehensive evaluation of the physicochemical properties of selected lakes in Chitradurga, including parameters such as pH, temperature, electrical conductivity, dissolved oxygen, turbidity, and total dissolved solids. These indicators are essential for understanding the baseline water quality and its suitability for various uses. In parallel, the study investigates the concentration and distribution of heavy metals—namely chromium (Cr), lead (Pb), copper (Cu), iron (Fe), nickel (Ni), and zinc (Zn) which are known to bioaccumulate in sediments and aquatic organisms, leading to toxicological effects across trophic levels.

Heavy metals can enter aquatic systems through multiple pathways and, once mobilized, may induce oxidative stress, disrupt cellular processes, and contribute to chronic health conditions such as neurotoxicity, carcinogenesis, and organ failure (Bangani *et al.,* 2023). Recent studies in Karnataka have revealed elevated levels of Pb, Cd, and Cr in urban lakes, often exceeding permissible limits set by the Bureau of Indian Standards (BIS) and World Health Organization (WHO), thereby necessitating urgent remediation and policy intervention.

By integrating physicochemical analysis with heavy metal profiling, this study seeks to elucidate the environmental status of Chitradurga's lakes and provide actionable insights for sustainable water resource management. The findings will contribute to regional water quality databases, inform public health strategies, and support ecological restoration efforts in vulnerable freshwater habitats.

MATERIALS AND METHODS

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Study Area and Sampling Duration

Water sample collection

Water samples were collected on particular dates of every month from the various selected lakes considered for the study. Water from the surface was collected using clean and sanitized BOD bottles and filled up to its neck. Collections were done from the Gonur Lake, Mallapura Lake, Matadahatti Kere Lake, and Chandravalli Lake, Chitradurga during morning at around 9-11 am for the months of July 2024 to December 2024.

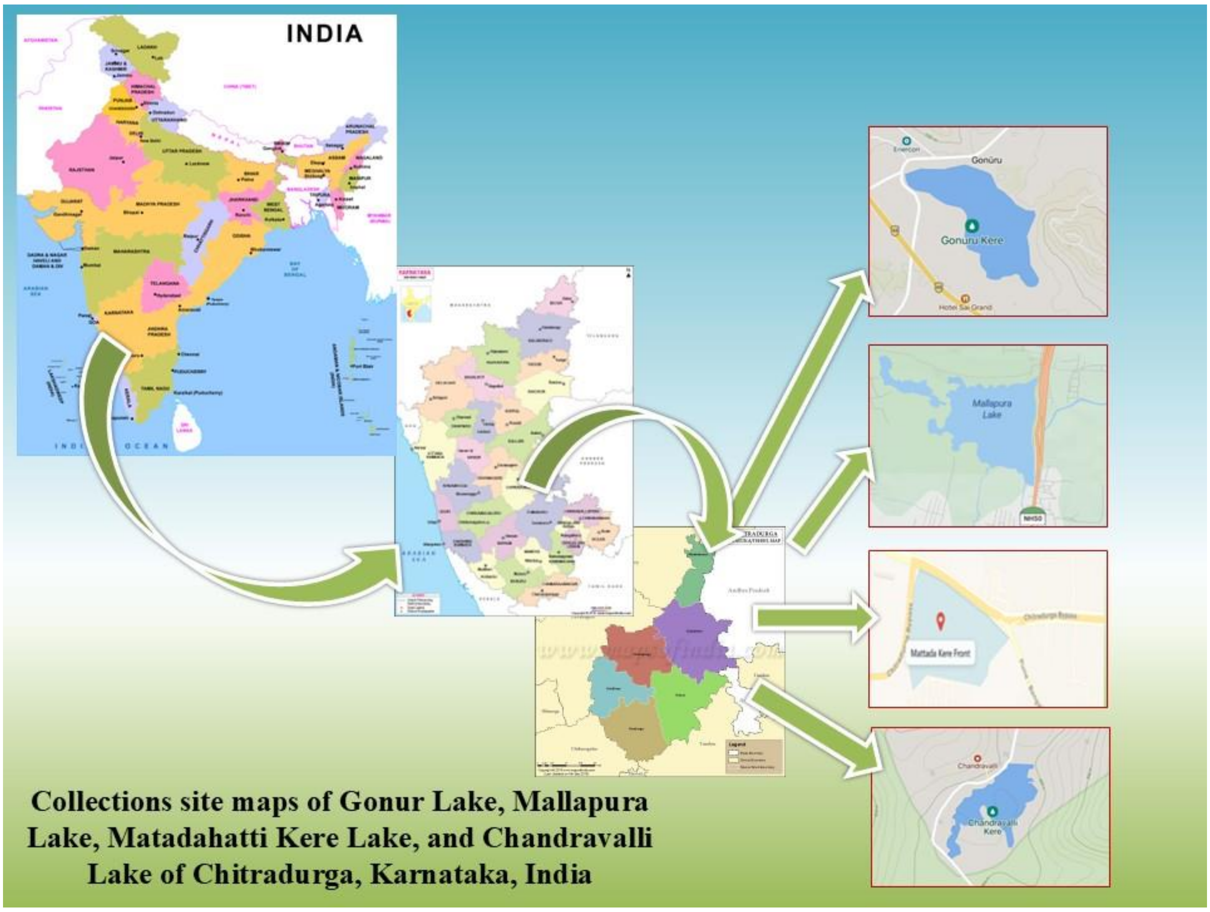

Figure 1: Water sampling area maps of various lakes of Chitradurga, Karnataka, India

Sampling Procedure

Surface water samples were systematically collected using pre-cleaned polyethylene bottles at multiple points within each lake to ensure spatial representation. Samples were stored at 4°C and transported to the laboratory for immediate analysis.

Physicochemical Analysis

Study of Physicochemical Parameters

Temperature of the water samples was recorded at the sampling point. AR grade chemicals and glass distilled water was used for the preparation of the reagents. Electrical Conductivity and pH was determined using Systronics - Conductometer and Digital Systronics pH – meter respectively. The water quality parameters like were mean pH, Total Dissolved Solids, Electrical Conductivity, Turbidity, Alkalinity, Hardness, Calcium, Magnesium, Nitrate, Phosphate, Fluoride, Sulphide, Chloride, Sulphate, Sodium, Potassium and TSS were studiedusing standard procedures (APHA, 2012).

Heavy Metal Analysis

Heavy metal concentrations Chromium (Cr), Lead (Pb), Cadmium (Cd), Copper (Cu), Nickel (Ni), Iron (Fe), and Zinc (Zn) were quantified using Atomic Absorption

Spectroscopy (AAS) following acid digestion (USEPA Method 3050B). Calibration standards and blanks were run to ensure analytical accuracy and precision.

Atomic absorption spectrometry (AAS): The elements like Chromium, Iron, Copper, Lead, Nickel and Zinc were analyzed by using AAS technique. AAS is a quantitative method of metal analysis suitable for the determination of approximately 70 elements. This method measures the concentration of the element by passing light in specific wave length emitted by a radiation source of a particular element through cloud of atoms from a sample. Atoms will absorb light from an energy source known as hollow cathode lamp (HCL). The reduction in the amount of light intensity reaching the detector is seen as a measure for the concentration of particular element in the original sample.

A typical AA spectrometer consists of energy (light) source, sample compartment (atomizer). The radiation source is usually a hollow cathode lamp (HCL) or electrodeless discharge lamp (EDL), while different atomizers are used in various AAS techniques such as flame, a graphite furnace, or a quartz tube. The Monochromator is eliminating scattered light of other wavelengths by a number of lenses and mirrors to focus the radiation and the detector is typically a photomultiplier tube that converts the light signal to an electrical signal proportional to the light intensity (Beaty and Kerber, 1993).

Data Interpretation

All measurements were performed in triplicate, and results were statistically analyzed using descriptive statistics and correlation matrices to identify relationships between physicochemical parameters and metal concentrations. Findings were compared against BIS (IS:10500) and WHO (2017) permissible limits to evaluate environmental and health risks.

Study Area and Topography:

Gonur Lake

Gonur Lake is situated in Chitradurga, Karnataka, India, a region known for its semi-arid climate and rugged terrain. The lake is positioned at approximately 14.2300° N latitude and 76.4000° E longitude, making it an important freshwater body within the district. Chitradurga is characterized by undulating topography, with rocky hills, plateaus, and scattered water bodies that play a crucial role in local hydrology and biodiversity.

The lake is primarily rain-fed, supplemented by minor inflows from surrounding catchment areas. The geomorphology of the region consists of granite formations and lateritic soil, which influence the lake's sediment composition and water retention capacity. The presence of seasonal streams contributes to periodic fluctuations in water levels, impacting aquatic ecosystems and water quality parameters.

The study area was selected due to its ecological significance and increasing anthropogenic pressures, including agricultural runoff, industrial effluents, and urban waste disposal. The methodology involves systematic sampling from multiple locations within the lake to assess physicochemical properties, heavy metal contamination, and microbial diversity. Additionally, GIS-based mapping will be employed to analyze spatial variations in water quality and identify potential pollution sources.

This research aims to provide comprehensive insights into the environmental health of Gonur Lake, contributing to sustainable water management strategies and conservation efforts.

Mallapura Lake

Mallapura Lake is situated in Chitradurga, Karnataka, at an approximate latitude of 14.1400° N and longitude of 76.1400° E. The lake is a rain-fed water body, influenced by seasonal variations and local hydrological conditions. The surrounding terrain consists of rocky outcrops and lateritic soil, which impact sediment deposition and water retention. The lake plays a crucial role in local irrigation, groundwater recharge, and biodiversity conservation. However, increasing anthropogenic activities, including agricultural runoff and urban waste disposal, pose significant threats to its ecological balance.

Matadahatti Kere Lake

Matadahatti Kere Lake is located within the Chitradurga district, though precise latitude and longitude data are currently unavailable. The lake is part of a semi-arid ecosystem, characterized by seasonal fluctuations in water levels. The surrounding landscape includes granite formations and sparse vegetation, contributing to the

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lake's hydrological dynamics. The lake serves as a critical water source for local communities, supporting agriculture, livestock, and aquatic biodiversity. However, industrial effluents and unregulated waste disposal have led to concerns regarding heavy metal contamination and eutrophication.

Chandravalli Lake

Chandravalli Lake is positioned at 14.2089° N latitude and 76.3861° E longitude. It is part of the Chandravalli archaeological site, a historically significant region known for its prehistoric settlements and ancient inscriptions. The lake is surrounded by three hills Chitradurga, Kirabanakallu, and Jolagudda, forming a natural valley that influences its hydrology. The semi-arid climate and scrub vegetation contribute to seasonal variations in water availability. The lake is an essential ecological and cultural landmark, supporting local biodiversity and historical conservation efforts. However, urban expansion and tourism-related activities have raised concerns about water pollution and sediment accumulation.

For each of these lakes, systematic sampling will be conducted to analyze physicochemical parameters, including pH, dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD), total dissolved solids (TDS), and electrical conductivity (EC). Additionally, heavy metal contamination will be assessed using spectroscopic techniques to detect chromium (Cr), lead (Pb), cadmium (Cd), copper (Cu), nickel (Ni), iron (Fe), and zinc (Zn). GIS-based mapping will be employed to visualize spatial variations in water quality and identify potential pollution sources.

Climate:

Gonur Lake

Gonur Lake, located in Chitradurga, Karnataka, experienced seasonal temperature fluctuations throughout the study period. The warmest months were April and May 2024, with temperatures peaking at 34.9°C (94.8°F), while the coolest months were December and January, averaging 22.0°C (71.5°F). Monsoon rains from June to September contributed to increased water levels, with July and August receiving the highest precipitation, averaging 110 mm (4.3 inches). The humidity levels varied, reaching 80% in July, which influenced evaporation rates and aquatic ecosystem stability.

Mallapura Lake

Mallapura Lake exhibited a semi-arid climate, with high temperatures in April and May, averaging 36.7°C (98.1°F). The monsoon season brought significant rainfall, particularly in October, which recorded 201 mm (7.9 inches). The dry months of February and March saw minimal precipitation, leading to lower water levels and increased salinity. Humidity levels peaked during the monsoon, exceeding 74%, while summer months saw a drop to 35%, affecting evaporation rates and aquatic biodiversity.

Matadahatti Kere Lake

Matadahatti Kere Lake followed a similar seasonal pattern, with high temperatures in April and May, reaching 35.2°C (95.3°F). Monsoon rains from June to September replenished the lake, with July and August receiving over 100 mm (4 inches) of rainfall. The post-monsoon period saw a gradual decline in water levels due to evaporation and reduced inflows. Humidity levels remained above 70% during the monsoon but dropped to 38% in February, impacting aquatic life and water quality.

Chandravalli Lake

Chandravalli Lake, situated in a valley surrounded by hills, exhibited moderate climatic variations. The hottest months were April and May, with temperatures reaching 34.3°C (93.7°F). Monsoon precipitation peaked in October, with 111 mm (4.4 inches) of rainfall, contributing to seasonal water level fluctuations. The humidity levels ranged from 35% in March to 81% in August, influencing evaporation rates and aquatic ecosystem dynamics.

These climate conditions played a crucial role in water quality assessments, influencing physicochemical parameters, heavy metal concentrations, and microbial diversity in the lakes.

RESULTS AND DISCUSSION

The quality of the water sample was analyzed by collecting samples from the Gonur Lake, Mallapura Lake, Matadahatti Kere Lake, and Chandravalli Lake of Chitradurga from July 2024 to December 2024. The

results obtained by the analysis of the water samples are listed as physicochemical parameters and heavy metal analysis during the experimental studies.

Study of physicochemical parameters and heavy metal analysis of Gonur Lake, Mallapura Lake, Matadahatti Kere Lake, and Chandravalli Lake of Chitradurga, Karnataka, India

The sampling was done for 06 months and covered three seasons (monsoon, winter and summer). Sampling and analysis were carried out on the selected lake water for eight times in the whole study period. Physicochemical parameters analyzed were pH, total dissolved solids, electric conductivity, turbidity, alkalinity, hardness, calcium, magnesium, nitrate, phosphate, fluoride, sulphide, sulphate, chloride, sodium, potassium, TSS, boron, chromium, lead, copper, iron, nickel and zinc (Table 1 to 4 and 4).

pH: Variation of pH was seen between 7.38 and 7.10 in Gonur lake, whereas in 7.75 to 7.50 in Mallapur lake, whereas in 6.52 to 7.09 in Matadahatti kere lake and in 6.61 to 7.12 in Chandravalli lake from April 2024 to April 2025 covering all the season. But in most of the samples, pH was maintained at an average of 7.2 only. On an average, the pH was high in winter and pre monsoon (Table 1 to 4). Most of the studies reported higher pH was usually observed in post monsoon and winter in the first sampling period and in winter and pre monsoon in the second sampling period in most of the samples (Satyanarayana and Krishna 2017; Goswami *et al.,* 2020).

Total Dissolved Solids: TDS varied from 655 to 966mg/lt in Gonur lake, whereas 150 to 688mg/lt in Mallapura lake, whereas 265 to 832mg/lt in Matadahatti kere lake and 120 to 250mg/lt in Chandravalli lake lowest from April 2024 to April 2025 covering all the season (Table 1 to 4). TDS was high in pre monsoon and monsoon and low in post monsoon and winter. Increase in monsoon was due to run off from the surrounding catchment, which was increased agricultural activities (Manohar et al 2017). Higher values were due to the decrease of water level and disturbances by various activities. Similar opinion was expressed by Veena et al (2020) on river Umschyripi at Shillong and by Kumar et al (2017) on surface water of Dehradun.

Electrical Conductivity (EC): The variation was observed between 500µs/cm and 1716µs/cm in Gonur lake, whereas 367µs/cm and 1248µs/cm in Mallapura lake, whereas 550µs/cm and 1508µs/cm in Matadahaati kere lake and 110µs/cm and 214µs/cm in Chandravalli lake (Table 1 to 4 to 4). EC was low in summer season in all the lakes and higher in monsoon season and moderate in winter season, due to variation in rainfall in the sampling year. The water level of these lakes was very low in monsoon and gradually increased in post monsoon. The presence of ionic solids and minerals in water increases conductivity. EC of water is proportional to the number of dissolved solids. Presence of dissolved salts due to poor irrigation system, leaching of salts or nutrients, agriculture runoff containing more Cl, phosphate and nitrate, anthropogenic discharges and minerals from rain water may enhance conductivity (Manohar et al 2017). EC is affected by Ca, Mg, Fe, or by anions and by the presence of inorganic dissolved solids like nitrate, phosphate, sulphate and Cl (Kumar et al 2017).

Total Alkalinity: It is the sum of carbonates, bicarbonates, Ca, Mg, hydroxides and other compounds in water and it make the water resistant to changes in pH. The values varied between 180 mg/lt and 236 mg/lt in Gonur lake, whereas 260 mg/lt and 328 mg/lt in Mallapura lake, whereas 60 mg/lt and 92 mg/lt in Matadahatti kere lake and 35 mg/lt and 64 mg/lt in Chandravanalli lake, it was observed that lowest total alkalinity was present in monsoon and early winter and highest in summer in all lakes (Table 1 to 4 to 4). Similar observations were made by Satyanarayana and Krishna (2017). In pre monsoon, alkalinity increases with increased decomposition of human and animal excreta and indicate severity of pollution (Singh 2015, Ojok et al 2017). Increase in utilization of bicarbonates by phytoplankton and macrophytes decreases alkalinity (Naik et al 2015).

Total Hardness: Total hardness varied between 170 mg/lt and 320 mg/lt in in Gonur lake, whereas 250 mg/lt and 328 mg/lt in in Mallapura lake, 200 mg/lt and 400 mg/lt in in Matadahatti Kere lake and 30 mg/lt and 52 mg/lt in in Chandravanahalli lake, this fluctuation is observed in only in winter and summer season maximum and very lower in monsoon season due to various activities near by the lake (Table 1 to 4). The increase in hardness in summer was due high photosynthetic activity, utilization of free carbon and conversion of bicarbonates to carbonate which precipitate as Ca salts (Riddhi et al 2011). The overall range of hardness in sampling period was 108 mg L-1 to 635 mg L-1. Hardness was usually higher in monsoon followed by pre monsoon in both the sampling year (Ojok et al 2017). Temporary hardness is due to carbonates and bicarbonates and permanent hardness is due to bivalent cations of sulphate and chlorides and it indicates the regional variation of hydrosphere (Naik et al 2015).

Chloride (Cl): Chloride content varied from 123 mg/lt to 372 mg/lt in Gonur lake, whereas 75 mg/lt to 148 mg/lt in Mallapura lake, whereas 180 mg/lt to 270 mg/lt in Matadahatti kere lake and 10 mg/lt to 20 mg/lt in Chandravalli lake observed lot of fluctuation in all the seasons (Table 1 to 4). This was due to the entry of surface runoff containing organic waste of animal origin and pesticides used for the horticulture plants (Manohar et al 2017). ICMR and BIS have suggested 250 mg L-1 as the maximum permissible value. Similar findings by Singh (2015) have justified this study. Cl concentration mainly depends on climatic variations, domestic wastes, run off during monsoon, humidity and evaporation. Increased temperature and evaporation of water bodies may increase Cl content (Mohemed et al 2017).

Magnesium: The value of magnesium (Mg) in the sampling period varied from 94 mg/lt to 196 mg/lt in Gonur lake, whereas 76 mg/lt to 140 mg/lt in Mallapura lake, whereas 35 mg/lt to 100 mg/lt in Matadahalli kere lake and 8 mg/lt to 28 mg/lt in Chandravalli lake with fluctuation in all the season (Table 1 to 4). Many investigators have the opinion that Ca concentration is usually higher than Mg (Kumar et al 2017). According to BIS 30 mg L-1 to 100 mg L-1 is the acceptable limit and any excess in these indicate contamination and pollution (Satyanarayana and Krishna 2017).

Ammonical Nitrogen: Nitrogen content varied from 0.26 mg/lt to 1.12 mg/lt in Gonur lake, whereas 0.46 mg/lt to 0.56 mg/lt in Mallapura lake, whereas 5.25 mg/lt to 41.44 mg/lt in Matadahatti lake and 0.50 mg/lt to 40.95 mg/lt in of nitrate were observed in Chandravalli lake, the nitrogen content was high in winter and summer season during study in all the lakes and lower in monsoon only (Table 1 to 4). The nitrate concentration was below 10 mg L-1 and it is below permissible limit as per BIS (2012) in all the samples. Nitrate is also an essential nutrient for plants and plankton, which converts it into cell protein, but higher concentration, may be harmful (Divahar et al 2019). The concentration of nitrate was high during winter and pre monsoon in the first sampling period and the increase in dry seasons were attributed to domestic pollution (Ojok et al 2017). It was high in monsoon and pre monsoon in the second sampling period. Nitrate was below detectable level in post monsoon 2017 and in early summer 2018 throughout the second sampling period. Decrease in rainfall was one of the reasons behind the low concentrations of nitrate in different samples (Manohar et al 2017).

Sulphate: The values of sulphate varied between 10.5 mg/lt to 39.6 mg/lt in Gonur lake, 20.6 mg/lt to 30.9 mg/lt in Mallapura lake, whereas 3.5 mg/lt to 6.5 mg/lt in Matadhahalli kere lake and in 2.5 mg/lt to 10.4 mg/lt in Chandravalli lake; Sulphate content lowest was observed in all the lake monsoon and highest in post winter and summer (Table 1 to 4). Sulphate was low in pre monsoon season. Increase in monsoon can be attributed to the surface runoff which contains organic fertilizers. Concentration of sulphate was higher in post monsoon and winter; lowest in monsoon during the first sampling period. Low concentrations sulphate in monsoon and high in winter season was recorded by Pawar (2010) which correlate with the present studies.

Calcium: Amount of Ca in the sampling period varied from 86 mg/lt to 124 mg/lt in Gonur lake, whereas 126 mg/lt to 188 mg/lt in Mallapura lake, whereas 116 mg/lt to 300 mg/lt in Matadahatti kere lake and 9 mg/lt to 24 mg/lt in Chandravalli lake, these studies were highest in late winter and summer (Table 1 to 4). Similar observations were made by Saad et al (2017). Ca increases due to decomposition of organic matter, hydro-chemical process, dissolution of sedimentary rocks will increase and by anthropogenic activities and its utilization by aquatic organisms will decrease Ca content (Satyanarayana and Krishna 2017).

Total Phosphate: Phosphate content of water varied between 0.18 mg/lt and 0.23 mg/lt in Gonur lake whereas 0.28 mg/lt and 0.43 mg/lt in Mallapura lake, whereas 0.008 mg/lt and 0.065 mg/lt in Matadahatti kere lake and in 0.005 mg/lt and 0.025 mg/lt in Chandravalli lake, these variations found highly fluctuation in winter and summer season (Table 1 to 4). Higher concentration of phosphate in monsoon season was due to inflow of rainwater

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(Vajravelu et al 2018). The aquatic systems whose terrains are made of agriculture and residential areas usually contain more phosphate in rain water runoff in the form of phosphate fertilizers, detergents, animal waste, septic tank effluent and industrial discharge (Manohar et al 2017). Increase in phytoplankton population shows more utilization of more phosphate and thus its concentration decreases. Phosphorus concentration of 0.03 mg L^{-1} is sufficient to cause algal bloom (Sheela et al 2011).

Carbon dioxide (CO_2): The value of CO_2 in the sampling period varied from 8.5 mg/lt to 19.7 mg/lt in Gonur lake, whereas 7.2 mg/lt to 10.2 mg/lt in Mallapura lake, whereas 15.5 mg/lt to 55.6 mg/lt in Matadahalli kere lake and 18.2 mg/lt to 31.4 mg/lt in Chandravalli lake with fluctuation in all the season (Table 1 to 4). Kushwaha et al. (2021) studied seasonal variations in water quality, highlighting the impact of nutrient loading and geochemical interactions on magnesium levels. Waghmare & Kulkarni (2013) assessed seasonal fluctuations of calcium and magnesium in river systems, emphasizing the role of hydrological cycles and anthropogenic influences. Shivashankar & Venkataramana (2015) analyzed seasonal water quality variations, demonstrating how temperature, precipitation, and human activities affect magnesium concentrations.

Total suspended solids (TSS): The wide variation between total suspended solids (TSS) concentrations 1.5 mg/lt to 4.8 mg/lt in Gonur lake, whereas 3.2 mg/lt to 5.4 mg/lt in Mallapura lake, whereas 2.5 mg/lt to 5.5 mg/lt in Matadahalli kere lake and 0.27 mg/lt to 1.93 mg/lt in Chandravalli lake for sampling site could be due to the presence of organic floatable observed during collection of the samples. The presence of these clumps of matter could significantly increase the TSS value for a sample in comparison to a similar sample without clumps. The overall range of TSS in sampling period was 0.12 mg L-1 to 1.2 mg L-1 (Nandal et al 2020) and was high when compare to the permissible limit (Table 1 to 4). Nandal (2020), solids refer to the matter that is suspended or dissolved in the water or waste water. The TSS, is a portion of total solids (TS) retained by a filter while the total dissolved solids (TDS) are the in filterable solids, mostly inorganic salts and small amount of organic matter dissolved in the water.

Table 1 to 4: Physicochemical status of Gonur Lake of Chitradurga, Karnataka, India

Months & Year	Physicochemical status of Gonur Lake												
	pH	**TDS (ppm)**	**Conductivity (µs/cm)**	**Alkalinity (mg/lt)**	**Hardness (mg/lt)**	**Cl (mg/lt)**	**Mg (mg/lt)**	**Nit (mg/lt)**	**SO_4 (mg/lt)**	**Ca (mg/lt)**	**Phosp (mg/lt)**	**CO_2 (mg/lt)**	**TSS (mg/lt)**
July 2024	7.12	590	1186	210	220	155	100	0.455	10.53	108	0.21	12.5	2.65
Aug 2024	7.23	650	1716	190	170	123	94	0.260	11.71	84	0.23	8.50	1.75
Sept 2024	7.18	655	1555	180	180	198	125	0.360	19.65	95	0.22	10.8	1.50
Oct 2024	7.22	695	1300	195	190	200	165	0.450	24.50	102	0.20	11.5	1.95
Nov 2024	7.25	685	1295	200	210	255	180	0.550	26.25	115	0.19	12.5	2.10

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Dec 2024	7.30	650	995	215	220	265	185	0.650	29.50	116	0.18	14.5	2.45

Table 2: Physicochemical status of Mallapura Lake of Chitradurga, Karnataka, India

Months & Year	**Physicochemical status of Mallapura Lake**												
	pH	**TDS (ppm)**	**Conductivity (µs/cm)**	**Alkalinity (mg/lt)**	**Hardness (mg/lt)**	**Cl (mg/lt)**	**Mg (mg/lt)**	**Nit (mg/lt)**	**SO_4 (mg/lt)**	**Ca (mg/lt)**	**Phosp (mg/lt)**	**CO_2 (mg/lt)**	**TSS (mg/lt)**
July 2024	7.15	650	1180	275	262	102	95	0.46	22.5	155	0.30	10.0	3.65
Aug 2024	7.05	660	1010	260	252	75	75	0.45	23.71	126	0.29	10.2	3.90
Sept 2024	7.10	640	565	270	255	88	85	0.49	25.65	135	0.28	10.0	3.50
Oct 2024	7.15	650	367	275	262	110	95	0.52	23.50	135	0.30	9.0	3.95
Nov 2024	7.19	665	650	280	283	125	105	0.53	27.25	140	0.32	8.5	3.80
Dec 2024	7.25	675	750	285	292	130	115	0.54	28.50	145	0.35	8.0	3.95

Table 3: Physicochemical status of Matadahatti Kere Lake of Chitradurga, Karnataka, India

Months & Year	**Physicochemical status of Matadahatti Kere Lake**												
	pH	**TDS (ppm)**	**Conductivity (µs/cm)**	**Alkalinity (mg/lt)**	**Hardness (mg/lt)**	**Cl (mg/lt)**	**Mg (mg/lt)**	**Nit (mg/lt)**	**SO_4 (mg/lt)**	**Ca (mg/lt)**	**Phosp (mg/lt)**	**CO_2 (mg/lt)**	**TSS (mg/lt)**
July 2024	6.85	510	965	80	255	180	85	16.45	5.05	195	0.035	15.90	1.65
Aug 2024	6.52	266	565	60	205	185	75	5.25	4.75	145	0.008	15.50	2.90
Sept 2024	7.02	440	550	65	200	205	35	10.45	5.60	116	0.018	26.40	3.45

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Oct 2024	7.03	550	665	75	262	225	60	15.52	5.85	155	0.025	29.50	4.50
Nov 2024	7.05	555	695	82	275	245	65	19.55	5.95	175	0.035	36.50	4.10
Dec 2024	7.09	475	795	85	295	255	70	22.50	6.00	185	0.45	40.05	5.55

Table 4: Physicochemical status of Chandravalli Lake of Chitradurga, Karnataka, India

Months & Year	**Physicochemical status of Chandravalli Lake**												
	pH	**TDS (ppm)**	**Conductivity (µs/cm)**	**Alkalinity (mg/lt)**	**Hardness (mg/lt)**	**Cl (mg/lt)**	**Mg (mg/lt)**	**Nit (mg/lt)**	**SO_4 (mg/lt)**	**Ca (mg/lt)**	**Phosp (mg/lt)**	**CO_2 (mg/lt)**	**TSS (mg/lt)**
July 2024	7.00	200	155	52	35	15	16	15.50	6.05	18	0.007	30.90	1.10
Aug 2024	6.91	175	110	34	30	12	09	10.05	2.50	9	0.005	31.40	0.70
Sept 2024	6.61	120	140	40	32	10	08	0.50	4.05	13	0.010	30.90	0.27
Oct 2024	6.95	150	135	45	36	12	12	10.50	5.90	15	0.015	29.65	0.90
Nov 2024	7.01	195	155	55	38	14	15	17.50	6.90	17	0.019	28.50	1.10
Dec 2024	7.03	215	204	60	41	15	19	20.95	7.70	18	0.020	27.05	1.50

Heavy metal analysis of Gonur Lake, Mallapura Lake, Matadahatti Ker Lake, and Chandravalli Lake of Chitradurga, Karnataka, India by Atomic Absorption Spectroscopy (AAS)

Chromium: In water, Cr ranged 0.57 – 4.07 ppm (2.13 ppm) exceeding the drinking water standards stipulated by BIS, EPA, and irrigation standards limit by FAO. Moreover, Cr exceeded tolerance limit for water bodies subject to pollution which is 2.0 ppm ((Nithya et al 2018). In water, the range of Cr in Gonur lake was shown 0.011 to 0.018 ppm, whereas in Mallapura lake was shown 0.033 to 0.055 ppm, whereas in Matadahatti kere lake was shown 0.005 to 0.010 ppm and in Chandravalli lake was shown 0.001 to 0.008 ppm observed with variation from season to season (Table 5). The critical level range is between 5.00 ppm – 30.0 ppm. Onchoke and Sasu (2016) put the critical range between 20 – 100 ppm. This was below the probable effect level (PEL) of 90.0 ppm and under the background value of 32.0 ppm reported by Elias et al (2018).

Lead: The study area of Gonur lake lead (Pb) range was 0.0010 – 0.0410 ppm, whereas in Mallapura lake range was 0.0110 – 0.0201 ppm, whereas in Matadahattim kere lake range was 0.0005 – 0.0010 ppm

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and Chandravanalli lake range was (Table 2). Lead's concentration is very high in Feb 2018 in all the lakes compare to other months and very lowest in winter season 2017 in all the lakes. This range exceeded the drinking water standards and effluent discharge limits prescribed by CPCB. Nevertheless, Lead (Pb) has been known to accumulate in aquatic macrophytes in considerable levels based on the rooted and floating species. Critical range for Pb as described by Mohanakavitha et al (2019) is 30-300 ppm. However, Pb concentration in Vartur Lake exceeded the background value for uncontaminated sediments reported by Onchoke and Sasu (2016). Pb can exist in several valences and are of critical environmental importance. In urban areas, the principal source of Pb in wetlands comes from gasoline additives, metal plating, e-waste and battery cells, electrical equipment, textile mills, dye and pigments, paper mills, chemical and fertilizer industries, and ghee manufacturing industries (Jumbe and Nandini 2009).

Copper: The study area of Gonur lake copper (Cu) in water was ranging between 0.09 – 0.19 mg/lt, whereas in Mallapura lake ranging between 0.15 – 0.19 mg/lt, whereas in Matadahatti kere lake ranging between 0.03 – 0.18 mg/lt and in Chandravalli lake ranging between 0.10 – 0.20 mg/lt. Cu was within drinking water standards stipulated by ICMR and EPA, but exceeded BIS limits of 0.05 ppm. The normal range of Cu in all the lakes shown in all the seasons was in the normal range should be 4 – 15 ppm (Jumbe and Nandini 2009). However, the mean exceeded the background value of 27.0 ppm reported by Mohanakavitha et al (2019). Cu reaches the aquatic environment through wet and dry depositions, mining activities and storm water run-offs, industrial, domestic, and agricultural waste disposal. Among industrial sources include copper plating, pulp and paper mills, e-waste, sewage and other forms of waste waters.

Iron: The (Fe) was usually below detectable level in most of the samples and in many seasons. The overall range of Fe in sampling site Gonur lake was 0.55 – 1.20 mg/lt, whereas in Mallapura lake was 0.15 – 0.98 mg/lt, whereas in Matadahatti kere lake was 0.15 – 0.87 mg/lt and in Chandravalli lake was 0.03 – 0.68 mg/lt, and it was high when compare to the permissible limit in some lakes of Chitradurga. It was high in pre winter and it was low in summer in study lake (month wise) (Table 2). In monsoon, the concentration of Fe was more due to the heavy runoff of water into lakes. Similar variation of parameter was also observed by Mallampati and Osman (2015). Decomposition process is the source in dry seasons (Manohar et al. 2017).

Nickel: The study area of Gronus lake water, Ni range was 0.009 to 0.10 mg/lt, whereas in Mallapura lake 0.05 – 0.10 mg/lt, whereas in Matadahatti kere lake 0.001 – 0.010 mg/lt and in Chandravalli lake 0.005 – 0.082 mg/lt, it was highest in early summer months in studied lake compare to winter and monsoon season (Table 2). This was above drinking water standards stipulated for Nickel (Ni). But the mean was within the tolerance limit for water bodies subjected to pollution discharge. Similarly, Ni has been found in a variety of plants and ranges up to 340 ppm have been recorded non-edible wild plants. The overall mean for Ni in macrophytes of Vartur lake was 47.91 ppm. The range was 26.0 – 65.32 ppm. This is in critical category of Ni contents in plants as described by Jumbe and Nandini (2009) which is between 10 – 50 ppm.

Zinc: The (Zn) concentration in water ranged 0.0008 – 0.1108 mg/lt, whereas in Mallapura lake 0.0009 – 0.1290 mg/lt, whereas in Matadahatti kere lake 0.0001 – 0.0002 mg/lt and in Chandravalli lake 0.0000 – 0.0001 mg/lt. This was within the stipulated drinking water standards by BIS, ICMR, EPA and irrigation limits by FAO. This fluctuated range of Zn was seen in all the months of 2 seasons during the study (Table 2). Zn in urban lake water is caused by a variety of industrial effluents including phosphates fertilizers, ghee manufacturing, metal processing units, zinc plating industries, silver plating industries, distillery units, landfill leachates, urban storm water, fly ashes of coal powered plants, poultry sewage and compost (Elias et al 2018). In Bengaluru lakes, the range for Zn was 42.93 ppm which was below the PEL limit reported by Jumbe and Nandini (2009).

Table 5: Heavy metal status of Gonur lake, Chitradurga, Karnataka, India

Months & Year	Heavy metal parameters of Gonur Lake					
	Cr (mg/lt)	Pb (mg/lt)	Cu (mg/lt)	Fe (mg/lt)	Ni (mg/lt)	Zn (mg/lt)
July 2024	0.010	0.0070	0.010	0.950	0.000	0.0055
Aug 2024	0.009	0.0010	0.009	0.705	0.000	0.0008
Sept 2024	0.008	0.0090	0.0011	0.550	0.000	0.0000
Oct 2024	0.009	0.0110	0.0015	0.595	0.000	0.0000
Nov 2024	0.010	0.0150	0.0017	0.695	0.000	0.0000
Dec 2024	0.010	0.0250	0.0019	0.755	0.009	0.0035

Table 6: Heavy metal status of Mallapura lake, Chitradurga, Karnataka, India

Months & Year	Heavy metal parameters of Mallapura Lake					
	Cr (mg/lt)	Pb (mg/lt)	Cu (mg/lt)	Fe (mg/lt)	Ni (mg/lt)	Zn (mg/lt)
July 2024	0.049	0.0155	0.0010	0.950	0.000	0.0055
Aug 2024	0.045	0.0125	0.0009	0.705	0.000	0.0008
Sept 2024	0.040	0.0110	0.0011	0.550	0.000	0.0000
Oct 2024	0.038	0.0115	0.0015	0.595	0.000	0.0000
Nov 2024	0.035	0.0120	0.0017	0.695	0.000	0.0000
Dec 2024	0.033	0.0125	0.0019	0.755	0.009	0.0035

Table 7: Heavy metal status of Matadahatti kere lake, Chitradurga, Karnataka, India

Months & Year	Heavy metal parameters of Matadahatti kere Lake					
	Cr (mg/lt)	Pb (mg/lt)	Cu (mg/lt)	Fe (mg/lt)	Ni (mg/lt)	Zn (mg/lt)
July 2024	0.045	0.0007	0.013	0.070	0.008	0.0002
Aug 2024	0.035	0.0005	0.012	0.0695	0.007	0.0001
Sept 2024	0.033	0.0007	0.007	0.0550	0.005	0.0001
Oct 2024	0.039	0.0008	0.0003	0.0395	0.004	0.0001
Nov 2024	0.040	0.0009	0.0009	0.150	0.001	0.0000
Dec 2024	0.042	0.0009	0.0015	0.500	0.007	0.0001

Table 8: Heavy metal status of Chandravalli lake, Chitradurga, Karnataka, India

Months & Year	Heavy metal parameters of Chandravalli lake					
	Cr (mg/lt)	Pb (mg/lt)	Cu (mg/lt)	Fe (mg/lt)	Ni (mg/lt)	Zn (mg/lt)
July 2024	0.006	0.0008	0.017	0.0500	0.055	0.0001
Aug 2024	0.005	0.0007	0.011	0.0300	0.045	0.0000
Sept 2024	0.005	0.0005	0.010	0.0450	0.015	0.0000
Oct 2024	0.006	0.0005	0.0010	0.0495	0.005	0.0000
Nov 2024	0.006	0.0006	0.0012	0.0500	0.007	0.0000
Dec 2024	0.006	0.0007	0.0013	0.0650	0.009	0.0001

CONCLUSIONS

The major source of pollution in the sampling lakes was the sewage and waste water from the village that entered in to the lakes without any prior treatment, agricultural runoff, washing and cleaning activities of people only in Mallpura lake compare to other three lakes. The experimental data indicate that the lake is severely polluted and certain precautionary and constructive steps may avoid further eutrophication of lakes in Mallapura lake compare to others. Some of the measures like maintaining grass buffer strip around the lake, remediation of sewage and domestic waste and sedimentation of agricultural runoff to reduce the particulate matter before entering lake may reduce rate of pollution. The entry of pesticide containers, thinners, lubricants and direct flow of drainage from livestock facilities into lake should be restricted to reduce pollution. People should be educated regarding method of domestic water treatment, type of toilet facility and human waste disposal. This may contribute to decrease in the water pollution.

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