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Analysis of Physicochemical parameters of Water and Sediment sample to assess the Water health in Pulicat Lake, India

Leena Tresa Ignatius Antony *, Meena Boominathan and Surya Prabha Unni Krishnan

Department of Zoology, Presidency College, Chennai - 600 005, Tamil Nadu, India.

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Abstract

Background: Environmental Chemistry study is an essential analysis for understanding and channelizing the pollution source by studying the various chemical effects of the environment, in order to conserve the natural resources and human health. The ecotoxicology study of the water and sediment gives us a picture of the various pollutants present in the site and helps in conserving it.

Aim: This study aimed to investigate the physiochemical parameters of selected water and sediment samples and their heavy metal presence in them.

Methods: Field collection were carried out over a period of two days to evaluate the various physiochemical parameters in five selected spots of Pulicat Lake. The water and sediment samples were carefully labelled and heavy metal analysis was carried out using standard methods.

Results: The water and sediment analysis showed that was no significant difference in the physiochemical variables between the five different samples. The water quality of Pulicat Lake remains within normal limits, with no evidence of pollution despite the recent development of industries in the region.

Conclusion: There is need for continuous, long-term monitoring and assessment in order to safeguard the biodiversity of the Pulicat Lake and its preservation.

Keywords: Water- Sediment quality; Pulicat Lake; Heavy metal; Pollution; Physicochemical parameters

1. Introduction

Coastal lakes and estuarine ecosystems serve as critical ecological interfaces between freshwater and marine environments. They provide habitats for diverse flora and fauna, support fisheries, and play a vital role in nutrient cycling and sediment trapping [3]. However, due to increasing urbanization, industrial discharge, agricultural runoff, and tourism activities, these ecologically sensitive zones are increasingly threatened by pollution and habitat degradation [9].

Pulicat Lake, the second-largest brackish water lagoon in India, straddling the states of Andhra Pradesh and Tamil Nadu, is a biodiversity hotspot. It supports livelihoods through fisheries, salt pans, and bird sanctuaries, including the migratory flamingo populations, thereby holding immense ecological and economic value [7]. The lake also functions as a natural buffer, reducing the impact of coastal erosion and flooding.

* Corresponding author: Leena Tresa Ignatius Antony.

However, escalating anthropogenic pressures—such as untreated sewage discharge, heavy metal contamination from industrial effluents, and changing land-use patterns—have deteriorated the water and sediment quality of Pulicat Lake [12]. Monitoring the physicochemical and heavy metal parameters of such aquatic systems is essential for understanding ecological health and guiding conservation strategies [11].

Objectives of the Study

The present study is designed with the following objectives:

- To evaluate the physicochemical properties (pH, DO, BOD, COD, etc.) of water and sediment samples from Pulicat Lake.
- To assess the concentrations of heavy metals (Pb, Cr, Cd) in both water and sediments.
- To analyse the composition of sediments in terms of total organic carbon, phosphate, and calcium carbonate, and to correlate these with observed water quality parameters [17].

1.1. Scope and Limitations

This study is restricted to five designated water sampling sites (WS1–WS5) and corresponding sediment sampling sites (SS1–SS5) in Pulicat Lake. While it provides a valuable snapshot of the lake's environmental status, it does not encompass seasonal variability, which is known to influence water chemistry and sediment composition [6]. Furthermore, the study is limited to surface water and surface sediments, without examining deeper sediment layers or biological indicators such as macroinvertebrates or phytoplankton diversity [10].

2. Literature Review

2.1. Physicochemical Indicators of Water Quality

The evaluation of water quality typically begins with the analysis of key physicochemical parameters such as pH, dissolved oxygen (DO), biological oxygen demand (BOD), chemical oxygen demand (COD), and alkalinity. These indicators help determine the trophic status, pollution load, and biological productivity of aquatic ecosystems [6]. pH reflects the acidic or basic nature of water, influencing the solubility of nutrients and heavy metals. DO is a direct indicator of water's ability to support aquatic life, while BOD and COD represent organic load and overall chemical pollution, respectively [10]. Alkalinity serves as a buffer against sudden pH changes and is essential in maintaining water's acid-neutralizing capacity.

2.2. Sediment Characteristics and Contamination

Sediments act both as a sink and as a secondary source of contaminants in aquatic ecosystems. Parameters such as total organic carbon (TOC), phosphate content, and calcium carbonate concentration are crucial in evaluating the geochemical behaviour of sediments [3]. TOC provides insights into the presence of organic matter, which can affect microbial processes and nutrient cycling. Phosphates are indicators of eutrophication potential, often linked with anthropogenic inputs like agricultural runoff. Calcium carbonate contributes to sediment structure and buffering capacity, influencing the sediment's capacity to immobilize or release pollutants.

2.3. Heavy Metal Contamination in Aquatic Ecosystems

Heavy metals such as chromium (Cr), lead (Pb), and cadmium (Cd) are of particular concern in water and sediment quality assessments due to their toxicity, persistence, and tendency to bio-accumulate [12]. Their sources include industrial discharges, urban runoff, mining operations, and agricultural leachates. In aquatic environments, these metals can impair physiological functions in biota and pose risks to human health through water consumption and food chains. The concept of Below Detectable Limit (BDL) is critical in such analyses, as it indicates that metal concentrations are below the sensitivity threshold of the analytical method used, which is crucial for risk assessments and regulatory compliance.

2.4. Preceding Studies on Pulicat Lake

Pulicat Lake has been the subject of several environmental studies due to its ecological and socioeconomic importance. Earlier research has indicated progressive degradation in water quality, influenced by both point and non-point sources of pollution, including industrial effluents, untreated domestic sewage, and increasing urbanization [9]. A number of studies have emphasized the need for integrated coastal zone management and community-based conservation strategies. However, there remains a gap in consistent long-term monitoring, particularly with respect to sediment quality and heavy metal accumulation.

3. Materials and Methods

3.1. Area of Investigation

Pulicat Lake, located along the east coast of India, is a brackish water lagoon situated on the border between Andhra Pradesh and Tamil Nadu. It is the second-largest coastal lagoon in India, covering an approximate area of 759 square kilometres. The lake is geographically positioned between 13°26'N to 13°37'N latitude and 80°03'E to 80°18'E longitude and is separated from the Bay of Bengal by the Sriharikota barrier island. Pulicat supports rich biodiversity, including fish, crustaceans, and a large population of migratory birds, particularly flamingos, and is part of the Pulicat Lake Bird Sanctuary [7]. Its ecological sensitivity, coupled with increasing anthropogenic stressors, makes it a vital site for environmental assessment.

3.2. Sampling Strategy

The present study involved the selection of five strategic sampling sites for both water (WS1–WS5) and sediment (SS1–SS5) based on accessibility, proximity to anthropogenic activities, and spatial distribution across the lake. Samples were collected during the dry season from December 2021 to April 2022 to minimize dilution effects caused by monsoon runoff.

Water samples were collected in sterilized polyethylene bottles and stored at 4°C until analysis. Sediment samples were collected using a grab sampler and stored in airtight containers. All samples were transported under cold conditions to ensure minimal alteration in sample composition during transit [1].

3.3. Laboratory Analysis Methods

3.3.1. Physicochemical Parameters

The physicochemical analysis of water samples included pH, temperature, dissolved oxygen (DO), biological oxygen demand (BOD), chemical oxygen demand (COD), total hardness, carbonate content, and total alkalinity. The procedures followed were in accordance with Standard Methods for the Examination of Water and Wastewater published by the American Public Health Association [1].

- pH and temperature were measured in situ using a portable pH meter and thermometer.
- DO was determined using the Winkler titration method.
- BOD was measured using the 5-day incubation method.
- COD was analyzed by the dichromate reflux method.
- Hardness, carbonates, and alkalinity were estimated through titrimetric methods.

3.4. Heavy Metal Analysis

Heavy metal concentrations—Chromium (Cr), Lead (Pb), and Cadmium (Cd)—in both water and sediment samples were analyzed using Atomic Absorption Spectroscopy (AAS) and validated with Inductively Coupled Plasma Mass Spectrometry (ICP-MS) for precision. The detection limits (DL) were as follows:

- Cr: 0.1 mg/L in water; 2.0 mg/kg in sediment
- Pb: 0.05 mg/L in water; 0.5 mg/kg in sediment
- Cd: 0.01 mg/L in water; 2.0 mg/kg in sediment

Samples showing concentrations below the detectable limit (BDL) were recorded accordingly.

3.5. Statistical Tools

All numerical data obtained from water and sediment samples were subjected to basic statistical analysis using Microsoft Excel and SPSS. Descriptive statistics such as **mean**, **standard deviation**, and **range** were calculated to interpret central tendencies and dispersion. Comparative **bar and line graphs** were used to visually represent spatial variation among sampling sites and to correlate physicochemical and heavy metal parameters across water and sediment samples [17].

Table 1 Physicochemical Parameters of Water Samples (WS1–WS5**)**

S. No	Parameter	WS1	WS2	WS3	WS4	WS5
1	pH	7.6 ± 0.208	7.9 ± 0.115	8.0 ± 0.96	7.4 ± 0.98	7.3 ± 0.117
2	Temperature (°C)	32 ± 0.153	31 ± 0.264	31 ± 0.200	30.5 ± 0.173	29.5 ± 0.234
3	DO (mg/L)	3.1 ± 0.1	2.8 ± 0.1	2.9 ± 0.3	3.2 ± 0.4	2.7 ± 0.3
4	BOD (mg/L)	42.3 ± 4.34	48.5 ± 5.59	51.3 ± 3.74	62.4 ± 2.54	68.4 ± 5.23
5	COD (mg/L)	322.4 ± 19.28	358.4 ± 19.84	352.6 ± 14.19	364.5 ± 17.2	384.6 ± 15.24
6	Carbonate (mg/L)	18.64 ± 0.87	21.55 ± 0.42	20.64 ± 0.30	22.42 ± 0.64	22.04 ± 0.30
7	Total Hardness (mg/L)	7824	7246	8121	6725	6924
8	Total Alkalinity (mg/L)	125.6	121.5	122.6	124.9	126.7

($p>0.05$) significance value in each parameter($n=5$), values are mean ± SD; WS - water sample; DO - dissolved oxygen; BOD - biochemical oxygen demand; COD - chemical oxygen demand

3.5.1. Observation

- pH values ranged from 7.3 to 8.0, indicating slightly alkaline conditions suitable for aquatic life (APHA 2017).
- DO levels were low (2.7–3.2 mg/L), suggesting stress on aquatic organisms, possibly due to high organic load.
- BOD and COD were high across all stations, indicating organic pollution and poor biodegradability of wastewater inputs.
- Carbonate and Alkalinity showed good buffering capacity; however, high total hardness suggests the influence of groundwater or saline intrusion.

Table 2 Sediment Physicochemical Characteristics (SS1–SS5)

S. No	Parameter	SS1	SS2	SS3	SS4	SS5
1	pH	7.6 ± 0.15	8.1 ± 0.042	8.2 ± 0.055	7.6 ± 0.037	7.4 ± 0.024
2	Total Organic Carbon (TOC, %)	1.2 ± 0.04	0.9 ± 0.10	1.3 ± 0.13	1.4 ± 0.18	1.1 ± 0.15
3	Phosphate (%)	0.87 ± 0.33	0.94 ± 0.26	0.82 ± 0.05	0.79 ± 0.21	0.91 ± 0.19
4	Calcium Carbonate (%)	1.6 ± 0.388	1.8 ± 0.54	1.6 ± 0.32	1.4 ± 0.42	1.5 ± 0.24
5	Soil Type	Sand 90%	Silt 60% + Sand 30%	Sand 60% + Silt 30%	Silt 60% + Clay 30%	Clay 25% + Sand 30% + Silt 40%

($n=5$); values are mean ± SD; SS - Sediment sample; % - percentage

Observation

- The sediment pH was slightly alkaline (7.4–8.2), consistent with water pH.
- TOC ranged from 0.9% to 1.4%, indicating moderate organic matter content.
- Phosphate levels were below eutrophication threshold, but their presence hints at agricultural runoff or domestic discharge.
- Soil composition varied, with sandy sediments dominating SS1–SS3 and siltier/clayey textures at SS4 and SS5—impacting metal adsorption and nutrient retention capacity [3].

Table 3 Heavy Metals concentration in Water Samples (mg/L)

S. No	Parameter	WS1	WS2	WS3	WS4	WS5
1	Cr	BDL (DL: 0.1)	BDL	BDL	BDL	BDL
2	Pb	0.60 ± 0.01	0.64 ± 0.12	0.58 ± 0.04	0.61 ± 0.02	0.63 ± 0.01
3	Cd	BDL (DL: 0.01)	BDL	BDL	BDL	BDL

BDL - below detectable limit; DL - detectable limit; Cr - Chromium; Pb – Lead; Cd - Cadmium; WS - water sample

Observation

Chromium (Cr) and Cadmium (Cd) were below detectable limits (BDL) across all samples.

Lead (Pb) levels (0.58–0.64 mg/L) exceed the BIS limit of 0.05 mg/L for drinking water, posing potential health risks [2,18].

Table 4 Heavy Metals in Sediment Samples (mg/kg)

S. No	Parameter	SS1	SS2	SS3	SS4	SS5
1	Cr	14.76 ± 0.02	11.89 ± 0.04	12.64± 0.02	10.27± 0.03	9.12± 0.05
2	Lead (Pb)	BDL (DL: 0.5)	BDL	BDL	BDL	BDL
3	Cadmium (Cd)	BDL (DL: 2.0)	BDL	BDL	BDL	BDL

Cr - chromium; Pb - lead; Cd - cadmium; BDL - below detectable level; DL - detectable limit; mean ± SD value

Observation:

- Chromium (Cr) concentrations were within acceptable sediment quality guidelines, highest at SS1.
- Lead (Pb) and Cadmium (Cd) were below detection limits (BDL), suggesting no significant sediment contamination.
- Sediments acted as a moderate sink for Cr but not for Pb or Cd [12].

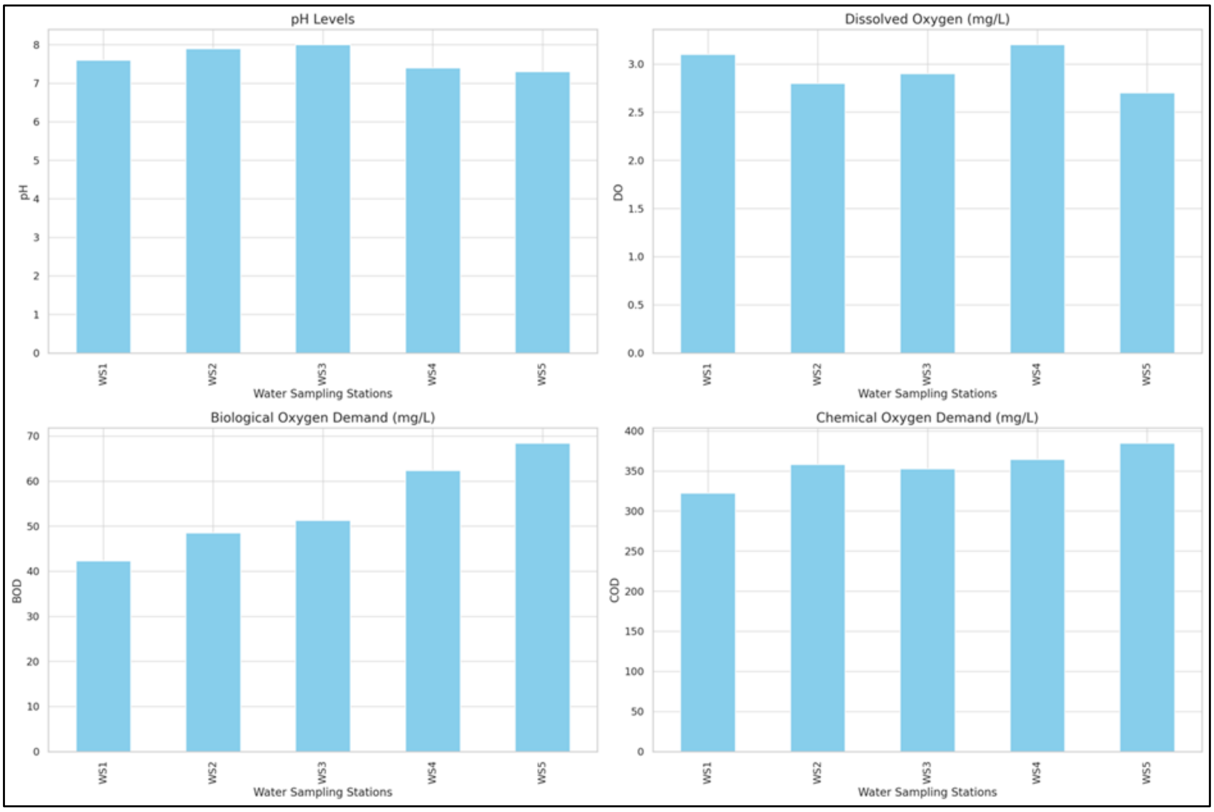

Figure 1 Physicochemical Parameters of Water Samples. Chemical Oxygen Demand (mg/L)

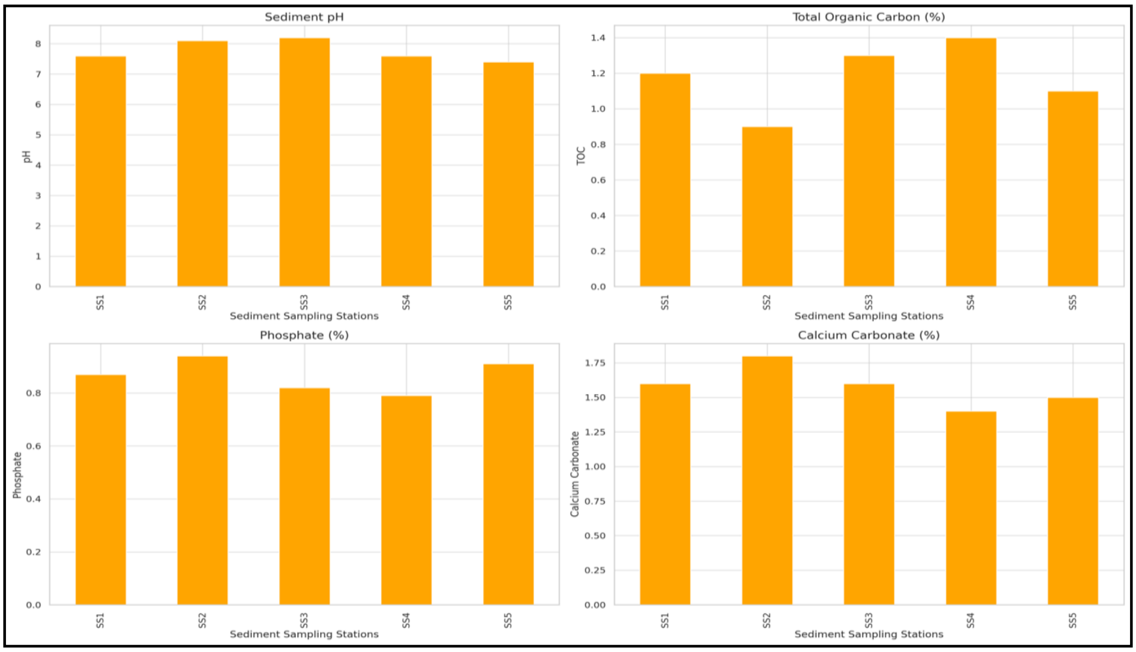

Figure 2 Physicochemical Parameters of Sediment Samples Calcium Carbonate (%)

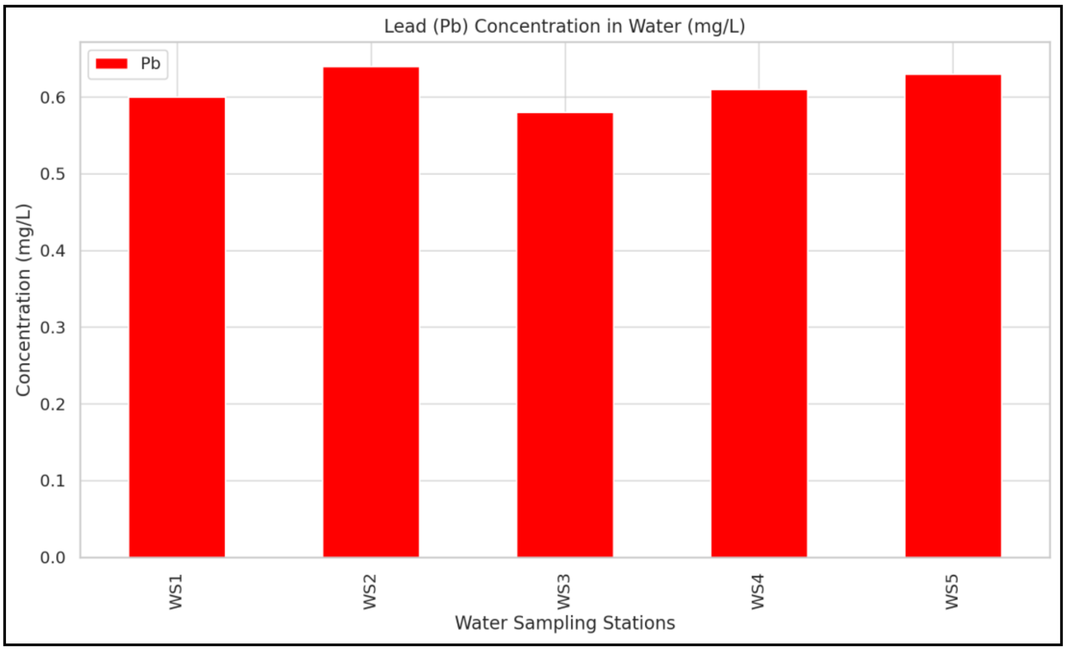

Figure 3 Heavy metal Concentration of Water samples Lead (Pb) Concentration in Water (mg/L)

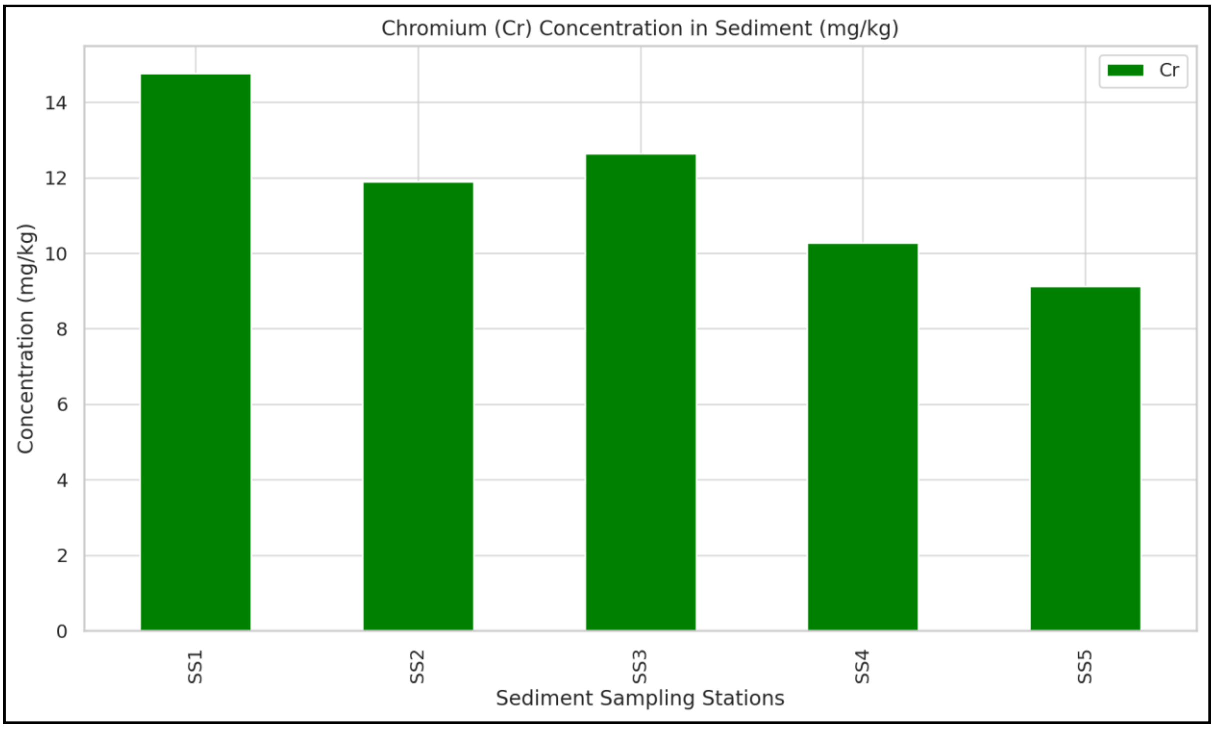

Figure 4 Heavy metal Concentration of Water samples. Chromium (Cr) Concentration in Sediment (mg/kg)

4. Results

4.1. Physicochemical Parameters of Water

The physicochemical assessment of water across the five sampling stations (WS1–WS5) revealed pH levels ranging from 7.3 to 8.0, indicating a slightly alkaline nature of the water, which is typical of estuarine environments [6]. Dissolved Oxygen (DO) values ranged between 2.7 and 3.2 mg/L, which are marginal and may not adequately support higher aquatic life. Critically, Biological Oxygen Demand (BOD) values ranged from 42.3 to 68.4 mg/L, and Chemical Oxygen Demand (COD) levels spanned 322.4 to 384.6 mg/L, both of which are significantly high and indicate strong organic pollution in the aquatic environment [1].

These elevated BOD and COD values suggest substantial input of biodegradable and non-biodegradable organic matter, potentially from untreated domestic sewage, aquaculture discharge, or agricultural runoff [10]. This organic load exerts pressure on the lake's assimilative capacity and threatens ecological stability.

4.2. Heavy Metal Concentration in Water Samples

Analysis of heavy metals in water samples showed that Chromium (Cr) and Cadmium (Cd) concentrations were below detectable limits (BDL) at all five stations, indicating an absence or negligible presence of these metals in the water column at the time of sampling [16]. However, Lead (Pb) was consistently detected in all stations, with concentrations ranging from 0.58 to 0.64 mg/L.

These Pb levels far exceed the permissible limit of 0.05 mg/L prescribed by the World Health Organization [18] and the Bureau of Indian Standards [2], signalling a serious contamination issue. This contamination may originate from industrial effluents, paint residues, and battery waste entering the lake system.

4.3. Sediment Parameters

The Total Organic Carbon (TOC) in sediment samples (SS1–SS5) ranged between 0.9% and 1.4%, suggesting moderate organic matter content, which could be a result of decaying biological material and external organic inputs [15]. Phosphate concentrations were recorded between 0.79% and 0.94%, while Calcium Carbonate ($CaCO_3$) content varied from 1.4% to 1.8%.

The composition of the sediments varied significantly: SS1 was predominantly sandy (90%), SS2 and SS3 showed a mixture of silt and sand, and SS4 and SS5 had higher proportions of clay and silt. The variability in texture influences the adsorption and transport behaviour of nutrients and contaminants [14].

4.4. Heavy Metal Concentration in Sediments

Among the heavy metals assessed in sediment, Cr was the only metal detected, with concentrations ranging from 9.12 mg/kg (SS5) to 14.76 mg/kg (SS1). The highest Cr load at SS1 may be due to proximity to localized industrial or boatyard activity [12]. Both Pb and Cd were below detectable limits (BDL) across all sediment samples, indicating minimal accumulation of these metals in the benthic layer during the study period.

Although the detected Cr concentrations are within acceptable sediment quality guideline levels, the spatial variability suggests the influence of site-specific pollution sources and sediment composition [19]. Regular monitoring is necessary to assess long-term sediment contamination risks.

5. Discussion

5.1. Interpretation of Water Quality Parameters

The observed high BOD (42.3–68.4 mg/L) and COD (322.4–384.6 mg/L) levels across all water samples point toward the presence of untreated organic waste, likely from domestic sewage, aquaculture, and agricultural runoff [19]. Such elevated values indicate poor biodegradation efficiency and raise concerns about oxygen depletion, which can severely impact aquatic fauna.

The marginally alkaline pH values (7.3–8.0) are typical for estuarine and brackish water systems and are conducive to the survival of most aquatic organisms. This alkaline range may also support the proliferation of microbial communities responsible for organic matter decomposition, thereby influencing nutrient cycling [20].

5.2. Heavy Metal Contamination Assessment

Among the three heavy metals analyzed (Pb, Cr, Cd), only Lead (Pb) was detected in the water samples. The concentration ranged from 0.58 to 0.64 mg/L, significantly exceeding the BIS (2012) and WHO (2020) permissible limits of 0.05 mg/L for drinking water. This clearly reflects anthropogenic pollution, possibly from battery waste, paints, and boatyard activities [14].

In contrast, Chromium (Cr) levels in sediments were moderate, ranging from 9.12 to 14.76 mg/kg, and remained within acceptable environmental thresholds as per sediment quality guidelines (BIS 2012). The absence of detectable Cadmium (Cd) in both water and sediment samples indicates either minimal contamination or effective natural attenuation mechanisms.

5.3. Sediment-Water Interactions

The sediment parameters revealed moderate TOC (0.9–1.4%) and phosphate (0.79–0.94%) content, which are indicative of nutrient loading, possibly from agricultural runoff or decaying organic matter. These components can re-enter the water column under specific redox conditions, making sediments an active participant in biogeochemical cycling [4].

Given the varied sediment texture across sites—from sandy to silty to clayey—the capacity of sediments to adsorb or release contaminants also varies spatially. Such dynamics reinforce the understanding that sediments can act as both a sink and a secondary source for pollutants [5].

5.4. Comparison with National Standards

The Pb concentrations in water not only breach national [2] and international [18] standards but also indicate serious public health implications, especially in communities relying on lake water for domestic or fishing purposes.

Although Cr levels in sediments are currently within tolerable environmental limits, the gradual accumulation could pose long-term ecological risks, particularly if dredging or hydrodynamic changes occur [8]. Regular and seasonal monitoring is recommended to evaluate cumulative exposure risks and to implement remedial strategies when necessary

6. Conclusion

The physicochemical analysis of Pulicat Lake water revealed significant organic pollution, evidenced by elevated BOD and COD values across all sampling stations. These values indicate the presence of untreated or poorly treated organic waste, likely originating from domestic sewage, aquaculture runoff, and other anthropogenic sources [17].

More concerning is the detection of lead (Pb) in water samples at concentrations (0.58–0.64 mg/L) that exceed the permissible limits set by WHO and BIS [18; 2]. This indicates serious toxicological risks to aquatic life and potential health hazards for nearby human populations that rely on the lake for livelihood and domestic purposes.

Sediment analysis demonstrated moderate levels of Chromium (Cr) ranging from 9.12 to 14.76 mg/kg, which are within acceptable environmental guidelines [2]. However, Lead (Pb) and Cadmium (Cd) were found to be below detectable limits (BDL) in sediments, suggesting minimal accumulation or effective natural buffering at the time of sampling [12].

Despite low heavy metal accumulation in sediments, the presence of organic matter and nutrients such as TOC and phosphate points to continuous nutrient loading, potentially from surrounding agricultural activities [3].

Both water and sediment data reflect significant anthropogenic influence on Pulicat Lake's ecosystem, requiring urgent intervention through regulatory monitoring, pollution control measures, and community awareness initiatives. Continued and seasonal assessment of both physicochemical and biological indicators will be essential in formulating long-term conservation strategies for the lake.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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