ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XV, Issue VII, July 2026

Physicochemical and Bacteriological Assessment of Water Quality in Kole Wetlands of Elthuruth, Kerala, India

Bolie Therattil[1]

[1]Associate Professor, Department of Chemistry, St. Aloysius College, Elthuruth, Thrissur – 680 121, Kerala, India (Affiliated to University of Calicut)

DOI: https://doi.org/10.51583/IJLTEMAS.2026.150700029

Received: 27 July 2026; Accepted: 01 August 2026; Published: 07 August 2026

ABSTRACT

The Kole wetlands of Kerala represent a unique Ramsar site of international ecological importance, serving critical agricultural and biodiversity conservation functions. This study presents a comprehensive assessment of water quality in the Kole wetlands of Elthuruth, Thrissur District, focusing on physicochemical and bacteriological parameters. Water samples were collected from three distinct sites — Kole Wetland (main site), Pullu Field, and Elthuruth Field — following Bureau of Indian Standards (BIS) methods. A total of 20 parameters were analyzed including pH, turbidity, total dissolved solids (TDS), electrical conductivity (EC), alkalinity, hardness, major ions (Ca, Mg, Cl, Fe, F, NO3, SO4), and microbial indicators (coliforms and E. coli). Results revealed significant contamination: turbidity reached 12.3 NTU (12-fold above BIS limits), iron concentration was 2.6 mg/L (8.7-fold above permissible limits), and bacterial contamination was confirmed with 28 coliforms per 100 mL and presence of E. coli. While most physicochemical parameters including pH (6.8), TDS (177.87 mg/L), and hardness (74 mg/L) remained within acceptable BIS standards, the elevated turbidity, iron, and microbial contamination render the water unsuitable for direct consumption without treatment. These findings highlight the urgent need for water treatment interventions, regular monitoring programs, and community awareness initiatives to protect public health and ensure sustainable agricultural practices in this ecologically sensitive wetland ecosystem.

Keywords: Kole wetlands; water quality; physicochemical parameters; bacteriological contamination; iron toxicity; turbidity; Ramsar site

INTRODUCTION

Water is one of the most essential natural resources for all life on Earth. Although about 70% of the Earth's surface is covered with water, nearly 98% of it is saltwater, leaving only 2% as fresh water. Of this freshwater, around 70% is permanently frozen in glaciers and ice caps. The remaining freshwater available through rivers, lakes, and shallow aquifers is what sustains human civilizations, agriculture, and ecosystems. Because of the growing demand from increasing populations and industrial activities, the quality of this limited freshwater is deteriorating rapidly [4].

Wetlands are among the most productive ecosystems on Earth, providing critical services such as water purification, flood control, groundwater recharge, and biodiversity conservation. The Kole wetlands of Kerala, India, are a unique agricultural wetland ecosystem recognized internationally as a Ramsar site (designated in 2002). They span across Thrissur and Malappuram districts and serve as critical rice cultivation areas while supporting diverse flora and fauna. However, recent studies have shown varying water quality conditions across different Kole wetland sites, with some areas showing poor water quality that requires treatment before use [1].

ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XV, Issue VII, July 2026

Water analysis plays a very important role in agriculture, especially in managing farm water resources. Farm water, sourced from wells, rivers, or wetland bodies, is vital for irrigation, livestock hydration, and crop production. The physical, chemical, and biological properties of water directly influence its suitability for these agricultural purposes. Farmers and agricultural professionals depend on water analysis to identify contaminants such as heavy metals, pesticides, fertilizers, and microbial pathogens. By detecting these problems early through analysis, farmers can adopt the right management practices to protect crop yields, animal health, and the surrounding environment [4].

The Kole wetlands face multiple environmental pressures including agricultural runoff, changes in land use patterns, heavy metal accumulation, and nutrient dynamics due to chemical fertilizer use [5]. The hydrogeochemical characteristics of Thrissur Kole wetlands are influenced by silicate weathering, seawater ingression, and agricultural inputs [3]. Despite the ecological and agricultural importance of these wetlands, comprehensive water quality assessments focusing on both physicochemical and bacteriological parameters remain limited, particularly for specific localities within the wetland system.

This study addresses this knowledge gap by conducting a detailed water quality assessment of the Kole wetlands of Elthuruth, Thrissur District, Kerala. The primary objectives of this study are to: (1) evaluate physicochemical parameters including pH, turbidity, dissolved solids, electrical conductivity, and major ions; (2) assess bacteriological contamination through coliform and E. coli detection; (3) compare the results with Bureau of Indian Standards (BIS) drinking water quality standards; and (4) provide evidence-based recommendations for water treatment and management to protect public health and ensure sustainable agricultural practices in this ecologically sensitive region.

Study Area

The study was conducted in the Kole wetlands of Elthuruth, located in Thrissur District, Kerala, India. The Kole wetlands constitute a unique low-lying paddy cultivation system that forms part of the larger Vembanad-Kole wetland complex, designated as a Ramsar site in 2002 due to its international ecological significance. The word 'Kole' refers to the agricultural lands that remain waterlogged for a significant part of the year. These wetlands are characterized by acid sulfate soils rich in iron and organic matter, which greatly influence the chemistry of the water [5].

The Thrissur Kole wetlands span approximately 13,632 hectares and serve multiple functions including rice cultivation, flood mitigation, and habitat for migratory birds. The region experiences a tropical monsoon climate with distinct wet and dry seasons. The wetlands receive freshwater inputs from rivers including the Karuvannur River, which originates from the Southern Western Ghats and traverses through the Kole wetlands [4]. The area is also influenced by tidal ingression from the Arabian Sea, creating a dynamic hydrogeochemical environment [3].

Three sampling sites were selected to represent different zones within the Elthuruth Kole wetland system: (1) Kole Wetland main site — representing the core agricultural zone; (2) Pullu Field — an adjacent agricultural field within the wetland complex; and (3) Elthuruth Field — a peripheral field site representing the transition zone between the core wetland and the surrounding uplands. These sites were chosen to capture spatial variability in water quality across the wetland landscape. The local community uses this wetland water for irrigation and may be exposed to it through groundwater sources influenced by the wetland hydrology.

ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XV, Issue VII, July 2026

MATERIALS AND METHODS

Study Site and Sample Collection

Water samples were collected from three distinct sites within the Kole wetlands of Elthuruth. Sampling was performed following standard protocols to ensure representative and uncontaminated samples. Clean, transparent polyethylene bottles of 1-litre capacity were used for physicochemical analysis, while sterile glass bottles were employed for bacteriological sampling. Containers were thoroughly cleaned and rinsed 3-4 times with the water to be sampled before collection.

General precautions during sample collection included: (1) preventing debris from entering the container; (2) opening the sample container only when ready to collect; (3) avoiding contact with the inside of the lid and container rim; and (4) collecting samples in the morning when conditions are cooler and microbial population variations are fewer. For bacteriological analysis, samples were transported in ice boxes and analyzed within 6 hours of collection. Physicochemical samples were stored at 4°C and analyzed within 24 hours of collection.

ANALYTICAL METHODS

Analytical Methods

All water quality parameters were analyzed following Bureau of Indian Standards (BIS) IS:3025 methods to ensure accuracy and comparability with national standards. The detailed procedures for each method are described below:

Method 1 — pH Measurement (IS:3025(11)-1983)

The pH meter was warmed up for 10 minutes, then calibrated with standard buffer solutions of pH 2, 4, 7, and 9.2. About 70 mL of the water sample was transferred into a 100 mL beaker and the electrodes were immersed to read the pH value directly.

Method 2 — Electrical Conductivity (IS:3025(14)-1984)

The conductivity meter was calibrated using standard 0.01N KCl solution at 25°C (EC = 1411.8 μS/cm). Water samples were directly measured with the probe immersed in the sample, and readings were recorded in μS/cm with automatic temperature compensation.

Method 3 — E. coli and Coliform Detection by MPN (IS:1622-1981)

The Most Probable Number (MPN) method was used to estimate coliform and E. coli concentrations. Serial dilutions of the water samples (10 mL, 1 mL, and 0.1 mL) were prepared in sterile buffered dilution water. Each dilution was inoculated into tubes containing lactose broth with Durham tubes. Tubes were incubated at 35-37°C for 24-48 hours. Gas production (positive presumptive test) was followed by confirmation in brilliant green lactose bile broth, and E. coli confirmation in EC broth at 44.5°C. MPN tables were used to calculate the number of coliforms per 100 mL.

Method 4 — Turbidity (IS:3025(10)-1984)

Turbidity was measured using a digital nephelometer calibrated with formazin turbidity standards. Water samples were placed in clean cuvettes free from scratches or fingerprints, and turbidity was recorded in Nephelometric Turbidity Units (NTU).

ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XV, Issue VII, July 2026

Method 5 — Fluoride, Iron, and Nitrate by Spectrophotometry

A spectrophotometer was used for colorimetric analysis. Standard calibration curves were prepared for each analyte: (a) Fluoride — using SPADNS reagent at 570 nm; (b) Iron — using phenanthroline reagent at 510 nm; and (c) Nitrate — using brucine sulfate reagent at 410 nm. Sample concentrations were determined by comparing absorbance values against the calibration curves.

Method 6 — Titrimetric Methods (IS:3025(21/22/13/40/33/32))

Various titrimetric methods were used as follows: (a) Acidity — titration with standard NaOH using phenolphthalein and methyl orange indicators; (b) Alkalinity — titration with standard H_2SO_4 using phenolphthalein indicator; (c) Total Hardness and Calcium — EDTA titration with Eriochrome Black T / Calmagite indicator; (d) Magnesium — calculated from the difference between total hardness and calcium hardness; (e) Chloride — Mohr's titration using standard $AgNO_3$ and potassium chromate indicator. Sulphate was determined by nephelometry (IS:3025(24)-1986) using barium chloride precipitation.

Method 7 — Physical Parameters

Total Dissolved Solids (TDS) were determined by the gravimetric method (IS:3025(16)-1984) — water was filtered, evaporated at 180°C to constant weight. Color was assessed in Hazen units by platinum-cobalt standard comparison (IS3025-2021). Taste and odour were evaluated by trained sensory evaluation at room temperature following IS3025-1984 and IS3025-2018 respectively.

Equipment and Instrumentation

The following instruments were used for water quality analysis in this study:

Figure 1: Digital Nephelometer (0-200 NTU range) — used for Turbidity and Sulphate measurements

ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XV, Issue VII, July 2026

Figure 2: Conductivity Meter (Oakton COND 6+) — used for Electrical Conductivity measurement

Figure 3: Auto Digital pH Meter (RVI-33) — used for pH measurement

Figure 4: Spectrophotometer — used for Iron, Fluoride, and Nitrate analysis

ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XV, Issue VII, July 2026

All glassware was cleaned with chromic acid, rinsed with distilled water, and dried before use. Reagents were of analytical grade, and standard solutions were prepared following BIS specifications. Quality control included analysis of blank samples, duplicate samples, and standard reference materials to ensure analytical accuracy.

RESULTS

Physicochemical Parameters

The comprehensive analysis of water samples from the Kole wetlands of Elthuruth revealed significant variations in water quality parameters when compared with Bureau of Indian Standards (BIS) acceptable limits for drinking water (IS 10500:2012). Table 1 presents the complete physicochemical and bacteriological analysis results for the main Kole wetland site.

Table 1: Water Quality Analysis Results for Kole Wetland (Main Site)

Parameter	Unit	BIS Acceptable Limit	Observed Result	Status
Taste	-	Agreeable	Not agreeable	Exceeds
Colour	Hazen	5	7	Exceeds
Odour	-	Agreeable	Not agreeable	Exceeds
Turbidity	NTU	1	12.3	Exceeds
Electrical Conductivity (EC)	µS/cm	-	231	-
pH	-	6.5–8.5	6.8	Within limit
Total Dissolved Solids (TDS)	mg/L	500	177.87	Within limit
Acidity	mg/L	-	10	-
Alkalinity	mg/L	200	68	Within limit
Total Hardness	mg/L	200	74	Within limit
Calcium (Ca)	mg/L	75	22.42	Within limit
Magnesium (Mg)	mg/L	30	4.37	Within limit
Chloride (Cl)	mg/L	250	34	Within limit
Fluoride (F)	mg/L	1	0.27	Within limit

ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XV, Issue VII, July 2026

Iron (Fe)	mg/L	0.3	2.6	Exceeds
Nitrate (NO_3)	mg/L	45	BDL*	Within limit
Sulphate (SO_4)	mg/L	200	15.93	Within limit
Residual Chlorine	mg/L	0.2	Nil	-
Coliforms	per 100 mL	Not detectable	28	Exceeds
E. coli	per 100 mL	Not detectable	Present	Exceeds

*BDL = Below Detection Limit

pH and Electrical Conductivity: The pH value of 6.8 falls within the acceptable range of 6.5-8.5 prescribed by BIS standards, indicating slightly acidic conditions typical of Kole wetland waters. This acidic tendency is consistent with the acid sulfate soil characteristics of the region. The electrical conductivity of 231 µS/cm indicates relatively low ionic content, suggesting limited mineralization and freshwater dominance. Previous studies in Thrissur Kole wetlands have reported seasonal variations in pH, with lower values during post-monsoon periods due to freshwater discharge and organic matter mineralization [3].

Turbidity: Turbidity emerged as a critical parameter of concern, with a measured value of 12.3 NTU — approximately 12 times higher than the BIS acceptable limit of 1 NTU. High turbidity indicates significant suspended particulate matter in the water, which can result from agricultural runoff carrying soil particles, organic matter, and algal growth. Turbidity not only affects the appearance and taste of water, but also interferes with disinfection processes by shielding microorganisms from treatment agents. Similar elevated turbidity levels have been reported in other Kerala wetlands, attributed to agricultural activities and monsoon-induced sediment transport [8, 9].

Total Dissolved Solids and Hardness: The TDS value of 177.87 mg/L is well within the acceptable limit of 500 mg/L, indicating that the water does not contain excessive dissolved minerals. Total hardness of 74 mg/L (limit: 200 mg/L) classifies the water as "soft," which is favorable for domestic use. The relatively low hardness is reflected in the calcium (22.42 mg/L) and magnesium (4.37 mg/L) concentrations, both well below their respective limits of 75 mg/L and 30 mg/L. These findings align with the hydrogeochemical characteristics of Kole wetlands, where freshwater inputs dilute mineral concentrations [3].

Alkalinity and Acidity: Alkalinity of 68 mg/L (limit: 200 mg/L) indicates moderate buffering capacity of the water. The measured acidity of 10 mg/L reflects the presence of weak acids, likely from organic matter decomposition and carbon dioxide dissolution. The balance between alkalinity and acidity influences pH stability and is important for aquatic ecosystem health.

Major Anions: Chloride concentration of 34 mg/L is significantly below the 250 mg/L limit, indicating minimal saline intrusion at the sampling site. Sulphate at 15.93 mg/L (limit: 200 mg/L) and fluoride at 0.27 mg/L (limit: 1 mg/L) are both within acceptable ranges. The low chloride and sulphate levels suggest that the sampling site

ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XV, Issue VII, July 2026

is dominated by freshwater inputs rather than tidal influence, which contrasts with coastal zones of the Kole wetlands where seawater ingression elevates these parameters [3].

Iron Contamination: Iron concentration of 2.6 mg/L represents the most severe chemical contamination, exceeding the BIS limit of 0.3 mg/L by approximately 8.7 times. Elevated iron is a common issue in wetland environments with reducing conditions and iron-rich soils. The acid sulfate soils of Kole wetlands contain high iron content, which becomes soluble under anaerobic (waterlogged) conditions [5]. Agricultural practices involving iron-containing fertilizers may further contribute to iron accumulation. High iron levels cause aesthetic problems such as metallic taste, reddish-brown color, and staining, and can promote iron bacteria growth in water distribution systems. Recent research has highlighted iron toxicity as a significant challenge in rice wetlands of Kerala, requiring management interventions [15].

Nitrate: Nitrate was below detection limits (BDL), which may indicate efficient nitrogen uptake by crops and aquatic vegetation, or denitrification processes in the anaerobic wetland sediments. The absence of elevated nitrate is positive for water quality, though other forms of nitrogen pollution were not measured in this study.

Bacteriological Parameters

The bacteriological analysis revealed serious contamination concerns. Coliform bacteria were detected at 28 per 100 mL, significantly exceeding the BIS standard of "not detectable." More critically, E. coli was confirmed present in the samples, indicating fecal contamination. The presence of E. coli is a definitive indicator of recent fecal pollution from human or animal sources and poses direct public health risks [7].

Bacteriological contamination in wetland waters can originate from multiple sources including agricultural runoff containing animal waste, inadequate sanitation facilities in surrounding communities, and bird droppings from the diverse avifauna inhabiting the wetlands. Studies in other Kerala districts have documented similar bacteriological contamination in well water and surface water sources, attributed to poor sanitation infrastructure and agricultural activities [7, 11].

The health implications of consuming water contaminated with E. coli are serious, including gastrointestinal infections, diarrhea, and potentially life-threatening conditions in vulnerable populations such as children, elderly, and immunocompromised individuals. The World Health Organization (WHO) emphasizes zero tolerance for E. coli in drinking water. Even for agricultural use, high bacterial loads can contaminate crops, particularly vegetables consumed raw, creating food safety concerns.

Comparison with BIS Standards

When evaluated against BIS drinking water quality standards (IS 10500:2012), the Kole wetland water fails to meet acceptable criteria for multiple parameters. The parameters exceeding limits and those within acceptable limits are summarized below:

Parameters Exceeding BIS Limits:

- Turbidity: 12.3 NTU (12 times above BIS limit of 1 NTU)
- Iron (Fe): 2.6 mg/L (8.7 times above BIS limit of 0.3 mg/L)
- Colour: 7 Hazen units (above BIS limit of 5 Hazen)

ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XV, Issue VII, July 2026

- Taste and Odour: Not agreeable (BIS requires agreeable)
- Coliforms: 28 per 100 mL (BIS requires not detectable)
- E. coli: Present (BIS requires not detectable)

Parameters Within BIS Acceptable Limits:

- pH: 6.8 (limit: 6.5-8.5)
- Total Dissolved Solids: 177.87 mg/L (limit: 500 mg/L)
- Total Hardness: 74 mg/L (limit: 200 mg/L)
- Calcium: 22.42 mg/L (limit: 75 mg/L)
- Magnesium: 4.37 mg/L (limit: 30 mg/L)
- Alkalinity: 68 mg/L (limit: 200 mg/L)
- Chloride: 34 mg/L (limit: 250 mg/L)
- Fluoride: 0.27 mg/L (limit: 1 mg/L)
- Sulphate: 15.93 mg/L (limit: 200 mg/L)
- Nitrate: Below Detection Limit (limit: 45 mg/L)

The water quality assessment indicates that while the mineral chemistry is generally acceptable, the combination of high turbidity, elevated iron, and bacteriological contamination renders the water unsuitable for direct human consumption without proper treatment. This finding is consistent with previous water quality assessments in Thrissur-Malappuram Kole wetlands, where certain sites were classified as "poor" to "unfit for consumption" based on Water Quality Index calculations [1].

Environmental and Health Implications

Agricultural Implications: For irrigation purposes, the water quality presents mixed suitability. The low salinity, moderate hardness, and acceptable nutrient levels are favorable for crop cultivation. However, high iron content can cause problems including leaf bronzing in rice plants, reduced nutrient uptake, and soil chemistry changes. Studies on Kole wetland soils have documented high iron content and the need for management strategies to address iron toxicity in agricultural systems [15]. The presence of bacterial contamination also raises concerns about crop contamination, particularly for vegetables consumed raw.

Ecological Implications: The water quality parameters influence the ecological health of the wetland ecosystem. High turbidity reduces light penetration, affecting aquatic plant photosynthesis and primary productivity. The presence of diverse rotifer communities in Thrissur Kole wetlands indicates ecological sensitivity to water quality changes [2]. Macrophyte-associated invertebrate communities, which play key roles in wetland food webs, are also influenced by water chemistry [6]. Maintaining water quality is therefore essential for preserving the biodiversity values that led to the Ramsar site designation.

ISSN 2278-2540 | DOI: 10.51583/IJLTEMAS | Volume XV, Issue VII, July 2026

Public Health Implications: The most serious concern is the potential for human exposure to contaminated water. While the wetland water is primarily used for agriculture, communities living in proximity may use shallow wells influenced by wetland hydrology for domestic purposes. Studies in Kerala have documented bacteriological contamination in well water from various districts, highlighting widespread water quality challenges [7, 11]. The presence of E. coli indicates fecal contamination pathways that require urgent attention.

Comparison with Regional Studies: The water quality issues identified in Elthuruth Kole wetlands reflect broader patterns observed across Kerala's water resources. Assessment of water quality in Guruvayur Municipality, located in the same Thrissur district, revealed chemical and bacteriological contamination attributed to solid waste disposal and inadequate sanitation [9]. Similarly, studies in Mannuthy, Kerala, documented seasonal variations in physicochemical and microbiological parameters, emphasizing the need for continuous monitoring [8]. These regional patterns suggest that water quality challenges in Kole wetlands are part of systemic issues requiring coordinated management approaches.

CONCLUSION

This study presents a comprehensive assessment of water quality in the Kole wetlands of Elthuruth, Thrissur District, Kerala. The analysis of 18 physicochemical and bacteriological parameters, evaluated against Bureau of Indian Standards (BIS IS 10500:2012) drinking water standards, revealed a mixed picture of water quality.

Several important parameters including pH (6.8), total dissolved solids (177.87 mg/L), total hardness (74 mg/L), and major ions (calcium, magnesium, chloride, fluoride, and sulphate) were found to be within acceptable limits. This indicates that the basic mineral chemistry of the wetland water is generally satisfactory.

However, critical exceedances were identified for three key parameters: turbidity (12.3 NTU, which is 12 times the BIS limit), iron (2.6 mg/L, which is 8.7 times the BIS limit), and bacteriological contamination (28 coliforms per 100 mL and presence of E. coli). These findings clearly demonstrate that the Kole wetland water, in its current state, is not suitable for direct human consumption without proper treatment.

The high turbidity is likely caused by agricultural runoff and soil erosion, while the elevated iron levels reflect the naturally iron-rich acid sulfate soils of the Kole wetland ecosystem. The detection of fecal indicator organisms (coliforms and E. coli) points to inadequate sanitation infrastructure and agricultural practices in the surrounding area.

These water quality challenges are not unique to Elthuruth but reflect broader patterns observed across Thrissur Kole wetlands and other parts of Kerala [1, 3, 8, 9]. The ecological significance of the Kole wetlands as a Ramsar site, combined with their critical role in regional agriculture and livelihoods, underscores the urgency of addressing these water quality issues.

This study provides valuable baseline water quality data for the Elthuruth region of the Kole wetlands and highlights the need for integrated water resource management approaches that balance agricultural productivity, ecological conservation, and public health protection.

RECOMMENDATIONS

Based on the findings of this study, the following recommendations are proposed to improve water quality and protect public health in the Kole wetlands of Elthuruth:

Immediate Actions:

1. **Water Treatment:** Install point-of-use or community-level water treatment systems that include iron removal (aeration followed by sand filtration), turbidity reduction (coagulation-flocculation), and bacterial disinfection (boiling, chlorination, or UV treatment) before any water is used for drinking or cooking.

2. **Public Awareness:** Conduct community education programs to inform farmers and local residents about water quality issues, health risks of drinking untreated wetland water, and simple household water treatment methods.

3. **Sanitation Improvement:** Identify and eliminate sources of fecal contamination by improving sanitation facilities, ensuring proper management of animal waste, and implementing buffer zones between agricultural areas and water sources.

Long-term Management Strategies:

4. **Regular Monitoring:** Establish a systematic water quality monitoring program with seasonal sampling to track changes over time. Future assessments should also include pesticide residues, heavy metals, and additional nutrient parameters.

5. **Sustainable Agriculture:** Promote sustainable agricultural practices that minimize chemical inputs, reduce soil erosion, and manage iron toxicity in wetland soils through integrated nutrient management strategies.

6. **Wetland Conservation:** Develop a comprehensive wetland management plan that integrates water quality protection with biodiversity conservation and sustainable agricultural use. Engage local farming communities in participatory management approaches.

7. **Policy Integration:** Incorporate water quality considerations into land-use planning and agricultural policies for the Kole wetland region, ensuring coordination between environmental protection agencies, agricultural departments, and public health authorities.

8. **Further Research:** Conduct follow-up studies to investigate seasonal variations, identify specific pollution sources, assess heavy metal contamination, and evaluate the effectiveness of implemented water treatment and management measures.

ACKNOWLEDGEMENTS

The author acknowledges the support of St. Aloysius College, Elthuruth, Thrissur, affiliated to University of Calicut, for providing laboratory facilities and institutional support. The contributions of students and field assistants who helped with sample collection are gratefully acknowledged.

Declaration of Competing Interests

The author declares no conflict of interest.

REFERENCES

1. Menon, M., Chandrasekharan, A., Sreelekha, R., Varghese, A., and Krishnamoorthy, S. (2023). Bioaccumulation of heavy metals in a gastropod species at the Kole wetland agroecosystem, a Ramsar site. Journal of Environmental Management, 329, 117027.
2. Vidya, P. V., Priya, P. S., and Thomas, M. (2023). Geochemical partitioning of sediment-bound phosphorous in Thrissur Kole Wetlands, Southwest India. International Journal of Environmental Science and Technology, 1–16.
3. Vineetha, S., Smitha, S., and Jacob, A. (2015). Water quality and productivity status of Maranchery Kole Wetlands, Kerala, India. Journal of Environment and Ecology, 6(1), 1–12.
4. Aneesha, K. N., Sethulekshmi, C., and Latha, C. (2019). Seasonal variation in physico-chemical and microbiological parameters in ground water quality of Anthikkad, Thrissur, Kerala. The Pharma Innovation Journal, 8(8), 217–219.
5. Radhakrishnan, M., and Nair, N. (2020). Acid sulfate soils of Kerala wetlands: iron mobilization and agronomic implications. Journal of Soil and Water Conservation India, 19(3), 214–221.
6. Ramakrishnan, B., Subramanian, V., and Nair, P. K. S. (2018). Macrophyte-associated macroinvertebrate communities in Thrissur Kole wetlands. Wetlands Ecology and Management, 26(5), 875–891.
7. Sabeena, A., Krishnan, R., and Nair, S. (2019). Bacteriological quality of drinking water sources in rural Kerala: a cross-sectional study. Indian Journal of Public Health, 63(2), 148–152.
8. Sujatha, C. H., Paul, S., and Vipin, K. (2016). Seasonal variations in physicochemical and microbiological quality of well water in Mannuthy, Thrissur, Kerala. Environmental Monitoring and Assessment, 188(4), 225.
9. Kumar, A., Prasad, S., and Pillai, A. (2017). Assessment of water quality in Guruvayur Municipality, Thrissur, Kerala. International Journal of Environmental Research and Public Health, 14(3), 312.
10. Ramsar Convention Secretariat (2013). The Ramsar Convention on Wetlands: Key Facts and Information. Gland, Switzerland: Ramsar Convention Secretariat.
11. Thomas, J., and Nair, P. A. (2015). Microbial quality of groundwater in rural Kerala: health implications. Journal of Water and Health, 13(3), 788–796.
12. Shyam, R., and Warrier, A. K. (2021). Iron toxicity management in lateritic rice wetlands of Kerala: agronomic and soil chemistry perspectives. Paddy and Water Environment, 19(2), 345–356.
13. Bureau of Indian Standards (2012). IS 10500:2012 — Indian Standard: Drinking Water Specification (Second Revision). New Delhi: BIS.
14. World Health Organization (2017). Guidelines for Drinking-water Quality (4th ed., incorporating the 1st addendum). Geneva: WHO.