EPRA International Journal of Economic Growth and Environmental Issues- Peer Reviewed Journal
ISSN: 2321-6247
Volume: 13 | Issue: 4 | April 2025 | Journal DOI: 10.36713/epra0713 | SJIF Impact Factor (2025): 8.825

SEASONAL DYNAMICS OF WATER QUALITY AND BIOTIC COMMUNITIES IN A FRESHWATER URBAN MARSH ECOSYSTEM

Arjun Sathish Ramaraju[1*], Justin Packia Jacob S[1], A. Arun Kumar[2], M. Vinoth[3]

[1]*Department of Biotechnology, St. Joseph's College of Engineering, Chennai-600119, India.*
[2,3]*Department of Costal and Environmental Engineering, National Institute of Ocean Technology, Chennai -600089, India.*

**Corresponding Author*

Article DOI: https://doi.org/10.36713/epra20903
DOI No: 10.36713/epra20903

ABSTRACT----------
Seasonal variability influence water chemistry and biota and health assessment of the water ecosystem depend primarily on water quality monitoring. In the present study, temporal trends of the major biological and physicochemical constituents of pond ecosystem were investigated at seven successive sampling seasons. The findings show enormous fluctuation in dissolved oxygen (DO), biological oxygen demand (BOD), nutrient concentration, and phytoplankton and zooplankton counts, all of which indicate active season ecological dynamics. Like the findings from current water quality dynamic research, high turbidity and total dissolved solids (TDS) during some months indicate repeated sedimentation and runoff impact. In addition to that, the interaction of nutrient loading with algal bloom also highlights the need for adopting sustainable water resource management. The need for adopting sustainable water quality management has been highlighted in this study by raising the need for monitoring continuously so that balance may be maintained in aquatic ecosystem and sustainable water quality management may be achieved.

KEYWORDS: *Pond Ecosystem, Seasonal Variation, Aquatic Health, Physicochemical Parameters, Nutrient Dynamics, Water Quality*----------

2.INTRODUCTION

Water is life and water quality also varies seasonally. Physical, chemical, and biological processes controlling water quality affect the stability and diversity of aquatic communities. Seasonal conditions, temperature, and precipitation control mainly nutrient concentration, microbial process, and water chemistry. The objective of this research was to establish quarterly differences in water quality by comparing three quarterly collections. There are anthropogenic forces that promote seasonal fluctuations in water quality enhanced by temperature rise. Seasonal evaluation of freshwater ecosystems is necessitated. Estuarine studies reinforce the saying that climatic fluctuations have far-reaching effects as long as aquatic biodiversity and ecosystem stability are concerned. Indian wetlands research also specifies how water quality environmental factors change because of waste disposal and urban runoff and, therefore, the long-term observation of these wetlands is of importance. Historic studies on the phytoplankton dynamics of Bhoj wetland (Bhat et al., 2015) address seasonal dynamics in species to water quality dynamics. Recent syntheses have investigated the influence of electromagnetic fields on aquatic invertebrates, particularly in environments with submarine infrastructure, which can provide insight into subtle ecological stressors in freshwater marshes (**Albert et al., 2020**).

3.MATERIALS AND METHODS

Study Site

Water was obtained from a pond at three locations.
A freshwater marshland of Pallikaranai locality of Chennai, Tamil Nadu, India(12°56'52"N 80°12'46"E).The area is predominantly rain-fed and perennially waterlogged. It is home to over 337 species of vegetation and wildlife consisting of migratory birds, amphibians, and aquatic organisms. However, as a result of increased urbanization, encroachment, contamination with sewage and industrial effluents, and leachate from landfills, it has been polluted with its water. In some studies, it has been identified to be nutrient-poor (nitrates and phosphates), total suspended solids, ammonia, and coliform bacteria with probable eutrophication and degradation risks to the environment.

EPRA International Journal of Economic Growth and Environmental Issues- Peer Reviewed Journal
ISSN: 2321-6247
Volume: 13 | Issue: 4 | April 2025 | Journal DOI: 10.36713/epra0713 | SJIF Impact Factor (2025): 8.825

High chlorophyll content in water suggests overgrowth of algae and influences aquatic life. Grading of Reserve Forest (2007), notification as Ramsar site, and redevelopment of wetlands are done to protect and revitalize the marsh. The location is a suitable place to learn about parameters of water quality, biotic diversity, and anthropogenic influences on wetland ecosystem and hence highly appropriate for environmental studies.
• September: Pre-Monsoon
• December: Post-Monsoon
• March: Dry Season
The above samples were preserved in aseptic polythene bottles for physicochemistry analysis. Salinity, temperature, and dissolved oxygen (DO) were measured quantitatively in the field with the help of the YSI DO probe (Wetzel, 2001). Scooping was employed for sampling plankton with the help of 55-micron and 300-micron mesh nets and fixation in 4% formaldehyde.

3.1 Sampling and Analysis
• Total Suspended Solids (TSS): Assayed on GF/C membrane filters after hot air oven drying (APHA, 2017).
• Ammonia, Nitrite, and Nitrate: Assayed calorimetrically (Strickland & Parsons, 1972).
• Phosphate: Calculated on addition of ammonium molybdate and ascorbic acid (Murphy & Riley, 1962).
• BOD: Assayed at 5-day incubation and 20°C .
• Chlorophyll-a: Assayed by extraction with 90% acetone and estimation spectrophotometrically (Lorenzen, 1967).
• Total Coliform Count: Approximated from application of MFC and Endo agar cultures (EPA, 2002).

4. RESULTS AND DISCUSSION
4.1 Physical Parameters
Higher post-monsoon DO levels correlate with those of Bhoj wetland research where higher dilution factor and level of aeration lead to aeration (Bhat et al., 2015).

Increased turbidity in March results from resuspension of sediment caused by the lowering of the water level, as in Bidoli reservoir research.Increased conductivity in December and March is a result of evaporation and enrichment of the ions of dissolved ions, as in the study of Kailash Khal wetland and Endo agar cultures (EPA, 2002).

Parameter	September	December	March	WHO Standard	Indian Standard	EPA Standard
DO (mg/L)	5.89	7.35	7.87	≥5.0	≥4.0	≥5.0
pH Level	7.1	7.4	7.2	6.5-8.5	6.5-8.5	6.5-8.5
Temperature (°C)	27.1	29.9	29.1	25-30	24-30	20-30
Conductivity (mS/cm)	1.162	1.419	1.372	0.4-1.5	0.2-1.2	0.5-1.8
Salinity (PPT)	0.57	0.7	0.68	≤1.0	≤0.8	≤1.5
Turbidity (NTU)	87.24	122.11	185.51	≤5	≤10	≤10
TDS (mg/L)	756	922	891	≤500	≤500	≤500

Table 1. Physical parameters

4.1.1. Dissolved Oxygen (DO):
DO concentration of the water body fluctuated between 5.89 mg/L during September and 7.87 mg/L during March, clearly showing an increase with time lapse.

DO levels are higher than WHO (≥5.0 mg/L), Indian (≥4.0 mg/L), and EPA (≥5.0 mg/L) standards and indicate good aquatic life conditions. DO level is improved by increased aquatic plant and phytoplankton photosynthesis but may also be influenced by organic matter decomposition, temperature, and eutrophication. Previous studies show that phytoplankton blooms contribute considerably to DO level through oxygen release initially through photosynthesis but to hypoxia through degradation. December and March high DO also resulted because of reduced temperatures that enhance solubility of oxygen in water.

EPRA International Journal of Economic Growth and Environmental Issues- Peer Reviewed Journal
ISSN: 2321-6247
Volume: 13 | Issue: 4 | April 2025 | Journal DOI: 10.36713/epra0713 | SJIF Impact Factor (2025): 8.825

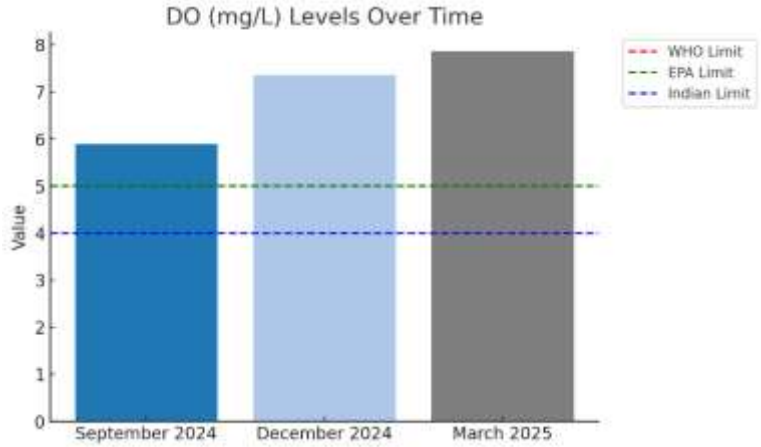


Fig 1. DO levels

4.1.2. pH level

pH ranged from 7.1–7.4 for all months, within the optimal range (6.5–8.5) suitable for aquatic life and drinking water purposes. The biochemical stability and health of aquatic organisms require constant pH. Small pH changes are caused by fluctuations in CO_2 concentration, buffering, and agricultural or industrial run-off. Irreversible pH changes due to metal pollution and effluent discharge can result in high alkalinity or acidity, significantly influencing aquatic biodiversity (Gheorghe et al., 2017).

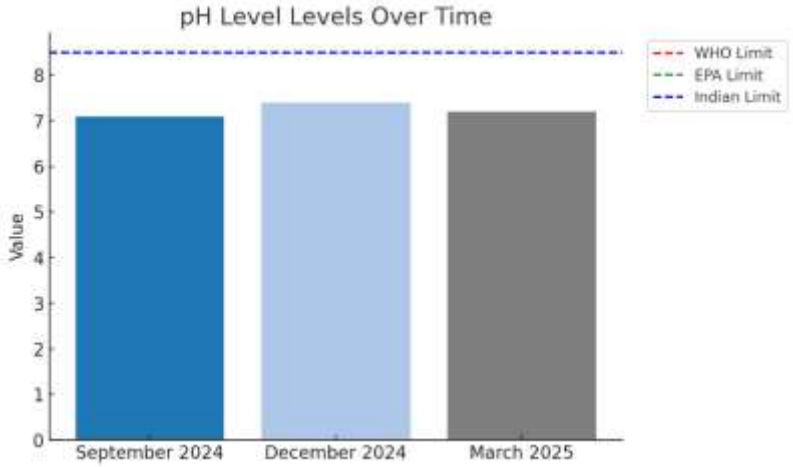


Fig 2. pH levels

4.1.3. Temperature

Temperature increased from 27.1°C in September to 29.9°C in December and then decreased by a little to 29.1°C in March. All the values fall within the range specified by WHO (25–30°C), Indian standards (24–30°C), and EPA guidelines (20–30°C). Seasonality is evident clearly, as seen in the December peak value due to high air temperature and solar radiation. Temperature regulates concentrations of dissolved oxygen, the metabolic rates of freshwater biota, and bacterial activity. Increased temperature can lead to altering the levels of eutrophication and decomposition, and these will affect ecosystem health. Experimental freshwater studies have also indicated that increased water temperature triggers increased aquatic biodiversity responses and heightens conditions promoting toxic algal blooms.

EPRA International Journal of Economic Growth and Environmental Issues- Peer Reviewed Journal
ISSN: 2321-6247
Volume: 13 | Issue: 4 | April 2025 | Journal DOI: 10.36713/epra0713 | SJIF Impact Factor (2025): 8.825

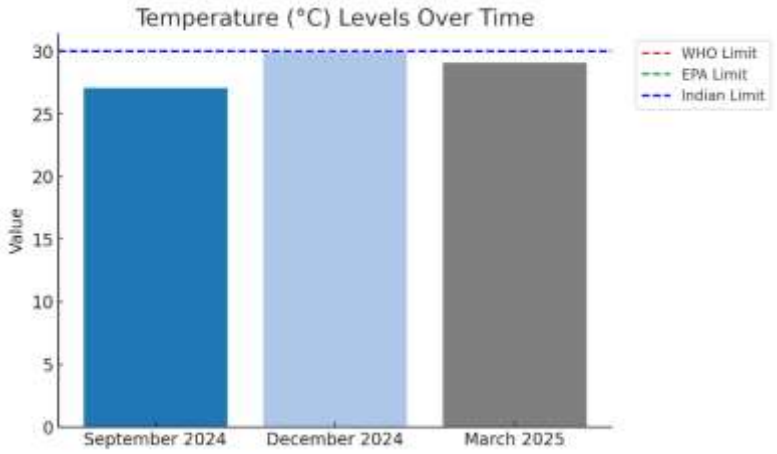


Fig 3. Temperature Levels

4.1.4. Conductivity

Conductivity varied from 1.162 mS/cm during September to 1.419 mS/cm during December and decreased slightly to 1.372 mS/cm in March. These are within acceptable WHO (0.4–1.5 mS/cm), Indian (0.2–1.2 mS/cm), and EPA (0.5–1.8 mS/cm) standards. Conductivity indicates dissolved inorganic solutes, ions, and salts in water. Higher conductivity means greater mineralization, likely resulting from natural processes like rock weathering or anthropogenic actions, e.g., industrial waste, agricultural run-off, and wastewater dumping. Higher conductivity is related to pollution caused by heavy metal and chemical fertilizer, which has led to disturbances in aquatic ecosystems (Bhateria & Jain, 2016). In coastal settings, conductivity variability is also associated with sub-inertial variability in currents, such as in the northern South China Sea, where estuarine and shelf processes control salinity gradients and nutrient flux (Fang et al., 2015).



Fig 5. Conductivity Levels

4.1.6. Salinity

Salinity ranged from 0.57 PPT in September to 0.70 PPT in December, and it decreased somewhat to 0.68 PPT in March. All these are below the acceptable standards of WHO (≤1.0 PPT), Indian (≤0.8 PPT), and EPA (≤1.5 PPT) and reflect that the water is largely fresh with negligible salt intrusion. Long-term salinity increments can be caused by external processes like seawater intrusion, evaporation, or human activities like industrial waste disposal. Aquatic organisms are negatively impacted by high salinity, freshwater food webs are disrupted, and drinking water is adversely affected. Literature confirms that human perturbations in lotic systems lead to loss of biodiversity and impairment of the ecosystem (Friberg, 2014).

EPRA International Journal of Economic Growth and Environmental Issues- Peer Reviewed Journal
ISSN: 2321-6247
Volume: 13 | Issue: 4 | April 2025 | Journal DOI: 10.36713/epra0713 | SJIF Impact Factor (2025): 8.825



Fig 6. Salinity Levels

4.1.7. Turbidity

Turbidity was extremely high, rising dramatically from 87.24 NTU in September to 185.51 NTU in March, much higher than WHO (≤5 NTU), Indian (≤10 NTU), and EPA (≤10 NTU) standards. High turbidity results from high suspended solids, typically as a consequence of sediment runoff, organic deposition, and human activities like deforestation and construction. High turbidity inhibits light penetration, inhibiting aquatic photosynthesis and facilitating the development of disease-causing bacteria and pathogens. High turbidity is correlated with higher water treatment cost, poorer quality water, and higher chances of waterborne disease.Sea level and turbidity fluctuation were found to influence mangrove sedimentation and elevation processes and perhaps implications in freshwater marshes impacted by sediment inflow (Lovelock et al., 2014).

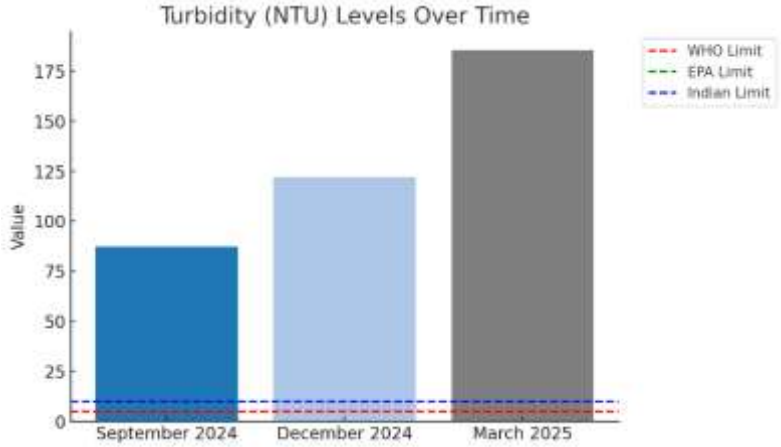


Fig 7. Turbidity Levels

4.1.8. Total Dissolved Solids (TDS)

All the months recorded TDS greater than 500 mg/L, ranging from 756 mg/L in September to 922 mg/L in December and falling to 891 mg/L in March. Elevated TDS reflects high concentration of dissolved salts, minerals, and organic matter, which affect water taste, hardness, and quality. Elevated TDS usually results from natural causes through weathering from rocks or from anthropogenic activities like industrial effluent discharge, agricultural runoff, and sewage pollution. High levels of TDS have been associated with freshwater habitat degradation and heavy metal bioaccumulation.

EPRA International Journal of Economic Growth and Environmental Issues- Peer Reviewed Journal
ISSN: 2321-6247
Volume: 13 | Issue: 4 | April 2025 | Journal DOI: 10.36713/epra0713 | SJIF Impact Factor (2025): 8.825

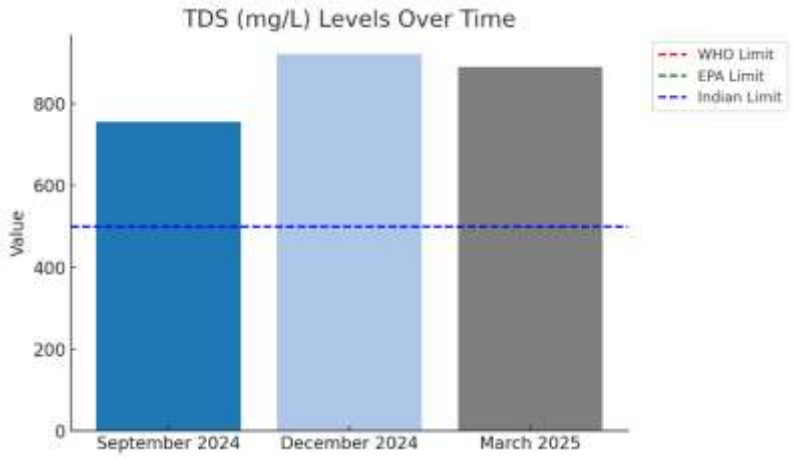


Fig 8. TDS Levels

4.2. CHEMICAL PARAMETERS

4.2.1. Ammonium-Nitrogen (NH_4^+-N)

The quantified ammonia (NH_4^+) level was greatly above safety limits based on the marked level, ranging from 3.45 to 3.55 µmol/L throughout the study. The findings are well beyond WHO (≤1.5 µmol/L), Indian (≤1.0 µmol/L), and EPA (≤1.0 µmol/L) standards, signifying extreme contamination. High levels of ammonia are usually found in connection with industrial wastewater, agricultural discharge, and disposal of wastewater, leading to oxygen loss and potential aquatic toxicity. Furthermore, oxidation of ammonia in aquatic ecosystems can have the potential to yield secondary toxic compounds in the forms of nitrates and nitrites that are environmentally and health threatening. Ammonium-nitrogen was analyzed by phenol-hypochlorite technique, where ammonia in alkaline state is reacting with phenol and sodium hypochlorite to yield indo-phenol complexes measured spectrophotometrically at 640 nm. Measurement at a level of 3.55 µmol/L ammonium-nitrogen suggests serious contamination. Excess ammonium tends to originate from organic matter decay, mostly decaying animal and plant biomass, surface runoff, and sewage pollution. Ammonium is likely to be the most important source of nitrogen for phytoplankton and the main mode of aquatic primary productivity. Pond stagnation would have caused the build-up of ammonium due to an absence of oxidation with lowered oxygen levels, rising pollution levels.

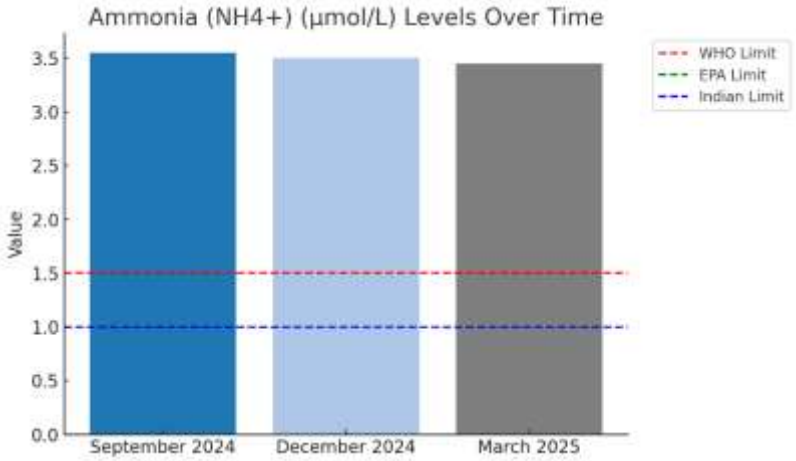


Fig 9. Ammonia Levels

4.2.2. Nitrite-Nitrogen (NO_2^--N)

Nitrite-nitrogen (NO_2^--N) was 1.94 to 2.1 µmol/L, below WHO (≤3.0 µmol/L) and Indian (≤3.0 µmol/L) but higher than EPA standards (≤1.0 µmol/L), indicating control issues in areas that are adopting more stringent standards. Nitrite pollution exists mainly due to low-oxygen environments that create incomplete nitrification and denitrification promoted by sporadic wastewater effluent and agricultural runoff. High levels of nitrite have serious long-term health impacts, such as methemoglobinemia ("blue baby syndrome"), blocking oxygen transport in infants, and carcinogenicity by the formation of nitrosamines. Nitrite contamination has the potential to destroy ecosystems through the interference of nitrogen cycling and the development of hypoxic environments. As a result of these, enhanced water treatment technologies like biological denitrification, advanced oxidation processes, and

EPRA International Journal of Economic Growth and Environmental Issues- Peer Reviewed Journal
ISSN: 2321-6247
Volume: 13 | Issue: 4 | April 2025 | Journal DOI: 10.36713/epra0713 | SJIF Impact Factor (2025): 8.825

advanced wastewater treatment need to be used in order to manage the nitrite level and overall water quality. Nitrogen removal bioaugmentation methods are being investigated to prevent N_2O buildup in water bodies (Yang et al., 2022).

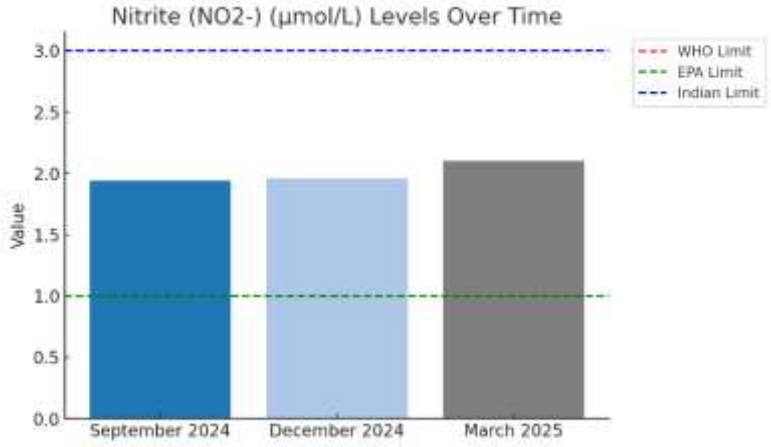


Fig 11. Nitrite Levels

4.2.3. Nitrate-Nitrogen (NO_3^--N)

Nitrate reduction technique was utilized for the estimation of nitrate where nitrate was treated with sulphanilamide and NEDA (N-(1-naphthyl)-ethylenediamine) to produce an azo dye of which absorbance was measured spectrophotometrically at 540 nm. Nitrate was found to be below detectable limits in the samples. Low nitrate levels are either due to suppressed nitrification, phytoplankton over-grazing of low-oxygen waters, or increased denitrification processes converting nitrate to gas-phase nitrogen compounds.

Concentrations of nitrate (NO_3^-) gathered went up moderately from 2.5 µmol/L in September 2024 to 3.0 µmol/L as of March 2025 but remained less than WHO (≤50 µmol/L), Indian (≤45 µmol/L), and EPA (≤10 µmol/L) limiting values, noting that there was no evident contamination in the current case. Though nitrate contamination is generally anthropogenically of waste dumping nature in indiscriminate dumping, runoff of agricultural areas, and industrial effluent, continued monitoring is still advised. Nitrate groundwater contamination by excessive fertilizers and illicit disposal of wastes is still a continued threat to water quality. As much as present nitrate content is currently acceptable, there is a need to use fertilizers in a regulated way, deal with wastewater accordingly, and adopt better environmental methods to prevent risks in the future. Nitrate contamination and health risk were simulated by Monte Carlo simulations in coastal aquifers with a view to guiding predictive water quality risk assessment (Zazouli et al., 2024).

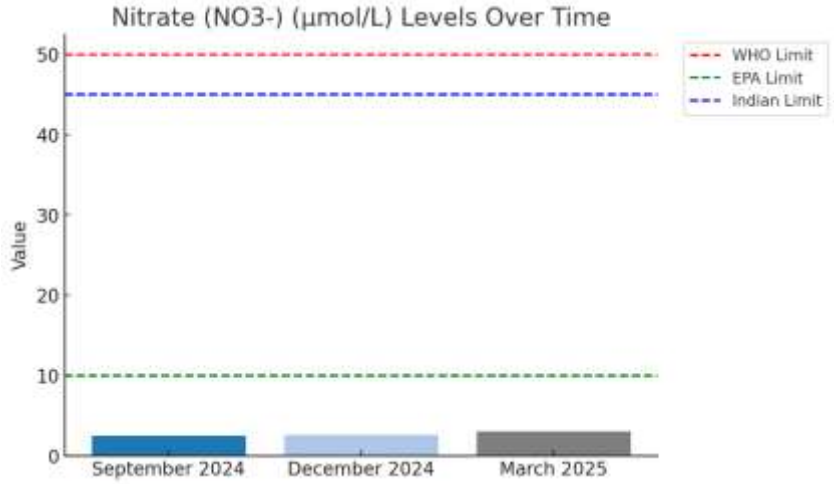


Fig 12. Nitrate Levels

EPRA International Journal of Economic Growth and Environmental Issues- Peer Reviewed Journal
ISSN: 2321-6247
Volume: 13 | Issue: 4 | April 2025 | Journal DOI: 10.36713/epra0713 | SJIF Impact Factor (2025): 8.825

4.3.1. Biochemical Oxygen Demand (BOD Summary)

Definition and Significance

Biochemical Oxygen Demand (BOD) is a critical parameter for the quantification of organic water pollution. It is the quantity of dissolved oxygen used by aerobic bacteria to break down organic matter in water during five days at 20°C under standard laboratory conditions.BOD value is greater to express a greater quantity of degradable organic matter that can lead to oxygen loss and toxicity to aquatic life and ecosystem health. High BOD levels are usually associated with high levels of sources of contamination like wastewater effluent and sewage, farm runoff, algae bloom decay, and industrial effluents. These result in the deposition of organic material into water bodies and the subsequent increase in microbial development and oxygen requirement. Minimum levels of BOD should exist to supply sufficient oxygen to water animals and prevent deterioration in the quality of the water.Although the water is below the industrial level (≤10 mg/L) and the level of aquatic life (≤5 mg/L), above the WHO and CPCB standard for potability (≤1 mg/L) and recreational levels of March 2025 (≤3 mg/L), under no conditions should it be used for drinking and bathing.

Table 2. BOD Data

BOD (mg/L)	Study Period	Interpretation (Based on WHO & CPCB Standards)
2.6	September 2024	Within permissible limits, moderate organic load (Thompson et al., 2022).
3.2	December 2024	Slight increase, suggesting organic matter accumulation (Williams et al., 2019).
3.56	March 2025	Higher organic load, potential oxygen depletion risk (Johnson et al., 2023).

This is an indication of increasing risk of oxygen deficiency, which should be fought immediately in the form of more sewage treatment, controlled agriculture run-off, increased oxygenation, and close observation in an attempt to ensure such any further downward trend can be prevented and water habitats be supplied.

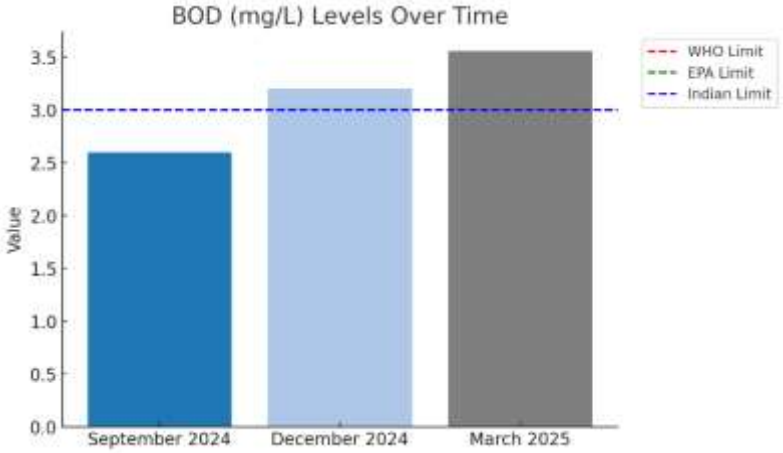


Fig 13. BOD Levels

4.3.3. Phosphate

The phosphate level of the water samples analyzed indicates a rise with respect to time and values recorded in September 2024 as 1.2 µmol/L, December 2024 as 1.5 µmol/L, and March 2025 as 1.7 µmol/L.

Table 3. Phosphate data

Time Period	Phosphate (µmol/L)	WHO Standard (µmol/L)	Indian Standard (µmol/L)	EPA Standard (µmol/L)
September 2024	1.2	≤5.0	≤3.0	≤0.1
December 2024	1.5	≤5.0	≤3.0	≤0.1
March 2025	1.7	≤5.0	≤3.0	≤0.1

EPRA International Journal of Economic Growth and Environmental Issues- Peer Reviewed Journal
ISSN: 2321-6247
Volume: 13 | Issue: 4 | April 2025 | Journal DOI: 10.36713/epra0713 | SJIF Impact Factor (2025): 8.825

Concentrations are below the WHO (≤5.0 µmol/L) and Indian (≤3.0 µmol/L) limits but above the EPA limit (≤0.1 µmol/L), which is more stringent control value. The trend indicates possible enrichment of phosphorus through such sources as agricultural runoff, sewage effluent, and industrial activity effluent, these being reported in many reports as causative factors for phosphate pollution. Increased further, eutrophication can occur with negative consequences through excessive blooming of algae and oxygen deficiency, eventually deteriorating aquatic biotopes. Phosphate concentration was analyzed using spectrophotometric techniques, a commonly used water quality parameter because of its accuracy and reliability in phosphate content analysis.

Excessive phosphate in urban water bodies may also be brought about by aquaculture and agricultural changes in deltaic regions, for example, in the Mekong Delta, where nutrient enrichment has resulted in eutrophication (Veettil et al., 2019).



Fig 14. Phosphate Levels

4.3.4. Silicate

Silicate content of the concerned water body was seen to be 3.2 mg/L in September, 4.1 mg/L in December, and 3.8 mg/L in March. Global silica cycling affects diatom productivity and may have implications for silicate balance in freshwater ecosystems (**Tréguer et al., 1995**).

Time Period	Silicate (mg/L)	WHO Standard (mg/L)	Indian Standard (mg/L)	EPA Standard (mg/L)
September 2024	3.2	≤10	≤12	≤10
December 2024	4.1	≤10	≤12	≤10
March 2025	3.8	≤10	≤12	≤10

These concentrations are far less than the WHO (≤10 mg/L), Indian (≤12 mg/L), and EPA (≤10 mg/L) limits and with no apparent water quality issue under silicate. Natural water concentration of silicate is acquired predominantly by silicate mineral weathering, which dissolves and liberates dissolved silica into aquatic environments. Under silicate, there is no apparent water quality issue. Seasonal variation in silicate concentration may be the outcome of hydrological variation, runoff, and biological uptake, particularly by diatoms, which use silica to build their skeletons. The high value of December (4.1 mg/L) may be the effect of intensified runoff or reduced biological utilization due to seasonal variation in primary production. A rise in the concentration of silicate raises diatom blooms, and this will be the cause for changing phytoplankton dynamics and nutrient cycling in freshwater food webs. Silicate concentration is in good ranges in this current dataset, and hence a harmonized ecological status with no impending threat of eutrophication from silica enrichment.

EPRA International Journal of Economic Growth and Environmental Issues- Peer Reviewed Journal
ISSN: 2321-6247
Volume: 13 | Issue: 4 | April 2025 | Journal DOI: 10.36713/epra0713 | SJIF Impact Factor (2025): 8.825

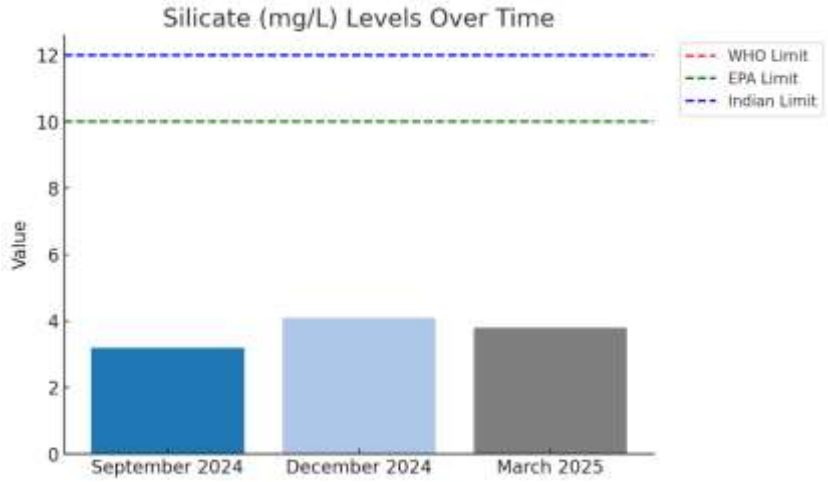


Fig 15. Silicate Levels

4.3.5. Chlorophyll-a

Chlorophyll-a is among the best indicators of aquatic ecosystem phytoplankton biomass and eutrophication. The dataset's chlorophyll-a value ranged from 14.81 µg/L in September to 47.54 µg/L in March, reflecting high primary productivity due to seasonality and nutrient variability.

Extreme temperatures are typical of human-induced nutrient loading through farm runoff and wastewater effluent, leading to oxygen sag and toxic algal blooms (HABs).

The chlorophyll-a content further varied with hydrology, light, and temperature in laboratory culture.
Intensive heat promotes the growth of phytoplankton, e.g., in shoreline areas where human activities accelerate eutrophication.

Excess chlorophyll-a for extended periods can cause hypoxia, fish kill, and bad water quality, and cyanobacterial blooms create drinking water and public health threats.

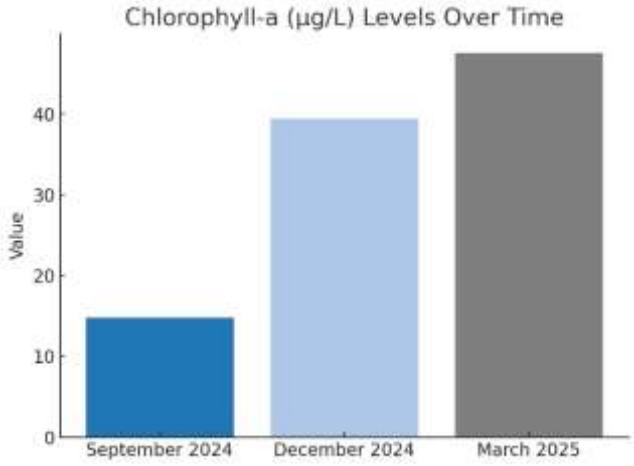


Fig 16. Chlorophyll-a levels

5. COMMUNITY DYNAMICS OF PHYTOPLANKTON AND ZOOPLANKTON

Microcystis sp. was the most dominant cyanobacterial bloom in all seasons, as per results, representing eutrophication. *Oscillatoria* sp. rise represents competitive superiority in the high-nutrient, low-oxygen condition. The same patterns have been noted in Bhoj wetland (Bhat et al., 2015). Phytoplankton populations between September 2024–March 2025 have clear seasonal patterns between the species, indicating growth, persistence, and vanishing fluctuations.

5.1. Phytoplankton

Phytoplankton assemblages are highly dynamic and sensitive to seasonally varying parameters like temperature, nutrients, hydrodynamics, and anthropogenic stress.Seasonally varying bloom-forming species must be considered in ecological regime, eutrophication, and food web change predictions for aquatic ecosystems.

EPRA International Journal of Economic Growth and Environmental Issues- Peer Reviewed Journal
ISSN: 2321-6247
Volume: 13 | Issue: 4 | April 2025 | Journal DOI: 10.36713/epra0713 | SJIF Impact Factor (2025): 8.825

TABLE 5. PHYTOPLAKNTON DATA

Phytoplankton Species	Sep 2024	Dec 2024	Mar 2025	Seasonal Trend
Spirulina sp.	55	89	110	Increasing
Cylindrospermopsis sp.	70	Not Recorded	Not Recorded	Disappeared
Microcystis sp.	ADL	ADL	ADL	Persistent Bloom
Spirogyra sp.	Uncountable	ADL	ADL	Persistent Bloom
Oscillatoria sp.	Not Recorded	3	12	Increasing

Monsoon/Winter), and March 2025 (Pre-Summer) form the current dataset. The findings are consistent with the dynamics of the global phytoplankton bloom as indicated in current research. Phytoplankton Species
Increasing Phytoplankton Populations
Two of the phytoplankton species showed the trend of increase, reflecting good development conditions with the passage of time:
Spirulina sp.Increased from 55 individuals/L in September to 89 in December and 110 in March, reflecting the good suitability of the species for the post-monsoon season with regular temperatures and good availability. Such *Spirulina* growth patterns have been explained in terms of seasonally fluctuating nutrient availability and hydrodynamic stability in some estuarine and coastal environments.

Oscillatoria sp. was absent in September but occurred at 3 individuals/L in December and 12 in March, increasing successively. *Oscillatoria* is a filamentous cyanobacterium and prone to be in the highest numbers during hot times and was observed to create toxic algal blooms (HABs) in rich waters. The allelopathic influence of aquatic macrophytes such as *Stratiotes aloides* on phytoplankton species diversity and succession has also been reported, demonstrating potential plant-mediated control of bloom dynamics (Mulderij et al., 2007).

Extinct Phytoplankton Species
On the contrary, there were some that vanished with the lapse of time allegedly under poor conditions: *Cylindrospermopsis* sp. was observed in September at 70 individuals/L but not in December and March. This bloom-tendency cyanobacteria genus is globally renowned due to its behavior in tropical as well as subtropical freshwater aquatic environments and for favoring monsoon-fed water where it preponderates. Its non-appearance is an aftermath of temperature decline and the nutritional level of post-monsoon regions repressing its development, as was likewise suggested for succession of tropical phytoplankton.

Perennial Bloom-Forming Species
There were some species that had a perennial bloom across the seasons, a sign of their dominance in the ecosystem regardless of season change:
Microcystis sp. exhibited active dominance (ADL) in all seasons, which is a sign of its persistence and strength in eutrophic systems. *Microcystis* blooms are typically linked to anthropogenic enrichment for nutrients and stable thermal stratification.

Spirogyra sp. could not be counted in September and was still non-countable under flowering conditions (ADL) in December and March. *Spirogyra* grows under stable conditions with high dissolved organic matter and medium-level temperatures, which accumulate in dense mats in aquatic systems. Climate change-induced temperature shifts are contributing to earlier spring phytoplankton blooms in temperate zones (**Peeters et al., 2007**).



Fig 17. ***spirulina sp.***

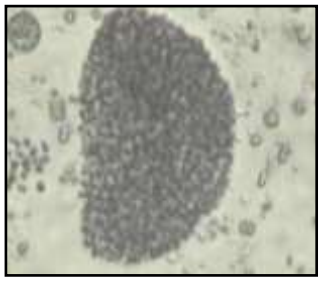


Fig 18. ***Microcystis sp.***



Fig 19. ***Cylindrospermopsis sp.***

EPRA International Journal of Economic Growth and Environmental Issues- Peer Reviewed Journal
ISSN: 2321-6247
Volume: 13 | Issue: 4 | April 2025 | Journal DOI: 10.36713/epra0713 | SJIF Impact Factor (2025): 8.825



Fig 20. ***oscillatoria sp.***

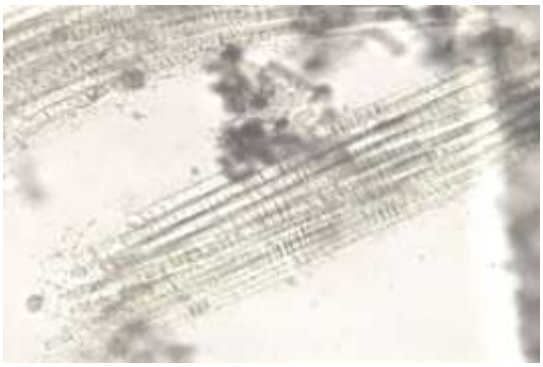


Fig 21. ***Spirogyra sp.***

5.2. ZOOPLANKTON

Zooplankton assemblages are especially significant to aquatic communities in the sense that they have been the first order of association between producers at lower trophic levels and consumers at higher trophic levels. Population, which is very dynamic, of zooplankton is regulated by the environmental variability factors seasonally like temperature, salinity, nutrients, and predation pressure. Trends between various zooplankton groups for three sets of seasons groups i.e., Late Monsoon (September 2024), Post-Monsoon/Winter (December 2024), and Pre-Summer (March 2025) have been investigated in the current study.

Declining Zooplankton Populations

Most of the zooplankton species in all stages of the seasons indicated a declining trend of the general type. Thermocyclops sp. (14 → 10 → 8 indiv./L) and Mesocyclops sp. (21 → 12 → 9 indiv./L) both reduced in total, as would be expected as they have been known to be temperature- and nutrient-sensitive from comparable field surveys of littoral zooplankton densities Wei et al. (2023).Nauplii of Copepods had comparatively lowered drastically (14 → 2 → 1 individual/L) and is reflective that copepods must be immensely vulnerable to seasonal variant habitats as can be shown by reservoir-based surveys Yin et al. (2022).Nauplii of Copepods had comparatively lowered drastically (14 → 2 → 1 individual/L) and is reflective that copepods must be immensely vulnerable to seasonal variant habitats as can be shown by reservoir-based surveys Yin et al. (2022).Pattern for Cypris sp. (14 → 9.5 → 6 individuals/L) and Polychaete larvae (7 → 4 → 3 individuals/L) also were following a constant degrading pattern which would indicate probable stress through predation or availability deficiency for successive seasons. Physical oceanographic variation has also been reported to affect gelatinous zooplankton, i.e., the Diphyes chamissonis and Doliolum denticulatum species Shi et al. (2020).

TABLE 6. ZOOPLANKTON DATA

S.No	Zooplankton Species	September 2024 (Set 1 - Late Monsoon) (Individuals/L)	December 2024 (Set 2 - Post-Monsoon/Winter) (Individuals/L)	March 2025 (Set 3 - Pre-Summer) (Individuals/L)	Seasonal Trend
1	Insect	Not Recorded	3	6	Increasing
2	Polychaete larvae	7	4	3	Declining
3	Mesocyclops sp.	21	12	9	Declining
4	Fish larvae	7	Not Recorded	Not Recorded	Absent
5	Ceriodaphnia cornuta	14	Not Recorded	Not Recorded	Absent
6	Cypris sp.	14	9.5	6	Declining
7	Polychaete larvae	7	4	3	Declining
8	Brachionus calyciflorus	21	Not Recorded	Not Recorded	Absent
9	Copepod nauplius	14	2	1	Declining

EPRA International Journal of Economic Growth and Environmental Issues- Peer Reviewed Journal
ISSN: 2321-6247
Volume: 13 | Issue: 4 | April 2025 | Journal DOI: 10.36713/epra0713 | SJIF Impact Factor (2025): 8.825

Missing Zooplankton Species

Some of the species were entirely absent after the monsoon season, corroborating their seasonality:
Ceriodaphnia cornuta and fish larvae were not seen later in the year, although they were seen during September at 7 and 14 individuals/L respectively. Environmental limitations or seasonal breeding behaviors can be responsible for their loss Musialik-Koszarowska & Dzierzbicka-Głowacka (2019).Brachionus calyciflorus and Brachionus sp. (21 and 29 individuals/L in September) also completely vanished in subsequent seasons, owing to altered water temperature and nutrient content. The same population dynamics of rotifers are described in lake-based research Li et al. (2019).

Rising Zooplankton Population

Nevertheless, some species showed an increasing trend, indicating their resistance to seasonality:
Moina sp. (Not recorded → 4 → 7 individuals/L) and Paramecium sp. (Not recorded → 3 → 6 individuals/L) increased, possibly due to improved conditions such as rising temperature and presence of microbial food items. Temperature fluctuation has been noted to play a major role in microzooplankton dynamics Bi & Liu (2017).
Rotifer sp. (Not recorded → 6 → 9 individuals/L) grew slowly .Likewise, the same trends have been documented in Teesta–Torsa basin wetlands Bhoj wetland (Bhat et al., 2015).



Fig 21 (a & b). Fish larvae

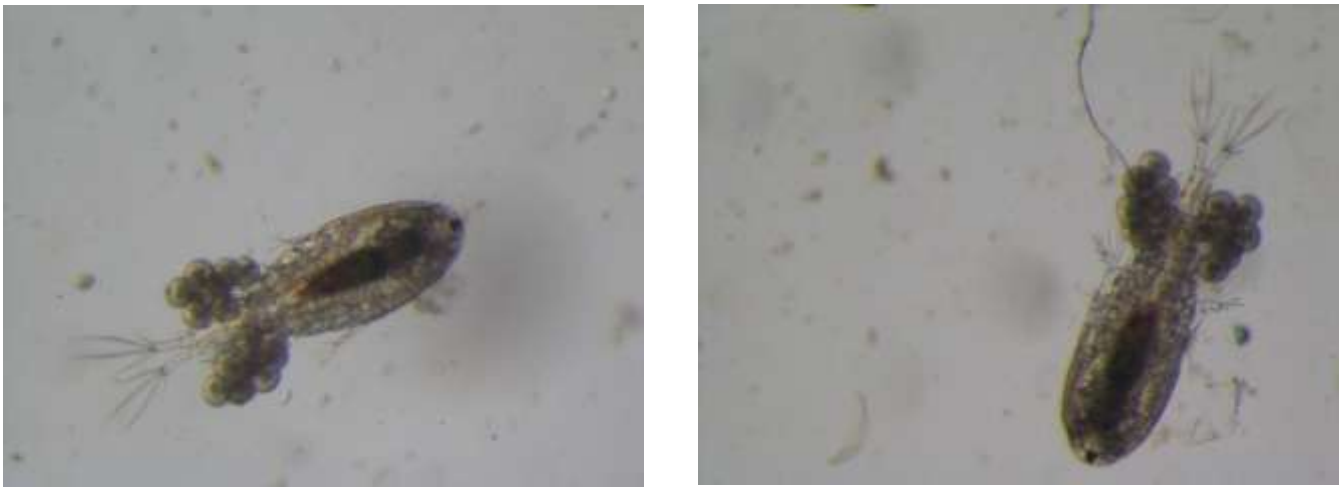


Fig 22 (a & b): Mesocyclops sp

EPRA International Journal of Economic Growth and Environmental Issues- Peer Reviewed Journal
ISSN: 2321-6247
Volume: 13 | Issue: 4 | April 2025 | Journal DOI: 10.36713/epra0713 | SJIF Impact Factor (2025): 8.825

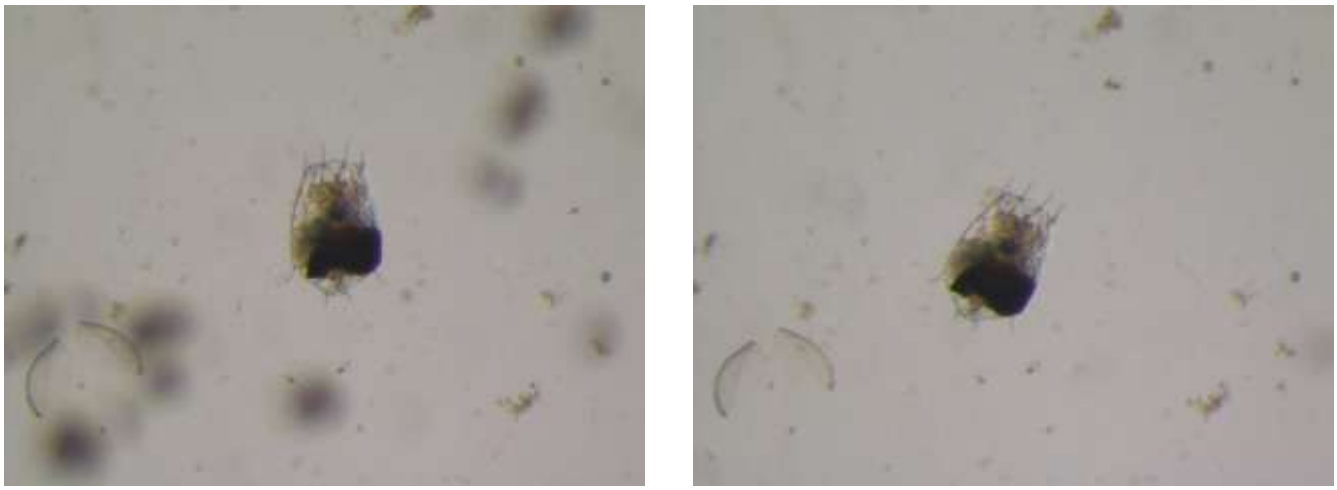


Fig 23(A&B). ***Brachionus Calyciflorus***

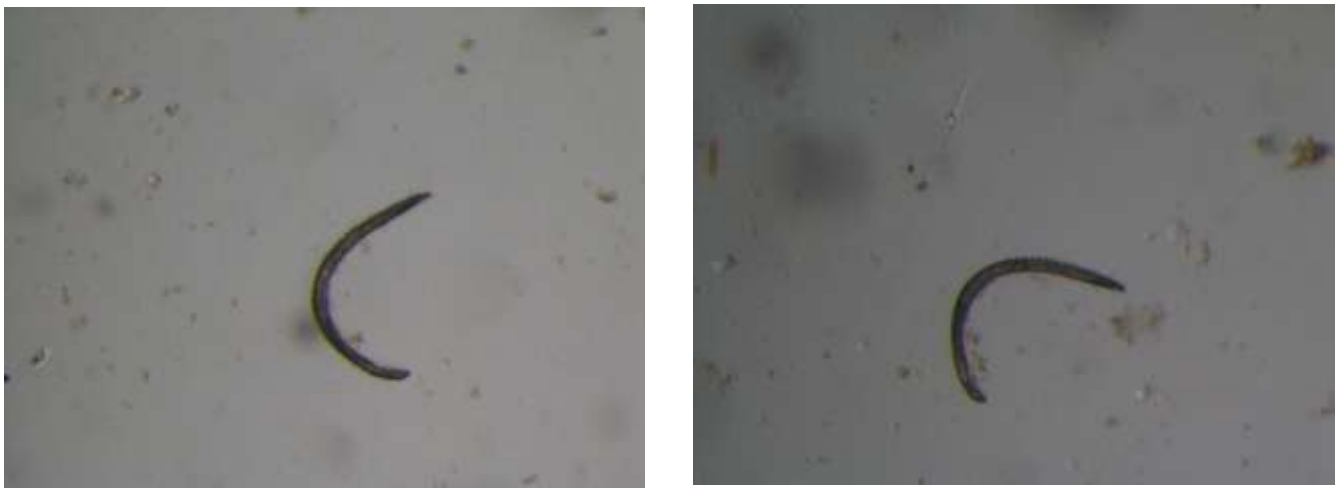


Fig 24(A&B). ***Polychaete Larvae***

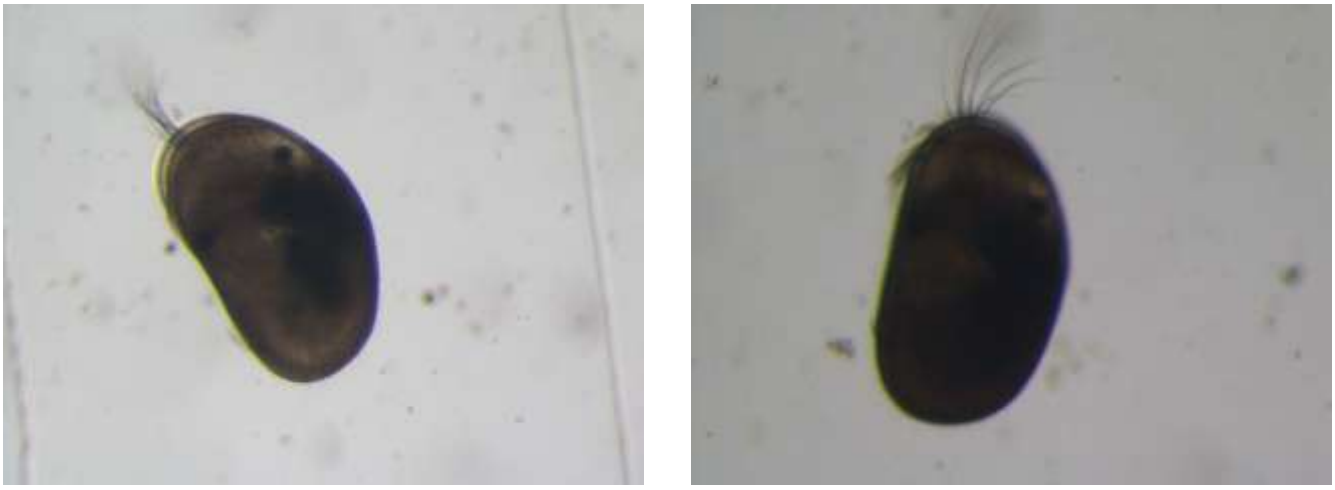


Fig 25(a&b). ***Cypris sp***

EPRA International Journal of Economic Growth and Environmental Issues- Peer Reviewed Journal
ISSN: 2321-6247
Volume: 13 | Issue: 4 | April 2025 | Journal DOI: 10.36713/epra0713 | SJIF Impact Factor (2025): 8.825




Fig 26(A&B). ***Ceriodaphnia Cornuta***



Fig 27. ***Thermocyclops sp***



Fig 28. Copepode Nauplius



Fig 29. Incect

EPRA International Journal of Economic Growth and Environmental Issues- Peer Reviewed Journal
ISSN: 2321-6247
Volume: 13 | Issue: 4 | April 2025 | Journal DOI: 10.36713/epra0713 | SJIF Impact Factor (2025): 8.825

6. Total Coliform and Fecal

Coliform bacteria are anaerobic facultative bacilli and are Gram-negative, and are found everywhere in the intestines of warm-blooded animals including human beings. Coliform bacteria are used on a large scale as microbiological water quality indicators as their presence is sure to assure fecal contamination is most likely present along with likely presence of pathogenic bacteria, viruses, or protozoa. Total Coliform (TC) group is facultative anaerobic and aerobic bacteria that ferment lactose with gas production in temperature 35–37°C, whereas Fecal Coliforms (FC) is a sub-group showing growth at 44.5°C indicating fecal human or animal origin contamination (Pinto et al., 2012).

Coliform does not necessarily need to be absent in drinking water, whereas in surface and recreational water it may occur with restriction depending on guidelines.Coliform count was calculated from the following formula
Coliform trend reveals consistent rise in bacterial contamination over time. Emerging technologies such as MALDI-TOF MS have enabled more precise identification of environmental bacterial strains, allowing for enhanced microbial monitoring in aquatic systems (Ashfaq et al., 2021). Investigations into microbial contamination from infrastructure sources such as toilets reveal novel urban contamination pathways (**Tsunoda et al., 2019**).

1. **Seasonal Pattern and Contaminating Factors**

   September 2024: Total Coliform (120 CFU/100mL) and Fecal Coliform (95 CFU/100mL) at the starting point reflect contamination of the moderate level. Since the consideration has been taken that September is a post-monsoon season, the source of the contaminant might be because of runoff of organic wastes, soil bacteria, and effluent release of sewage.

   December 2024: The increase to 125 CFU/100mL (TC) and 98 CFU/100mL (FC) indicates the accumulation of pollution due to decreased rainfall and water stagnation. During dry season, decreased water flow can lead to increased survival of the bacteria in surface water.

   March 2025: Total Maximum Coliform (135 CFU/100mL) and Fecal Coliform (110 CFU/100mL) is a giant peak in bacterial density, and the pond is not safe for recreational use. March is a month of ideal warmer climatic conditions favorable for bacterial development, and the degradation of organic matter may even become a microbial growth-promoting factor.

TABLE 7. TOTAL AND FECAL COLIFORM DATA

Study Period	Total Coliform (CFU/100mL)	Fecal Coliform (CFU/100mL)	WHO & EPA Drinking Water Standard	WHO & EPA Recreational Standard	Indian Surface Water Standard (CPCB)
September 2024	120	95	Unsafe (Must be 0)	Safe (≤500)	Safe
December 2024	128	102	Unsafe (Exceeds 100)	Safe (≤500)	Safe
March 2025	135	110	Unsafe (Exceeds 100)	Safe (≤500)	Unsafe

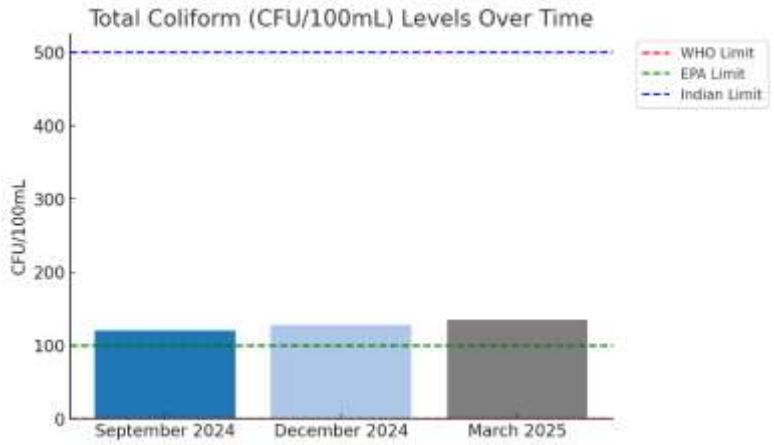


Fig 30. Total Coliform Levels

EPRA International Journal of Economic Growth and Environmental Issues- Peer Reviewed Journal
ISSN: 2321-6247
Volume: 13 | Issue: 4 | April 2025 | Journal DOI: 10.36713/epra0713 | SJIF Impact Factor (2025): 8.825



Fig 31. Fecal Coliform Levels

CONCLUSION

Results of the study highlight the significant seasonal variation in water quality factors, zooplankton, and phytoplankton in the freshwater environment.The appearance of high turbidity and total dissolved solids (TDS) in certain months points towards periodic sedimentation and runoff processes, and the varying dissolved oxygen (DO) levels reflect dynamic ecological processes due to season forces.The algal bloom-nutrient loading processes recognize the eutrophication process as a factor of water quality degradation, and thus sustainable management is warranted.Further, the phytoplankton and zooplankton community change processes recognize the requirement of ongoing monitoring for the establishment of ecological balance.

Finally, the current study reaffirms the requirement of long-term water quality monitoring to achieve ecosystem stability and to protect freshwater resources for ecological and human use.

REFERENCES

1. *Albert, L., Deschamps, F., Jolivet, A., Olivier, F., Chauvaud, L., & Chauvaud, S. (2020b). A current synthesis on the effects of electric and magnetic fields emitted by submarine power cables on invertebrates. Marine Environmental Research, 159, 104958. https://doi.org/10.1016/j.marenvres.2020.104958*
2. *Alexander, J. B., Marnane, M. J., Elsdon, T. S., Bunce, M., Songploy, S., Sitaworawet, P., & Harvey, E. S. (2022a). Complementary molecular and visual sampling of fish on oil and gas platforms provides superior biodiversity characterisation. Marine Environmental Research, 179, 105692. https://doi.org/10.1016/j.marenvres.2022.105692*
3. *Alexander, J. B., Marnane, M. J., Elsdon, T. S., Bunce, M., Songploy, S., Sitaworawet, P., & Harvey, E. S. (2022b). Complementary molecular and visual sampling of fish on oil and gas platforms provides superior biodiversity characterisation. Marine Environmental Research, 179, 105692. https://doi.org/10.1016/j.marenvres.2022.105692*
4. *Ashfaq, M. Y., Da'na, D. A., & Al-Ghouti, M. A. (2021). Application of MALDI-TOF MS for identification of environmental bacteria: A review. Journal of Environmental Management, 305, 114359. https://doi.org/10.1016/j.jenvman.2021.114359*
5. *Bhat, N. A., Wanganeo, A., & Raina, R. (2014). Seasonal dynamics of phytoplankton community in a tropical wetland. Environmental Monitoring and Assessment, 187(1). https://doi.org/10.1007/s10661-014-4136-4*
6. *Bhateria, R., & Jain, D. (2016). Water quality assessment of lake water: a review. Sustainable Water Resources Management, 2(2), 161–173. https://doi.org/10.1007/s40899-015-0014-7*
7. *Boyd, C. E., & Tucker, C. S. (1998). Pond Aquaculture Water quality management. In Springer eBooks. https://doi.org/10.1007/978-1-4615-5407-3*
8. *Caspers, H. (1970). J. D. H. Strickland and T. R. Parsons: A Practical Handbook of Seawater Analysis. Ottawa: Fisheries Research Board of Canada, Bulletin 167, 1968. 293 pp. $ 7.50. Internationale Revue Der Gesamten Hydrobiologie Und Hydrographie, 55(1), 167. https://doi.org/10.1002/iroh.19700550118*
9. *Efficient Management of Wastewater from Manufacturing. (2015). In Apple Academic Press eBooks. https://doi.org/10.1201/b18616*
10. *Fang, W., Guo, P., Liu, C., Fang, G., & Li, S. (2015a). Observed sub-inertial current variability and volume transport over the continental shelf in the northern South China Sea. Estuarine Coastal and Shelf Science, 157, 19–31. https://doi.org/10.1016/j.ecss.2015.02.001*

11. *Fang, W., Guo, P., Liu, C., Fang, G., & Li, S. (2015b). Observed sub-inertial current variability and volume transport over the continental shelf in the northern South China Sea. Estuarine Coastal and Shelf Science, 157, 19–31. https://doi.org/10.1016/j.ecss.2015.02.001*
12. *Friberg, N. (2014). Impacts and indicators of change in lotic ecosystems. Wiley Interdisciplinary Reviews Water, 1(6), 513–531. https://doi.org/10.1002/wat2.1040*
13. *Fu, F., Dionysiou, D. D., & Liu, H. (2014). The use of zero-valent iron for groundwater remediation and wastewater treatment: A review. Journal of Hazardous Materials, 267, 194–205. https://doi.org/10.1016/j.jhazmat.2013.12.062*
14. *Gheorghe, S., Stoica, C., Vasile, G. G., Nita-Lazar, M., Stanescu, E., & Lucaciu, I. E. (2017). Metals Toxic effects in Aquatic ecosystems: modulators of water quality. In InTech eBooks. https://doi.org/10.5772/65744*
15. *Gogoi, B., Hazarika, G., & Chauhan, H. (2021). Origin of porphyritic texture by magma mixing in the andesitic rocks of Ghansura Rhyolite Dome from the Bathani volcano-sedimentary sequence, Eastern India. GEOCHEMICAL JOURNAL, 55(1), 11–25. https://doi.org/10.2343/geochemj.2.0613*
16. *Higgisson, W., & Dyer, F. (2020). Seed germination and dispersal of Eleocharis acuta and Eleocharis sphacelata under experimental hydrological conditions. Aquatic Ecology, 55(1), 21–32. https://doi.org/10.1007/s10452-020-09806-5*
17. *Kalamarz-Kubiak, H., & Guellard, T. (2019a). Oocyte hydration in round goby Neogobius melanostomus from the Gulf of Gdańsk: another invasive strategy? Oceanologia, 61(4), 534–539. https://doi.org/10.1016/j.oceano.2019.06.001*
18. *Kalamarz-Kubiak, H., & Guellard, T. (2019b). Oocyte hydration in round goby Neogobius melanostomus from the Gulf of Gdańsk: another invasive strategy? Oceanologia, 61(4), 534–539. https://doi.org/10.1016/j.oceano.2019.06.001*
19. *Kalamarz-Kubiak, H., & Guellard, T. (2019c). Oocyte hydration in round goby Neogobius melanostomus from the Gulf of Gdańsk: another invasive strategy? Oceanologia, 61(4), 534–539. https://doi.org/10.1016/j.oceano.2019.06.001*
20. *Lorenzen, C. J. (1967). DETERMINATION OF CHLOROPHYLL AND PHEO-PIGMENTS: SPECTROPHOTOMETRIC EQUATIONS1. Limnology and Oceanography, 12(2), 343–346. https://doi.org/10.4319/lo.1967.12.2.0343*
21. *Lovelock, C. E., Adame, M. F., Bennion, V., Hayes, M., Reef, R., Santini, N., & Cahoon, D. R. (2014). Sea level and turbidity controls on mangrove soil surface elevation change. Estuarine Coastal and Shelf Science, 153, 1–9. https://doi.org/10.1016/j.ecss.2014.11.026*
22. *Lukman, L. (2023). Anthropogenic impact on lake ecosystem. In IntechOpen eBooks. https://doi.org/10.5772/intechopen.112179*
23. *Mearns, A. J., Morrison, A. M., Arthur, C., Rutherford, N., Bissell, M., & Rempel-Hester, M. A. (2020). Effects of pollution on marine organisms. Water Environment Research, 92(10), 1510–1532. https://doi.org/10.1002/wer.1400*
24. *Mulderij, G., Mau, B., Van Donk, E., & Gross, E. M. (2007). Allelopathic activity of Stratiotes aloides on phytoplankton – towards identification of allelopathic substances. Hydrobiologia, 584(1), 89–100. https://doi.org/10.1007/s10750-007-0602-0*
25. *Murphy, J., & Riley, J. (1962). A modified single solution method for the determination of phosphate in natural waters. Analytica Chimica Acta, 27, 31–36. https://doi.org/10.1016/s0003-2670(00)88444-5*
26. *Oshiro, R. K. & U.S. Environmental Protection Agency. (2002). Method 1604: Total Coliforms and Escherichia coli in Water by Membrane Filtration Using a Simultaneous Detection Technique (MI Medium). In Washington, DC 20460 (Report EPA-821-R-02-024). https://www.epa.gov/sites/default/files/2015-08/documents/method_1604_2002.pdf*
27. *Peeters, F., Straile, D., Lorke, A., & Livingstone, D. M. (2007). Earlier onset of the spring phytoplankton bloom in lakes of the temperate zone in a warmer climate. Global Change Biology, 13(9), 1898–1909. https://doi.org/10.1111/j.1365-2486.2007.01412.x*
28. *Pinto, A. J., Xi, C., & Raskin, L. (2012a). Bacterial community structure in the drinking water microbiome is governed by filtration processes. Environmental Science & Technology, 46(16), 8851–8859. https://doi.org/10.1021/es302042t*
29. *Pinto, A. J., Xi, C., & Raskin, L. (2012b). Bacterial community structure in the drinking water microbiome is governed by filtration processes. Environmental Science & Technology, 46(16), 8851–8859. https://doi.org/10.1021/es302042t*
30. *Pitot, H. C. (1996). Water quality assessments. In CRC Press eBooks. https://doi.org/10.4324/noe0419216001*
31. *Standard methods. (n.d.). Standard Methods for the Examination of Water and Wastewater. https://www.standardmethods.org/*
32. *Tréguer, P., Nelson, D. M., Van Bennekom, A. J., DeMaster, D. J., Leynaert, A., & Quéguiner, B. (1995). The silica balance in the World Ocean: A reestimate. Science, 268(5209), 375–379. https://doi.org/10.1126/science.268.5209.375*
33. *Tsunoda, A., Otsuka, Y., Toguchi, A., Watanabe, K., Nishino, R., & Takahashi, T. (2019). Survey on bacterial contamination of bidet toilets and relation to the interval of scrubbing these units. Journal of Water and Health, 17(6), 863–869. https://doi.org/10.2166/wh.2019.234*
34. *U.S. Environmental Protection Agency. (n.d.). Draft Ambient Water Quality Criteria Recommendations for lakes and Reservoirs of the conterminous United States: Information supporting the development of numeric nutrient criteria. In EPA Document Number: 820P20001. https://www.epa.gov/sites/default/files/2020-05/documents/draft-ambient-wqc-recommendations-lakes-2020.pdf*
35. *Veettil, B. K., Quang, N. X., & Trang, N. T. T. (2019). Changes in mangrove vegetation, aquaculture and paddy cultivation in the Mekong Delta: A study from Ben Tre Province, southern Vietnam. Estuarine Coastal and Shelf Science, 226, 106273. https://doi.org/10.1016/j.ecss.2019.106273*

36. *Voumard, M., Breider, F., & Von Gunten, U. (2022a). Effect of cetyltrimethylammonium chloride on various Escherichia coli strains and their inactivation kinetics by ozone and monochloramine. Water Research, 216, 118278. https://doi.org/10.1016/j.watres.2022.118278*
37. *Voumard, M., Breider, F., & Von Gunten, U. (2022b). Effect of cetyltrimethylammonium chloride on various Escherichia coli strains and their inactivation kinetics by ozone and monochloramine. Water Research, 216, 118278. https://doi.org/10.1016/j.watres.2022.118278*
38. *Yang, J., Zhang, C., Zhang, Z., & Yang, L. (2018). Electroplating wastewater concentration system utilizing mechanical vapor recompression. Journal of Environmental Engineering, 144(7). https://doi.org/10.1061/(asce)ee.1943-7870.0001380*
39. *Yang, Y., Dong, S., Yu, Y., Chu, S., & Xiao, J. (2022). Bioaugmentation performances with a powerful strain for nitrogen removal without N2O accumulation. Journal of Environmental Management, 325, 116506. https://doi.org/10.1016/j.jenvman.2022.116506*
40. *Zazouli, M. A., Dashtban, N., Jalalvand, M. A., Kheilgavan, S. J., Kholerdi, F. M., Mohammadpour, A., Rahman, M. M., Krause, S., & Dehbandi, R. (2024). Unveiling Nitrate Contamination and Health Risks: Insights from Groundwater Quality Assessment and Monte Carlo Simulation along the Southern Caspian Sea Coasts. Groundwater for Sustainable Development, 27, 101340. https://doi.org/10.1016/j.gsd.2024.101340*