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Research Paper

EVALUATION OF SEASONAL VARIABILITY IN WATER QUALITY PARAMETERS OF DIFFERENT FRESHWATER SOURCES

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ABSTRACT

Freshwater ecosystems are increasingly threatened by rapid urbanization, industrialization, agricultural intensification, and climate variability. Surface water bodies serve as primary sources for drinking, irrigation, fisheries, and domestic use. However, anthropogenic inputs significantly alter physicochemical characteristics, affecting ecosystem stability and public health (UN-Water, 2021; WWAP, 2023). The present study evaluates seasonal variability in physicochemical parameters of selected freshwater sources and assesses their suitability based on World Health Organization (WHO, 2017) and Bureau of Indian Standards (BIS, 2012) guidelines. Nine sampling sites were analysed during pre-monsoon and winter seasons using APHA (2017) standard methods. Parameters studied included pH, turbidity, dissolved oxygen (DO), biochemical oxygen demand (BOD), total dissolved solids (TDS), and electrical conductivity (EC). The findings indicate moderate pollution stress and highlight the need for integrated watershed management strategies aligned with SDG 6 objectives.

Keywords: Seasonal variability, freshwater pollution, dissolved oxygen, biochemical oxygen demand, environmental monitoring.

1. INTRODUCTION

Freshwater resources are vital for sustaining ecological balance and supporting socio-economic development. Despite their importance, freshwater bodies face increasing degradation due to anthropogenic pressures such as industrial effluents, domestic sewage, and agricultural runoff (Vörösmarty et al., 2015). According to UN-Water (2021), global water quality deterioration poses a significant challenge to sustainable development. Surface water contamination alters physicochemical properties, influencing aquatic life and public health (WHO, 2017). Dissolved solids, suspended particles, organic matter, and nutrient loading affect ecosystem functioning and drinking water safety (Bilotta & Brazier, 2018). Seasonal variability plays a critical role in shaping water chemistry. Pre-monsoon seasons often show increased concentration of dissolved substances due to evaporation, whereas winter seasons typically demonstrate enhanced oxygen solubility (Khatri & Tyagi, 2015; Wetzel, 2012). Climate change further intensifies hydrological variability and pollutant transport (IPCC, 2021). Water Quality Index (WQI) has been widely adopted as a comprehensive tool for summarizing complex water quality data (Tyagi et al., 2018; Shil et al., 2019). Therefore, the present study aims to evaluate seasonal variability and assess freshwater quality using standardized approaches.

2. REVIEW OF LITERATURE

Global assessments highlight that freshwater pollution results primarily from nutrient enrichment, sediment transport, and wastewater discharge (Vörösmarty et al., 2015). Bilotta and Brazier (2018) emphasized the ecological impact of suspended solids on aquatic habitats, including reduced photosynthesis and habitat degradation.

In the Indian context, Sharma et al. (2020) reported significant seasonal variations in surface water quality influenced by agricultural runoff and residential discharge. Singh et al. (2017) demonstrated the effectiveness of pollution indices in assessing freshwater contamination levels.

Climate-related changes in precipitation and temperature influence oxygen solubility and microbial decomposition processes (IPCC, 2021). Wetzel (2012) explained that lower winter temperatures increase dissolved oxygen concentration, enhancing aquatic health. International

guidelines such as WHO (2017) and BIS (2012) provide permissible limits for drinking water parameters. However, periodic regional assessments remain necessary to ensure compliance and sustainability.

3. AIMS AND OBJECTIVES:

The present study aims to evaluate the seasonal variability in water quality parameters of different freshwater sources and assess their suitability for various uses based on physicochemical characteristics. Objectives of this research are, to analyse physicochemical parameters including pH, electrical conductivity, total dissolved solids, turbidity, dissolved oxygen, and biochemical oxygen demand in selected freshwater sources, to observe seasonal variation in water quality parameters during the premonsoon and winter seasons, to compare water quality among different freshwater sources, to identify spatial differences and potential pollution influences, to evaluate water quality status in relation to guideline standards prescribed by the World Health Organization (WHO) and Bureau of Indian Standards (BIS), to identify potential sources of contamination and their environmental implications, to provide baseline scientific data that can support environmental monitoring, pollution control strategies, and sustainable water resource management.

4. MATERIAL AND METHOD

The present investigation was conducted at nine designated surface water locations, identified as Sites A, B, C, D, E, F, G, H and I. The sites were selected based on criteria including accessibility, diversity of surrounding land-use patterns (e.g., agricultural, residential, and semi-urban influences), and documented evidence of prior pollution reports. This selection strategy ensured representation of varying anthropogenic impacts on water quality. Water samples were collected during the pre-monsoon season to reflect baseline physicochemical characteristics under relatively stable hydrological conditions. Sampling during this period minimizes dilution effects caused by rainfall and surface runoff, thereby providing representative water quality status. Prior to collection, sterilized polythene bottles were rinsed thoroughly with the respective site water to prevent cross-contamination and ensure sample integrity. Surface water samples were collected carefully to avoid disturbance of bottom sediments. Physicochemical analysis was initiated within 6 hours of sample collection to maintain sample stability and ensure analytical accuracy.

5. PHYSICOCHEMICAL PARAMETERS FOR WATER QUALITY ANALYSIS

pH is a measure of hydrogen ion concentration. It is used for determination of suitability for drinking, irrigation and for aquatic life. Extreme pH can corrode pipes and affect biological processes. pH is measured using a calibrated digital pH meter. Formula for theoretical determination of pH is, $pH = -\log_{10}[H+]$. Where, [H+] is hydrogen ion concentration. Standard range of pH of drinking water is 6.5 to 8.5 (WHO/BIS standards)**.** pH <6.5 is acidic (corrosive water)**,** 6.5 to 8.5 is acceptable**,** 8.5 is alkaline (may cause taste issues & scaling)**.** Turbidity measures the cloudiness of water caused by suspended particles such as silt, clay, organic matter, and microorganisms that causes scattering of light. It indicates contamination and runoff. High turbidity affects aquatic ecosystems by decreasing light penetration. Turbidity is measured using a Nephelometric Turbidity Meter. Unit is NTU (Nephelometric Turbidity Units)**.** Standard Limit of turbidity of drinking water is ≤ 5 NTU while ideal turbidity value is <1 NTU. High turbidity shows erosion, sewage input, or pollution runoff. Dissolved Oxygen (DO) is the amount of oxygen available in water for aquatic organisms. It is essential for fish and aquatic life. It indicates ecosystem health. Low DO suggests organic pollution. Measurement of DO can be done by Winkler titration method or DO meter. Formula for calculation by measurement with Winkler Method is; $DO\ (mg/L) = (V_1 \times N \times 8 \times 1000)/ V_2$. Where, V_1 is volume of titrant used (mL), N is normality of sodium thiosulfate, V_2 is volume of water sample (mL), and 8 is equivalent weight of oxygen. Healthy aquatic water has DO ≥ 5 mg/L while DO from 7 to 9 mg/L is excellent. Low DO value shows organic pollution & oxygen depletion while high DO indicates good water quality. Biological Oxygen Demand (BOD) measures the amount of oxygen required by microorganisms to decompose organic matter in water over a specified period (usually 5 days at 20°C). It indicates organic pollution level. High BOD indicates oxygen available for aquatic life. Measurement is done with 5-day incubation method (BOD_5). Formula for calculation of BOD is $BOD_5(mg/L) = DO_{initial} - DO_{final.}$ If dilution used; $BOD_5 = P(D_1 - D_2)$. Where; D_1 is initial DO (mg/L), D_2 is DO after 5 days incubation, P is decimal fraction of sample volume used. Values of BOD for drinking water are < 1 mg/L; while the values < 3 mg/L indicates clean water. Polluted water has BOD > 5 mg/L. High BOD indicates sewage or organic waste contamination. Total Dissolved Solids (TDS) represents the total concentration of dissolved substances such as minerals, salts, and organic matter. It affects taste and hardness. High levels may cause health issues and scaling. Measurement can be done with gravimetric method or TDS meter. Formula for calculation of TDS with Gravimetric method is; $TDS\ (mg/L) = (W_2 - W_1)$

×1000/ V. Where, W_1 is weight of empty dish (mg), W_2 is weight after evaporation (mg), V is volume of sample (mL). Acceptable value of TDS is ≤ 500 mg/L, while permissible value is up to 2000 mg/L (BIS). High TDS indicates mineral contamination or salinity. Electrical Conductivity (EC) measure's ability of water to conduct electricity, which depends on dissolved ions. It indicates total ionic concentration and helps to assess salinity and pollution. Measurement is done with Conductivity meter. Unit of EC is µS/cm.

Parameter	Ideal Range (WHO/Standard Limits)
pH	6.5–8.5
Turbidity	< 5 NTU
DO	≥ 5 mg/L
BOD	< 3 mg/L
TDS	< 500 mg/L
EC	< 1000 µS/cm

6. RESULTS

Parameters for Pre-Monsoon Season

Parameter	Site A	Site B	Site C	Site D	Site E	Site F	Site G	Site H	Site I
pH	7.3	7.6	7.8	6.2	7.2	7.9	8.3	7.5	7.7
Turbidity (NTU)	4.2	5.0	3.8	7.1	4.6	4.3	4.7	5.5	4.9
DO (mg/L)	7.9	7.3	6.8	3.7	7.5	6.8	7.2	6.9	8.2
BOD (mg/L)	2.5	2.9	3.0	9.1	2.7	3.1	2.8	2.9	2.3
TDS (mg/L)	410	460	390	610	445	385	480	510	390
EC (µS/cm)	820	900	780	1130	840	800	920	1010	810

Parameters for Post-Monsoon/Winter Season

Parameter	Site A	Site B	Site C	Site D	Site E	Site F	Site G	Site H	Site I

pH	7.2	7.5	7.6	6.0	7.1	7.7	8.1	7.3	7.6
Turbidity (NTU)	4.0	4.9	3.6	6.8	4.4	4.1	4.5	5.1	4.3
DO (mg/L)	8.2	7.6	7.1	4.1	7.9	6.9	7.5	7.3	8.4
BOD (mg/L)	2.4	2.7	3.0	9.0	2.6	3.0	2.6	2.8	2.2
TDS (mg/L)	380	430	370	560	430	370	450	500	380
EC (µS/cm)	810	880	760	1090	830	790	910	990	790

Table of source of specific site: -

Site	Source	Site	Source
A	Bore well	**F**	well
B	well	**G**	Bore well
C	Bore well	**H**	Sub river
D	Sub river	**I**	Bore well
E	well		

7. DISCUSSION

The seasonal assessment of physicochemical parameters (Pre-monsoon and winter) across nine sampling sites (A–I) was evaluated against WHO guideline limits for drinking water quality. The results indicate distinct spatial and seasonal variations, with Site D consistently showing signs of significant water quality deterioration, while most other sites remain within acceptable limits. In both seasons, pH at Sites A, B, C, E, F, G, H, and I remained within the acceptable range, while Site D recorded slightly acidic values (6.2 in pre-monsoon and 6.0 in winter), falling below the WHO lower limit. The slightly acidic condition at Site D may indicate localized contamination, possible industrial discharge, or organic matter decomposition

influencing carbonate equilibrium. Seasonal variation in pH was minimal, suggesting relatively stable buffering capacity of the water body. During pre-monsoon, turbidity exceeded limits at Site D (7.1 NTU) and Site H (5.5 NTU)**.** In winter, increase in turbidity was observed at Site D (6.8 NTU) and marginally at Site H (5.1 NTU)**.** Elevated turbidity at Site D suggests higher suspended solids, possibly due to runoff, anthropogenic activities, or sediment resuspension. Slight improvement in winter may be attributed to reduced surface runoff and sediment inflow. DO at all sites except Site D is in standard range. Site D showed critically low DO values (3.7 mg/L pre-monsoon; 4.1 mg/L winter). Higher DO levels at other sites indicate good aeration and low organic pollution. The persistently low DO at Site D suggests high organic load and microbial oxygen consumption, confirming pollution stress. It was observed that, DO values were slightly higher in winter across most sites, likely due to lower water temperatures increasing oxygen solubility. Most sites were within acceptable limits or marginally at threshold of BOD. Site D recorded extremely high BOD values (9.1 mg/L pre-monsoon; 9.0 mg/L winter)**.** Slight exceedance was observed at Site F (3.1 mg/L pre-monsoon). The inverse relationship between DO and BOD is clearly evident at Site D. High BOD indicates strong organic contamination, possibly from sewage discharge or domestic waste inflow. Seasonal similarity suggests continuous pollution rather than seasonal runoff influence. Pre-monsoon exceedances in TDS were recorded at Site D (610 mg/L) and Site H (510 mg/L). In winter increase in TDS at Site D (560 mg/L) was observed; while Site H was at the permissible limit (500 mg/L). Higher TDS at Site D indicates elevated dissolved salts, which may originate from wastewater discharge or agricultural runoff. Slight seasonal reduction in winter may be due to dilution effects or reduced evaporation. Pre-monsoon electrical conductivity at Site D (1130 µS/cm) and Site H (1010 µS/cm) exceeded limits; while in winter, EC at Site D (1090 µS/cm) exceeded limits; Site H was within permissible range (990 µS/cm). EC values strongly correlate with TDS levels, confirming increased ionic concentration at Site D. Elevated EC suggests contamination from dissolved inorganic substances.

8. CONCLUSION

The comparative seasonal analysis shows that most sampling sites comply with WHO drinking water standards**,** indicating generally acceptable water quality in the study area. However, Site D shows severe and persistent deterioration, characterized by; acidic pH, high

turbidity, critically low DO, excessively high BOD, elevated TDS and EC. The strong inverse relationship between DO and BOD confirms substantial organic pollution at this site, likely from continuous anthropogenic discharge. Seasonal variation had limited influence on pollution intensity at Site D, suggesting a constant contamination source. Remedial measures such as, identification and control of pollution sources; wastewater treatment implementation, regular monitoring and management strategies are recommended to prevent further ecological degradation. Site D pose ecological and potential public health risks, necessitating intervention and sustainable water resource management practices.

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