

ASSESSMENT OF DRINKING WATER SAFETY AND CONTAMINANT LOAD IN THE PORUR REGION, CHENNAI: A PUBLIC HEALTH PERSPECTIVE

Rahul Aravind Raj A¹, Divya Devi G², Vasundra L³, Vishnupriyan.V⁴, Belin.S⁵, Vinodhini C^{6*}

¹M. Pharm, Department of Pharmaceutical Chemistry, Sri Ramachandra Faculty of Pharmacy, Sri Ramachandra Institute of Higher Education and Research, SRIHER(DU), Porur-600116, Chennai, India.

²Ph.D. Scholar Department of Pharmaceutical Chemistry, Sri Ramachandra Faculty of Pharmacy, Sri Ramachandra Institute of Higher Education and Research, SRIHER(DU), Porur-600116, Chennai, India.

³M. Pharm, Department of Pharmaceutical Chemistry, Sri Ramachandra Faculty of Pharmacy, Sri Ramachandra Institute of Higher Education and Research, SRIHER(DU), Porur-600116, Chennai, India.

⁴Ph.D. Scholar Department of Pharmaceutical Chemistry, Sri Ramachandra Faculty of Pharmacy, Sri Ramachandra Institute of Higher Education and Research, SRIHER(DU), Porur-600116, Chennai, India.

⁵M. Pharm, Department of Pharmaceutical Chemistry, Sri Ramachandra Faculty of Pharmacy, Sri Ramachandra Institute of Higher Education and Research, SRIHER(DU), Porur-600116, Chennai, India.

^{6*}Associate Professor, Department of Pharmaceutical Chemistry, Sri Ramachandra Faculty of Pharmacy, Sri Ramachandra Institute of Higher Education and Research, SRIHER(DU), Porur-600116, Chennai, India, Mail: vinpharma1979@gmail.com, Phone: 9840298021

ABSTRACT

Water is a key natural resource that is necessary for human well-being, agriculture, and industry. Yet, high industrialization, urbanization, and population increase have led to water quality degradation through contamination with physicochemical pollutants as well as heavy metals. Water samples were obtained from different sources in the Porur area of Chennai, Tamil Nadu, such as effluent water, Porur Lake, a municipal treatment plant, and packaged drinking water. Physicochemical parameters such as temperature, pH, electrical conductivity (EC), total dissolved solids (TDS), turbidity, total alkalinity, total hardness, and biochemical oxygen demand (BOD) were examined as per the Bureau of Indian Standards (BIS) guidelines. The heavy metals, arsenic (As) and lead (Pb), were measured by Atomic Absorption Spectroscopy (AAS), whereas sodium (Na⁺) and potassium (K⁺) were analyzed by flame photometry. Some of the effluent and lake water samples had values higher than permissible limits for TDS, hardness, alkalinity, and turbidity, pointing towards high mineralization and pollution. Heavy metals were found in a few samples, which carry possible health risks. Packaged water samples had safe values for all other parameters. The results highlight the critical necessity for ongoing water quality monitoring, strict regulation compliance, and efficient treatment processes to maintain the potability of water.

KEYWORDS: Water quality, physicochemical parameters, Heavy metals, Atomic Absorption Spectroscopy, Flame photometry, Water Quality Index (WQI).

INTRODUCTION

Water surrounds about 71% of the planet and is crucial for human sustenance, agriculture, industry, and environmental sustainability^[1,2]. Access to safe drinking water has been identified as an inherent right of the human being; yet about 1.1 billion people worldwide do not have access to clean water, which leads to millions of cases of waterborne diseases annually. The World Health Organization (WHO) accounts for almost 80% of human ailments as the consequence of unsafe water^[3]. Accelerating industrialization, urbanization, population expansion, and climatic change have augmented water resource pressure, and therefore water quality assessment becomes vital^[4].

The quality of drinking water is ascertained by assessing different physicochemical parameters, such as temperature (thermal status of water), pH (acid-base status), electrical conductivity (EC) (ion level), turbidity (suspended matter), total dissolved solids (TDS) and total suspended solids (TSS), total alkalinity (acid-neutralizing capacity), total hardness (calcium and magnesium salts), and biochemical oxygen demand (BOD) (organic load)^[5,6]. When water quality parameters rise above permissible limits prescribed by the World Health Organization (WHO), the Bureau of Indian Standards (BIS), or the National Drinking Water Quality Standards (NDWQS), they may present considerable health hazards^[3].

Heavy metal contamination is of particular concern, as elements such as arsenic (As), lead (Pb), and mercury (Hg) are toxic, persistent in the environment, and known to accumulate in living systems^[7,8]. To evaluate these contaminants accurately, analytical tools such as Atomic Absorption Spectroscopy (AAS) and flame photometry are commonly employed. These methods are also valuable for detecting trace levels of essential ions, including potassium (K⁺) and sodium (Na⁺), in water samples^[9].

The focus of the present study is to analyze and compare both the physical and chemical characteristics of water from various sources in the Porur region of Chennai, Tamil Nadu. The purpose is to determine whether these samples comply with BIS standards and thereby assess their safety and suitability for human use^[10].

MATERIALS AND METHODS

Study Area and Sample Collection

Water samples were also obtained from various sources in the Porur locality of Chennai, Tamil Nadu and designated as MQ (Milli-Q water), KW (Kovur water), IW (Iyyappanthangal water), BW (Brand water), EWF (Effluent water, Filtered), EWPF (Effluent, Pre-Filter), PLWF (Porur Lake Water Front), and PLWB (Porur Lake Water Back). Collection was carried out in clean, sterilized polyethylene containers. Samples were transported to the laboratory in controlled conditions to avoid contamination.

Physicochemical Analysis

Temperature

Temperature was measured by immersing a calibrated thermometer to a depth of 10 cm in the sample and taking three readings to ensure stability. Results were averaged ^[11].

pH

pH was measured using a calibrated pH meter. Samples were stirred and stabilized for one hour before measurement. The pH values were compared with BIS (10500:2012) and WHO (2017) drinking water guidelines ^[12, 13].

Electrical Conductivity (EC)

EC was measured using a conductivity meter with automatic temperature compensation. The probe was rinsed with distilled water before each measurement. Values are indicative of ionic content in water ^[12].

Total Dissolved Solids (TDS)

TDS was determined by gravimetric analysis. Known volumes of filtered water were evaporated, and the residual mass was calculated to quantify TDS in mg/L ^[14].

Turbidity

Turbidity was measured in Formazin Turbidity Units (FTU) using a Nephelometric Turbidity Meter, calibrated with formazin standard solutions. FTUs correlate closely with NTU as per ISO 7027 standards ^[15].

Chemical Analysis

Total Alkalinity

Alkalinity was determined by titration using 0.02N HCl and methyl orange indicator. Calculations were based on the volume of titrant consumed until the endpoint colour change ^[16].

Total Hardness

Total hardness was determined by complexometric titration with EDTA, using Eriochrome Black T as the indicator. The titrations were carried out at approximately pH 10, maintained with an ammonia buffer. Results were expressed in terms of milligrams per liter of CaCO₃ ^[16].

Biochemical Oxygen Demand (BOD)

BOD was measured using the three-day incubation method at 27 °C. Seed inoculation was carried out, and dilution water prepared with buffer salts was used for the tests. Dissolved oxygen (DO) before and after incubation was estimated through the iodometric titration method ^[17].

Flame Photometry

Flame photometry was used to quantify sodium (Na⁺) and potassium (K⁺) concentrations. Standard calibration curves were prepared and applied for accurate measurement ^[18].

Atomic Absorption Spectroscopy

AAS was employed for the determination of heavy metals, specifically arsenic (As) and lead (Pb). Sample solutions were filtered prior to analysis, and calibration was performed using standard solutions to ensure accuracy ^[16].

Standards and Compliance

The results obtained were compared with the permissible limits recommended by the World Health Organization (WHO), the Bureau of Indian Standards (BIS), and the National Drinking Water Quality Standards (NDWQS) to assess compliance and safety of the samples.

Results and Discussion

The physicochemical characteristics of certain samples of water collected around Porur in Chennai were analyzed. Values for various sources of samples of water revealed marked differences in their physicochemical values. These are given in a tabulated form in later sections while comparing with predefined standards defined by World Health Organization (WHO) as well as Bureau of Indian Standards (BIS 10500:2012).

Temperature

The range in water sample temperature varied between 26°C and 27°C with a negligible variation between sources (Table 1, Figure 1). MQ and BW had 26°C in their samples while all other sources had 27°C in their samples such as KW, IW,

EWF1, EWF2, EWPF, PLWF, and PLWB. These are within a plausible range for ambient temperature for the location and do not show any unusual thermal pollution or extraneous thermal effect.

Table 1. Temperature readings of various water samples collected from different sources in the Porur region.

Sample	Temperature (°C)
MQ	26
KW	27
IW	27
BW	26
EWF2	27
EWF1	27
EWPF	27
PLWF	27
PLWB	27

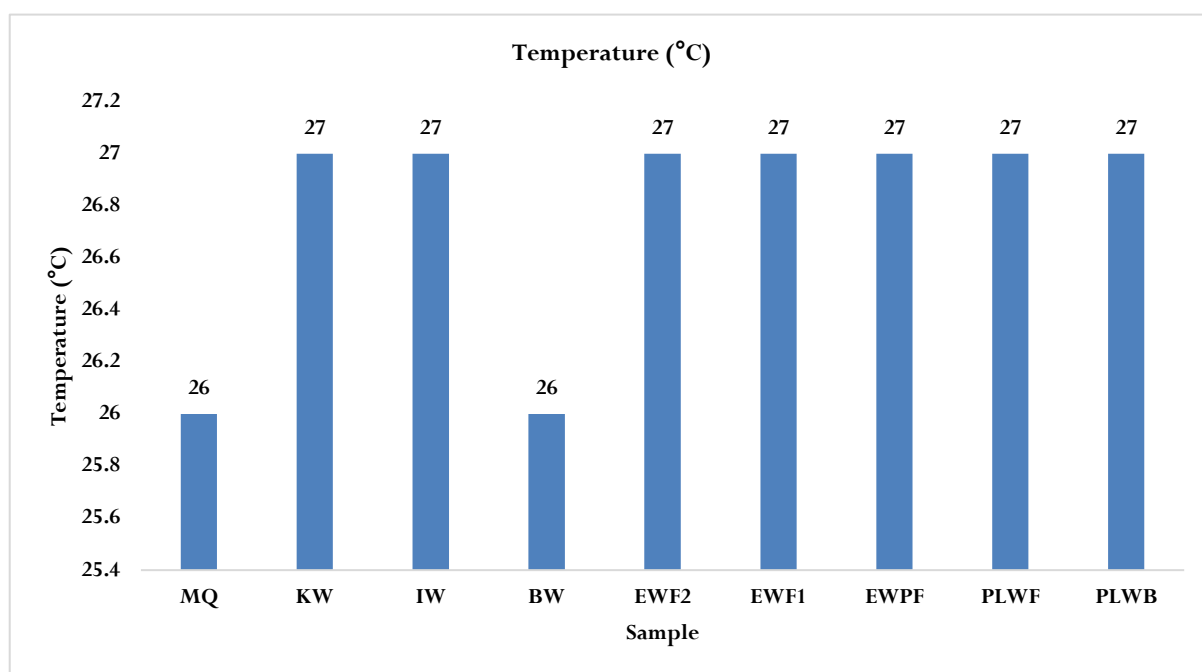


Figure 1. Temperature (°C) of different water samples

pH

pH values of the water samples are presented in Table 2 and Figure 2. IW was acidic (5.82), while highest was in EWF1 (7.57), which is weakly alkaline in nature. Packaged as well as municipal water samples like MQ (7.22), PLWF (7.50), and PLWB (7.56) were within the WHO prescribed range 6.5–8.5, which implies satisfactory quality. On the contrary, IW (5.82) was less than the allowable limit, which can explain potential contamination or industrial effect. Other samples like KW (6.52) and BW (6.59) were close to lower acceptable limit, while effluent samples (EWF1, EWF2, EWPF) had weakly alkaline pH but within safety limits.

Table 2. pH values of water samples from different sources and their comparison with WHO/BIS permissible limits.

Sample	pH
MQ	7.22
KW	6.52
IW	5.82
BW	6.59
EWF2	7.42
EWF1	7.57
EWPF	7.33
PLWF	7.50
PLWB	7.56

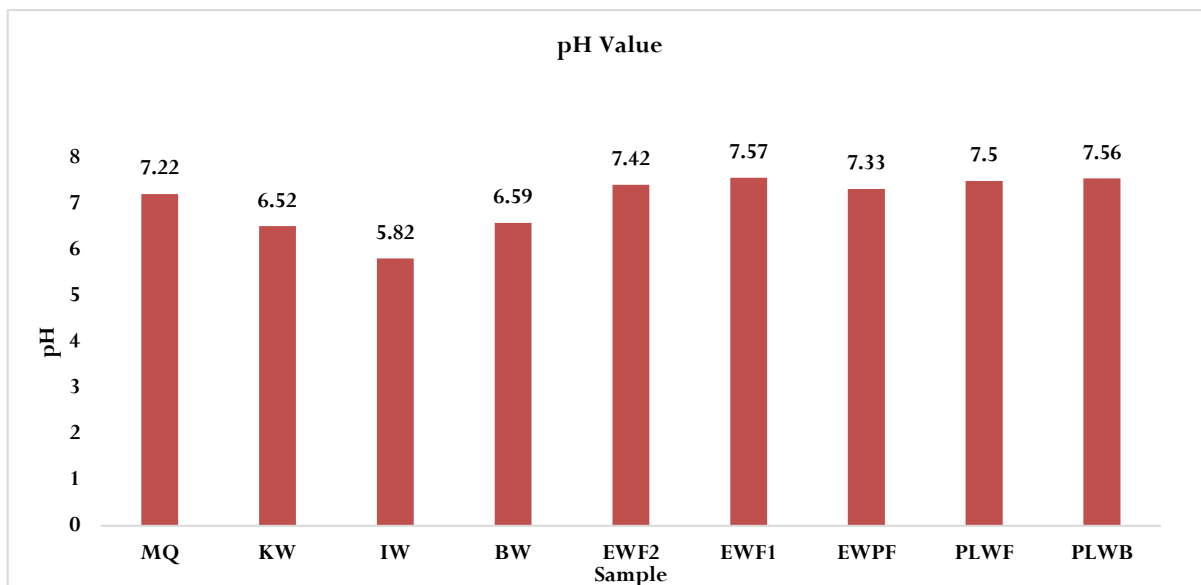


Figure 2. pH of different water samples

Electrical conductivity

The electrical conductivity (EC) of the water samples ranged from 16.4 Ω /ppm to values exceeding 190 Ω /ppm (Table 3, Figure 3). The lowest EC was recorded in MQ (16.4 Ω /ppm), indicating very low ionic content, which is typical of distilled or purified water. In contrast, BW (184.3 Ω /ppm) and KW (116.1 Ω /ppm) exhibited significantly higher EC, suggesting greater dissolved ion concentration. Industrial water (IW) showed a moderate EC of 89.8 Ω /ppm, while all effluent samples (EWF1, EWF2, EWPF) and packaged lake water samples (PLWF, PLWB) recorded values greater than 190 Ω /ppm, indicating extremely high ionic strength and possible contamination from industrial discharges or chemical residues.

Table 3. Electrical conductivity (EC) measurements of water samples, indicating ion content and mineralization levels.

Sample	EC (Ω /ppm)
MQ	16.4
KW	116.1
IW	89.8
BW	184.3
EWF2	>190
EWF1	>190
EWPF	>190
PLWF	>190
PLWB	>190

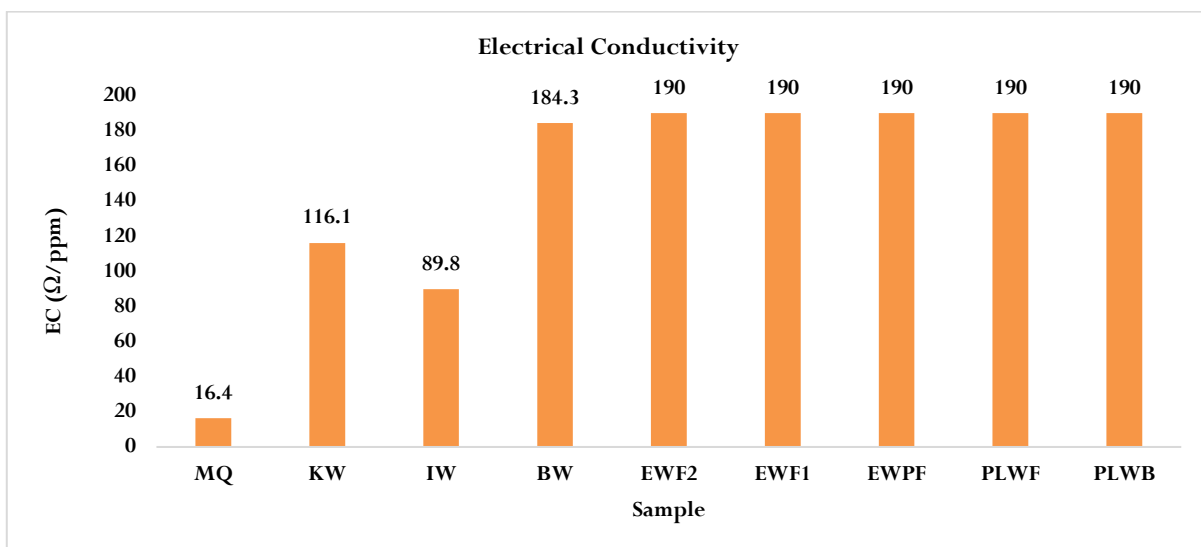


Figure 3. Electrical conductivity (Ω /ppm) of different water samples

Total Dissolved Solids (TDS)

The TDS levels of the analyzed samples (Table 4, Figure 4) showed significant variation, ranging from 40 mg/L to 1280 mg/L. The lowest TDS was recorded in KW (40 mg/L), followed by BW (80 mg/L) and IW (160 mg/L), all well within the permissible limit of 500 mg/L set by WHO. MQ (200 mg/L) also remained within the safe range for drinking water. However, effluent water samples exhibited extremely high TDS concentrations, with EWF2 (1280 mg/L) and EWF1 (1080 mg/L) exceeding the acceptable limit, indicating heavy contamination likely due to dissolved industrial salts and chemicals. EWPF and PLWF both recorded 480 mg/L, which is near the upper permissible limit, while PLWB (320 mg/L) was moderately high but within the safe range. These findings suggest that effluent sources contribute significantly to dissolved solids in the water.

Table 4. Total dissolved solids (TDS) levels in water samples were determined by gravimetric analysis, expressed in mg/L.

Sample	TDS (mg/L)
MQ	200
KW	40
IW	160
BW	80
EWF2	1280
EWF1	1080
EWPF	480
PLWF	480
PLWB	320

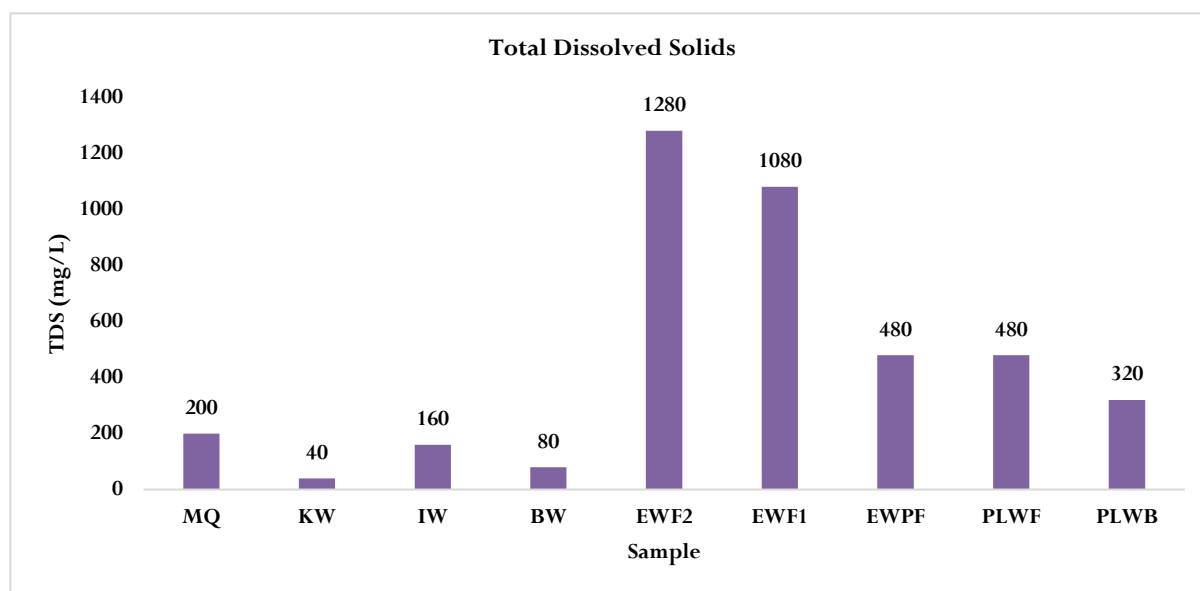


Figure 4. Total dissolved solids (mg/L) of different water samples

Turbidity

All turbidity values of the samples are presented in Table 5 and Figure 5. Measured turbidity ranged between 86 FTU (PLWF) and 98 FTU (BW) and clearly indicates that all samples greatly exceed the BIS allowable limit of 5 FTU in potable water. Even potable water supplies like BW and KW showed high levels of turbidity (96-98 FTU), signifying poor filtration or likely contamination during handling.

Effluent samples (EWF1, EWF2, EWPF) and waters of Porur Lake showed higher turbidity levels due to suspended solids, organic detritus, silt, and industrial effluents. High turbidity reduces penetration of light, adversely affecting aquatic life and increasing microbial growth possibilities. These results indicate poor quality water and possible health hazards, and hence the need for appropriate sedimentation and filtering processes before use.

Table 5. Measured turbidity levels (FTU) in water samples and comparison with permissible drinking water limits.

Sample	Turbidity (FTU)
MQ	94
KW	96
IW	95
BW	98
EWF2	96
EWF1	95
EWPF	89

PLWF	86
PLWB	94

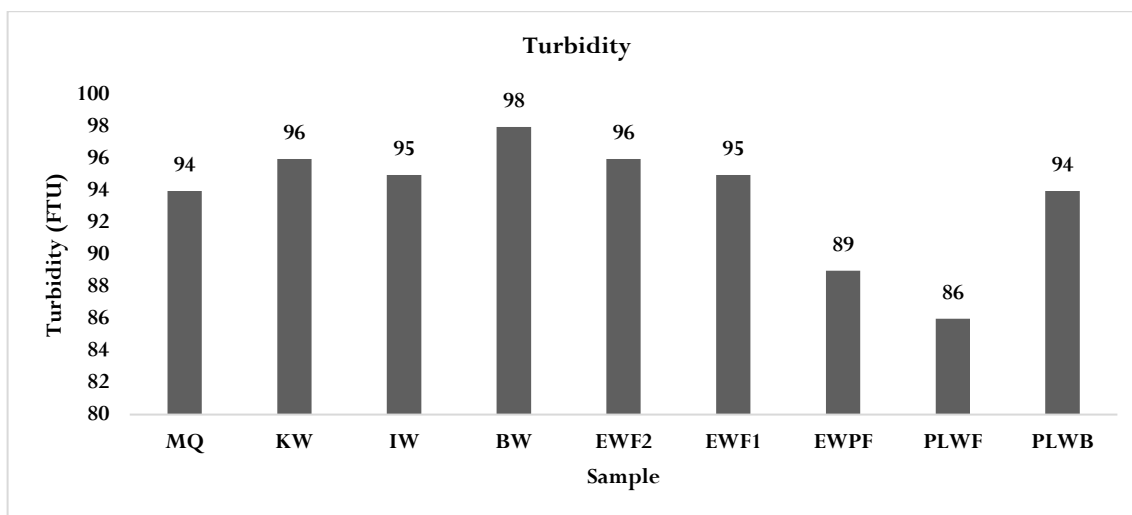


Figure 5. Turbidity levels (FTU) of different water samples

Total Alkalinity

Total alkalinity concentrations in water samples are tabulated in Table 6 and illustrated in Figure 6. MQ has minimum alkalinity (2.5 mg/L), which is anticipated owing to ultra-pure water, whereas BW has 4.5 mg/L and KW has 5.2 mg/L alkalinity concentrations that fall within BIS permissible limit of 200 mg/L for drinking applications.

Meanwhile, EWF2 18.3 mg/L, EWF1 16.5 mg/L, EWPF 10.2 mg/L, PLWF 9.8 mg/L and PLWB 11.4 mg/L showed relatively higher alkalinity levels compared to treated sources. High levels of alkalinity suggest the presence of carbonate and bicarbonate ions. They may be a resultant effect of domestic wastewater effluent discharge and the natural buffer effect within surface water bodies. Although within tolerable levels, higher levels within effluent samples and within lake samples suggest probable pollution and poor-quality waters.

Table 6. Measurement Trials and Average Readings for Water Samples

Sample	Total Alkalinity (mg/L as CaCO ₃)
MQ	2.5
KW	5.2
IW	8.1
BW	4.5
EWF2	18.3
EWF1	16.5
EWPF	10.2
PLWF	9.8
PLWB	11.4

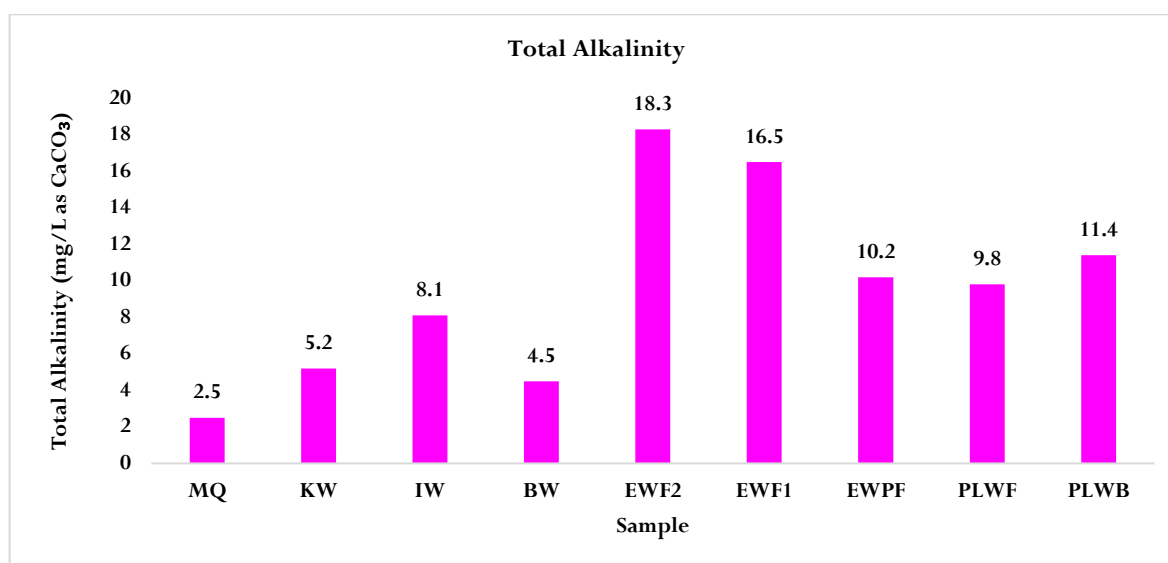


Figure 6. Total Alkalinity (mg/L as CaCO₃) of different water samples

Total Hardness

Tabulated below (Table 7) and illustrated in Figure 7 are the total hardness levels obtained for the collected water samples. MQ, KW, and BW gave lowest hardness (2.8–3.1 mg/L), which was anticipated for treated/purified mains drinking water. IW gave a higher reading (4.5 mg/L) but still within the BIS specified limit of 200 mg/L for drinking waters. Nevertheless, effluent samples (EWF2: 22.5 mg/L; EWF1: 20.0 mg/L; EWPF: 13.6 mg/L) and samples collected from Porur Lake (PLWF: 12.0 mg/L; PLWB: 15.4 mg/L) showed higher hardness compared to treated waters but within BIS limits. The presence of calcium and magnesium salts points to contamination from sources such as industrial effluents, domestic sewage, and detergent residues. While the observed concentrations may not pose immediate risks to human health when used for drinking, they are important indicators of pollution. Elevated levels can cause scaling in pipelines and reduce the effectiveness of soap and detergents in household applications.

Table 7. Two-Trial Measurement Results and Averages for Water Samples

Sample	Total Hardness (mg/L as CaCO ₃)
MQ	2.8
KW	3.1
IW	4.5
BW	3.0
EWF2	22.5
EWF1	20.0
EWPF	13.6
PLWF	12.0
PLWB	15.4

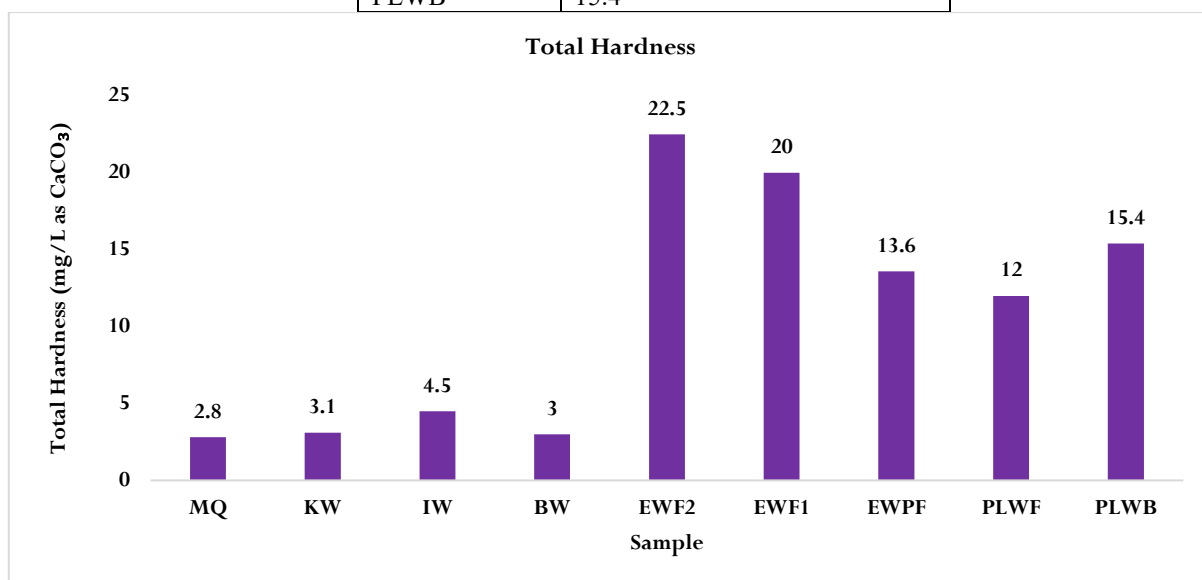


Figure 7. Total Hardness (mg/L as CaCO₃) of different water samples

Biochemical Oxygen Demand

The results of BOD measurements (Table 8, Figure 8) showed the highest concentrations at EWPF and EWF1 (6.0 mg/L each) and at EWF2 (5.5 mg/L). These elevated values point to significant organic pollution, most likely caused by sewage inflows or industrial effluents. Similarly, at PLWF (5.0 mg/L) and PLWB (4.8 mg/L), the high BOD levels suggest contributions from domestic wastewater. All of these values exceed the maximum limit of 2 mg/L prescribed by BIS for drinking water, clearly indicating high organic load and microbial activity.

The municipal supply water (MQ) produced a negative reading (−0.5 mg/L), which is almost certainly the result of instrument or analytical error, since pure water is not expected to show any BOD. In contrast, bore well water (BW) and packaged drinking water (KW) recorded values of about 1.0 mg/L, which remain well within acceptable limits.

Taken together, the higher BOD in effluent and lake samples aligns with other poor-quality indicators such as high turbidity, hardness, and total dissolved solids. These conditions show that such water is heavily degraded and may pose both environmental and public health risks.

Table 8. Biochemical oxygen demand (BOD) values measured after 3 days of incubation at 27°C for selected water samples.

Sample	BOD (mg/L)
MQ	-0.5
KW	1.0
IW	1.2

BW	1.0
EWF2	5.5
EWF1	6.0
EWPF	6.0
PLWF	5.0
PLWB	4.8

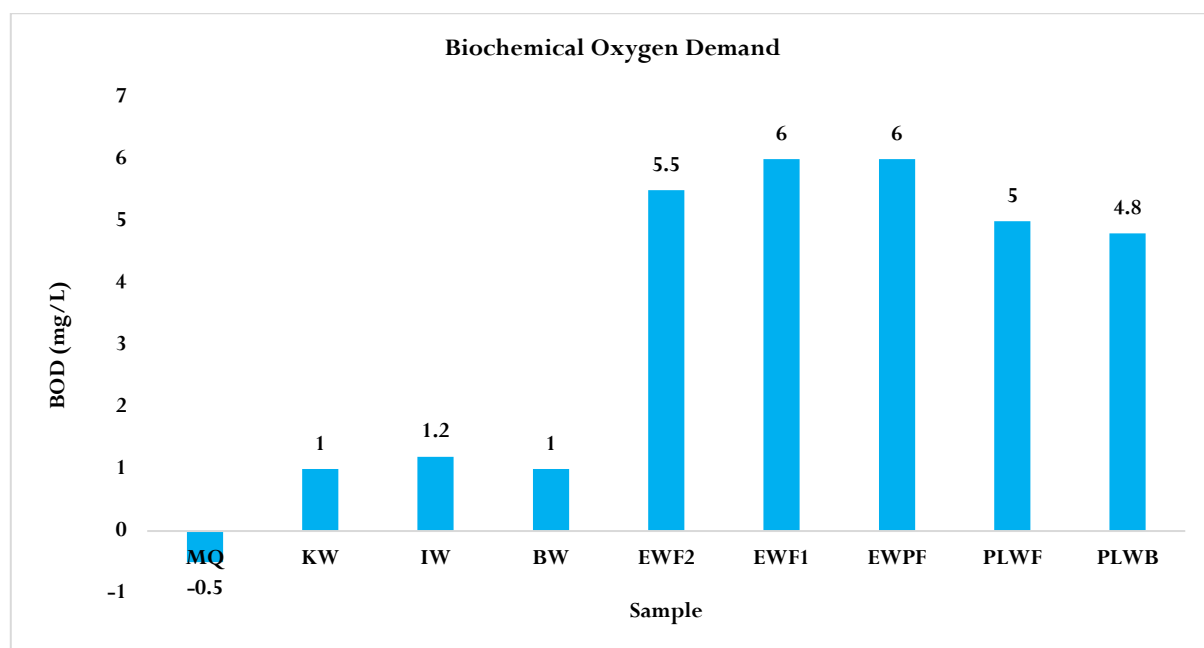


Figure 8. Bio-chemical Oxygen Demand(mg/L) of different water samples

Atomic Absorption Spectroscopy

Qualitative analysis verified the occurrence of lead (Pb) and arsenic (As) in selected samples. Pb was present in EWPF, PLWF, and PLWB, and As was present in MQ, KW, and EWPF, suggesting localized contamination due to industrial effluent inputs, geogenic sources, or pipe corrosion. Although qualitative, identification of these metals presents a cause for concern since even trace concentrations exceed WHO's allowable limit of 0.01 mg/L and carry serious hazards to human health. Pb exposure can lead to neurological and renal injuries, while exposure to As has been associated with cancer, cardiovascular diseases, and skin lesions. Bio-detection in effluent and lake waters suggests a need to monitor and treat these waters regularly.

Table 9. Samples with Detectable Presence of Lead and Arsenic

Element	Samples with Detectable Presence
Pb	EWPF, PLWF, PLWB
As	MQ, KW, EWPF

Flame Photometry

Flame photometry was employed to check sodium and potassium concentrations. Sodium (Na^+) levels were between 0.62 mg/L in MQ and 185.6 mg/L in EWPF, and potassium (K^+) levels were between 0.21 mg/L in MQ and 26.4 mg/L in EWPF (Table 10). Packaged drinking water (BW) and MQ contained within BIS limits (Na^+ : 200 mg/L, K^+ : 12 mg/L), but effluent samples (EWF1, EWF2, EWPF) and samples collected from Porur Lake (PLWF, PLWB) contained higher levels of potassium compared to safe limits. High levels of Na^+ and K^+ suggest plausible contamination due to domestic effluent, industrial effluent, and agricultural runoff. High Na^+ can cause salination and decrease potability of potable waters; however, high K^+ has an impact on human consumption and agricultural applications.

Table 10. Sodium and Potassium Concentrations in Water Samples

Sample	Na^+ (mg/L)	K^+ (mg/L)
MQ	0.62	0.21
KW	12.40	1.85
IW	18.20	2.60
BW	9.80	1.50
EWF2	172.00	24.50
EWF1	160.40	22.30
EWPF	185.60	26.40

PLWF	86.50	14.20
PLWB	79.80	12.80

CONCLUSION

The assessment of water quality across different sources in the Porur region of Chennai revealed marked variations. Samples from the lake and effluent outlets exhibited significantly higher levels of total dissolved solids, turbidity, alkalinity, hardness, and biochemical oxygen demand, often exceeding the permissible limits prescribed by WHO and BIS standards. Such findings point to serious contamination issues and raise valid concerns regarding the safety of local water resources. The detection of toxic heavy metals, including arsenic and lead, in certain samples further suggests potential long-term health risks for the local population.

In contrast, municipal supply and packaged drinking water largely complied with the regulatory standards, reflecting more effective treatment methods and consistent monitoring practices.

Overall, the results emphasize the urgent need for continuous surveillance of water quality and stringent regulatory measures in the region. Industrial discharges and poor waste management practices appear to be key contributors to the pollution observed, highlighting the importance of ensuring that wastewater is adequately treated before release into natural systems. In addition, ongoing community awareness initiatives encouraging safe water use, hygienic practices, and adherence to established quality standards will be crucial in reducing the risk of waterborne illnesses and safeguarding a sustainable supply of clean drinking water.

ACKNOWLEDGMENT

The authors would like to sincerely thank Sri Ramachandra Faculty of Pharmacy, SRIHER (DU), for their assistance with the study and for their provision of lab facilities and equipment. Special thanks to the Department of Pharmaceutical Chemistry for their provision of technical guidance and assistance with sample collection and sample analysis. Special appreciation to colleagues and lab workers for their eagerness to participate with study activities.

REFERENCES

1. Zhang K, Chang S, Tu X, Yu Y, Shang H, Wang E, Fu Q. A comprehensive study of heavy metals in centralized drinking water sources of the Yangtze River Basin: levels, sources, and probabilistic health risk. *Water*. 2024;16(23):3495.
2. Tetali RR, Salomi K, Gope ER. Analysis of water quality parameters across diverse sources. *J Pharma Insights Res*. 2024;2(3):210-6.
3. Jurczynski Y, Passos R, Campos LC. A review of the most concerning chemical contaminants in drinking water for human health. *Sustainability*. 2024;16(16):7107.
4. Rehman Hu, Munir M, Ashraf K, Fatima K, Shahab S, Ali B, et al. Heavy metals, pesticide, plasticizers contamination and risk analysis of drinking water quality in the newly developed housing societies of Gujranwala, Pakistan. *Water*. 2022;14(22):3787.
5. Namrata P. Review paper on the role of pH in water quality implications for aquatic life, human health, and environmental sustainability. *Int Adv Res J Sci Eng Technol*. 2023;10(6).
6. Sivakumar V, Ramamoorthy VL, Muthaiyan UM, Kaliyappan S, Ravindiran G, Shanmugam S, et al. Assessing groundwater quality for sustainable drinking and irrigation: a GIS-based hydro-chemical and health risk study in Kovilpatti Taluk, Tamil Nadu. *Water*. 2023;15(22):3916.
7. Ishtiaq M, Khan MJ, Khan SA, Ghani J, Ullah Z, Nawab J, et al. Potentially harmful elements and health risk assessment in groundwater of urban industrial areas. *Front Environ Sci*. 2024;12:1332965.
8. Zhang Q, Qian H, Xu P, Hou K, Yang F. Groundwater quality assessment using a new integrated-weight water quality index (IWQI) and driver analysis in the Jiaokou Irrigation District, China. *Ecotoxicol Environ Saf*. 2021;212:111992.
9. S S, C CG, P R, D DD. Long-term groundwater quality assessment and management strategies in rapidly urbanizing regions: a case study of Tiruvallur. *Pol J Environ Stud*. 2025.
10. Vijayakumar A, Kumar G, Selvakumar S. Groundwater salinization and suitability assessment in the coastal aquifer of the Thiruvallur district, India. *Water Qual Res J*. 2025;60(1):60-75.
11. Islam MA, Roy SC, Utsho MFU, et al. An IoT-enabled intelligent water quality monitoring system for tourist safety using machine learning. *Discov Electron*. 2025;2:28.
12. Raghunath KM, Khan SB, Govindarajan P, Mahesh TR, Alojail M, Gadekallu TR. Machine learning-driven intelligent water quality assessment for enhanced drinking safety and real-time consumer awareness. *Hydrol Res*. 2025;56(2):136-52.
13. World Health Organization. Guidelines for drinking-water quality. 4th ed. Geneva: World Health Organization; 2017.
14. Adjovu GE, Stephen H, James D, Ahmad S. Measurement of total dissolved solids and total suspended solids in water systems: a review of the issues, conventional, and remote sensing techniques. *Remote Sens*. 2023;15(14):3534.
15. Matos T, Martins MS, Henriques R, Gonçalves LM. A review of methods and instruments to monitor turbidity and suspended sediment concentration. *J Water Process Eng*. 2024;64:105624.
16. Bhat A, O'Hara T, Tian F, Singh B. Review of analytical techniques for arsenic detection and determination in drinking water. *Environ Sci Adv*. 2023;2:171-95.

17. Syafrudin S, Sarminingsih A, Juliani H, Budihardjo MA, Puspita AS, Mirhan SAA. Water quality monitoring system for temperature, pH, turbidity, DO, BOD, and COD parameters based on Internet of Things in the Garang Watershed. *Ecol Eng Environ Technol*. 2024;25(2):1-16.
18. Mishra VK, Sharma V, Rai RK. Application of flame photometry in environmental monitoring of water quality. *Chemosphere*. 2023;311:136757.