Assessment of Drinking Water Quality Using WQI: A Case Study of Filtration Plants in TandoJam, Pakistan

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Citation | Mehmood. F, Mashori. A. S, Nindwani. B. A, Awan. G. H, Rajput. N. A, Jafferi. G. M, Rana. U. S, "Assessment of Drinking Water Quality Using WQI: A Case Study of Filtration Plants in TandoJam, Pakistan", IJASD, Vol. 7 Issue. 3 pp 428-440, Aug 2025

Received | July 19, 2025 **Revised |** Aug 12, 2025 **Accepted |** Aug 18, 2025 **Published |** Aug 23, 2025.

Access to safe drinking water is a basic human right, yet it is increasingly at risk due to population growth and human activities—particularly in developing countries where monitoring and maintenance are often inadequate. This study evaluated the water quality of filtration plants in TandoJam city by analyzing 17 samples for parameters such as pH, EC, TDS, hardness, turbidity, potassium (K^+), sodium (Na^+), calcium (Ca^{2+}), magnesium (Mg^{2+}), bicarbonates (HCO_3^-), chloride (Cl^-), sulphates (SO_4^{2-}), nitrates (NO_3^-), fluoride, arsenic, iron, chlorine, alkalinity, total coliforms, and E. coli. The Water Quality Index (WQI) was used to classify the water as excellent, good, poor, very poor, or unsuitable. Results showed that HCO_3^- (2 samples), Cl^- (1), SO_4^{2-} (1), alkalinity (4), total coliforms (17), and E. coli (17) exceeded WHO limits. WQI values ranged from 0.25 to 35.08, indicating overall excellent to good quality and suggesting the water is generally safe for drinking. However, effective treatment—including proper screening, chlorination, and regular monitoring—is essential to ensure water safety.

Keywords: Drinking Water Quality; Water Quality Index (WQI); Physico-Chemical Parameters; Microbiological Contamination

Introduction:

The quality of drinking water has become an increasingly critical global concern, as contaminated water poses severe threats to public health, environmental sustainability, and economic development [1]. At present, approximately two billion individuals—around 26% of the world's population do not have access to safe drinking water, while nearly 771 million remain without even essential water services [2]. Clean and safe drinking water is a basic human right; however, countless individuals globally continue to depend on polluted water sources, resulting in serious health consequences. The World Health Organization (WHO) stresses that potable water must be free from harmful physical, chemical, and microbiological pollutants to avoid waterborne illnesses [3].

Numerous research efforts worldwide have assessed water quality in relation to international drinking water standards and guidelines. Yazici-Karabulut, et al. [4] applied the entropy-weighted water quality index (EWQI) to analyze bottled water and revealed that even commercially available products may fail to fully meet established safety standards. Similarly, Al-Shammary and Al-Mayyahi [5] analyzed groundwater quality in Iraq using water quality indices and highlighted significant contamination issues, particularly due to agricultural and industrial runoff. These studies emphasize the importance of regular monitoring and strict regulatory frameworks to maintain water safety.

In Pakistan, water contamination is a major public health concern, with reports indicating high levels of microbial and chemical pollutants in drinking water sources. Approximately 80% of Pakistan's population is compelled to consume contaminated water, leading to widespread health issues, including malnutrition and waterborne diseases [6]. About 40% of the population depends on surface water sources—such as rivers, streams, and canals—for drinking purposes, while the remaining 60% relies on underground water reserves to meet their consumption needs [7][8]. Like many other developing nations, Pakistan is grappling with a severe water crisis that encompasses both quality and availability. The need for clean drinking water is increasing rapidly, primarily due to population growth and evolving living conditions [9]. However, in many developing countries, including Pakistan, water treatment facilities often fail to meet international standards, resulting in compromised water quality. Filtration plants are designed to remove impurities and make water safe for consumption, but their effectiveness varies due to inconsistent maintenance, outdated technology, and external environmental factors. Therefore, assessing the drinking water supplied by filtration facilities is essential for safeguarding public health and encouraging environmental sustainability.

Groundwater extraction in Pakistan predominantly relies on privately operated tube wells and pumps [10]. The quality of drinking water in Pakistan is rapidly declining due to the presence of hazardous pollutants. Major contaminants include toxic heavy metals such as lead, arsenic, cadmium, and iron; pesticide residues; and pathogenic microorganisms, including Escherichia coli, total coliforms, and fecal coliforms. Furthermore, increased concentrations of fluoride and nitrate in specific regions are exacerbating the issue [11]. These contaminants pose a serious public health risk, highlighting the need for better water management. Research indicates that Pakistan's drinking water sources are widely contaminated with microbes—such as fecal coliforms, total coliforms, and Escherichia coli—as well as heavy metals like iron, arsenic, nickel, and mercury, along with pesticide residues [12]. In recent years, the country has witnessed a sharp rise in waterborne diseases, especially among children, including diarrhea, typhoid, hepatitis, dysentery, intestinal worms, and giardiasis. This alarming trend highlights the urgent need to address water quality issues to safeguard public health [13].

Tandojam, a semi-urban city in Sindh, Pakistan, relies on filtration plants for clean drinking water. However, the extent to which these facilities meet international water quality standards remains uncertain. In areas with underdeveloped water infrastructure, such as Tandojam, ensuring safe drinking water poses a significant challenge, contributing to public health risks, including diarrhea, typhoid, and hepatitis. This study examines the quality of drinking water specific filtration plants in Tandojam and compares the results with international guidelines to determine their performance.

Objectives and Novelty Statement of the Study:

This study is novel in focusing on semi-urban filtration plants in TandoJam, Sindh. It provides a comprehensive multi-parameter assessment covering physical, chemical, and biological indicators. By applying the Water Quality Index (WQI), the work translates complex data into a clear and practical classification for decision-makers. Importantly, the detection of E. coli and total coliforms in all samples reveals critical treatment failures despite filtration systems. The main aim of the study was to analyze the drinking water quality of selected filtration plants and to evaluate the suitability of the water samples using the Water Quality Index (WQI).

Materials and Methods:

Study Area:

The study was conducted in Tandojam, Sindh, Pakistan, located at 25°25'40"N and 68°31'40"E, at an elevation of 23 meters above sea level. The study area and sampling locations are shown in Figure 1.

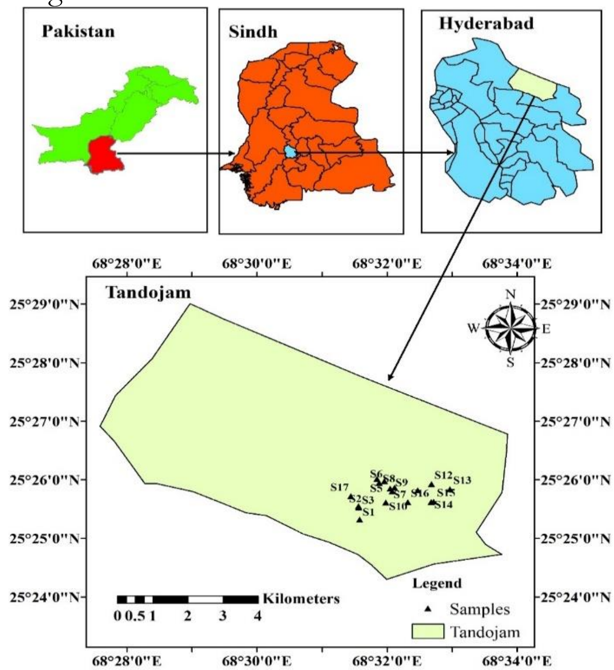

Figure 1. Map showing the study area and sampling sites

Table 1. Sample ID, name, and coordinates of the sampling locations

S. NO	Sample ID	Name	Longitude (N) Degrees	Latitude (E) Degrees
1	S1	Muhammad RO plant	25.42196	68.52626
2	S2	Tariq RO plant, Near Wadra	25.42538	68.52608
3	S3	Jiddat RO plant, Nadra Office	25.4258	68.52599
4	S4	Khalil Ahmed RO plant Near Phatak Muzaffarabad	25.4329	68.53263
5	S5	Latif RO plant	25.43355	68.53072
6	S6	Taj Muhammad RO plant, Muzaffarabad	25.4324	68.53127
7	S7	Hafiz Mirani RO plant Al-Madina colony	25.43081	68.53411
8	S8	Qasim RO plant	25.43106	68.53527
9	S9	Al. Khidmat RO plant	25.42991	68.53461
10	S10	Bilal filter plant, WAPDA Colony	25.42686	68.53302
11	S11	Meppil farm colony RO plant	25.43029	68.54115
12	S12	Farm colony RO plant	25.43206	68.54468
13	S13	DVM RO plant	25.43056	68.54943
14	S14	Hostel RO plant	25.42697	68.54466
15	S15	Qazi Hostel RO plant	25.42705	68.54529
16	S16	SAU Filtration plant in front of the CPD faculty	25.42694	68.5386
17	S17	Sunny RO plant, Mir colony	25.42861	68.52400

Water Sample Collection and Water Quality Evaluation:

Water samples were collected for both physicochemical and bacteriological analyses using sterile 1-liter polyethylene bottles from the outlet of a treatment facility in November 2024. Samples were then collected by holding the bottles steadily under the water stream, with the caps positioned downward to minimize external contamination. Samples were sealed, labeled, and transported in an icebox maintained at 4 ℃ to the Water and Sanitation Agency (WASA) laboratory in Hyderabad, where they were analyzed within 24 hours of collection. In the laboratory, groundwater samples were analyzed for different water quality parameters (pH, EC, TDS, total hardness, turbidity, K^+, Na^+, Fe^{2+}, Ca^{2+}, Mg^{2+}, HCO_3^-, Cl^-, SO_4^{2-}, NO_3^-, alkalinity, fluoride, arsenic, chlorine, total coliform, and E. coli) for drinking purposes. The detailed methodology of the study is illustrated in Figure 2. The detailed procedure for the analysis is presented in Table 2. The water quality parameters were analyzed using standard laboratory methods of the American Public Health Association, 22nd edition [14]. All analyses were performed in triplicate, and average values were reported to minimize analytical error. In addition, reagent blanks and standard calibration were used to ensure the accuracy and reliability of the results. Results of all water quality parameters of different groundwater samples were compared with permissible limits recommended by the World Health Organization [15] for safe drinking water utilization.

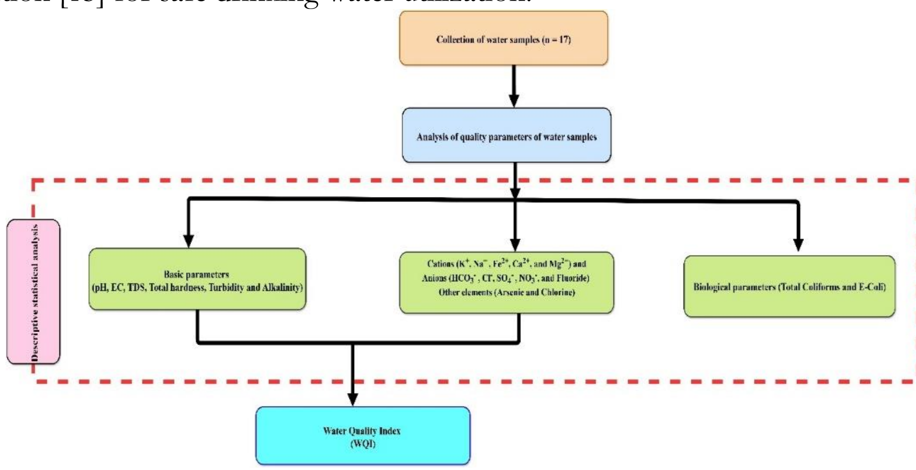

Figure 2. Layout of detailed methodology

Table 2. Analytical methods employed

S. No	Parameter	Unit	Method
1	pH	-	pH meter
2	Electrical conductivity (EC)	µS/cm	EC meter
3	Total dissolved solids (TDS)	mg/L	TDS meter
4	Total hardness	mg/L	Spectrophotometer
5	Turbidity	Nephelometric Turbidity Unit (NTU)	Nephelometric method using a Turbidity meter
6	Potassium (K^+)	mg/L	Flame photometer
7	Sodium (Na^+)	mg/L	Flame photometer
8	Iron (Fe^{2+})	mg/L	Atomic absorption spectrophotometer
9	Calcium (Ca^{2+})	mg/L	Titration method
10	Magnesium (Mg^{2+})	mg/L	Titration method
11	Bicarbonate (HCO_3^-)	mg/L	Acid titration
12	Chloride (Cl^-)	mg/L	Titration method
13	Sulphate (SO_4^{2-})	mg/L	Turbidity method
14	Nitrate (NO_3^-)	mg/L	Spectrophotometer
15	Alkalinity	mg/L	Titrimetric method

16	Fluoride	mg/L	Spectrophotometer
17	Arsenic	mg/L	Atomic absorption spectrophotometer
18	Chlorine	mg/L	Titration method
19	Total coliform	Colony-forming unit (cfu)	Membrane filtration method
20	E-Coli	Colony-forming unit (cfu)	Membrane filtration method

Water Quality Index:

The Water Quality Index (WQI) is an important instrument for evaluating the overall status of water. The index simplifies complex datasets by integrating multiple water quality parameters into a single composite score. This approach offers a concise representation of overall water quality, thereby supporting decision-makers and relevant authorities in effective environmental monitoring and management. The WQI was developed and computed by following the equations [16].

Water quality rating or sub-index (qn) was calculated by following equation (1).

$$qn = 100\left(\frac{Vn - Vi}{Sn - Vi}\right) (1)$$

Where Vn is the estimated value, Vi is the ideal value, and Sn is the standard value.

Unit weight (Wn) was calculated by the following equation (2).

$$Wn = \frac{K}{Sn} (2)$$

Where K is the proportionality constant, and Sn represents the standard/reference value.

The Water Quality Index (WQI) was determined using the following equation (3).

$$WQI = \sum qnwn / \sum wn \ (3)$$

The ideal values for all water quality parameters are assumed to be zero, except for pH, which is considered optimal at 7. The calculated WQI values are classified into five categories: excellent (<25), good (25–50), poor (50–75), very poor (75–100), and unsuitable for drinking (>100) [17].

Results:

Hydro Chemical Assessment:

Figure 3 illustrates the examination of important water quality indicators, such as pH, electrical conductivity (EC), total dissolved solids (TDS), hardness, and turbidity among 17 water samples (S1–S17). The pH levels ranged from 6.3 to 7.7, averaging 7.16, and except for sample S11 (6.3), all values were within the WHO-recommended range of 6.5–8.5 (Figure 3a), indicating that the water was generally neutral to slightly alkaline. Electrical conductivity (EC) varied between 62 and 1017 µS/cm, with a mean of 419.88 µS/cm (Figure 3b). TDS ranged from 39 to 789 mg/L, with an average of 327 mg/L (Figure 3c), and although all samples were within the WHO limit of 1000 mg/L, samples S15 and S16 showed comparatively higher concentrations at 633 mg/L and 789 mg/L, respectively. Hardness ranged from 30 to 300 mg/L, with an average of 104.88 mg/L (Figure 3d), remaining below the WHO threshold of 300 mg/L in most cases, except for S16, which reached the limit. Turbidity levels were between 1.0 and 2.0 NTU, with a mean value of 1.53 NTU (Figure 3e). All samples complied with the WHO guideline of 5 NTU, ensuring acceptable clarity.

Figure 4 illustrates the concentrations of cations (K^+, Na^+, Fe^{2+}, Ca^{2+}, and Mg^{2+}) in water samples S1 to S17. Potassium (K^+) levels ranged from 0.6 to 8.9 mg/L, averaging 3.19 mg/L (Figure 4a), with all values below the WHO limit of 12 mg/L; the highest concentration was observed in sample S17. Sodium (Na^+) ranged from 19 to 88 mg/L, with a mean of 50.59 mg/L (Figure 4b), remaining well under the WHO limit of 200 mg/L. Iron (Fe^{2+}) levels varied from 0 to 0.1 mg/L, averaging 0.04 mg/L (Figure 4c), all within the acceptable WHO guideline of 0.3 mg/L. Calcium (Ca^{2+}) ranged from 8 to 100 mg/L, with an average of 40.76 mg/L (Figure 4d), and all samples stayed below the WHO threshold of 150 mg/L. Magnesium (Mg^{2+}) levels were between 0 and 14.5 mg/L, with an average of 5.14 mg/L (Figure 4e), also remaining well within the WHO recommended limit of 100 mg/L.

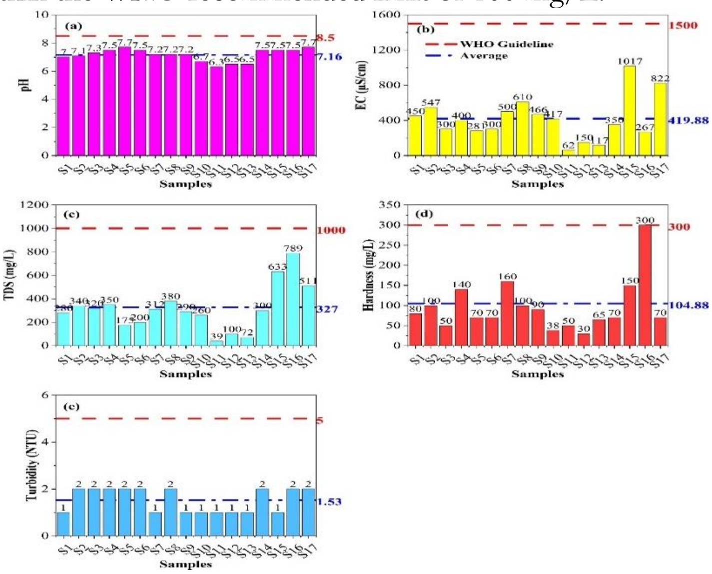

Figure 3. Concentrations of pH (a), electrical conductivity (EC) (b), total dissolved solids (TDS) (c), Hardness (d), and Turbidity (e) of samples

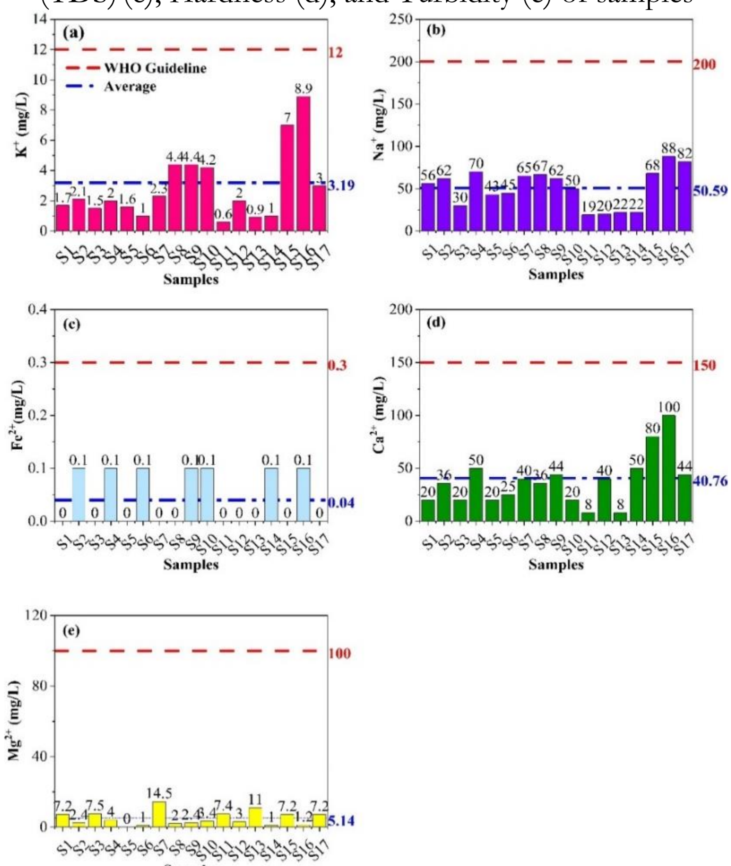

Figure 4. Concentrations of potassium (K^{+}) (a), sodium (Na^{+}) (b), iron ($Fe2^{+}$) (c), calcium (Ca^{2+}) (d), and magnesium (Mg^{2+}) of samples

Figure 5 illustrates the concentrations of anions (HCO_3^-, Cl^-, SO_4^{2-}, and NO_3^-) across water samples S1 to S17. Bicarbonate (HCO_3^-) levels ranged from 50 to 500 mg/L, with an average of 171.76 mg/L (Figure 5a); samples S15 (350 mg/L) and S16 (500 mg/L) exceeded the WHO recommended limit of 300 mg/L. Chloride (Cl^-) levels ranged from 40 to 250 mg/L, averaging 110.24 mg/L (Figure 5b); all samples complied with the WHO limit of 250 mg/L, except S17, which was exactly at the threshold. Sulfate (SO_4^{2-}) concentrations varied from 2 to 424 mg/L, with a mean value of 81.76 mg/L (Figure 5c); most samples remained within WHO standards, apart from S17, which showed a notably high level of 424 mg/L. Nitrate (NO_3^-) levels ranged between 0 and 5.4 mg/L, with an average of 1.78 mg/L (Figure 5d), and all samples were well below the WHO guideline of 10 mg/L.

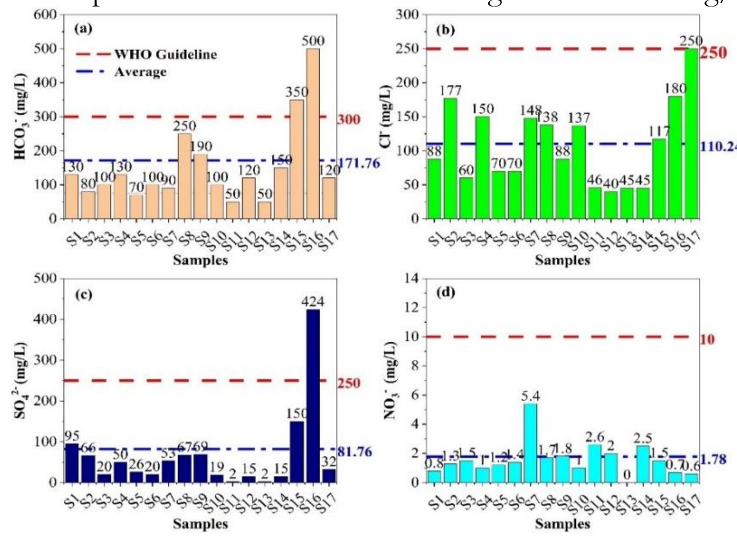

Figure 5. Concentrations of bicarbonates (HCO_3^-) (a), chloride (Cl^-) (b), sulphate (SO_4^{2-}) (c), and nitrate (NO_3^-) (d) of samples

Table 3 presents the analysis of 17 water samples (S1–S17) for parameters such as alkalinity, fluoride, arsenic, chlorine, total coliforms, and E. coli. Alkalinity values ranged from 76.10 to 560.50 mg/L, averaging 220.32 mg/L, with four samples (S7, S14, S15, and S16) exceeding the WHO-recommended limits for drinking water, while fluoride, arsenic, and chlorine were not detected in any sample.

Table 3. Concentration of alkalinity, Fluoride, Arsenic, Chlorine, Total Coliforms, and E. coli in the samples

S. No	Samples	Alkalinity (mg/L)	Fluoride (mg/L)	Arsenic (mg/L)	Chlorine (mg/L)
1	S1	160.14	0	0	0
2	S2	200.18	0	0	0
3	S3	200.18	0	0	0
4	S4	200.18	0	0	0
5	S5	100.10	0	0	0
6	S6	200.18	0	0	0
7	S7	320.29	0	0	0
8	S8	200.18	0	0	0
9	S9	180.16	0	0	0
10	S10	76.10	0	0	0
11	S11	100.10	0	0	0
12	S12	100.10	0	0	0
13	S13	130.12	0	0	0
14	S14	300.27	0	0	0
15	S15	300.27	0	0	0

16	S16	560.50	0	0	0
17	S17	140.13	0	0	0
Average		220.32	0	0	0
WHO guideline		300 mg/L	1.5 mg/L	0.01 mg/L	5 mg/L

Bacteriological Assessment:

Table 4 illustrates the bacteriological concatenation of samples. The microbiological contamination (total coliforms and E. coli) is consistently in excess across all samples.

Table 4. Total Coliforms and E. coli in the water samples

S. No	Samples	Total Coliforms (cfu/100 ml)	E. Coli (cfu/100 ml)
1	S1	Excess	Excess
2	S2	Excess	Excess
3	S3	Excess	Excess
4	S4	Excess	Excess
5	S5	Excess	Excess
6	S6	Excess	Excess
7	S7	Excess	Excess
8	S8	Excess	Excess
9	S9	Excess	Excess
10	S10	Excess	Excess
11	S11	Excess	Excess
12	S12	Excess	Excess
13	S13	Excess	Excess
14	S14	Excess	Excess
15	S15	Excess	Excess
16	S16	Excess	Excess
17	S17	Excess	Excess
WHO guideline		0/100 ml	0/100 ml

Note: cfu indicates colony-forming unit

Water quality index (WQI):

Based on the results, WQI of samples S1, S3, S5, S7, S8, S11, S12, S13, S15, and S17 were classified as excellent, while S2, S4, S6, S9, S10, S14, and S16 were rated as good (Figure 6).

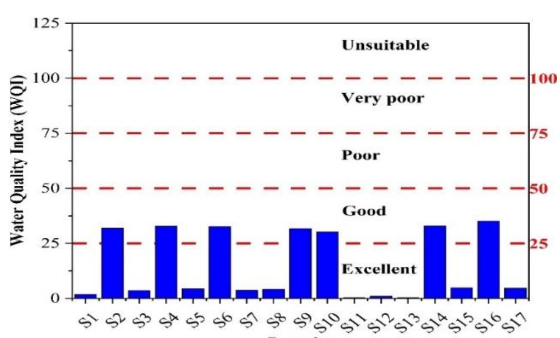

Figure 6. Water quality index (WQI) of different samples in the study area

Discussion:

Physicochemical Water Quality:

pH:

pH values ranged from 6.3 to 7.7, with all samples within the WHO [3] permissible range except S11, which showed slightly acidic conditions. Samples S10-S13 are regarded as lightly acidic. The low pH in some samples may be linked to alum use in treatment [18], while overall values indicate no major risk to water safety. An excessive dose of aluminum sulfate ($Al_2(SO_4)_3$) can reduce the pH of water. When the pH falls below 6.5, it can promote pipe corrosion, while values above 8.5 hinder effective disinfection.

Electrical Conductivity:

Electrical conductivity (EC) values were within permissible limits except in S17, where elevated EC suggests higher dissolved salts, likely from saline aquifers or agricultural inputs, and may also be associated with the use of coagulants and disinfectants added to reduce turbidity [19][20]. Additionally, it indicates localized salinity issues [21][3] in water samples.

Total Dissolved Solids:

In this study, total dissolved solids (TDS) levels in the water samples ranged from 39 to 789 mg/L, all of which were within acceptable limits. Although elevated TDS can impart a salty taste that affects palatability and may pose health risks to living organisms, the recorded values remain below harmful thresholds.

Total Hardness:

All samples, except S16, had total hardness levels within the WHO permissible limit. The elevated hardness in S16 likely reflects interaction with calcareous or gypsum-rich formations. While not a direct health risk, excessive hardness can cause scaling in pipes and appliances, affecting household use and consumer acceptability. The hardness level of drinking water is crucial for its aesthetic appeal to consumers as well as for economic and operational factors [3].

Turbidity:

The results indicated that turbidity levels in all samples were below the WHO permissible limit of 5 NTU, suggesting minimal contamination and suitability for drinking purposes.

Bicarbonate:

Bicarbonate (HCO_3^-) levels ranged from 50 to 500 mg/L, with samples S15 and S16 exceeding the permissible drinking water limit. Elevated HCO_3^- may result from carbonate rock dissolution and can lead to scaling and taste issues, indicating localized geogenic influence in the study area. Carbonate minerals dissolve when carbon dioxide infiltrates rocks and soil, leading to the formation of HCO_3^- ions in groundwater [3].

Chloride:

Chloride (Cl^-) is an element that dissolves easily and is found in small quantities in water under typical conditions [23]. Cl^- concentrations in the study area ranged from 40 to 250 mg/L, with all values remaining well below the WHO [3] except for sample S17. Elevated chloride levels, such as in S17, could be linked to localized pollution or the intrusion of saline water, a known issue in Sindh due to over-extraction of groundwater. It can give water a salty taste and accelerate the corrosion of infrastructure.

Sulphate:

Sulfate (SO_4^{2-}) concentrations were within permissible limits in all samples except S16, which exceeded the WHO [3] guideline of 250 mg/L. Elevated SO_4^{2-} in S16 may cause taste problems and potential health effects, indicating localized contamination likely from mineral dissolution.

Nitrate:

Nitrate (NO_3^-) concentrations ranged from 0 to 5.4 mg/L, which is well below the WHO permissible limit of 10 mg/L for drinking water, indicating that nitrate contamination is not a concern in these samples. The dominant anions were present in the following decreasing order: $HCO_3^- > Cl^- > SO_4^{2-} > NO_3^-$.

Potassium:

In this study, Potassium (K^+) concentrations remained below the WHO recommended limit of 12 mg/L, with the low levels likely attributed to limited weathering of K-bearing minerals in the groundwater [24].

Sodium:

Sodium (Na^+) is often found in groundwater from the dissolution of soils and rocks, and was detected within safe limits in every sample. While not a significant health issue, concentrations exceeding 200 mg/L can impact flavor and present risks for those with high blood pressure [24].

Iron:

The iron (Fe^{2+}) concentration in all samples was within the WHO permissible limit of 0.3 mg/L. This indicates that the groundwater supplying these filtration plants is not significantly influenced by Fe^2-rich minerals. The absence of excess iron also suggests that aesthetic issues such as discoloration and metallic taste are not a concern in the study area.

Calcium:

The levels of Calcium (Ca^{2+}) in all water samples were within the WHO-recommended threshold of 150 mg/L for potable water. The Ca^{2+} primarily enters groundwater via the leaching of minerals that contain calcium into the aquifer system.

Magnesium:

Magnesium (Mg^{2+}) is a crucial element that contributes to water hardness. In the research, Mg^{2+} levels were found to be below the permissible threshold of 100 mg/L.

The K^+, Na^+, Fe^{2+}, Ca^{2+}, and Mg^{2+} values obtained in the water samples meet the standards recommended by WHO (2017). The concentration of major cations followed in the decreasing order: $Na^+ > Ca^{2+} > Mg^{2+} > K^+ > Fe^{2+}$.

Alkalinity:

Alkalinity in the study area ranged from 76.10 to 560.50 mg/L, with samples S7, S14, S15, and S16 exceeding the WHO recommended limit of 300 mg/L. These elevated levels may cause taste issues and indicate possible mineral dissolution or inadequate treatment in some filtration plants of TandoJam.

Fluoride:

Fluoride was not detected in any of the samples, indicating no risk of dental or skeletal fluorosis [3][26] from the filtration plants in TandoJam. Many studies in the literature recommend the removal of fluoride when it is present at elevated levels in groundwater [27][28][29].

Arsenic:

Arsenic concentrations in all samples were none, indicating no contamination risk in the study area.

Chlorine:

No residual chlorine was detected in any of the samples, indicating inadequate disinfection at the filtration plants. This absence increases the risk of microbial contamination during storage and distribution in TandoJam. Chlorine concentrations are consistently checked to guarantee they are adequate for eradicating pathogens and preserving water quality in the distribution system until it reaches users [30][31].

The research showed that most essential physicochemical parameters fell within the WHO's acceptable ranges for drinking water, apart from hardness, HCO_3^-, Cl^-, and SO_4^{2-}, which surpassed the allowed limits.

Bacteriological Water Quality:

All samples exceeded the WHO guideline of 0/100 mL for total coliforms and E. coli, indicating fecal contamination and potential health risks. The absence of residual chlorine and lack of regular monitoring likely contributed to this contamination. These findings highlight the urgent need for improved disinfection and consistent water quality checks in the study area's filtration plants. The elevated concentrations of total coliforms and E. coli in all water samples suggest that the water must be boiled or adequately treated at home prior to its use for domestic activities.

Water Quality Index:

The Water Quality Index (WQI) was applied to evaluate the suitability of water samples for drinking, with fifteen parameters analyzed for each sample, including pH, EC, TDS, total hardness, turbidity, alkalinity, HCO_3^-, Cl^-, SO_4^{2-}, NO_3^-, Ca^{2+}, Mg^{2+}, K^+, Na^+, and Fe^{2+} to ensure accurate calculation. WQI of samples ranged from 0.25 to 35.08. The results indicate that 10 samples were deemed excellent, whereas 7 received a good rating. In general, the results indicate that the water quality was moderately suitable for consumption.

Conclusions:

Availability of safe and inexpensive drinking water continues to be a major public health issue. The research revealed that specific parameters—hardness, HCO_3^-, Cl^-, SO_4^{2-}, total coliforms, and E. coli—surpassed WHO drinking water guidelines, although the Water Quality Index (WQI) varied from excellent to good. To enhance water quality, it is crucial to implement appropriate initial treatments (e.g., screening), efficient chlorination, and consistent monitoring and upkeep of treatment facilities. There should be an increase in public awareness about water safety. Recommended purification methods include chlorination, boiling, and solar disinfection, which are cost-effective and environmentally friendly. Subsequent studies should also examine metals, microbial content, and various physicochemical factors for a thorough evaluation of water quality.

Author Contributions: Faisal Mehmood designed and planned the research, interpreted the results, prepared the manuscript, supervised the entire study, and provided overall guidance. Uzair Saeed Rana, Ghulam Hussain Awan, and Ghulam Mustafa Jafferi collected the data and prepared the illustrations. Abdul Sattar Mashori and Barkat Ali Nindwani contributed assistance in research planning and methodology, development, and reviewing manuscripts. Nadir Ali Rajput carried out proofreading to ensure accuracy and clarity.

Conflict of Interest: The authors assert that they have no conflicts of interest to declare.

Data Availability Statement: The data can be obtained from the corresponding author upon a reasonable request.

Ethics Approval: Not applicable to this paper.

Funding Source: No funding was received for this study.

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