University of Baghdad
College of Engineering
JE
JOURNAL OF ENGINEERING

Journal of Engineering

journal homepage: www.jcoeng.edu.iq

Volume 32 Number 8 August 2026

An Integrated Evaluation of Drinking Water Quality and Environmental Planning Implications Using WQI and Exceedance Analysis: Al-Doura Water Treatment Plant, Baghdad

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ABSTRACT

The quality of drinking water is of critical importance to the health of people, especially in river-based supply systems facing the growing environmental uncertainty. Nevertheless, most of the tests are based on coarse indices like the Water Quality Index (WQI) that might fail to capture short-term surpluses and incidental degradation. This paper will provide a combined assessment of drinking water quality in the Al-Doura Water Treatment Plant, Baghdad, Iraq, which receives a direct supply of raw water from the Tigris River. WQI was used to test monthly monitoring parameters of physicochemical key parameters in raw and treated water under mean- and maximum-based exceedance analysis in relation to the World Health Organization standards from January to December 2024. The WQI of treated water (mean = 61.31) is moderate. Mean-based exceedance analysis proves that in the case of average operating conditions, all analyzed parameters are generally compliant with the guideline values. However, extreme turbidity changes in raw water have been described as one of the consistent operational stressors. The maximum-based exceedance analysis further revealed that calcium levels in treated water exceeded the WHO permissible limit by up to 28%, highlighting short-term risks and treatment constraints that remain hidden within aggregated indices, a phenomenon known as the eclipsing effect. By exposing these masked exceedances, the maximum-based approach offers a more reliable early-warning tool than WQI alone for safeguarding public health in river-dependent supply systems.

Keywords: Exceedance analysis, Temporal variability, Environmental planning, Conventional water treatment, River-dependent water supply, Al-Doura Water Treatment Plant.

1. INTRODUCTION

The need to supply drinking water has never been more urgent in light of the growing world water crisis. The existence of a demanding standard of high water quality is justified, as it

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Peer review under the responsibility of University of Baghdad.
https://doi.org/10.31026/j.eng.2026.08.05

Article received: 26/03/2026
Article revised: 03/07/2026
Article accepted: 18/07/2026
Article published: 01/08/2026

has far-reaching consequences for the health of the population, microbial health, and aquatic environments **(Alver, 2019)**. WHO statistics indicate that water pollution causes 80 % of human diseases **(WHO, 2022).** The ultimate goal of water treatment plants (WTPs) is to provide consumers with water that is free of microorganisms and is safe to drink. As no particular arrangement of treatment can be sure of full remediation in all circumstances, it is necessary to monitor and assess performance. The operational status of WTPs needs to be investigated to determine the best mechanisms for maintaining consistency and quality in the production and management of drinking water. The performance appraisal provides a more profound understanding of the design issues and improvement operations, and the inferences reached in the course of the appraisal can be used to make adjustments that support recommendations with regard to the long-term operation and design plans **(Burile and Nagarnaik, 2010).**

The release of hazardous waste into riverine systems is detrimental to the environment. Some riparian communities and agrarian stakeholders use the Tigris River as a conveniently located dumping place. The design and operation of the water treatment plant should consider, among others, the chemical, physical, and microbiological properties of the source water. Drinking water plants must react to worsening water quality in the design specifications, frequently by altering the treatment regimen, such as changing the dosage of chemicals, to satisfy the exceptions of potable water and performance targets. Delays in quality caused by algal blooms or cyanobacterial growth can lead to temporary plant closures, which can inflate capital investment and, thus, reduce consumer welfare. Thus, we need to question changes in the quality of raw water because such changes influence the effectiveness of treatment and, therefore, health risks posed by treated water **(Henry, 2013; KDHE, 2011).**

Safe and drinkable water is an issue of paramount concern to urban governance, especially in water-deprived areas like Baghdad. The Tigris River, the main source of water supply to the water treatment facilities in the city, is increasingly being exposed to an influx of municipal discharge, industrial effluents, and agricultural runoffs, which requires a strong monitoring system **(Al-Mayah et al., 2022; Khudair, 2013).** The Al-Doura Water Treatment Plant is one of the main infrastructures of the city; it serves the southern regions of the city; however, it functions in a high-variability operating environment whereby the quality of raw water often varies due to hydrological control and infrequent turbidity **(Abdullah et al., 2024; Raheem and Al-Juhaishi, 2024).** The adequate operation of such facilities presupposes a complex approach going beyond simple control over the parameters and comprehensive environmental planning, taking into account both the existing and prospective threats **(Antwi et al., 2022; Vogelmann et al., 2026).** In this respect, a water quality index has been proposed as a standardized way of converting a complicated set of physicochemical data into a single, communicable measure of general well-being **(Al-Mousawey and Abed, 2023; Ewaid et al., 2020).**

Similar climate-driven degradation of water quality in arid and semi-arid river systems has been documented elsewhere; for instance, long-term monitoring of the River Murray in Australia revealed that drought and flooding cycles substantially alter electrical conductivity, pH, and turbidity over decadal timescales **(Biswas and Mosley, 2019).** These parallels suggest that the operational challenges observed at Al-Doura are not unique to the Tigris but reflect a broader pattern affecting conventional treatment plants across water-stressed regions facing comparable hydroclimatic pressures.

Although useful, the construction of a WQI faces fundamental constraints that can undermine its reliability. The so-called eclipsing effect, or the concealment of one parameter that is out of control by the rest of the compliant parameters, is a major impediment **(Fortes et al., 2023; Mogane et al., 2023).** Their investigations of the Tigris River prove that the WQI values could change significantly between wet and dry seasons and that some WTPs, such as Al-Doura, produced water that could be considered destitute or even unfit to drink **(Al-Janabi et al., 2024; Al-Mayah et al., 2022).** Such variability explains the need to isolate certain events of episodic pollution that are likely to remain unnoticed by composite indices **(Álvarez and Müller-Eie, 2017).** Using average WQI scores as a source of information can therefore lead to a partial account of the real water-quality situation, which may put the population at risk of health issues related to toxic parameters if they are neglected **(Păun et al., 2016).**

In order to overcome these constraints, this paper proposes Exceedance Analysis as an additional measure to the traditional WQI model. Exceedance analysis assesses the frequency, magnitude, and duration of pollutant levels exceeding the local or international standards, e.g., the Iraqi drinking-water guidelines **(Al-Mousawey and Abed, 2023).** Through the examination of the surpassing of such parameters as turbidity, total dissolved solids, and sulfates, environmental planners can gain deeper insight into the hydrological mechanisms of water quality control **(Abdullah et al., 2024; Gao et al., 2025).** To illustrate, excessive levels of TDS of over 600 ppm in specific areas within Baghdad require higher interventions than generic treatment procedures **(Al-Mousawey and Abed, 2023).** This analysis combined with environmental planning, helps to create risk-based water safety plans that encourage more severe limits in terms of harmful substances **(Vogelmann et al., 2026).**

The WQI and exceedance analysis combination represents a potent diagnostic instrument for streamlining the functioning of a treatment center like Al-Doura WTP. The existing studies explain that although the plant can provide a high removal efficiency of almost 98% of turbidity, secondary parameters, including electrical conductivity and total hardness, tend to fall outside the target range **(Abdullah et al., 2024; Raheem and Al-Juhaishi, 2024).** Such data is vital to transportation and land-use planning since the urban runoff and road-trail runoff may cause the deterioration of clean water resources **(Manier and O'Donnell, 2018).** In addition, climate variability, such as shifts in precipitation and temperature, will further increase the number of surface-runoff contamination events, which may decrease the effectiveness of treatment in the following decades **(Álvarez and Müller-Eie, 2017).** The adaptive management approaches should, thus, be based on hybrid models to incorporate the indices and prediction algorithms to guarantee a stable classification and early notification **(Güneş Şen, 2025).** This study aims to provide a comprehensive analysis of the Al-Doura Water Treatment Plant by integrating WQI methodologies with in-depth exceedance analysis for the years 2024 and 2025. This research fills the gap between raw data collection and strategic environmental planning by targeting ten key physical and chemical indicators, that is, the pH, turbidity, magnesium, and sulfate parameters **(Abdullah et al., 2024).** The findings of this study can support sustainable water governance in Baghdad by providing an evidence base for water policy formulation, strengthening local water-quality management, and promoting alignment with internationally recognized drinking-water guidelines.

Finally, such a combined assessment would provide a convincing evidence base to the municipal decision-makers, as it is possible to identify the long-term plans to reduce the

land-use impacts on the critical drinking-water resources of the city **(Álvarez and Müller-Eie, 2017; Vogelmann et al., 2026).**
Considering the above, this study follows a holistic approach that combines the Water Quality Index (WQI) and the mean-based and maximum-based exceedance analysis. This approach aims to provide a more detailed evaluation of drinking water quality in the Al-Doura Water Treatment Plant and to make the water resources adaptable to management and environmentally conscious planning.

2. MATERIALS AND METHODS

2.1 Study Area Description

The Al -Doura Water Treatment Plant WTP is a conventional drinking -water plant on the southern bank of the Tigris River south of Baghdad, Iraq, which draws raw water out of the river to provide potable tap water to different districts within the capital. The plant was originally planned to have a treatment capacity of about 112,000 m^3/day, but the plant was designed to meet the rising water demand caused by the rapid rate of population increase in the metropolitan region. WTP is based on traditional treatment procedures and currently lacks the use of advanced technologies; its functioning is, therefore, highly dependent on changes in the quality of the raw water and the capacity of the available treatment units at the moment. **Fig. 1** shows the geographical location and main elements of the Al-Doura WTP utilizing a Universal Transverse Mercator (UTM) projection based on the World Geodetic System 1984 (WGS84) to allow accurate representations of the space of the plant and the underlying intake structures.

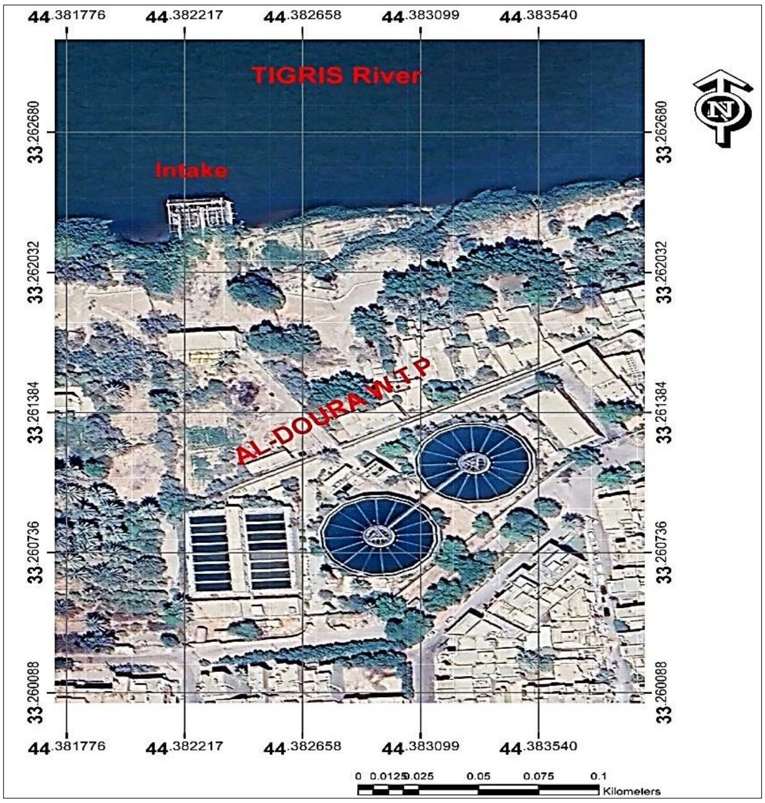

Figure 1. Geographical location and main components of Al-Doura Water Treatment Plant (WTP) on the southern bank of the Tigris River, Baghdad, Iraq (Coordinate System: **UTM, WGS84)**

The satellite view clearly shows how the plant is close to the Tigris River and where the raw-water intake is situated, which directly pulls the water out of the river. This highlights the fact that the facility relies on the quality and hydrology of the river. The layout of the treatment units, especially the main basins and clarifiers, clearly shows the traditional nature of the treatment processes of the plant. In addition, the urban footprint around the WTP site shows that it is located in a highly populated neighborhood, which makes it a strategic point of potable water source to the nearby residential neighborhoods.

2.2 Environmental Pressures and River Conditions

The Tigris River is an exclusive source of raw water to the Al-Doura Water Treatment Plant, as the river faces a range of environmental challenges in its course, specifically the upstream municipal wastewater effluents, agricultural discharges, seasonal hydrological flow changes, and increased sediment loads during high-flow events **(WHO, 2022; Uddin et al., 2021).** Such perturbations introduce significant temporal heterogeneity to the native water quality, and they serve as exogenous conditions in the environment to alter the efficacy of treatment, especially in the conventional water treatment models **(Banda and Kumarasamy, 2020; Parvez et al., 2017).** Recognizing these environmental pressures provides essential context for interpreting the observed temporal variations and exceedance events in water quality. Understanding these dynamics is also important for adaptive water-resource management, as it helps identify critical periods requiring intensified treatment interventions and supports informed decisions to maintain a safe and sustainable drinking-water supply **(WHO, 2022).**

2.3 Sampling Program and Frequency

Water quality data used in this study were obtained from the routine monthly monitoring conducted by the Al-Doura Water Treatment Plant. Sample collection was carried out by the plant's personnel during the first week of each month between January and December 2024, limiting the influence of temporary operational disturbances and providing a standard temporal representation. This monthly frequency captures seasonal changes and the effect of operations on drinking water quality, and is widely recommended for river-based drinking water systems **(WHO, 2022; Uddin et al., 2021).**

A total of twenty-four monthly records were compiled, comprising 12 influent (raw water) and 12 effluent (treated water) data points. This paired dataset allowed a comparison of water quality conditions before and after treatment, enabling an assessment of treatment performance across different source-water conditions.

2.4 Sampling Locations

Influent samples were collected from the untreated raw water that was positioned right before the grit chamber, thus indicating the quality of water that enters the treatment facility. Sampling was done on effluent samples at the end of the treatment chain, which is the disinfection and hence reflects the quality of the treated water that is to be distributed to consumers.

3. METHODOLOGY

3.1 Water Sampling and Laboratory Analysis

Laboratory measurement of the influent and effluent samples was carried out by the Al-Doura Water Treatment Plant's laboratory in accordance with the Standard Methods for the Examination of Water and Wastewater **(APHA, 2017).** According to the plant's reported methodology, pH and turbidity were measured using calibrated field instruments; total dissolved solids, total hardness, calcium, and magnesium were determined through titrimetric methods; and nitrate was determined spectrophotometrically via the cadmium reduction method **(APHA, 2017; WHO, 2022).** As these raw measurements were obtained from the plant's monthly monitoring records rather than from independent sampling and analysis by the authors, the specific analytical instrumentation and internal QA/QC procedures applied by the plant's laboratory were not disclosed and could not be independently verified. The Water Quality Index calculation, exceedance analysis, and interpretation of the results presented in this study, however, were conducted independently by the authors using the raw physicochemical values reported by the plant. The parameter suite analyzed pH, turbidity, EC, TDS, total hardness, calcium, magnesium, chloride, sulphate, and nitrate was selected because of its central role in assessing drinking water quality and treatment effectiveness **(Uddin et al., 2021; Banda and Kumarasamy, 2020).**

3.2 WHO Guideline Values

The drinking water quality guidelines were based on the World Health Organization (WHO) Guidelines on Drinking Water Quality in 2022. These values were used as the reference standards by which we assessed the water quality and used to determine the exceedance of the measured parameters. In **Table 1**, a short overview of the WHO guidelines restricted in the given study is presented.

Table 1. WHO guideline limits for drinking water parameters **(WHO, 2022)**

No.	Parameter	Unit	WHO Guideline Value	Health/Quality Significance
1	pH	–	6.5 – 8.5	Aesthetic & operational (no direct health risk within range)
2	Turbidity	NTU	≤ 5	Indicator of treatment efficiency & microbial risk
3	Electrical Conductivity (EC)	µS/cm	≤ 1500	Indicator of salinity and dissolved ions
4	Total Dissolved Solids (TDS)	mg/L	≤ 1000	Palatability & chronic effects
5	Total Hardness (as $CaCO_3$)	mg/L	≤ 500	Scaling & long-term health effects
6	Calcium (Ca^{2+})	mg/L	≤ 200	Scaling: essential nutrient
7	Magnesium (Mg^{2+})	mg/L	≤ 150	Laxative effect at high concentrations
8	Chloride (Cl^-)	mg/L	≤ 250	Taste & corrosion
9	Sulphate (SO_4^{2-})	mg/L	≤ 250	Taste; gastrointestinal effects
10	Nitrate (NO_3^-)	mg/L	≤ 50	Methemoglobinemia risk

The values of the World Health Organization (WHO) guidelines fall under the health-based limits and aesthetic or working limits. Health-based limits are established to protect the health of human beings against negative influences related to both the short-run and long-run exposure to such contaminants as nitrates and other harmful elements **(WHO, 2022).** Contrarily, aesthetic and operational limits refer to the acceptability of water, which includes taste, odor, scaling potential and water treatment performance. Such limits are normally related to the parameters of total dissolved solids, hardness, turbidity, and electrical conductivity **(WHO, 2022; Uddin et al., 2021).** When aesthetic or operational limits are overstepped, it does not automatically mean that there is an immediate health risk, but it may affect consumer acceptability or the efficiency of treatment processes. This difference was considered during the interpretation of results and the observation of adherence to drinking water quality standards.

3.3 Water Quality Index (WQI) Calculation

Although various specifications and indicators are available to evaluate the quality of water, a large number of variables are redundant when compared with the values against regulatory standards, thus allowing the results to be interpreted as compliance or non-compliance **(Al-Rikabi and Abed, 2021).**
Applications of the water quality index are usually based on a group of main physicochemical and biological parameters, including temperature, biochemical oxygen demand (BOD), fecal coliform, pH, dissolved oxygen, total phosphate, nitrate, and turbidity. They are highly accepted parameters because they represent the general conditions of water quality and have been broadly utilized in the studies of water quality assessment **(Alobaidy et al., 2010).**

$$\text{WQI} = \frac{\sum_i^n qiwi}{\sum wi} \quad (1)$$

Where qi: quality rating scale, which can be calculated by

$$\text{qi} = \frac{ci}{si} * 100 \quad (2)$$

Ci: Observed variable concentration (i)
Si: parameter(i) regular value according to WHO
The formula determines the relative weight (w)

$$\text{W} = \frac{1}{si} \quad (3)$$

The (i) variable's standard value was also inversely related to the varying weight. The relative weight (wi) can be calculated by using the following **(Alwaeli et al., 2021).**

$$\text{Wi} = \frac{w}{\sum_1^n w} \quad (4)$$

Sub-index (SI_i) and water quality index (WQI) were determined by using Eqs. (1) and (4), respectively. In this case, the parameters are represented by SI_i, which indicates the sub-index of each parameter, and q_i is the quality rating obtained from the concentration of each parameter. The value of SI_i was computed with the following equation:

SIi = wi * qi
WQI = $\sum SIi$

After that, the result was compared with WHO limitations listed in **Table 2.** WQI was used as a screening indicator rather than a standalone decision tool.

Table 2. Water quality evaluations according to WHO limitations **(WHO, 2022)**

WQI level	Ratings of water quality
91–100	Excellent
71–90	Good
51-70	Medium
26-50	Bad
0-25	Very Bad

3.4 Exceedance Analysis

The use of exceedance analysis is to measure the degree of the exceedance of the measured water quality parameters to the values of the established guidelines and, as such, provide a stringent measurement of the level of compliance with drinking water standards. This approach provides a clear and straightforward signal of the water quality decline in comparison with the health-based or working limits, which is especially relevant to modern environmental epidemiology. One area of growing popularity is the use of exceedance-based assessments, particularly to represent short-term deviations and extreme eventualities that can be difficult to capture using aggregated measures such as the Water Quality Index (WQI) **(WHO, 2022; Parvez et al., 2017).**
The exceedance percentage was calculated using the following equation:

$$\text{Exceedance (\%)} = \frac{S-C}{S} * 100 \quad (5)$$

In which C is the measured value of a specific parameter, and S is the guideline value that is proposed by the World Health Organization (WHO), the exceedance metric should be defined such that, when the measured value does not exceed the guideline (S > C), the exceedance should be given a value of zero. Such a method has been selected in many recent works, which allows the explicit quantification of the extent of violating the standards **(Uddin et al., 2021).**

S > C The Exceedance equal 0%
C > S There is an unacceptable percentage of excess.

In the current research, two different exceedance frameworks are used. Mean-based exceedance is applied to assess long-term adherence to the WHO guideline values as well as to represent the current water-quality status. On the other hand, maximum-based exceedance is used to evaluate sporadic and highly severe pollution episodes by comparing the maximum levels to the regulation levels. It is a two-pronged approach that is supported in modern drinking-water literature because it provides a solution to chronic exposure and episodic contamination concerns that mean-only measures fail to represent **(WHO, 2022; Uddin et al., 2021).**

It is of the utmost importance to focus on maximum levels since short-term situations of pollution bursts and isolated incidences of deterioration of water quality can trigger significant operational and societal problems; such instances are often overshadowed once evaluations rely solely on central values and aggregate numbers. More recent studies have demonstrated that extreme values provide the necessary information concerning the variability over time and hidden risks that WQI based classifications cannot capture **(WHO, 2022; Uddin et al., 2021).** Based on this, it is observed that the application of maximum-based exceedance analysis enhances the strength and relevance of drinking-water quality analysis in terms of public health. **Fig. 2** illustrates the workflow of the present study.

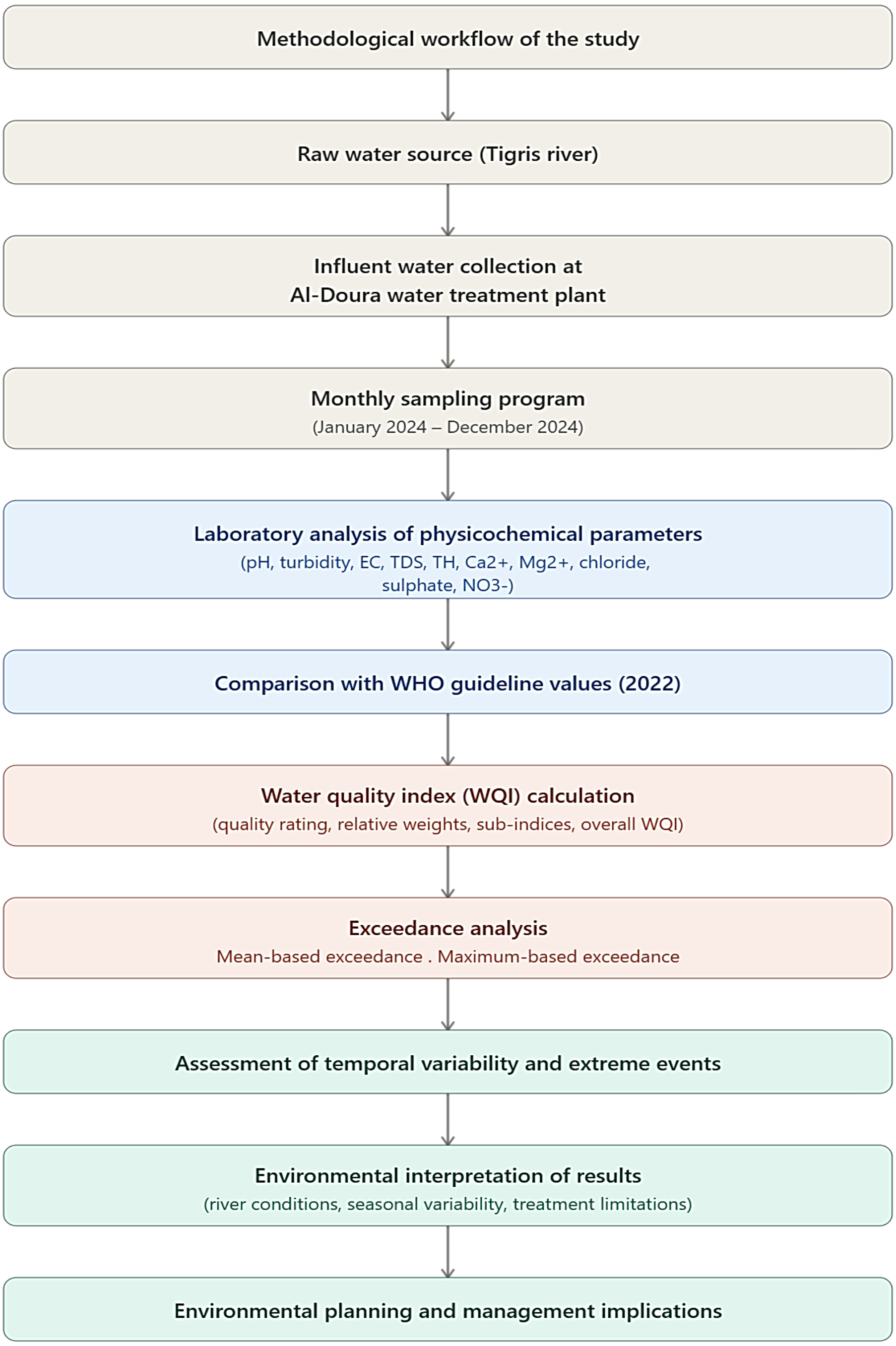

Figure 2. Methodology workflow of the study

4. RESULTS AND DISCUSSION

4.1 WQI Result

To obtain a single metric of the quality of potable water at the Water Treatment Plant at Al-Doura, the Water Quality Index (WQI) was calculated using the determined physicochemical parameters. The WQI is the aggregate impact of the individual variables of water quality, and it provides a simplified but overall view of the general water situation. **Table 3** presents quality ratings (qi) with relative weights (wi), sub-indexes (SIi), and the final WQI based on the existing WQI standards. This part will be limited to the numerical results of the WQI calculations, without making any interpretive comment. These WQI findings are discussed comprehensively in the discussion, where they have been linked to certain parameter exceedances.

Table 3. Quality rating scale calculations

Parameters	Unit	Permissible value (s_i)	Observed values (c_i)	$q_i = (c_i/s_i) \times 100$	$W = 1/s_i$	$w_i = W/\Sigma W$	$SI_i = w_i \times q_i$
TDS	mg L^{-1}	500	514.75	102.95	0.00	0.01	0.57
Turb	NTU	5	2.68	53.67	0.20	0.55	29.62
E.C.	µS cm^{-1}	1000	856.42	85.64	0.00	0.00	0.24
Ca^{2+}	mg L^{-1}	200	129.71	64.85	0.01	0.01	0.90
Mg^{2+}	mg L^{-1}	150	25.06	16.71	0.01	0.02	0.31
TH	mg $CaCO_3$ L^{-1}	500	229.88	45.98	0.00	0.01	0.25
pH	Unitless	8.5	7.34	86.31	0.12	0.32	28.03
Cl^-	mg L^{-1}	250	72.50	29.00	0.00	0.01	0.32
SO_4^{2-}	mg L^{-1}	250	142.67	57.07	0.00	0.01	0.63
NO_3^-	mg L^{-1}	50	4.05	8.10	0.02	0.06	0.45
Sum	—	—	—	—	**0.362314**	—	**61.31**

4.1.1 Total Dissolved Solids (TDS)

Fig. 3 illustrates the monthly variation of total dissolved solids (TDS) in raw and treated water at the Al-Doura Water Treatment Plant during 2024. In raw water, TDS values ranged from 412.5 mg/L (April) to 631 mg/L (January), with most months exceeding the WHO permissible limit of 500 mg/L. Treated water showed similar behavior, varying between 401 mg/L (April) and 623 mg/L (January), indicating limited TDS removal efficiency. The close similarity between influent and effluent values highlights the inability of conventional treatment processes to effectively remove dissolved salts, emphasizing TDS as a critical water quality constraint. A more conservative TDS threshold (500 mg/L) was adopted in WQI calculations to reflect palatability considerations.

4.1.2 Turbidity

Fig. 4 shows that there are significant changes in the turbidity per month between the treated and untreated water of the Al -Doura Water Treatment Plant in the year 2024. Raw water turbidity ranged between a minimum of 9.6NTU in July and a maximum of 121NTU in April, hence surpassing the World Health Organization allowable limit of 5NTU in the entire calendar year. In contrast, the turbidity of the treated effluent was always within the guideline values, which had a range between 1.65 NTU in July and 4.4 NTU in March. The removal efficiencies were more than 95%, when it was at peak events, e.g. in April, the turbidity dropped to 2.5 NTU, compared to 121 NTU at peak events, which demonstrates excellent treatment efficacy, although extreme turbidity of the raw water could present an operational challenge.

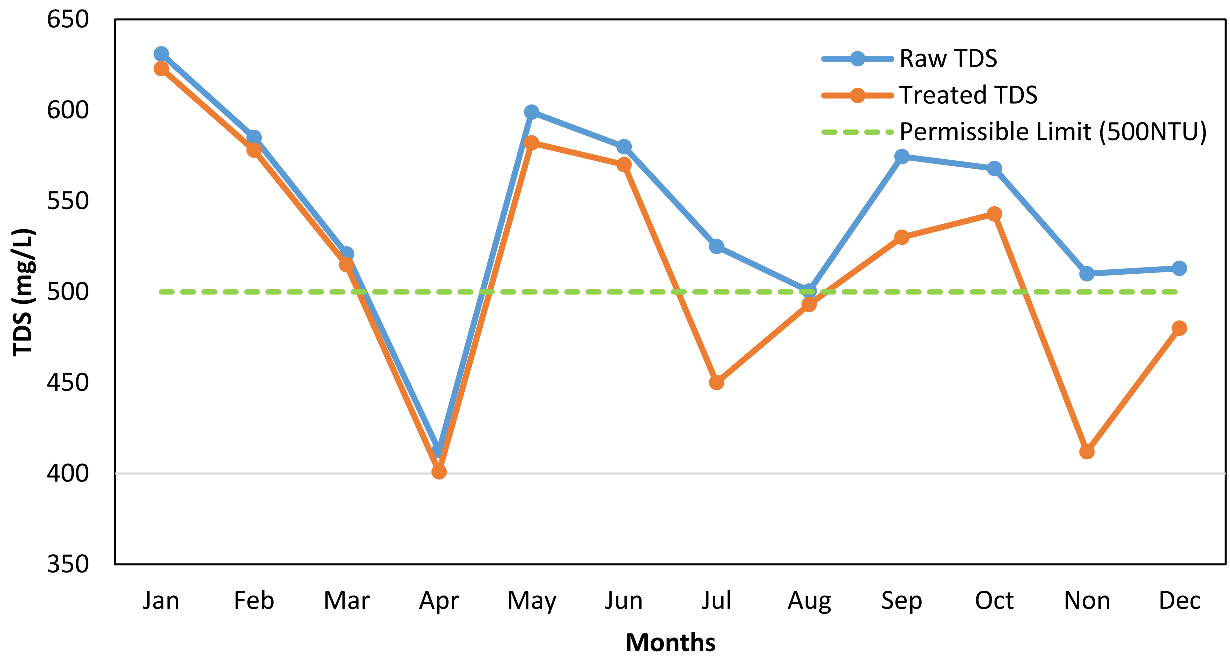

Figure 3. Monthly Variation of Raw and Treated Total Dissolved Solids (TDS) Relative to the Permissible Limit.

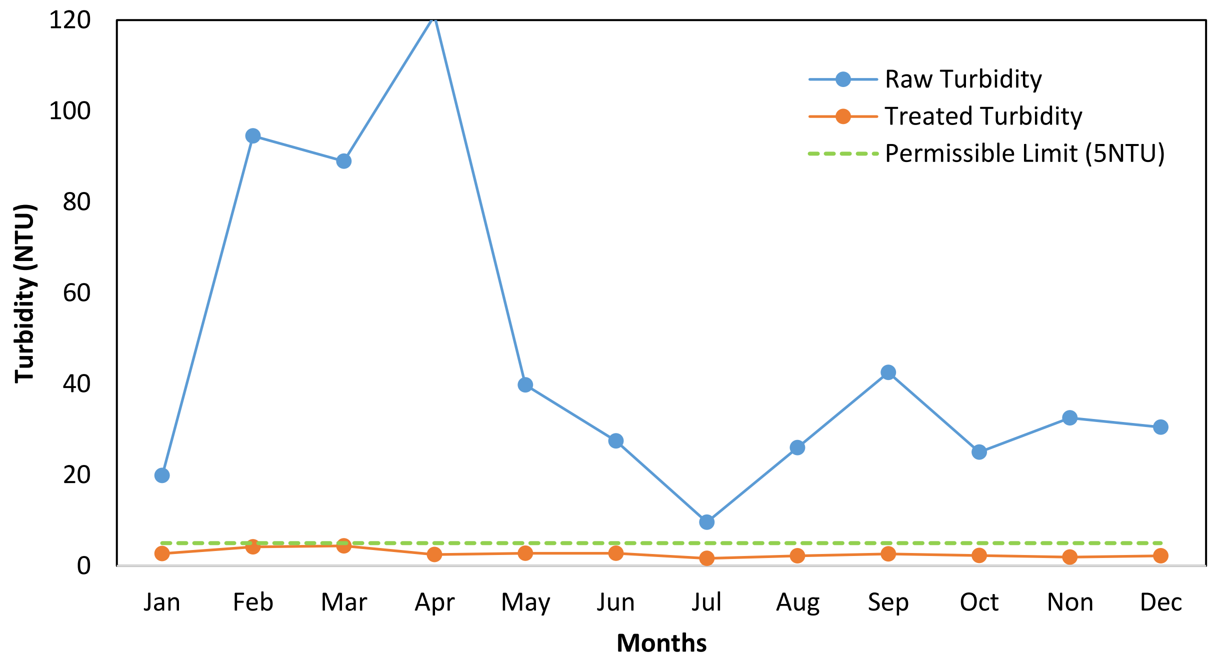

Figure 4. Monthly Variation of Raw and Treated Turbidity Relative to the Permissible Limit

4.1.3 Electrical Conductivity

Fig. 5 shows changes in electrical conductivity (EC) of raw and treated water in (Al-Doura) in the year 2024 monthly. Raw water EC was 642 µS cm^{-1} to 1002 µS cm^{-1} in March and December, respectively, which is close to the WHO allowable limit of 1000 µS cm^{-1} without exceeding guidelines. The small change between influent and effluent values shows that there is a relative lack of dissolved ion removal, which is a strength and, at the same time, exposes the system to exceedance in instances of higher salinity levels.

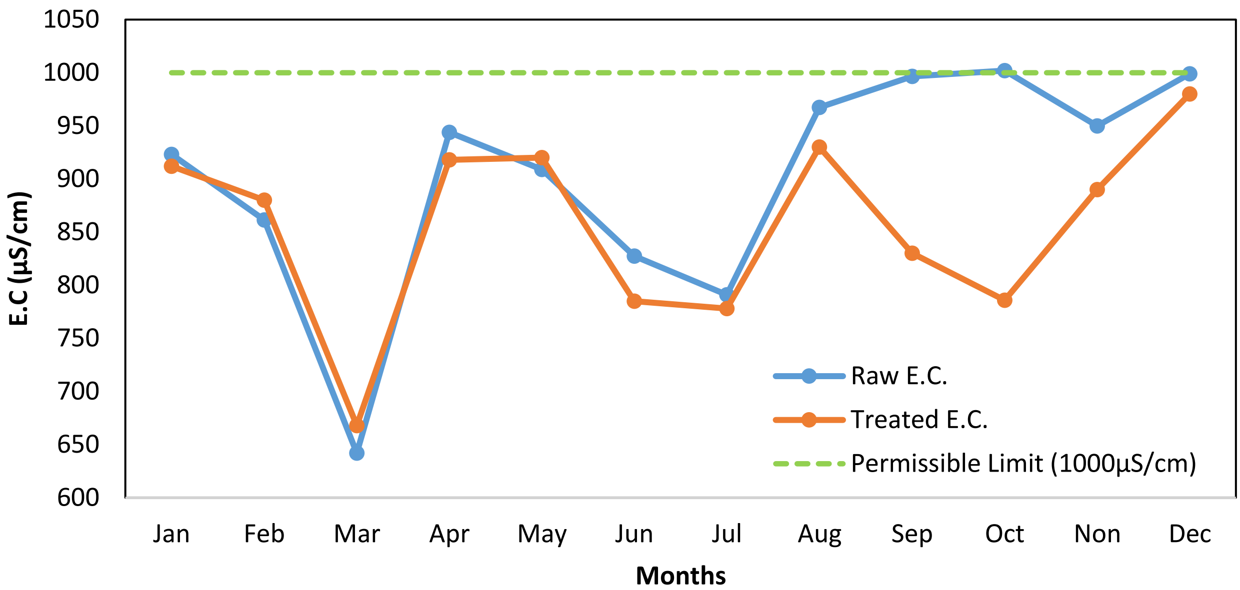

Figure 5. Monthly Variation of Raw and Treated Electrical Conductivity Relative to the Permissible Limit

4.1.4 Calcium and Magnesium

The monthly changes in the concentrations of calcium in the raw and treated water within the Al-Doura Water Treatment Plant in 2024 show that there is a strong seasonality in the data. The concentration of raw calcium was greater than the allowable limit of 200 mg/L in the winter months (peak of 268 mg/L in January) and lowest (62.5 mg/L) in May. Despite the lower calcium levels obtained following the treatment processes, higher levels were still being experienced at the beginning of the year, with the concentration of calcium in the treatments reaching a high of 256 mg/L, which is an indication of lower calcium levels being removed once the seasons had passed (**Fig. 6**). This pronounced winter peak in raw calcium is consistent with enhanced dissolution of carbonate (limestone) bedrock and soils within the river basin during periods of increased surface runoff and infiltration associated with winter rainfall, which mobilizes calcium ions into the river **(Xu et al., 2024).** Because the Al-Doura WTP relies solely on conventional coagulation–flocculation and disinfection and does not incorporate a dedicated softening stage (e.g., lime softening or ion exchange), the plant has limited capacity to remove this seasonal excess calcium load, explaining why elevated influent concentrations are only partially attenuated in the treated effluent during the winter months. Beyond its operational implications for treatment, the seasonal calcium load is also relevant from a public-health nutrition perspective, since drinking water can represent a meaningful contribution to total dietary calcium intake, particularly in populations with low baseline consumption **(Cormick et al., 2022).**

The level of magnesium in raw and treated water was kept below the maximum allowable level of 150 mg/L during the period of observation. The raw magnesium levels were 25.25-64.00 mg/L, and the treated levels were 7.7-60.00 mg/L, which were stable and conformed to the guideline levels as in **Fig. 7.**

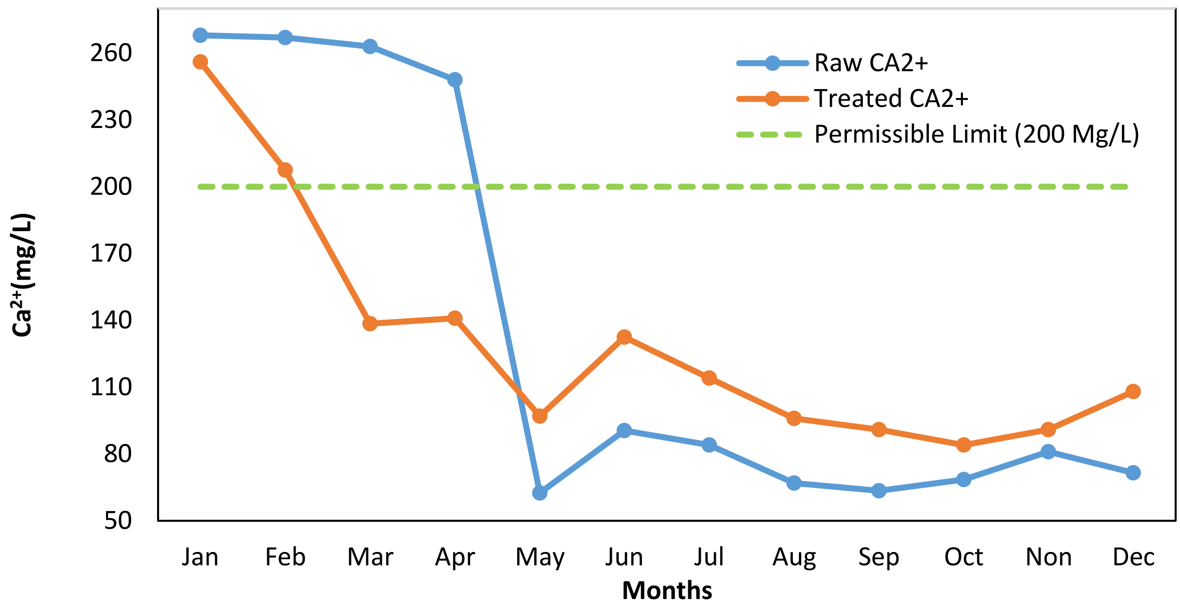

Figure 6. Temporal variation of calcium (Ca^{2+}) concentrations in raw and treated water

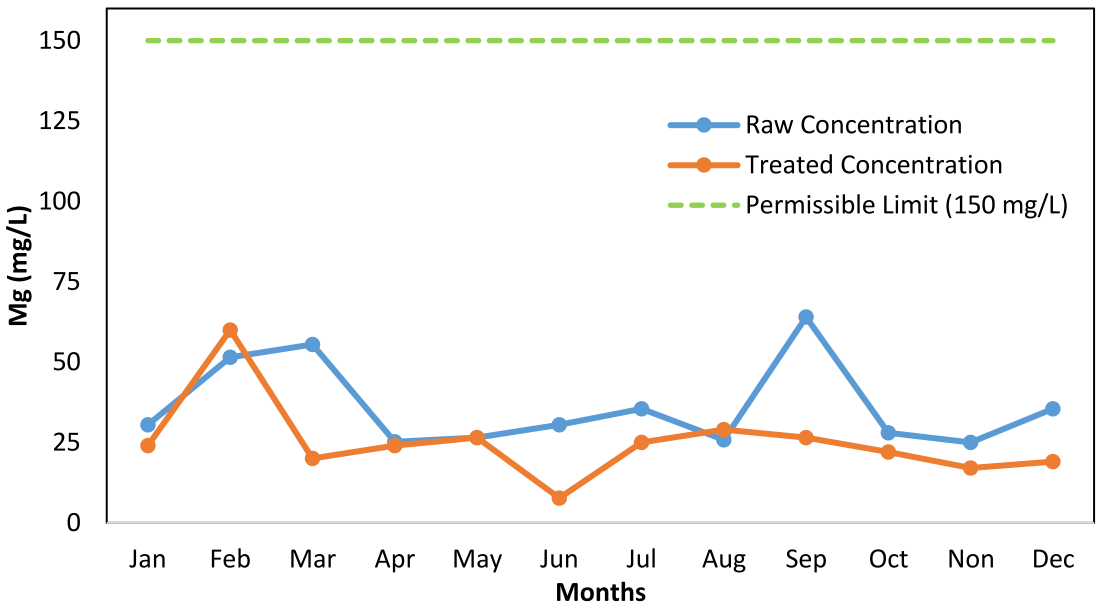

Figure 7. Temporal variation of magnesium (Mg^{2+}) concentrations in raw and treated water

4.1.5 Total Hardness

Fig. 8 illustrates the change in total hardness (TH) of raw and treated water in the Al-Doura Water Treatment Plant in 2024 by month. The total range of raw water TH was between 177.5 and 351mg/L in the months of March and December, with a constant limit of 500 mg/L. By comparison, only moderate decreases were observed in treated water, and the concentrations of 155.5 mg/L and 317.5 mg/L were found in November and December, respectively. This is due to the low influent-to-effluent TH ratio, which means that the traditional treatment processes are characterized by low effectiveness in removing the dissolved hardness ions. Although compliance with regulations has been attained, the recurrent existence of high hardness shows a lack of structural treatment precautions that can jeopardize the quality of water in the long run and consumption by the consumers.

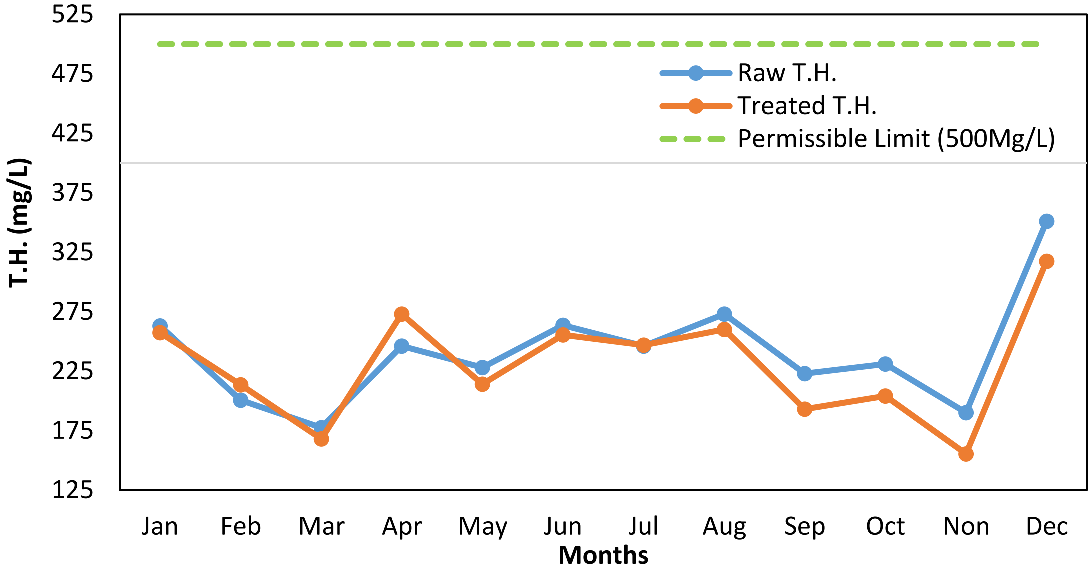

Figure 8. Temporal variation of total hardness (T.H., as $CaCO_3$) in raw and treated water

4.1.6 PH

A detailed analysis of pH, turbidity, and dissolved solids shows that there are deviant performance traits at the Al-Doura Water Treatment Plant. Although the pH of treated effluent did not exceed the acceptable range of 6.86 -7.62, the data of raw inflow indicate seasonal variability related to the increase in turbidity and suspended solids. Periods of gross turbidity as great as 121 NTU, and ongoing overloads of total dissolved solids reduce the effectiveness of coagulation, increase chemical consumption and consequently indirectly affect the phase of pH modification in the treatment train. Though the process of turbidity reduction was very successful, the slight decrease in dissolved solids indicates internal structural constraints in the treatment process. Based on the guidelines of the WHO and the APHA standard practices, the use of strong drinking water treatment requires simultaneous control of turbidity, solids, and pH to ensure a stable and strong operation as in **Fig. 9.**

4.1.7 Chloride and Sulphate (SO_4^{2-})

Figs. 10 and 11 represent the changes in both the monthly chloride (Cl^-) and sulfate (SO_4) levels in the raw and treated water of the Al-Doura Water Treatment Plant in 2024 and reflect the temporality of the influent and effluent of the plant. The levels of chlorides were kept at a comfortable range of 250 mg/L, which ranged between 57.5 -110 mg/L in raw water and 50-95 mg/L in treated water, showing a successful adherence to regulatory levels. The discharge of sulfates had a wider spread of seasonality with maximum values of 216.5 mg/L in April and 224 mg/L in December in the influent, although even after treatment, the levels remained within the guideline limits; this is a slight decrease between the influent and effluent, implying that conventional treatment processes largely controlled the particulatebound components but not the dissolved anions. Based on WHO drinking-water criteria and APHA standard methods, continued adherence masks the possible long-term aesthetic and scaling issues, which emerge in the face of increasing salinity stresses. While both anions remained within WHO guideline limits throughout the study period, their persistence from raw to treated water reflects the inherent limitation of conventional treatment processes in removing dissolved ionic species; chloride loading in urban surface waters such as the Tigris River is frequently linked to municipal wastewater discharge upstream, which may represent an underlying long-term source of the baseline chloride concentrations observed even before treatment **(Beom et al., 2021).**

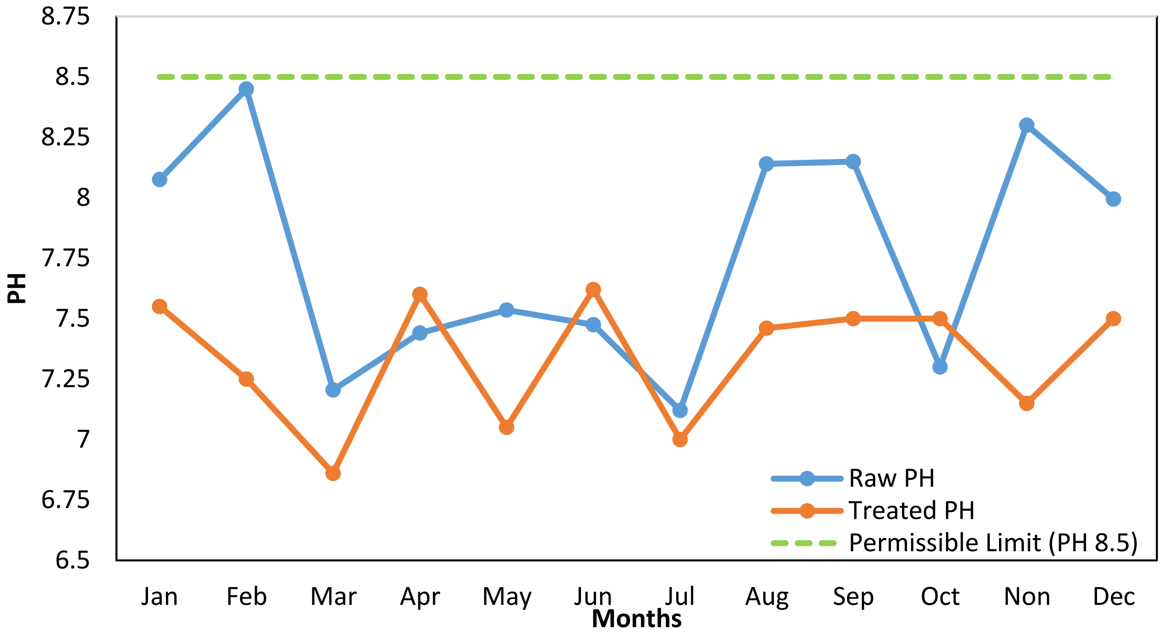

Figure 9. The pH of raw water and treated water

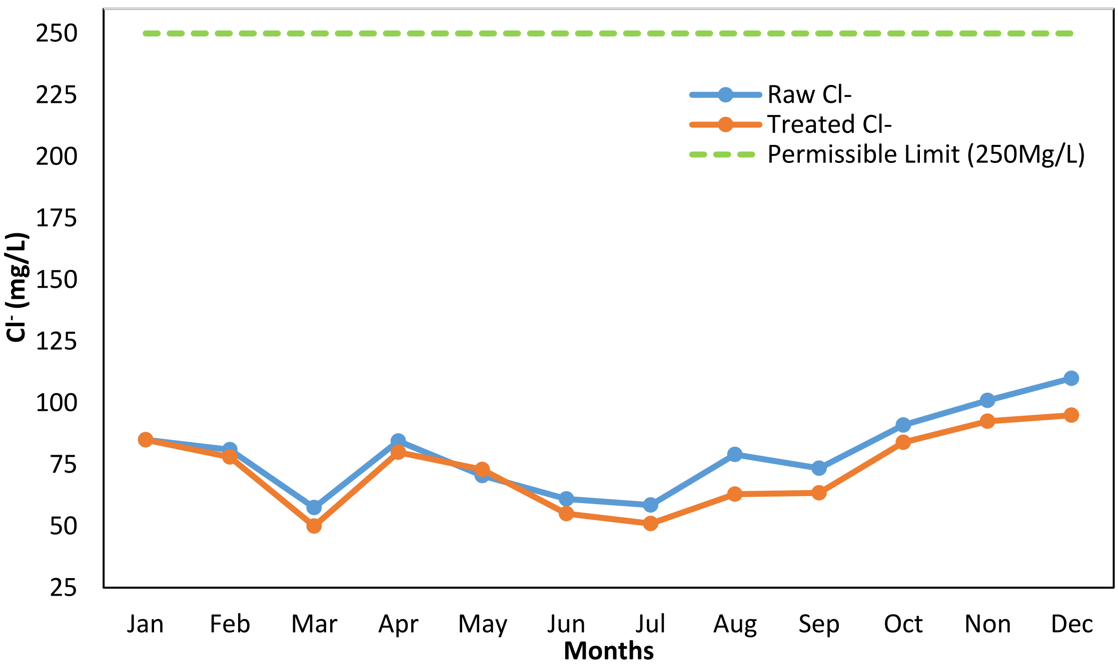

Figure 10. Temporal variation of chloride (Cl^-) concentrations in raw and treated water

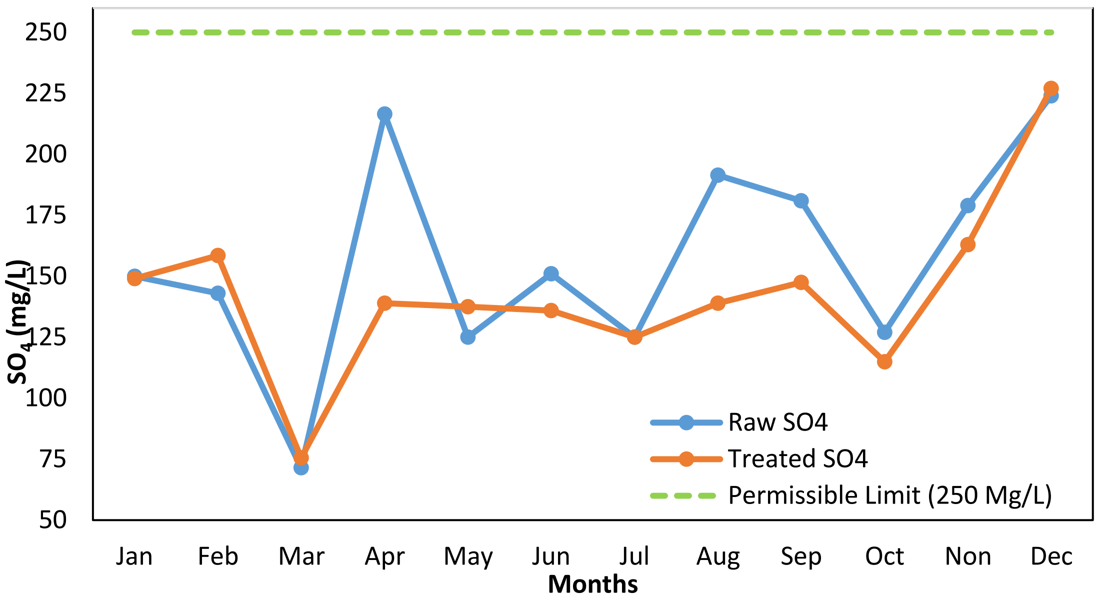

Figure 11. Temporal variation of sulphate (SO_4^{2-}) concentrations in raw and treated water

Overall, sulphate and chloride exhibited stable behavior and contributed minimally to health-related exceedance patterns, reinforcing the importance of turbidity and calcium as the primary drivers of water quality variability.

4.1.8 Nitrate (NO_3^-)

Fig. 12 illustrates the empirical data that expound on the temporal change of nitrate (NO_3^-) in raw and treated effluent streams in the Al-Doura Water Treatment Plant in the year 2024.

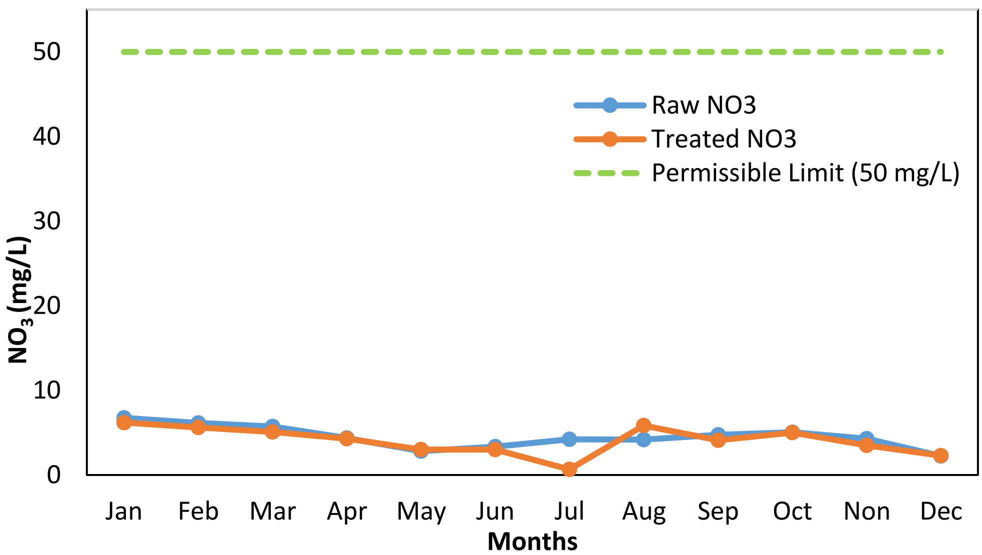

Figure 12. Temporal variation of nitrate (NO_3^-) concentrations in raw and treated water

Raw influent nitrate quantitatively reaches a minimum of 2.25 mg/L in December and reaches a maximum of 6.75 mg/1 in January, which is 10 times lower than the WHO admissible threshold of 50 mg/L. In line with this, the effluent nitrate levels are relatively small, amounting to 0.66 to 6.2 mg/L, and hence support the fact that there is no nitrate-based contamination. This empirical data emphasizes the quality of the source water and the treatment program. The continuously low nitrate load, however, dilutes its contributory weight in the construct of the Water Quality Index (WQI) and thus may obscure the relative significance of the other, more perturbing parameters.

4.2 Exceedance Results

The exceedance analysis was done to assess the level to which the measured water quality parameters were found to deviate from the WHO guideline values using the mean and max methods. The findings of the mean-exceedance test are summarized in **Table 4,** and those obtained using the maximum values are in **Table 5**. The mean-based findings show that most of the parameters adhere to the WHO guideline principles. On the other hand, the analysis in the form of maximum-based analysis shows that some of the parameters have short-term exceedances. It is noteworthy to note that the exceedance percentage of turbidity is the highest, and thus indicates the presence of strong episodic worsening in the quality of raw water; calcium is also above the recommended WHO guideline limit when it is measured using the maximum values. These results highlight the existence of temporal variability and extreme concentration events, which are not clear when focusing on the mean values only.

Table 4. Analyze the results of the average value.

Parameter	**WHO limit**	**Mean value**
Chloride (Cl^-)	≤ 250 mg/L	72.5
Sulphate (SO_4^{2-})	≤ 250 mg/L	143
Total Hardness (as $CaCO_3$) T.H.	≤ 500 mg/L	230
Total Dissolved Solids (TDS)	≤ 1000 mg/L	514.75
Calcium (Ca^{2+})	≤ 200 mg/L	102.58
Magnesium (Mg^{2+})	≤ 150 mg/L	25
pH	6.5 – 8.5	7.34
Nitrate (NO_3^-)	≤ 50	4.05
Electrical Conductivity (EC)	≤ 1500 µS/cm	857
Turbidity	≤ 5 NTU	2.7

The percentage of exceedance was calculated against mean concentrations and compared with the WHO guideline values. **Table 4** provides the mean-based exceedance of the quality of treated water, which show that all assessed physicochemical parameters complied with the values recommended by the World Health Organization (WHO). The mean concentrations of chloride (72.5 mg L^{-1}), sulfate (143 mg L^{-1}), total hardness (230 mg $CaCO_3$ L^{-1}), and total dissolved solids (514.75 mg L^{-1}) were considerably below their respective permissible limits, indicating acceptable mineral content and salinity levels. Calcium (102.58 mg L^{-1}) and magnesium (25 mg L^{-1}) also exhibited stable concentrations with no recorded exceedances, suggesting a limited risk of hardness-related scaling or adverse health effects. The mean pH value of 7.34 was within the recommended range of 6.5–8.5, indicating adequate control of water chemistry during treatment. Electrical conductivity (857 µS cm^{-1}) was below the adopted limit of 1,500 µS cm^{-1}, while the mean nitrate concentration (4.05 mg L^{-1}) was substantially lower than the health-based limit of 50 mg L^{-1}. Furthermore, the mean turbidity value was 2.7 NTU, with no exceedance of the adopted guideline value. Overall, the results demonstrate efficient and consistent long-term treatment performance under the investigated operating conditions.

Table 5. The analysis results of the maximum value

Parameter	WHO limit	Maximum value	Exceedance (%)
Chloride (Cl^-)	≤ 250 mg/L	92.5	0 %
Sulphate (SO_4^{2-})	≤ 250 mg/L	158.5	0 %
Total Hardness (as $CaCO_3$) T.H.	≤ 500 mg/L	317.5	0 %
Total Dissolved Solids (TDS)	≤ 1000 mg/L	623	0 %
Calcium (Ca^{2+})	≤ 200 mg/L	256	28 %
Magnesium (Mg^{2+})	≤ 150 mg/L	60	0 %
pH	6.5 – 8.5	7.62	0 %
Nitrate (NO_3^-)	≤ 50	6.2	0 %
Electrical Conductivity (EC)	≤ 1500 μS/cm	980	0 %
Turbidity	≤ 5 NTU	4.4	0 %

Table 5 summarizes the exceedance examination on the basis of the maximums of the treated water parameters concerning the WHO standard. There was 0% exceedance of all parameters under peak conditions except calcium, which had a 28% exceedance with a maximum of 256 mg/L. This finding highlights a specific weakness of calcium removal, which is explainable by the lack of softening processes. In general, the analysis ascertains regulatory compliance and unveils parameter-specific treatment constraints that do not manifest in aggregate indicators like the Water Quality Index (WQI). The mean and maximum-based exceedance tests reveal that in the majority of cases, treated water has the limits of World Health Organization (WHO) guidelines regarding physicochemical parameters. Mean-based values validate general regulatory compliance of treated water, but strong supranorm levels of turbidity were observed in untreated water, which exert a sustained working pressure associated with the variability of source water and not entirely reflected in the average values of treated water. In addition to the preceding, the maximum-based exceedance analysis indicates the episodic exceedance of calcium in the treated water, which indicates the limitations in removing hardness due to the absence of softening processes. The results establish that exceedance analysis offers vital details of short-term degradation and vulnerabilities of treatment, which cannot be represented merely through the Water Quality Index (WQI).

The outcome of the Water Quality Index (WQI) indicated that the overall quality of treated water in the Al-Doura Water Treatment Plant was moderate. This categorization is an indication that most of the physicochemical parameters, such as chloride and sulfate, total dissolved solids, total hardness, calcium, magnesium, pH, nitrate, and electrical conductivity, were within the guideline range approved by the World Health Organization (WHO). Therefore, the combined score of the WQI indicates that the treated water has a satisfactory quality for drinking.

The classification of WQI, however, hides the effect of single parameters that may show extreme behavior. Specifically, turbidity levels were significantly higher than those recommended by WHO, but this issue was not adequately represented in the cumulative index due to the averaging nature of WQI calculations. This finding demonstrates a long-known weakness of WQI-based assessments, in which a short-term, or parameter-specific, water quality problem can be underestimated when using composite indices alone. The exceedance analysis was more insightful about the water quality behavior than the WQI itself. An analysis of the exceedance of the treated water using mean analysis revealed that the treated water met all the values of the parameters stipulated by the WHO guidelines, such as turbidity, thus showing an acceptable average performance of the treatment process. On the other hand, maximum-based exceedance analysis showed parameter-specific weaknesses, especially when it comes to calcium that was found to be out of its guideline range by over 28%, and it signified that there were still restrictions of hardness-based ion removal.

Beyond regulatory compliance, the extreme turbidity peak of 121 NTU recorded in April, which was successfully reduced to 2.5 NTU in the treated effluent, also carries a high operational cost. Coagulant dose requirements at conventional treatment plants are strongly influenced by raw water turbidity, meaning that achieving this level of removal under such an extreme raw-water load typically requires a substantial increase in the dosage of chemical coagulants such as alum to maintain adequate flocculation and settling efficiency **(Shakeri et al., 2021).** This elevated coagulant demand not only raises the operating cost of the plant but can also indirectly affect the pH of the treated water, since alum hydrolysis consumes alkalinity and tends to lower pH, requiring additional chemical adjustment downstream to keep the effluent within the WHO-recommended range of 6.5–8.5 **(Yan et al., 2008).** This illustrates that even when a treatment plant successfully meets compliance limits, extreme turbidity events impose hidden operational costs in chemical consumption and process control that are not captured by the WQI or by compliance-based reporting alone. The difference between the comparison of mean and maximum exceedance analysis has significant implications for environmental planning and management of drinking water. **Fig. 13** shows that a series of environmental-driven fluctuations in the quality of the raw water at the time of peaks of seasonal occurrences spread through conventional treatment systems and cause episodic operational strain that is not adequately reflected in routine compliance testing and aggregate indices like the WQI. This pattern is consistent with broader observations in the water quality index literature regarding the limitations of aggregation-based assessment **(Uddin et al., 2021)**.

A further structural limitation of the Al-Doura WTP is evident in its inability to reduce dissolved mineral content. The nearly identical influent and effluent values observed for total dissolved solids (401–631 mg/L raw versus 401–623 mg/L treated) and electrical conductivity (642–1002 μS/cm raw versus comparably close treated values) confirm that the conventional coagulation–flocculation and disinfection train employed at the plant is structurally incapable of removing dissolved ionic content. Unlike turbidity and particulate matter, which are effectively addressed through coagulation and sedimentation, dissolved salts and ions require advanced treatment processes such as reverse osmosis, nanofiltration, or ion exchange to be substantially reduced. The persistence of near-equal TDS and EC values across the treatment train therefore highlights a structural design constraint rather than an operational deficiency, and indicates that any future reduction in dissolved mineral content at Al-Doura would require infrastructural upgrades beyond the scope of conventional treatment.

Having extreme turbidity events in raw water and the sporadic surpassing of calcium in treated water from an environmental planning point of view, adaptive management strategies, which explicitly address the seasonal and event-based water quality variability, are needed. It has become increasingly suggested to incorporate exceedance-based indicators with traditional ones in order to complement the decision-making process with the identification of critical periods that should be monitored more closely, optimized in operations, or upgraded with specific infrastructures **(Sutadian et al., 2016).**

Moreover, the results highlight the need to integrate river basin management and protection of source water in long-term planning of drinking water supply. It has been demonstrated that adaptive planning strategies of addressing sediment transportation, upstream discharge management, and early warning of high-turbidity incidences can substantially increase the resilience of treatment systems against the increasing environmental and climatic stressors **(WHO, 2022; Imen et al., 2018).**

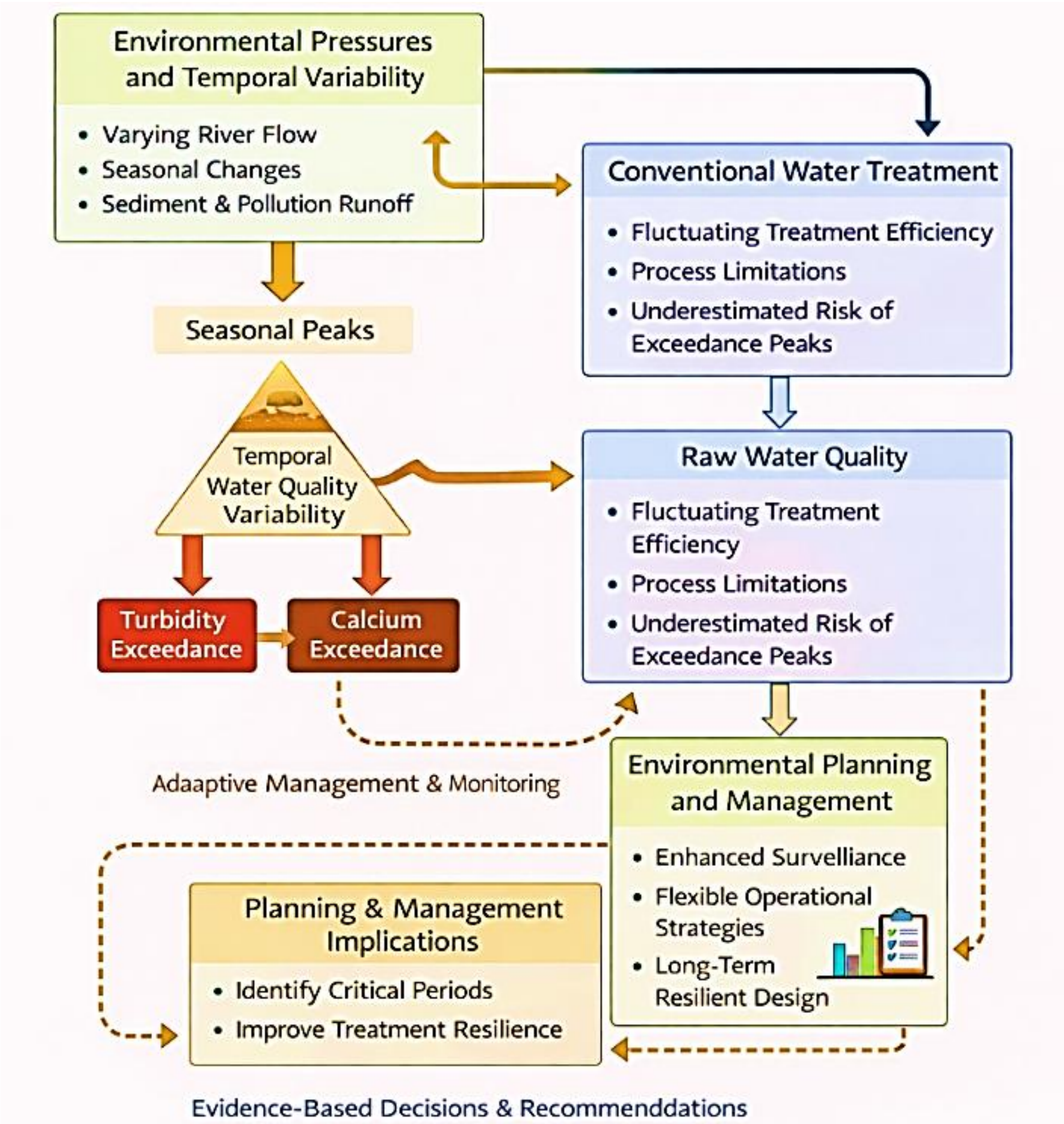

Figure 13. Conceptual Environmental Planning Framework for Drinking Water Quality Assessment

Building on the conceptual environmental planning framework summarized in **Fig. 13**, these findings translate into concrete engineering and policy recommendations for Al-Doura WTP. Given the recurrent winter calcium peaks and the structural inability of the conventional treatment train to reduce TDS and EC, infrastructure upgrades incorporating a dedicated softening unit (e.g., lime softening or ion exchange) and/or advanced membrane filtration (e.g., nanofiltration or reverse osmosis) should be prioritized to manage the seasonal hardness and salinity spikes that periodically exceed WHO guideline values. Targeting such upgrades to the plant's specific parameter-level vulnerabilities, rather than pursuing uniform plant-wide modifications, would allow these risks to be addressed cost-effectively and in line with broader water-policy frameworks for sustainable drinking water management **(Vogelmann et al., 2026).** In parallel, the recurrent extreme turbidity events observed in raw water, such as the April peak of 121 NTU, underscore the value of implementing upstream continuous water-quality monitoring as an early warning system. Real-time tracking of turbidity and related parameters at the intake point would allow plant operators to anticipate incoming pollution pulses and proactively adjust coagulant dosing or operational parameters before the treatment process is shocked by sudden raw-water deterioration **(Imen et al., 2018).**

Taken together, these findings reinforce the central conclusion of this study: relying solely on the Water Quality Index for public health protection is inadequate in highly variable, river-dependent supply systems, as its averaging nature can obscure short-term, parameter-specific risks such as the calcium and turbidity exceedances identified here. Exceedance Analysis, particularly its maximum-based form, should therefore be treated not as a supplementary tool but as a mandatory component of adaptive water quality management, ensuring that episodic degradation events are identified and addressed before they translate into public health or operational risks **(WHO, 2022; Uddin et al., 2021).**

5. CONCLUSIONS

In the current study, the quality of drinking water in the Al-Doura Water Treatment Plant was evaluated using an integrated model that involves the use of the Water Quality Index (WQI) alongside the mean-based and maximum-based exceedances. In spite of the fact that the calculated WQI classified the treated water as having a moderate level of quality, such a general classification was not enough to reflect the complexity of the dynamics of water quality in a river-based supply system but also potentially misleading. The analysis using mean exceedance showed that all the physicochemical parameters tested in the treated water always had values below or equal to the World Health Organization (WHO) guideline values. Thus, the long-term performance of the treatment under average operating conditions is satisfactory. However, there were significant temporal fluctuations and episodic increases in turbidity in the raw water, which subjected the treatment system to repetitive operational strain that was not reflected in the averaged treatment system and WQI results. Exceedance analysis based on maximum values further revealed a few instances of calcium exceedances in the treated water, thus pointing to structural constraints on hardness removal due to a lack of softening processes. These results reveal treatment gaps that average-based indications or composite indices alone fail to capture. Generally, the findings confirm the presence of a more holistic and realistic drinking water assessment with the use of exceedance metrics in addition to conventional WQI metrics. The integrated method improves the tracking of short-term degradation, aids in the identification of operational limitations, and provides useful information on environmental planning, adaptive water management, and the formation of more tolerant drinking water treatment systems in the face of increasing environmental changes.

Acknowledgements

This work was supported by the (Baghdad University, College of Engineering, Environmental Department of Engineering).

Credit Authorship Contribution Statement

Hala Ali Meer Hussein: writing, reviewing, and editing. Nuralhuda Aladdin Jasim: Writing – review & editing, Software, validation and methodology. Eman J. Younos: Writing – review & editing. Ahmed Adel Naji: Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

REFERENCES

Abdullah, B.K., Al-Juboory, Y.H.O. and Shakir, R.J., 2024. Physical and chemical analysis of water quality at Al-Dur Water Treatment Plant. *Journal of Primeasia*, 5(1), pp. 1–9. https://doi.org/10.25163/primeasia.519766

Al-Janabi, Z.Z., Hassan, F.M. and Al-Obaidy, A.H.M.J., 2024. Overall index of pollution (OIP) for Tigris River, Baghdad City, Iraq. *The Iraqi Journal of Agricultural Sciences*, 55(2), pp. 905–916. https://doi.org/10.36103/gqq14f43

Al-Mayah, W.T., Al-Heety, E.A.M.S., Al-Tmemy, W.B., Al-Fanharawi, A.A., Karim, Y.R. and Khuraywit, A.S., 2022. Evaluation of efficiency of water treatment plants in Baghdad City using comprehensive pollution and water quality indices. *AIP Conference Proceedings*, 2398(1), Article 040053. https://doi.org/10.1063/5.0093956

Al-Mousawey, H.J. and Abed, B.S., 2023. Water quality assessment of Al-Najaf City potable water network. *Journal of Engineering*, 29(4), pp. 14–29. https://doi.org/10.31026/j.eng.2023.04.02

Al-Rikabi, W.J. and Abed, B.S., 2021. Improvement of the hydrodynamic behavior and water quality assessment of Al-Chibayish Marshes, Iraq. *Journal of Engineering*, 27(12), pp. 50–68. https://doi.org/10.31026/j.eng.2021.12.05

Alobaidy, A.H.M.J., Abid, H.S. and Maulood, B.K., 2010. Application of water quality index for assessment of Dokan Lake ecosystem, Kurdistan Region, Iraq. *Journal of Water Resource and Protection*, 2(9), pp. 792–798. https://doi.org/10.4236/jwarp.2010.29093

Álvarez, A.L. and Müller-Eie, D., 2017. Quality of urban life and its relationship to spatial conditions. *WIT Transactions on Ecology and the Environment*, 223, pp. 285–296. https://doi.org/10.2495/SC170251

Alver, A., 2019. Evaluation of conventional drinking water treatment plant efficiency according to water quality index and health risk assessment. *Environmental Science and Pollution Research*, 26(26), pp. 27225–27238. https://doi.org/10.1007/s11356-019-05801-y

Alwaeli, J.M., Ali, S.K. and Mohammed, A.H., 2021. Using Geographic Information Systems (GIS) program and Water Quality Index (WQI) to assess and manage groundwater quality in the city of Baghdad. *Journal of Engineering*, 27(3), pp. 93–112. https://doi.org/10.31026/j.eng.2021.03.07

American Public Health Association (APHA), 2017. *Standard Methods for the Examination of Water and Wastewater*. 23rd ed. Washington, DC: American Public Health Association.

Antwi, S.H., Rolston, A., Linnane, S. and Getty, D., 2022. Communicating water availability to improve awareness and implementation of water conservation: A study of the 2018 and 2020 drought events in the Republic of Ireland. *Science of the Total Environment*, 807, Article 150865. https://doi.org/10.1016/j.scitotenv.2021.150865

Banda, T.D. and Kumarasamy, M.V., 2020. Development of water quality indices (WQIs): A review. *Polish Journal of Environmental Studies*, 29(3), pp. 2011–2021. https://doi.org/10.15244/pjoes/110526

Beom, J., Jeung, M., Choi, W., Her, Y. and Yoon, K., 2021. Characteristics of chloride loading from urban and agricultural watersheds during storm and non-storm periods. *Water Supply*, 21(4), pp. 1567–1579. https://doi.org/10.2166/ws.2020.343

Biswas, T.K. and Mosley, L.M., 2019. From mountain ranges to sweeping plains, in droughts and flooding rains: River Murray water quality over the last four decades. *Water Resources Management*, 33, pp. 1087–1101. https://doi.org/10.1007/s11269-018-2168-1

Burile, A.N. and Nagarnaik, P.B., 2010. Performance evaluation of a water treatment plant: A case study. In: *Proceedings of the 3rd International Conference on Emerging Trends in Engineering and Technology*, pp. 57–60. https://doi.org/10.1109/ICETET.2010.89

Cormick, G., Gibbons, L. and Belizán, J.M., 2022. Impact of water fortification with calcium on calcium intake in different countries: A simulation study. *Public Health Nutrition*, 25(2), pp. 344–357. https://doi.org/10.1017/S1368980020002232

Ewaid, S.H., Abed, S.A., Al-Ansari, N. and Salih, R.M., 2020. Development and evaluation of a water quality index for the Iraqi rivers. *Hydrology*, 7(3), Article 67. https://doi.org/10.3390/hydrology7030067

Fortes, A.C.C., Barrocas, P.R.G. and Kligerman, D.C., 2023. Water quality indices: Construction, potential, and limitations. *Ecological Indicators*, 157, Article 111187. https://doi.org/10.1016/j.ecolind.2023.111187

Gao, Z., Huang, T., Chen, J., Tian, H., Tan, M., Niu, Y. and Lou, K., 2025. Comprehensive hydrochemical analysis, controlling mechanisms, and water quality assessment of surface and groundwater in a typical intensive agricultural area, Northern China. *Water*, 17(2), Article 276. https://doi.org/10.3390/w17020276

Güneş Şen, S., 2025. From indices to algorithms: A hybrid framework of water quality assessment using WQI and machine learning under WHO and FAO standards. *Water*, 17(21), Article 3050. https://doi.org/10.3390/w17213050

Henry, T., 2013. Carroll Township's scare with toxin a "wake-up call": Water plant shut over lethal microcystin from algae. *Toledo Blade*, 15 September 2013.

Imen, S., Chang, N.-B., Yang, Y.J. and Golchubian, A., 2018. Developing a model-based drinking water decision support system featuring remote sensing and fast learning techniques. *IEEE Systems Journal*, 12(2), pp. 1358–1368. https://doi.org/10.1109/JSYST.2016.2538082

Kansas Department of Health and Environment (KDHE), 2011. *Water Quality Standards White Paper: Chlorophyll-a Criteria for Public Water Supply Lakes or Reservoirs*. Topeka, Kansas: Bureau of Water.

Khudair, B.H., 2013. Assessment of water quality index and water suitability of the Tigris River for drinking water within Baghdad City, Iraq. *Journal of Engineering*, 19(6), pp. 764–773. https://doi.org/10.31026/j.eng.2013.06.08

Manier, D.J. and O'Donnell, M.S., 2018. Compilation and Assessment of Resource Values and Hazards to Inform Transportation Planning and Associated Land-Use Planning. *U.S. Geological Survey Scientific Investigations Report 2018-5039*. https://doi.org/10.3133/sir20185039

Mogane, L.K., Masebe, T., Msagati, T.A.M. and Ncube, E., 2023. A comprehensive review of water quality indices for lotic and lentic ecosystems. *Environmental Monitoring and Assessment*, 195, Article 926. https://doi.org/10.1007/s10661-023-11512-2

Parvez, S., Frost, K. and Sundararajan, M., 2017. Evaluation of drinking water disinfectant byproducts compliance data as an indirect measure for short-term exposure in humans. *International Journal of Environmental Research and Public Health*, 14(5), Article 548. https://doi.org/10.3390/ijerph14050548

Păun, I., Cruceru, L.V., Chiriac, F.L., Niculescu, M., Vasile, G.G. and Marin, N.M., 2016. Water quality indices: Methods for evaluating the quality of drinking water. In: *Proceedings of the 19th INCD ECOIND International Symposium—SIMI 2016: The Environment and the Industry*, pp. 395–402. National Research and Development Institute for Industrial Ecology. https://doi.org/10.21698/simi.2016.0055

Raheem, H.M. and Al-Juhaishi, M.R., 2024. Assessment of raw and produced water quality at Al-Doura Water Treatment Plant. *IOP Conference Series: Earth and Environmental Science*, 1374(1), Article 012070. https://doi.org/10.1088/1755-1315/1374/1/012070

Shakeri, N., Asgari, G., Khotanlou, H. and Khazaei, M., 2021. Prediction of the optimal dosage of coagulants in water treatment plants through developing models based on artificial neural network fuzzy inference system (ANFIS). *Journal of Environmental Health Science and Engineering*, 19(2), pp. 1543–1553. https://doi.org/10.1007/s40201-021-00710-0

Sutadian, A.D., Muttil, N., Yilmaz, A.G. and Perera, B.J., 2016. Development of river water quality indices: A review. *Environmental Monitoring and Assessment*, 188(1), Article 58. https://doi.org/10.1007/s10661-015-5050-0

Uddin, M.G., Nash, S. and Olbert, A.I., 2021. A review of water quality index models for surface water assessment. *Ecological Indicators*, 122, Article 107218. https://doi.org/10.1016/j.ecolind.2020.107218

Vogelmann, E.S., Prevedello, J. and Tiruneh, G.A., 2026. Assessing policies and guidelines for drinking water quality. *Discover Applied Sciences*, 8, Article 332. https://doi.org/10.1007/s42452-026-08413-7

World Health Organization (WHO), 2022. *Guidelines for Drinking-Water Quality: Fourth Edition Incorporating the First and Second Addenda*. Geneva: World Health Organization.

Xu, Y., Jin, Z., Zhang, F., Gou, L.-F., Li, C., Wang, J., Jin, C. and Deng, L., 2024. Intensified carbonate weathering during storm events in a highly erosion-prone river catchment. *Journal of Hydrology*, 642, Article 131860. https://doi.org/10.1016/j.jhydrol.2024.131860

Yan, M., Wang, D., Yu, J., Ni, J., Edwards, M. and Qu, J., 2008. Enhanced coagulation with polyaluminum chlorides: Role of pH/alkalinity and speciation. *Chemosphere*, 71(9), pp. 1665–1673. https://doi.org/10.1016/j.chemosphere.2008.01.019

تقييم متكامل لجودة مياه الشرب وآثارها على التخطيط البيئي باستخدام مؤشر جودة المياه وتحليل التجاوزات: محطة معالجة مياه الدورة، بغداد

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[2] قسم الهندسة المدنية، كلية الهندسة، جامعة واسط، واسط، العراق

الخلاصة

تُعد جودة مياه الشرب ذات أهمية بالغة لصحة الإنسان، ولا سيما في أنظمة الإمداد القائمة على الأنهار والتي تواجه تزايدًا في عدم اليقين البيئي. ومع ذلك، تعتمد معظم الاختبارات على مؤشرات عامة مثل مؤشر جودة المياه (WQI) التي قد لا تتمكن من رصد التجاوزات قصيرة الأجل والتدهور العرضي. ستقدم هذه الورقة تقييمًا شاملاً لجودة مياه الشرب في محطة معالجة مياه الدورة ببغداد،العراق، والتي تتلقى إمدادات مباشرة من المياه الخام من نهر دجلة. استُخدم مؤشر جودة المياه (WQI) لاختبار معايير الرصد الشهرية للخصائص الفيزيائية والكيميائية الرئيسية في المياه الخام والمعالجة، وذلك من خلال تحليل تجاوز القيم المتوسطة والقصوى، وفقًا لمعايير منظمة الصحة العالمية، خلال الفترة من يناير إلى ديسمبر 2024. يُصنف مؤشر جودة المياه للمياه المعالجة (المتوسط = 61.31) بأنه متوسط. أثبت تحليل تجاوز القيم المتوسطة أن جميع المعايير المُحللة، في ظل ظروف التشغيل العادية، تتوافق عمومًا مع القيم الإرشادية. مع ذلك، وُصفت التغيرات الشديدة في عكارة المياه الخام بأنها أحد عوامل الضغط التشغيلية المستمرة. كما أظهر تحليل تجاوز القيم القصوى أن مستويات الكالسيوم في المياه المعالجة تجاوزت الحد المسموح به بنسبة تصل إلى 28%، مما يُسلط الضوء على المخاطر والقيود قصيرة الأجل لعملية المعالجة التي تتجاوزها المؤشرات المُجمعة. وهو ما يُعرف بـ"تأثير الحجب .(eclipsing effect) ومن خلال الكشف عن هذه التجاوزات المخفية، يوفر تحليل التجاوزات القصوى أداة إنذار مبكر أكثر موثوقية مقارنة بمؤشر جودة المياه وحده.

الكلمات المفتاحية: تحليل التجاوزات، التباين الزمني، التخطيط البيئي، المعالجة التقليدية للمياه، إمدادات المياه المعتمدة على الأنهار، محطة معالجة مياه الدورة.