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Impact of Euphrates Water Levels on the Hydraulic Properties and Water Quality Parameter in Anbar Province, Iraq

Sari Aymen Alrawi[1,*], Arkan Dhari Jalal[2] & Uday Hatem Abdulhameed[2]

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Abstract: Concentrating on the Haditha Dam reservoir in Anbar Province, Iraq, this study examines the connection between water quality parameters and changes in the Euphrates River's water level. Based on time-series data and using SPSS software, key variables such as discharge Q, electrical conductivity EC, pH, total suspended solids TSS, and major ions Na, K, Mg, Ca, Cl, SO_4 were evaluated through a combination of statistical and graphical techniques. The findings show that high water levels considerably improve water quality by lowering sedimentation TSS and electrical conductivity EC, as well as affecting ion concentrations like potassium K and chloride Cl. Parameters like pH and magnesium Mg showed little variations hence stability in the changed hydrological conditions. The findings are corroborated by graphical representations, showing the skewness and variability of the parameters under examination and conforming to their statistical associations. In order to reduce hazards to domestic and agricultural water consumption, these findings highlight the significance of adaptive water management techniques, such as controlling salinity and sedimentation during low water levels and routinely monitoring important ions. In order to ensure long-term water quality and availability in the face of hydrological and human demands, this research offers practical insights for encouraging sustainable water management in Haditha dam reservoir by combining statistical correlations.

Keywords: Water Level, Hydraulic properties, Water quality management, and adaptive water governance.

Introduction

Water is one of the most valuable resources on the earth and is a key component of a great many businesses in Iraq. However, a series of challenges connected with water management still remain as problems of Iraq, for instance the problems of lack of water, the deterioration of the water quality, pollution, climate change and development of constructed water infrastructures (1). The impact of varying discharge levels on a river's hydraulic properties and water quality can be studied using statistical models, which analyze data through mathematical and analytical methods [2]. Environmental elements, including soil erosion, precipitation, and weather, impact surface water quality. Surface water quality is also impacted by the need to use water resources and other artificial activities, including industrialization, urbanization, the production of municipal wastewater, and runoff from agricultural areas. Over 80% of human illnesses are caused by contaminated water (3). The quality of groundwater is determined by its physical and chemical components, which are influenced by soluble compounds, weathering, breakdown, and spatial and temporal variations [4]. Cut back on the ecological demand for waterworks. Surveillance was the outcome of quality testing and evaluation of the environment for future trends in water quality. It should be mentioned that the Handbook of Numerous Analytical Data Current Data Processing Conditions provides Realistic, speedy result interpretation (5). Considered to be Iraq's two primary water sources, the Tigris and Euphrates Rivers are currently experiencing a rapid and sharp decline in quality (6). Several water quality trend detection approaches for records were employed, with theoretical investigations and trend analysis (7). Discharge levels and water elevation, together with the spatial components of the river water quality models, stress temporal changes (8). In continuous models, components or variables are gradually incorporated into an analysis of the evolution of water-related problems during the previous periods (9). Adopting a single standard is difficult since different criteria for river water qualities must be evaluated for diverse applications. Different definitions and the substance of the measured parameters are the basis for different classifications. To accommodate the various applications of water quality assessments, other alterations and classifications have also been created (10). The Euphrates River is the main water source for Iraq, providing water requirements for agricultural and urban uses and the industrial sector (11). Discharge fluctuations influence hydraulic properties, including velocity of flow and depth, as well as water quality factors necessary for human consumption and crops (12). Over the course of the last century, floods have significantly altered the course of the Euphrates River. Bends, twists, islands, and the progression and retreat of banks are some examples of these features (13). Despite the low levels of heavy metal pollution in the Euphrates River within the research area, residential buildings cannot directly receive the

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1 MSC student, Dams and Water Resources Department Engineering, College of Engineering, University of Anbar, 31001 Ramadi, Anbar province, Iraq
*Corresponding author email: sar23e4003@uoanbar.edu.iq
2 Department of Dams and Water Resources Engineering, College of Engineering, University of Anbar, 31001 Ramadi, Anbar province, Iraq

river water. This is because the river water may include pathogens in addition to other contaminants including turbidity and suspended particles. includes viruses and bacteria. Therefore, before it can be used for drinking, it needs to be treated at the water treatment facility (14). The increasing sodium levels intensify the detrimental effects of water on the soil, and the high EC value raises the salinity of the soil, rendering it unsuitable for irrigation (15). The amount of water entering the Euphrates River has been continuously decreasing in comparison to its intake during the fifth and sixth decades of the previous century (16). This is a result of rising demand for its water from Syria, Iraq, and Turkey. In addition to Syria's excessive water use, Turkey has filled water reservoirs with water by building many dams as part of the Southeast Anatolia Project. As a result, the salinity and quality of Iraq's river water have decreased (17). stated that the physical, chemical, and elemental quantities of rivers are influenced by their defined flows and how they alter over the year. Additionally, it significantly affects the amount of silt carried, which affects the variation of these elements (18). discovering a connection between the quantities of dissolved oxygen, nitrates, and suspended particles and the flow rate. There is an inverse relationship between temperature and flow rate. Flow rate either has no statistically significant correlation or has distinct correlations with the other parameters (19). River temperature is affected when discharge or water flow is reduced. Because of their impact on variations in water temperature, dam releases in the outflows have grown in significance (20).

Objectives of the Study

The primary objective of this study is to analyze the impact of water level fluctuations in the Euphrates River on both hydraulic properties and water quality parameters, with a specific focus on the Haditha Dam region. The study aims to:

1. Assess the relationship between discharge levels, water elevation, and key water quality parameters, including EC, pH, TSS, K, Na, Mg, Ca, Cl, and SO_4.
2. Utilize statistical models to identify trends and correlations between hydraulic properties and water quality parameters.

Materials and Methods

Area Study

Due to its three countries of passage, Iraq, Syria, and Turkey, the Euphrates River is regarded as an international river (21). Iraq's primary water supply is the Euphrates River, which flows into the Tigris River. It is home to the major cities that depend on it for agricultural, industrial, and municipal water (22). One of the Euphrates River's biggest and most significant bodies of water is the Haditha Reservoir. It is situated eight kilometers north of Haditha City in the western region of Iraq (figure 1); it was created as a result of the 1986 establishment of the Haditha dam. It is now a multifunctional use of water; the study region is situated between longitudes (42° 26´ and 41° 55´) East and latitudes (34° 40´ and 34° 13´) North, With a maximum flood water level of 147 meters above sea level and 10 kilometers of shoreline, the river and reservoir span roughly 500 km2. The research area experiences minimal rainfall, with an average of 127 mm per year and a range of 45 to 200 mm. The region is classified as semi-arid or dry (23).

Figure (1): The Haditha Reservoir is location (23).

Collection Data

Monthly water samples were collected from selected sites during the period from January 2019 to January 2021. The study analyzed the following parameters: discharge (Q), water level (W.L), electrical conductivity (EC), pH, total suspended solids (TSS), potassium (K), sodium (Na), magnesium (Mg), calcium (Ca), chloride (Cl), and sulfate (SO_4). These parameters were measured at two critical locations: upstream (in front of the dam) and downstream (behind the dam).

Analytical techniques were employed to test each parameter, adhering to the recommended procedures in standard methodologies. Sampling was conducted during both wet and dry seasons to capture seasonal variations in water quality, following the standard procedures outlined in the Iraqi standards manual for water quality.

Water sampling adhered to standardized protocols to ensure accurate representation of the water quality parameters. Before sample collection, all plastic bottles were thoroughly washed, dried, and rinsed with the water samples to be collected during the process. After collection, the samples were properly labeled and transported to the laboratories of the Haditha Dam Project for chemical analysis.

This comprehensive methodology ensured the reliability and accuracy of the data, allowing for an in-depth assessment of the relationship between water levels and the chemical and physical quality of water in the Euphrates River.

The study relied on data collected from the Haditha Dam, including water levels, discharges, and specific elements related to water quality. The aforementioned time series data was collected from the Upper Euphrates Basin Development Center affiliated with Anbar University (unpublished data) from 2019 to 2021. The highest water level in the dam reservoir was recorded at 147.07 meters in April 2021, while the lowest water level was 137.03 meters in December 2021. Monthly data was used for the analysis.

Statistical Package for Social Sciences (SPSS)

Another emerging important statistical program that has tremendously increased in the usage among the researchers for carrying out various mathematical computations is statistical analysis software. Many branches of science utilize it, sociology, engineering science, administrative science, and agriculture. Through such tools SPSS aids in the presentation of data and research results where transparency and clarity are facilitated through an adoption of certain mechanisms. It helps the users to generate different types of graphical such as box plot, pie graph and bar chart which are very important in data summarization(24). Nevertheless, SPSS provides a series of SYNTAX files which provide a view of the raw data together with values of the summarized statistics, contributing to transparency within the scientific environment (25). Furthermore, for identifying quantities of interest, it includes per Functionalities for table making and graph drawing, so anybody can use it without having any statistical knowledge whatsoever(26).

Sampling, Measures, and Analysis

Samples were taken from the site during the selected period from January 2019 to December 2021. The study included 11 parameters: such as: flow discharge, water level, electrical conductivity (EC), pH, total suspended solids (TSS), potassium (K), sodium (Na), magnesium (Mg), calcium (Ca), chloride (Cl) and sulfate (SO_4). These parameters were analyzed in front of the dam. The above parameters were analyzed using the SPSS software to determine the impact of the above parameters. Bottle washing and labeling were properly done in the respective laboratories of the Haditha Dam Project while chemical analysis was also done.

Results and Discussion

Table 1 contains the statistical summary features like Discharge (Q), water level (W.L), pH, TSS, and major ions of Na, K, Ca, Mg, Cl, SO_4. Such measures range from the range mean, median, standard deviation, variance, skewness, and kurtosis, provide full descriptive of the data.

Table (1): Frequencies Statistics.

		Q	W.L	EC	pH	TSS	K	Na	Mg	Ca	Cl	So_4
N	Valid	46	46	46	46	46	46	46	46	46	46	46
	Missing	0	0	0	0	0	0	0	0	0	0	0
Mean		458.57	144.6720	751.0435	7.6728	513.78	7.559	31.591	23.628	40.015	59.224	160.650
Median		400.00	145.8150	754.5000	7.7000	517.00	7.600	30.750	24.350	40.500	58.000	162.500
Std. Deviation		155.120	2.78382	104.17314	.09147	93.283	1.4491	8.4380	4.5413	5.3923	13.5555	28.6524
Variance		24062.296	7.750	10852.043	.008	8701.641	2.100	71.200	20.623	29.077	183.751	820.962
Skewness		1.962	-1.520	.917	.371	.670	-.031	-.223	-1.164	-.836	.510	-.212
Std. Error of Skewness		.350	.350	.350	.350	.350	.350	.350	.350	.350	.350	.350
Kurtosis		3.581	1.130	.783	1.294	.183	-.511	1.406	1.937	2.073	.375	-1.438
Std. Error of Kurtosis		.688	.688	.688	.688	.688	.688	.688	.688	.688	.688	.688
Range		700	10.04	444.00	.44	369	6.1	41.0	22.2	28.8	59.3	93.0
Minimum		300	137.03	586.00	7.50	369	4.3	8.0	9.5	23.2	33.0	114.0
Maximum		1000	147.07	1030.00	7.94	738	10.4	49	31.7	52.0	92.3	207.0

The graphical analysis of the data, illustrated in Figures 4 to 14, complements the statistical findings by providing detailed insights into the distribution patterns and the skewness of each parameter:

Figure 2 (Discharge - Q): The histogram for Q exhibits a slight left skew, with high values ranging between 300 and 1000. This pattern highlights variability in river discharge, influenced by hydrological conditions and operational management, affecting the hydrodynamics of the system.

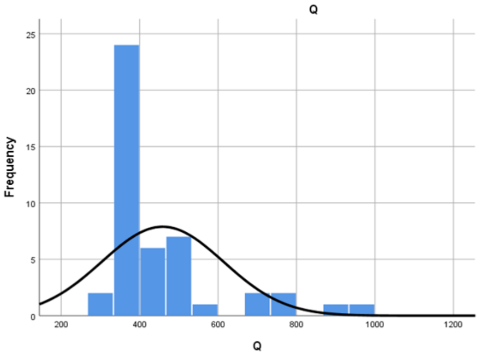

Figure (2): Discharge - Q

Figure 3 (Water Level - W.L): The distribution of W.L displays a slight right skew, with high values ranging from 137.03 to 147.07. These variations suggest occasional peaks due to reservoir operations or seasonal inflows.

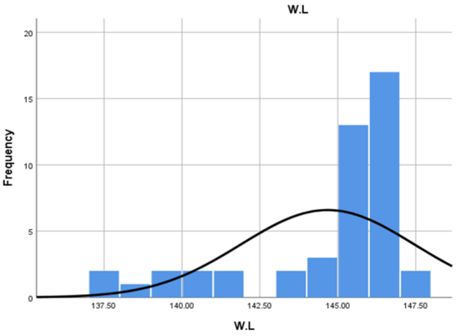

Figure (3): Water Level - W.L

Figure 4 (Electrical Conductivity - EC): EC shows a slight left skew, with high values between 586 and 1030. This indicates elevated salinity during periods of low water levels, consistent with the strong negative correlation (r = -0.819) observed in Table 3.

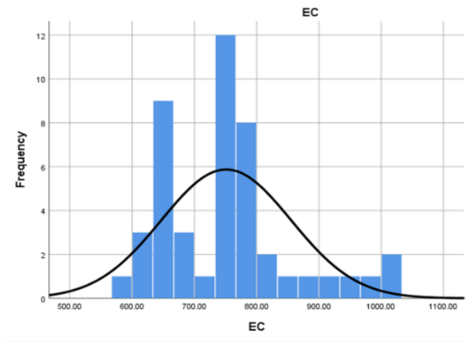

Figure (4): EC

Figure 5(pH): The pH distribution exhibits a slight left skew, with values ranging from 7.5 to 7.94. This indicates a stable pH range across varying water levels, with minimal variation despite the skewness.

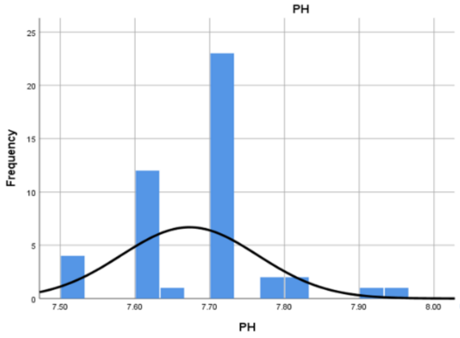

Figure (5): PH

Figure 6 (Total Suspended Solids - TSS): TSS demonstrates a slight left skew, with high values between 369 and 738. This suggests significant sediment loads during low flows, impacting turbidity and water clarity.

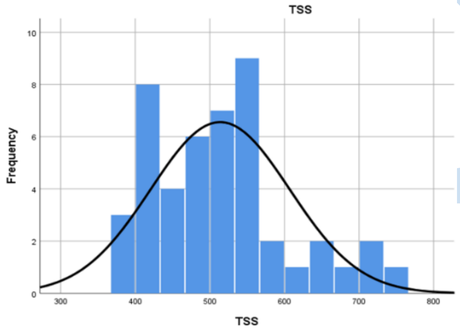

Figure (6): Total Suspended Solids - TSS

Figure 7 (Potassium - K): The histogram for K is slightly left-skewed, with higher concentrations between 4.3 and 10.4. This reflects potential agricultural runoff or soil leaching as contributors during specific conditions.

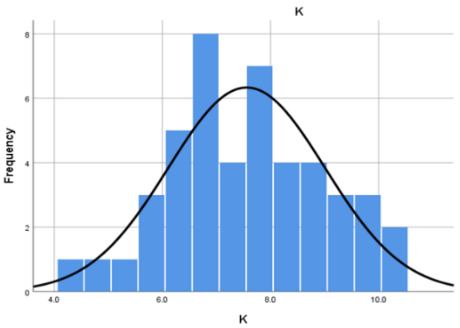

Figure (7): Potassium - K

Figure 8 (Sodium - Na): Na shows a left-skewed distribution, with values ranging from 8 to 49. Elevated sodium levels during low water periods highlight potential salinity concerns for agricultural and domestic use.

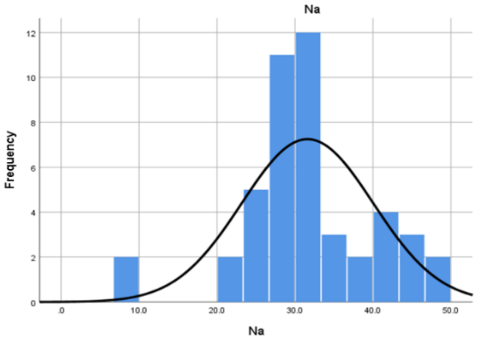

Figure (8): Sodium - Na

Figure 9 (Magnesium - Mg): Mg demonstrates a slight right skew, with high values between 9.5 and 31.7. This suggests a geochemical influence with moderate variability under fluctuating water levels.

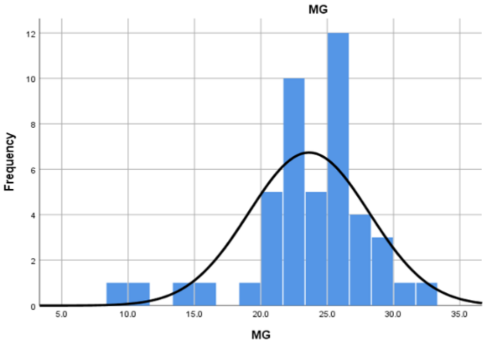

Figure (9): Magnesium - Mg

Figure 10 (Calcium - Ca): The histogram for Ca shows a left skew, with values between 23.2 and 52. This indicates variability in water hardness, affecting scaling potential in irrigation systems.

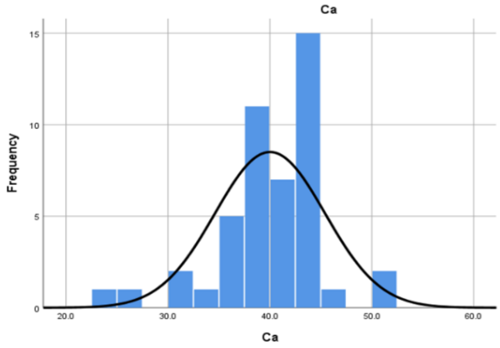

Figure (10): Ca

Figure 11 (Chloride - Cl): Cl distribution shows a left skew, with concentrations ranging from 33 to 92.3. The strong negative correlation (r = -0.838) in Table 3 aligns with these observations, emphasizing its sensitivity to water level fluctuations.

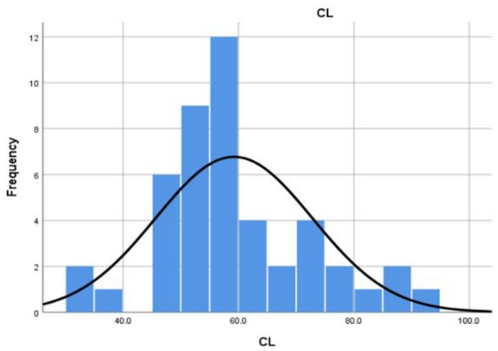

Figure (11): Chloride - Cl

Figure 12 (Sulfate - SO_4): SO_4 distribution is slightly right-skewed, with values ranging from 114 to 207. This indicates potential scaling issues during periods of elevated sulfate concentrations.

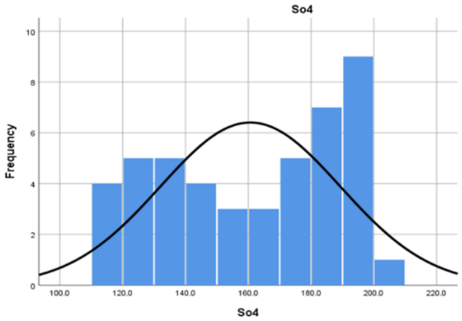

Figure (12): Sulfate - SO_4

Table (2): Parameters, Skewness and Range of Values

Parameter	Skew	Min. To Max. Val
Q	**left**	**300 to 1000**
W.I	**right**	**137.03 to 147.07**
PH	**left**	**7.5 to 7.94**
EC	**left**	**586 to 1030**
TSS	**left**	**369 to 738**
K	**left**	**4.3 to 10.4**
Na	**left**	**8 to 49**
Mg	**right**	**9.5 to 31.7**
Ca	**left**	**23.2 to 52**
Cl	**left**	**33 to 92.3**
SO_4	**right**	**114 to 207**

Table (3): Person Correlation.

Correlations											
	Q	**W.L**	**EC**	**pH**	**TSS**	**K**	**Na**	**Mg**	**Ca**	**Cl**	**SO_4**
Q	1										
W.L	0.336*	1									
EC	- 0.438**	-0.819**	1								
pH	0.08	-0.302**	0.101	1							
TSS	-0.102	-0.706**	0.854**	0.81	1						
K	-0.633**	-0.728**	0.696**	0.017	0.517**	1					
Na	-0.32*	-0.341*	0.449**	-0.233	0.475**	0.462**	1				
Mg	-0.573**	-0.295*	0.295*	-0.123	0.054	0.356*	0.46**	1			
Ca	-0.207	-0.623**	0.703**	0.016	0.746**	0.482**	0.761**	0.362*	1		
Cl	-0.538**	-0.838**	0.901**	0.119	0.777**	0.718**	0.539**	0.488**	0.798**	1	
SO_4	-0.577**	-0.577**	0.85**	-0.055	0.692**	0.634**	0.353*	0.335*	0.543**	0.796**	1

**Correlation is significant at the 0.01 level.
*Correlation is significant at the 0.05 level.

Table 4 summarizes the correlation analysis between water level (W.L) and various water quality parameters, highlighting the strength of the relationships, their distribution patterns, and the impact on water quality. It is evident that Electrical Conductivity (EC) has the strongest negative correlation with W.L (-0.819), indicating that higher water levels significantly reduce salinity, which is critical for irrigation purposes. Conversely, pH exhibits a weak negative correlation (-0.302), suggesting minimal variation with changes in water level. Other parameters, such as Chloride (Cl) (-0.838) and Potassium (K) (-0.728), also show strong negative correlations, emphasizing the need for targeted management strategies to mitigate their effects during periods of low water levels.

Table (4): Water Level Correlation Analysis and Recommendations.

Parameter	Correlation Coefficient (r)	Distribution Analysis	Impact on Water Quality (27)	Recommendations
Electrical Conductivity (EC)	-0.819	Slight left skew due to high values (586-1030) other values are normally distributed.	Significant reduction in salinity at higher water levels; critical for irrigation quality.	Regular EC monitoring to mitigate salinity issues in low water levels.
pH	-0.302	Slight left skew with high values (7.5-7.94) majority are normal.	Negligible impact on pH with changes in water level; stable parameter.	Maintain standard pH monitoring; no significant adjustments required.
Total Suspended Solids (TSS)	-0.706	Slight left skew due to high values (369-738) rest are normal.	Substantial reduction in sediment load; improves turbidity at higher levels.	Enhance erosion control and sediment management during low water levels.

Potassium (K)	-0.728	Slight left skew due to high values (4.3-10.4) others are normal.	Considerable decline in potassium; indicates reduced agricultural runoff influence.	Control potassium inputs from fertilizers to reduce runoff impacts.
Sodium (Na)	-0.341	Slight left skew with high values (8-49) remaining values are normal.	Moderate reduction in sodium; improves water suitability for agriculture.	Monitor sodium to manage salinity risks, especially during low water periods.
Magnesium (Mg)	-0.295	Slight right skew with high values (9.5-31.7); rest conform to normal distribution.	Minimal effect on magnesium; does not significantly affect water hardness.	Focus on critical factors as magnesium shows weak correlation with water level.
Calcium (Ca)	-0.623	Slight left skew with high values (23.2-52); other values normal.	Noticeable decrease in calcium; impacts water hardness and scaling potential.	Adjust treatment processes to manage hardness fluctuations due to calcium.
Chloride (Cl)	-0.838	Slight left skew due to high values (33-92.3); most conform to normal distribution.	Significant chloride reduction; enhances water taste and reduces corrosion risk.	Implement chloride reduction strategies during low water periods to improve quality.
Sulfate (SO_4)	-0.577	Slight right skew due to high values (114-207); rest are normal.	Moderate sulfate reduction; mitigates scaling risks and improves usability.	Monitor sulfate to prevent scaling and enhance water suitability for domestic use.

Figure 13 visualizes the correlation coefficients for these parameters, providing a clear graphical representation of their relationships with W.L. The negative correlations dominate, with notable exceptions for weak correlations observed in Magnesium (Mg) (-0.295). The figure highlights the significant dependencies of key parameters such as EC, Cl, and TSS on water levels, which align with the statistical trends observed in Table 3. These insights underscore the importance of adaptive water quality management practices in the Euphrates River to mitigate the effects of fluctuating water levels.

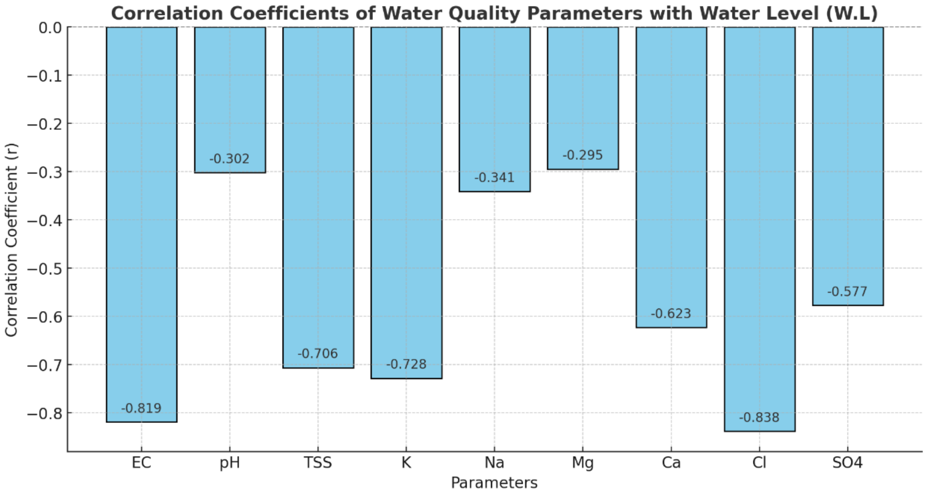

Figure (13): Correlation Coefficients of Water Quality Parameters with Water Level (W.L).

Conclusion and recommendation

This study effectively shows the complicated relationship between water levels and water quality measures in the Euphrates River, notably at the Haditha Dam reservoir in Anbar Province, Iraq. By assessing key factors such as discharge (Q), electrical conductivity (EC), pH, total suspended solids (TSS), and main ions (Na, K, Mg, Ca, Cl, SO_4), the research demonstrates the significant impact of varying water levels on water quality.

The findings reveal that EC, Cl, and TSS demonstrate strong negative correlations with W.L, indicating that higher water levels improve salinity conditions, reduce sedimentation, and enhance overall water quality. On the other hand, pH and Mg show weak correlations, reflecting relative stability under varying hydrological conditions. The diversity of these parameters is further highlighted by the distribution patterns shown in Figures 4 to 14, where the skewness of some variables, like EC and TSS, corresponds with their statistical correlations.

The management of water resources will be significantly impacted by these discoveries. Effective salinity and sedimentation controls during low flows, along with routine monitoring of critical ions, are necessary to mitigate the detrimental effects on residential and agricultural water demands. To guarantee sustainable water use in the Haditha dam reservoir, adaptive water quality standards that take these findings into account should be created.

This study collects statistical correlations, as presented in Table 4, and graphical analysis, as shown in Figure 15, to offer a holistic framework for understanding and managing water quality dynamics under changing water levels. The findings are very important for assuring long-term water sustainability in areas that experience both hydrological variability and anthropogenic pressures.

To evaluate the effect of varying water levels on water quality, seasonal monitoring procedures should be put in place. Insights into the dynamics of regional water quality can be gained by comparing the outcomes with those of other dams and reservoirs around Iraq. Furthermore, in order to effectively predict changes in water quality, more sophisticated statistical models—like multiple regression analysis and hydrological models—must be used. By improving knowledge of the connection between water levels and quality, these methods would result in more sensible management plans for long-term water resources.

DISCLOSURE STATEMENT

- Ethics clearance and participation consent: Not Applicable.
- Consent for publication: Not Applicable.
- Author's contribution: Sari Aymen Alrawi, Arkan Dhari Jalal, Uday Hatem Abdulhameed: Study design and conception & Draft manuscript preparation. Sari Aymen Alrawi: Computations and theoretical modeling & Data analysis and validation

– Conflicts of interest: The authors declare that there is no conflict of interest regarding the publication of this article.

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