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Comparison of the Water Quality and Salinity Modeling for AL-Rumaitha and AL-Atshan Rivers

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Keywords:
Comparison; Water quality; AL-Rumaitha River; AL-Atshan River; Salinity; Total dissolved solid.

Highlights:

- *A water quality index measures the quality of water using (WAQIM) methods.*
- *The analyses done using SPSS software.*
- *Salinity was the main parameter of modeling.*

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Abstract: Many rivers suffer acutely from various pollutants that pose risks to plant and animal life, the environment, and human health due to the lack of regulations to protect the rivers' water quality and environmental safety. Weight Quality index method (WAQIM) based on 12 water quality parameters (Mg, Cl, EC, TDS, Ca, PO_4, SO_4, TH, Na, Turbidity, TSS, and Temp) using (SPSS) program Artificial Neural Network (ANN) methods. The water quality index results for AL-Atshan River were greater than 100, classified as poor and polluted water, compared to AL-Rumaitha River, which showed less than 100 pollution for most of the study period, classified as more suitable and needing less treatment than AL-Atshan River. The neural network obtained a mathematical model that can predict the total dissolved solids of AL-Atshan and Al-Rumaitha rivers with very high accuracy, as the determination coefficients were 96% and 98%, respectively, and the sampling results support this analysis, indicating that AL- Atshan River has a salinity higher than World Health Organization Standard limits. (EC was about 3000μs/cm TDS about 1600 ppm), while Al-Rumaitha's results were within WHO specification limits (EC about 1500 μs/cm, TDS about 800 ppm).

مقارنة جودة المياه ونمذجة الملوحة لنهري الرميثة والعطشان

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الخلاصة
تعاني العديد من الأنهار بشكل حاد من مجموعة متنوعة من الملوثات التي تشكل مخاطر على الحياة النباتية والحيوانية والبيئة وصحة الإنسان بسبب عدم وجود لوائح لحماية جودة المياه والسلامة البيئية للأنهار، الهدف من هذه الدراسة النظر في مستوى التلوث الذي يحدث في نهري العطشان والرميثة باستخدام مؤشر جودة المياه (WQI) (طريقة المؤشر الحسابي للوزن) اعتمادًا على ١٢ معيارًا لجودة المياه Mg, Cl, EC,TDS, Ca, PO4, SO4, TH, Na, Turbidity, TSS, Temp. باستخدام (SPSS) الشبكة العصبية الاصطناعية (ANN). كانت نتائج مؤشر جودة المياه لنهر العطشان أكبر من ١٠٠، مصنفة على أنها مياه فقيرة وملوثة، مقارنة بمياه نهر الرميثة الذي أظهر أقل من ١٠٠ تلوث لغالبية فترة الدراسة، مصنفاً على أنه أكثر ملاءمة ويحتاج إلى معالجة أقل من مياه نهر العطشان. أظهرت نتائج الشبكة العصبية الحصول على نموذج رياضي يمكنه التنبؤ بمجموع المواد الصلبة الذائبة لنهري العطشان والرميثة بدقة عالية للغاية حيث كانت معاملات التحديد ٩٦ % و ٩٨% على التوالي، كما أن نتائج أخذ العينات تدعم هذا التحليل الذي يشير إلى ان نهر العطشان ذو ملوحة اعلى من حدود مواصفات الصحة العالمية (كانت EC حوالي ٣٠٠٠ مايكرو سيمنز على السنتيمتر ، و TDS حوالي ١٦٠٠ جزء في المليون) بينما كانت نتائج نهر الرميثة ضمن حدود مواصفة منظمة الصحة العالمية (EC حوالي ١٥٠٠ مايكرو سيمنز على السنتيمتر، TDS حوالي ٨٠٠ جزء في المليون).

الكلمات الدالة: مقارنة، جودة الماء، نهر الرميثة، نهر العطشان، الملوحة، إجمالي المواد الصلبة الذائبة.

1.INTRODUCTION

Human activity and infrastructure frequently endanger water quality, making the source of life itself a threat to life [1]. Water resources are one of the pillars of sustainable development worldwide [2]. Water availability, in quantity and quality, is not only a critical resource for industrial and agricultural development but also urban life [3]. In addition, in villages, with the increasing frequency of discussion about the possibility of the world's countries succumbing to water poverty in the coming years, there is an urgent need to develop development plans to protect water sources from depletion and pollution [4]. Developing a plan for monitoring water sources is one of the fundamental operations of water quality management by installing monitoring stations at fixed points that represent river water specifications [5]. They are used to perform basic checks factored into the water assessment over specific periods in which objectives are met due to the variables chosen considering the region's environmental and climatic conditions [6]. Water quality studies are regarded as one of the most critical aspects of water resource management, establishing the present evaluation, requirements, and methods for treating quality [6]. As a result, evaluation and monitoring processes are required to take advantage of these sources, especially given the suffering of countries worldwide from droughts and the need for optimal water resource utilization [7]. Many academics have focused on river water pollution in Iraq due to the deterioration of this sector in recent decades, which has been exacerbated by the country's wars and political upheavals [8]. These studies help to diagnose pollution sources and provide remedies and suggestions to eliminate or lessen pollution's effects [9]. A water quality index measures the quality of water employed to assess and categorize the quality of a water source and the extent to which it can be used for human, animal, and plant purposes, so it is an essential component in the water quality management system [10]. When developing a water quality index, the relative importance of various parameters is determined by the intended use of the water [11], which is mostly done to determine its suitability for human consumption [12] since the AL-Rumaitha and AL-Atshan rivers are the only two that flow through Al-Muthanna Governorate, and the governorate's reliance on the AL-Rumaitha River to create drinking water purification stations, the objective of the research is to assess the fitness of bath water rivers for human use using water quality index, based on a combination of chemical, physical, and biological elements united into a single number that ranges from 0 to 100 and needs four steps: (1) variable selection, (2) initial data conversion into a standard scale, (3) giving weights, and (4) aggregation of sub-index value. Also, the study intends to compare the water quality of the two rivers, Al-Rumaitha and Al-Atshan, to determine their current status and indicate the suitability of the river's water for human use, using a water quality index and to create a mathematical model to demonstrate the relationship between dissolved salts and other water elements.

2.AREA OF STUDY

AL-Muthana governorate is in southern Iraq, bordering Saudi Arabia; it is the second biggest governorate in Iraq in terms of area and classified as the second smallest governorate in terms of population [13]. The main source of water supply in the AL-Muthana governorate is the Euphrates River, which branches at the Hindeyah area in the Babylon governorate [14]. The first branch (Al-Atshan River) flows to the south and then to the east, crossing AL-Samawa City continue to Nasiriya City in The-Qar governorate with annual discharge of about (12-22) m^3/sec with high salinity > 1500ppm due to drainage of outfalls from the irrigation of rice fields to the river. The second branch (AL-Rumatha River) flows to the east and then south, crossing the AL-Rumaitha and AL-Warqa cities in the AL-Muthana governorate, which has better quality and low sanity that makes it the only suitable source for water supply with annual discharge of (15-25) m^3/sec [15]. The area of study depict a Map of the Euphrates River between Hindyia Barrage, Samawa and Nasiriya city.

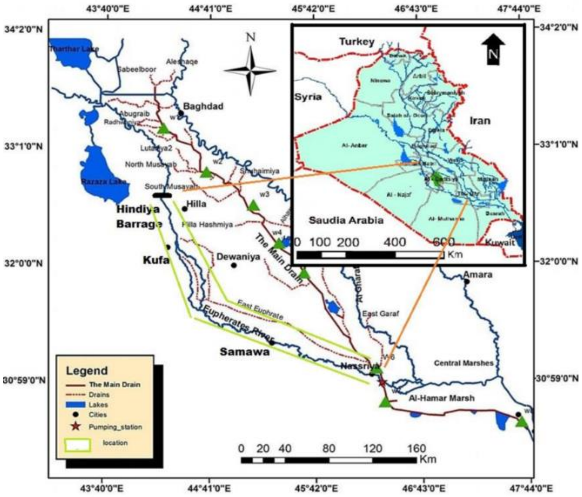


Fig. 1 Area of Study [16].

3.EXPERIMENTAL PROGRAM

3.1.Apparatus and Procedures

1- The Statistical Package for Social Sciences (SPSS) software (Artificial Neural Network (ANN) methods were used to analyze data.

2- Analyzing samples collected (The AL-Muthanna Governorate Environment Directorate collected) from the AL- Atshan River and Al-Rumaitha River for three years (2020, 2021, and 2022) from places representing river water characteristics along the watercourse. The water quality index has been studied to detect suitable water quality for human consumption. To determine the extent of pollution in the two rivers, the gravimetric method was used, and to calculate the water quality index, (12) variables were chosen (Mg, Cl, EC, TDS, Ca, PO_4, SO_4, TH, Na, Turbidity, TSS, and Temperature) according to their significance and the availability of measuring devices, and the WAWQI was used.

3- Calculated water quality index using the following steps [17].

Step 1: Collect data on various physico-chemical water quality parameters.

Step 2: Calculate the proportionality constant "K" value using the formula k= $(1/1/\sum_{i=1}^{n} s\, i))$, where "$s_i$" is the standard permissible for the ^{n}th parameter.

Step 3: Calculate quality rating for the nth parameter (q_n), where there are n parameters, q_n is calculated using

$q_n = 100 \{ (v_n - v_{io})/(s_n - v_{io}) \}$

where v_n is the estimated value of the nth parameter of the given sampling station, v_{io} is the ideal value of the nth parameter in pure water, and s_n is the standard permissible value of the ^{n}th parameter.

Step 4: Calculate the unit weight for the nth parameter. $W_n = (k/s_n)$.

Step 5: Calculate the Water Quality Index (WQI) using the formula WQI= $((\Sigma w_n * q_n)/\Sigma w_n)$.

Then, compare the results with Table 1, ranking water quality according to the amount of WQI.

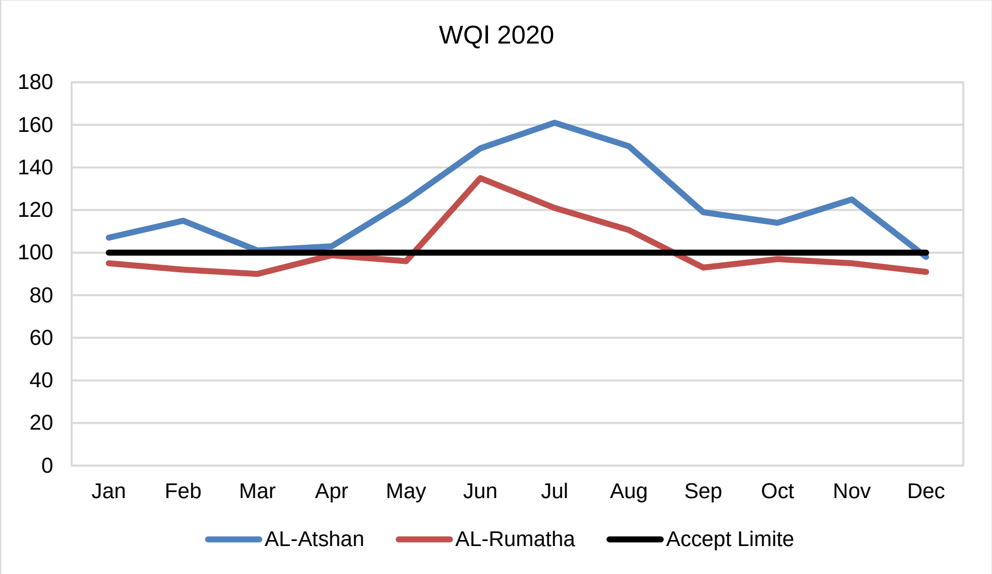
Table 1 Water Quality Classification Based on the Measurement of WQI [11].

WQI Classification	Water Quality Index
less than 50	excellent
50-100	Good
100-200	Poor
200-300	Very poor
More than 300	non-drinkable

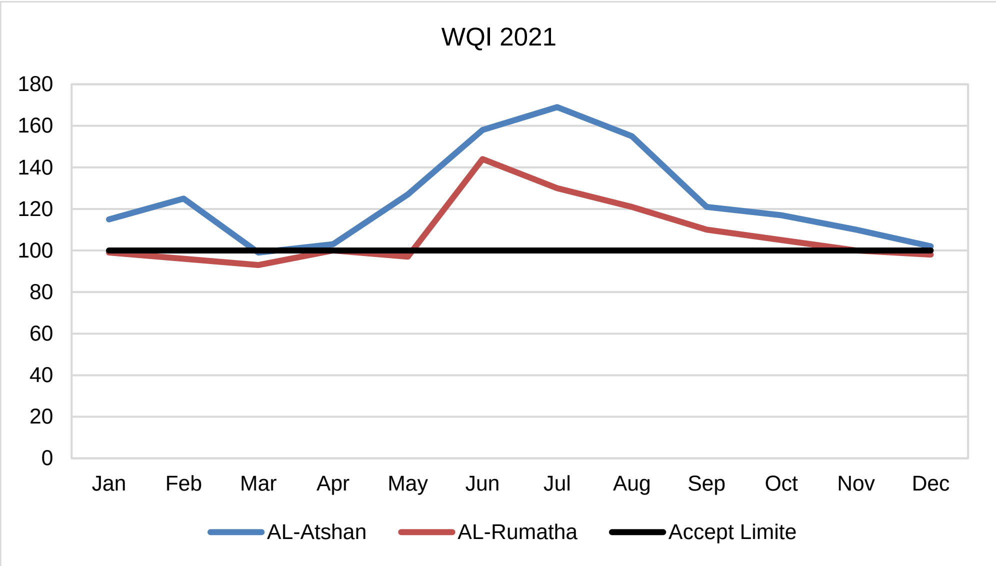
4- Employing Artificial Neural Network (ANN) Statistical Package for the Social Sciences (SPSS) v26 to create a mathematical model for estimating the value of total dissolved solids (TDS) for both rivers based on (Ca, EC, Mg, SO_4, and Cl).

4.RESULTS AND DISCUSSION

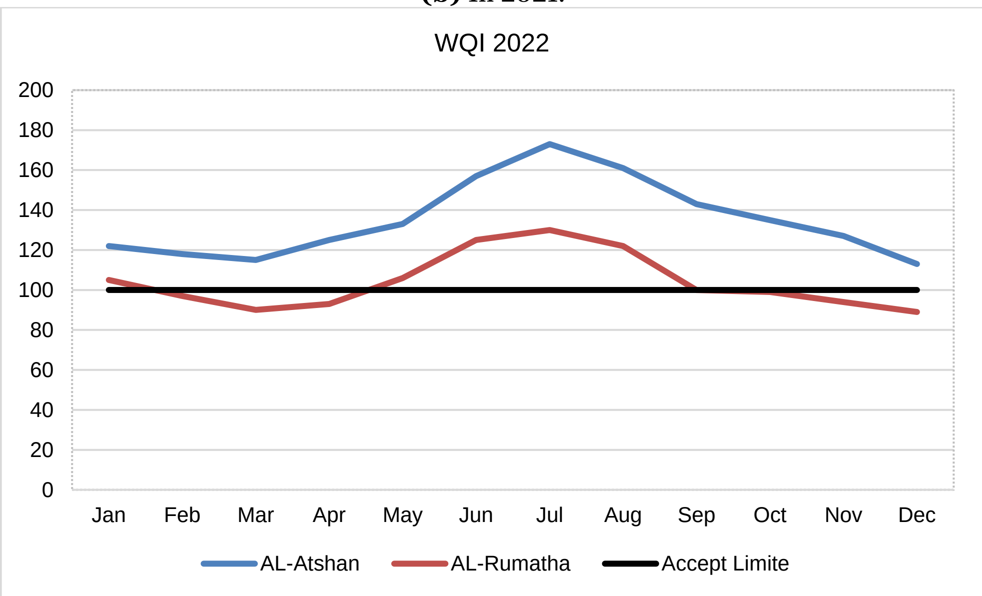
The Water Quality Index (WQI) is a numerical rating that provides an overview of water quality based on many main factors and their weights, which can be used to assess and communicate the health of water bodies, such as rivers, lakes, and groundwater sources [18]. To assess water quality, the index considers various physical, chemical, and biological parameters [19]. Figure 2 depicts the amount of monthly variation in the water quality index of AL-Atshan and AL-Rumaitha rivers for (2020, 2021, and 2022) in relation to the upper limit to indicate water fit for human consumption. The figures show that during all three years and at most times of each year, the AL-Atshan River's water quality index was greater than 100 according to Iraqi standards, meaning that the river water is polluted and must be treated before using it. This pollution happens due to a drop in river discharges and a rise in evaporation due to high temperatures and excess drainage along the river [20]. While AL-Rumaitha River had significantly less pollution than the AL-Atshan River, in which WQI was generally within acceptable standards ≤ 100, except in the summer period when it was outside of acceptable limits because it has a greater discharge and is located far from the trocars' drain line [21].



(a) In 2020.



(b) In 2021.



(c) In 2022.

Fig. 2 Water Quality Monthly Variation for AL-Atshan and AL-Rumaitha Rivers.

The Artificial Nural Network (ANN) software is a valuable tool to estimate water quality in water treatment facilities to lower testing and operational costs, assess performance, and further comprehensively manage conditions of operation [22]. The ANN model was developed to anticipate TDS in the AL-Atshan and Al-Rumaitha Rivers according to the effect of EC, Mg, Ca, SO_4, and Cl. The model considered 36 input data points, 24 used for training and 12 for testing. The information scale technique involves standardization, while the number of hidden layers is one. The degree to which minor and substantial elements in the input, hidden, and output layers are related. The model's aim was a total dissolved solid. The activation function is shown in Figs. 3 and 4. Although Tables 2 (a) and (b) show the estimated parameter prediction of the input layer bias, a hidden layer of covariates, and the output layer, each value in the data table is denoted by the thickness of the line in the figure, where the grey line indicates positive, and the blue line reflects negative values. The width of the line represents the level of impact exerted by the component in the prediction model, regardless of whether the values are either positive or negative [23].

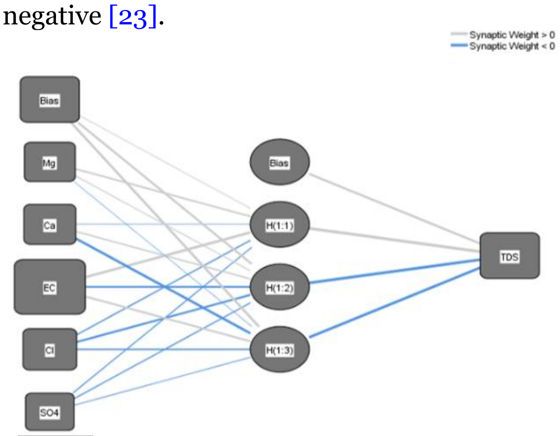


Fig. 3 Artificial Neural Network (AL-Atshan River).

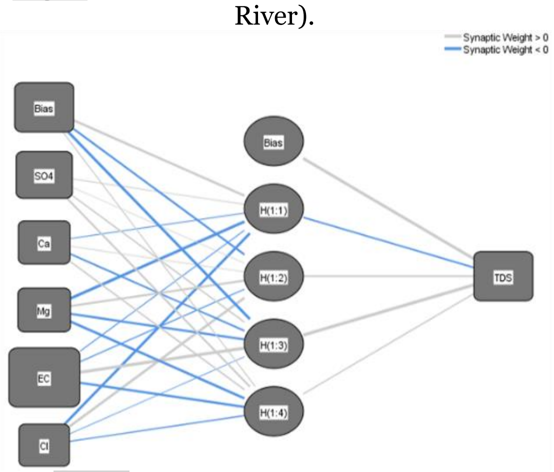


Fig. 4 Artificial Neural Network (AL-Rumaitha River).

Table 2 Parameter Estimation for:

(a) AL-Atshan River

Predictor		Predicted			
		Hidden Layer 1			Output Layer
		H(1:1)	H(1:2)	H(1:3)	TDS
Input Layer	(Bias)	.029	.317	.369	
	Mg	.181	.090	-.024-	
	Ca	0.178	.118	-.465-	
	EC	.719	-.243-	.263	
	Cl	.175-	-.273-	-.179-	
	SO4	.157-	-.162-	-.065-	
Hidden Layer 1	(Bias)				.329
	H(1:1)				1.524
	H(1:2)				-1.280-
	H(1:3)				-.975-

(b) AL-Rumaitha River

Predictor		Predicted				
		Hidden Layer 1				Output Layer
		H(1:1)	H(1:2)	H(1:3)	H(1:4)	TDS
Input Layer	(Bias)	.428	-.305-	-.583-	.143	
	SO4	.109	.050	.232	.298	
	Ca	.112-	.057	-.262-	.245	
	Mg	0.313-	.203	-.366-	-.434-	
	EC	-.139	-.144-	.770	-.366-	
	Cl	.582	.506	-.089-	-.213-	
Hidden Layer 1	(Bias)					.841
	H(1:1)					-.252-
	H(1:2)					.263
	H(1:3)					1.525
	H(1:4)					.229

The impact of (independent variables) on total dissolved solids (dependent variable) was established in Eqs. 1 and 2 for AL-Atshan and AL-Rumaitha Rivers, respectively [25].

$$TDS= 0.029 +0.181\ Mg + 0.178\ Ca + 0.719\ EC+0.175Cl+0.157\ SO_4 \quad (1)$$

$$TDS=0.428+0.109\ SO_4+0.112\ Ca + 0.313\ Mg + 0.77\ EC +0.506 \quad (2)$$

Tables 3 (a) and (b) demonstrate that the total quantity of mistakes in training and testing input data was little, with squared errors and relative errors being small, i.e., (0.028, 0.034), (0.376, 0.11) (0.025, 0.091), and (0.014, 0.012) for the AL-Atshan and AL-Rumaitha rivers, meaning that the model has been effective in predicting the total dissolved solid of the river's raw water [24]. Divide the data available throughout the network's training into three categories: the Training set, the Validation set, and the Test set, in which the Training set error was employed to modify the network's weights and biases, the Validation set error was used to stop the training process if this error began to rise for a particular amount of iterative cycles, and the Test set error was utilized for contrasting the various models [25]. Figures 5 and 6 show the coefficient of determinations and the equations between the predictors and observed value of total dissolved solid for AL-Atshan and AL-Rumaitha rivers, respectively, in which the best value of coefficients of determinations were (0.96) and (98).

Table 3 Model Summary for:
(a) AL-Atshan River

Model Summary		
Training	Sum of Squares Error	.028
	Relative Error	.031
	Stopping Rule Used	1 consecutive step(s) with no decrease in error[a]
	Training Time	0:00:00.00
Testing	Sum of Squares Error	.025
	Relative Error	.091
Dependent Variable: TDS		
a. Error computations are based on the testing sample.		

(b) AL-Rumaitha River.

Model Summary		
Training	Sum of Squares Error	0.376
	Relative Error	.110
	Stopping Rule Used	1 consecutive step(s) with no decrease in error[a]
	Training Time	0:00:00.00
Testing	Sum of Squares Error	.014
	Relative Error	.012
Dependent Variable: TDS		
a. Error computations are based on the testing sample.		

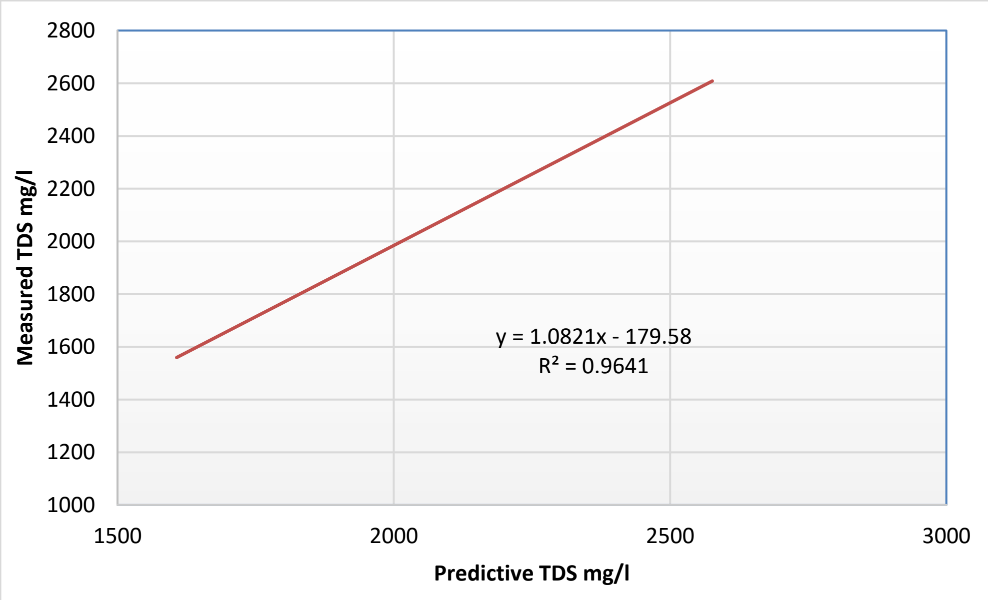


Fig. 5 Actual Total Dissolved Solid (TDS) Versus Predicted Total Dissolved Solid for AL-Atshan River.

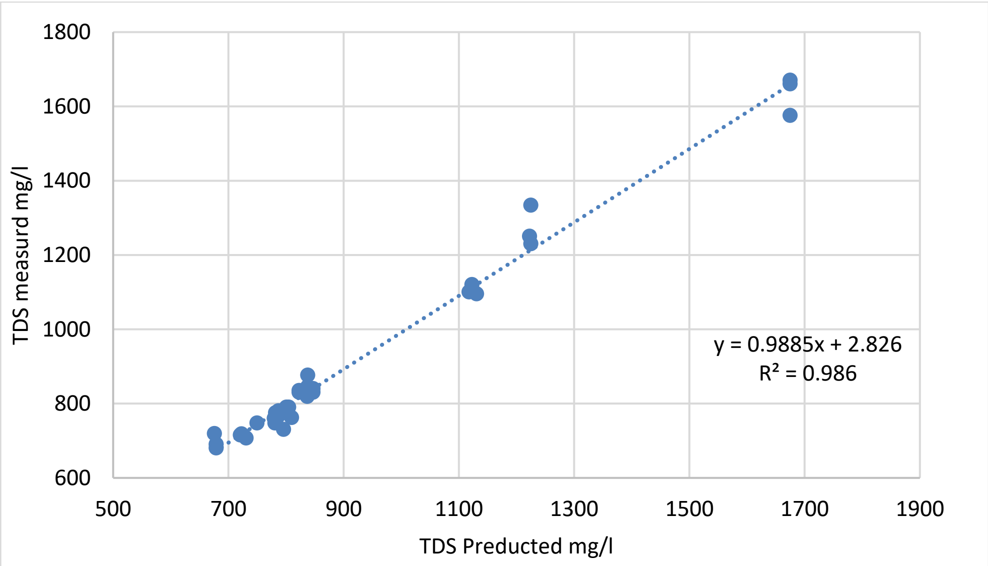


Fig. 6 Actual Total Dissolved Solids (TDS) Versus Predicted Total Dissolved Solid for AL-Rumaitha River.

The laboratory test leads to promote this investigation, indicating that the AL-Atshan River suffers from a high salinity level, i.e., EC was around 3000, and TDS was around 1600 ppm, whereas the AL-Rumaitha River has a lower salinity, i.e., EC was around 150 µs/cm 0, and TDS was around 800ppm according to the World Health Organization guidelines for water for consumption, where TDS should be less than (1000ppm). Since the traditional approach is used to operate drinking water treatment facilities, these plants were built on the AL-Rumaitha River, where the salinity of the water is within acceptable limits, as opposed to the AL-Atshan River, where the percentage of salts is extremely high, requiring constructing modern treatment plants capable of eliminating dissolved salts [26].

5.CONCLUSIONS

River Water pollution is a significant environmental issue threatening aquatic ecosystems and human health. It occurs when harmful substances enter rivers and contaminate the water, making it unsuitable for its intended purposes. During the investigation period, the water quality of AL-Rumaitha River was better and less polluted than AL-Atshan River, where the neural network results (ANN) revealed a close link between total dissolved solids (TDS) and independent parameter (EC, Ca, Mg, SO4, and Cl) with confidence of determinations (R^2) 96 and 98 respectively for AL-Atshan and AL-Rumaitha River in which Laboratory testing revealed that the AL-Rumaitha River is less saline than the AL-Atshan River, making it more suitable for human consumption than the Atshan River.

ABBREVIATIONS

Abbreviations	Meaning
WQI	Water Quality Index
TDS	Total Dissolved Solids
Mg	Magnesium
EC	Electrical Resistivity
Ca	Calcium
SO4	Sulfate
Cl	Chloride
PO4	Phosphate
DO	Dissolved Oxygen
SPSS	Statistical Package for The Social Sciences
ANN	An Artificial Neural Network
R^2	In Statistics, The Coefficient of Determination
Cs	Standard Permissible for ^{N}th Parameter
qi	Quality Rating
Wi	
TH	Total Hardness
TSS	Total Suspended Solids

REFERENCES

[1] Moussa KM, Hadi HJ. **River Water Salinity Impact on Drinking Water Treatment Plant Performance Using Artificial Neural Network**. *Journal of Engineering* 2019; **25**(8): 149-159.

[2] Karimi MN, Banihashemi AH. **Performance Evaluation of Dohuk Water Treatment Plant**. *Journal of the University of Duhok* 2017; **20**(1): 207–219.

[3] Hu XY, Arnold DM. **Effect of pH of Coagulant on the Treatment of Wastewater from Tofu Industry**. *American Journal of Environmental Science* 2010; **67**(15): 3–6.

[4] Shahab MM, Hardan SM. **Design and Evaluation of Household Horizontal Slow Sand Filter**. *Current Journal of Applied Science and Technology* 2017; **23**(1): 1–10.

[5] Abdelkareem AE, Sharif BS. **Influence of Type and Dose of Coagulants on Effectiveness of PAH Removal in Coagulation Water Treatment**. *Journal of Water Science and Engineering* 2018; **14**(3): 193–200.

[6] Louis EO. **Conventional Water Treatment of Domestic Groundwater Supplies**. *Journal of University of Babylon for Engineering Sciences* 2019; **27**(1): 354-365.

[7] Wang CR, Ren XL, Hou ZF. **Turbidity and Removal Efficiency in the Main Water Purification Plants of Nineveh Province**. *Journal of Science* 2013; **24**(6): 39-53.

[8] Alabdraba WM, Ahmed YR. **Prediction of Turbidity in Tigris River Using Artificial Neural Networks**. *Journal of Engineering* 2018; **14**(3): 2483–2493.

[9] Abdulmajeed KS. **Health Effects from Exposure to Sulphates and Chlorides in Drinking Water**. *Pakistan Journal of Medical and Health Sciences* 2012; **6**(3): 648–652.

[10] Aalami BO. **Performance Evaluation of Drinking Water Treatment Plant in Iraq**. *Journal of Physical Sciences* 2019; **4**(1): 18–29.

[11] Allerdings DN, Vasyukova EL. **The Practical Influence of Rapid Mixing on Coagulation in a Full-Scale Water Treatment Plant**. *Journal of Water Science and Technology* 2015**; 71**(4):566-571.

[12] Akram SD, Rehman FM. **Hardness in Drinking-Water, Its Sources, Its Effects on Humans and Its Household Treatment**. *Journal of Engineering* 2018; **4**(1): 1-4.

[13] Almuktar BO, Hamdan DA, Scholz YU. **Assessment of the Effluents of Basra City Main Water Treatment Plants for Drinking and Irrigation Purposes**. *Journal of Engineering* 2018; **12**(12): 1–26.

[14] Badr NP, Al-Naeem SO. **Assessment of Drinking Water Purification Plant Efficiency in Al-Hassa, Eastern**

Region of Saudi Arabia. *Journal of Medical and Health Sciences* 2015; **13(**11): 6122, (1-17).

[15] Bakshi FM, Kyser EN. **Centralized Softening as A Solution to Chloride Pollution: An Empirical Analysis Based on Minnesota Cities**. *Journal of Medical and Health Sciences* 2021; **16**(2): 8-17.

[16] Balakrishnan RM, Kathpalia NA. **A Chaos Based Artificial Neural Network Architecture for Classification**. *An Interdisciplinary Journal of Nonlinear Science* 2019; **29**(11):11312.

[17] Chandra OL, Asadi ED. **Estimation of Water Quality Index by Weighted Arithmetic Water Quality Index Method**. *International Journal of Civil Engineering and Technology* 2017; **8**(4): 1215-1222.

[18] Bashir EN, Bashir OR. **Health Effects from Exposure to Sulphates and Chlorides in Drinking Water**. *Pakistan Journal of Medical and Health Sciences* 2012; **3**(8):648-652.

[19] Baxter DE, Zhang HK, Stanley. **Drinking Water Quality and Treatment: The Use of Artificial Neural Networks**. *Canadian Journal of Civil Engineering* 2001**; 28**(S1):26-35.

[20]Verbyla CC, Whiteford EN. **Emerging Challenges for Pathogen Control and Resource Recovery in Natural Wastewater Treatment Systems**. *Journal of Medical and Health Sciences* 2013; **2**(6):701-714.

[21] Carrim TY, Kruger LE. **A Guide to Plant Evaluation and Optimization Proceedings Water Institute of South Africa (WISA)**. *Journal of Water and Health* 2010; **155** (13):220-230.

[22] Catling SS, Abubakar DF. **A Systematic Review of Analytical Observational Studies Investigating the Association between Cardiovascular Disease and Drinking Water Hardness**. *Journal of Hydraulic Research* 2008; **6**(4):433-442.

[23] Artshorn EL, George RE. **Assessing Filter Robustness at Drinking Water Treatment Plants**. *Water and Environment Journal* 2015; **29**(1): 16–26.

[24] Hassan AA, Mahmood HA. **Evaluate the Efficiency of Drinking Water Treatment Plants in Baghdad City-Iraq.** *Journal of Applied and Environmental Microbiology* 2018; **6**(1):1–9.

[25] Chie BD. **Derivation of Engineering Design Criteria for Flow Field around Intake Structure: A Numerical Simulation Study**. *Journal of Marine Science and Engineering* 2020; **8**(10): 827, (1-16).

[26] Soori NS, Asmael ER. **A Review of the Recent Development in Machining Parameter Optimization**. *Jordan Journal of Mechanical and Industrial Engineering* 2008; **16**(2): 205-223**.**