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WQ assessment of water treatment plants using environmental and statistical indicators within Baghdad City

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ABSTRACT

The primary task that is facing most developing countries is the untreated disposal of wastewater into the water bodies. In order to meet the water needs of future generations, the integrated water resources should be managed within a sustainable method. This study illustrates the assessment and judgment of the suitability of Tigris River for drinking purposes using water quality index (WQI) and the selection of the mostly significant water quality WQ parameters that affect Tigris River deterioration using Artificial Neural Network (ANN). Along with Baghdad city, nine stations of Tigris River were assessed for fourteen physicochemical parameters. Results, Tigris River, was classified (poor – polluted) according to the Weighted arithmetic WQI (WA-WQI) with turbidity and Total dissolved solids (TDS) are the most parameter affecting on the WQ.

Keywords: WQI (WQI); Artificial Neural Network (ANN); Turbidity; Total dissolved solids (TDS).

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1. Introduction

Recently, developing countries have concentrated on evaluating WQ because freshwater will be a scarce resource in the future. There are natural processes governing surface WQ, such as precipitation and soil erosion, in addition to weathering and human impacts such as urban, agricultural, and industrial areas [1]. It is known in natural aquatic ecosystems that human and industrial developments require clean water, which is an essential requirement and is directly linked to human activities. Deterioration of WQ decreases the potable WQ, production of algae and macrophytes and undesirable characteristics with water uses result from Eutrophication [2-4]**.** Furthermore, if eutrophication plagues water, the treatment of such waters is costly, and it becomes unfit for use. Nutrients are leading to depleting the dissolved Oxygen (DO) to below 4 mg/L, so it endangers aquatic life [5, 6]. In the environmental policy of protection, WQ monitoring has the uppermost precedence for controling pollution difficulties and providing suitable WQ for serving various determinations like irrigation, drinking, etc. [7]. The simplest method is the WQI (WQI) to evaluate the WQ conditions. Quality levels in various sites of a river able to be compared for precedence for the necessary site treatment [8]. Another essential device is analysis of statistics that can practice large amounts of data through clarifying the association between 2 variables. Therefore, it assisted to decrease the variables number which might not impact the variable as dependent with no losing necessary data [9]. Numerous research revisions are there in the surface WQ assessing field such as, Khudair [2] selected Baghdad city as a case study with eight stations during the period 2004-2010 to find the quality of the Tigris River using sixteen physicochemical parameters as inputs and WQI by weighted arithmetic index method as an output. Results showed that a "inferior quality" is the class of Tigris River quality. Muisa [10] studied the effect of sewage effluent from the Hatcliffe sewage treatment plant (HSTP) on Chinyika

River using nine physicochemical parameters over four months in 2007. It was concluded that the primary pollution source for Chinyika River was the partially treated sewage effluent from HSTP. The present study's objectives are to evaluate Baghdad WQ for purposes of drinking using WQI, expecting the mostly noteworthy parameters which impact WQI utilizing an artificial neural network (ANN).

2. Methodology and materials

2.1. Areas of study description and collection of data

One of the largest rivers in the Middle East is the Tigris River, with a length of 1800 km, of which is 110 km inside Baghdad city. Baghdad city is divided into two major parts (AL-Karkh and AL-Rusafa) by Tigris River, where it enters the boundary of the city at coordinates 33˚36' N, 44˚24' E with water flowing from north to south [11]. Nine stations (Al-Karkh, Al-Sader, Al-Wathba, East Tigris, Al-Wahda, Al-Karama, Al-Dora, Al-Qadisiyah, and Al-Rashed) along Tigris River were selected to collect river water samples and to examine physical and chemical characteristics as shown in **Figure 1**. Fourteen WQ parameters set were elected according to both data availabilities from each station and significance from 2012-2019. Such 14 parameters are Ca, TDS, TH, Mg, Cl^-, pH, SO_4^{-2}, EC, NO_3^-, and Orthophosphate (PO_4^{-3}), (NO_2), (NH_3), Alkalinity and Turbidity.

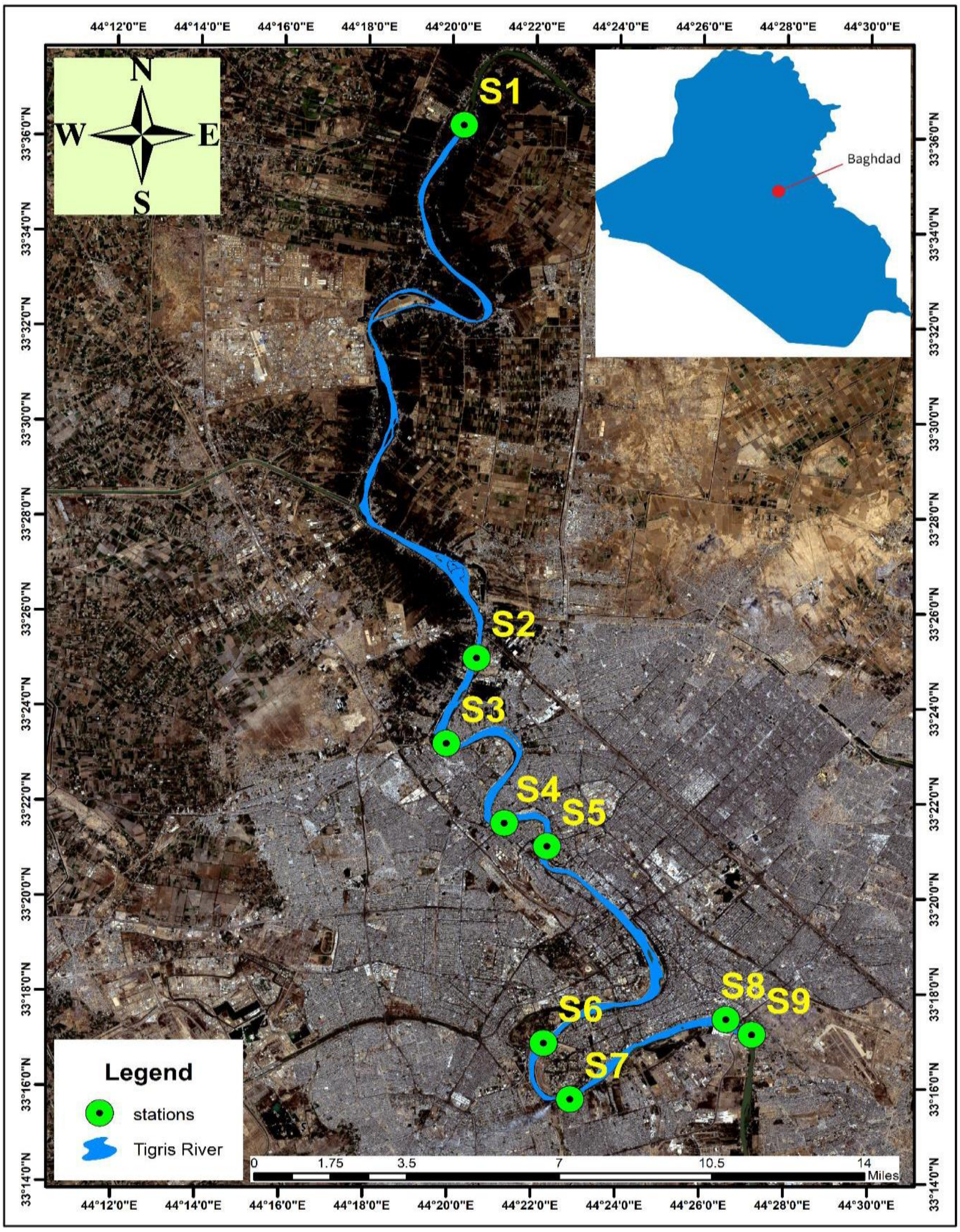

Figure 1. Sampling stations at Tigris River through Baghdad City

2.2. WQI (WQI)

The principle of WQI depends on collecting the parameters of WQ and comparing them with allowable limits of regulatory standards for producing a single number representing the overall WQ [12, 13]. The weighted arithmetic index method and the permissible limits recommended by the Iraqi standard organization (ISO/417, 2001) (Iraqi Standard Organization (ISO), [14] for drinking WQ, as shown in **Table 1** were used to calculate the WQI. The WQI was determined using the following equations [15].

1. Calculate proportionality constant (K) value using Eq.1

$$k = \frac{1}{\sum_{i=1}^{n}(\frac{1}{s_i})} \tag{1}$$

Where: s_i is permissible standard for parameter nth.

2. Compute the rating quality (Q_i) for the parameter nth utilizing Eq.2

$$Q_i = 100\left(\frac{v_i - v_{I0}}{s_i - v_{I0}}\right) \tag{2}$$

Where: v_i is measured nth parameter value at point of sampling. v_{I0} is the epitome nth parameter value in water being pure and s_i is the permissible standard value of the parameter nth. For the drinking water, each of the V_{I0} is considered Zero value, while the ideal values for DO and pH and are 14.6 mg/L and 7.0 respectively.

3. Unit weight (W_i) for the nth parameters is calculated using Eq.3

$$W_i = \left(\frac{k}{s_i}\right) \tag{3}$$

4. Calculate WQI (WQI) using Eq.4

$$WQI = \left(\frac{\sum W_i \times Q_i}{\sum W_i}\right) \tag{4}$$

Table 1. Iraqi drinking WQ specifications standard [16]

Parameter	**Symbol**	**Unit**	**Guideline**
Hydrogen Ion	pH	-	6.5 – 8.5
Phosphate as Ortho-phosphate	PO_4^{-3}	mg/L	1
Chloride	Cl^-	mg/L	250
Calcium	Ca^{+2}	mg/L	50
Magnesium	Mg^{+2}	mg/L	50
Total Hardness	TH	mg/L as $CaCO_3$	500
Nitrate	$NO3^-$	mg/L	50
Sulfate	SO_4^{-2}	mg/L	250
Ammonia	NH_3	mg/L	0.5
Fluoride	F^-	mg/L	1
Nitrite	NO_2^-	mg/L	3
Turbidity	Turb.	NTU	5
Dissolved Oxygen	DO	mg/L	>5
Biological Oxygen Demand	BOD5	mg/L	<5
Total Dissolved Solids	TDS	mg/L	1000
Electrical Conductivity	EC	µS/cm	2000
Total Alkalinity	TA	mg/L as $CaCO_3$	500
Sodium	Na	mg/L	200

The classification of WQ of any source according to drinking water specifications for the weighted arithmetic index method is exposed in Table 2.

Table 2. WQ classification according to value of WQI for drinking proposes [17]

WQI Level	WQ classification	Class
0 -25	Excellent	1
26 – 50	Good	2
51 - 75	Poor	3
76–100	Very poor	4
> 100	polluted	5

2.3. Artificial neural network (ANN)

The ANN is a modeling mathematical tool inspired biologically via studies pereformed on the nervous system of human. Such process is advantageous in predicting and predicting the complex phenomenon as underlying [18]**.** The ANN was a design being non-linear which has the ability to handle a large number of variables as independent for defining the variable being dependent [19]**.** Network as neural is a processor containing numerous parameters for processing the inputs alongwith inter-connections. It has various blocks of building; the mostly significant are layers as input, hidden and output ones as exposed in **Figure 2.** Such 3 layers are connected in a way as feed-forward in which every square signifies data as input. The subsequent **Equation 5** might be utilized for normalizing the data as output and input [20, 21]
(5)
Since: x_{norm} is the rate being normalized, x_i is the data as original, x_{min} and x_{max}, is the minimum and maximum values, correspondingly.

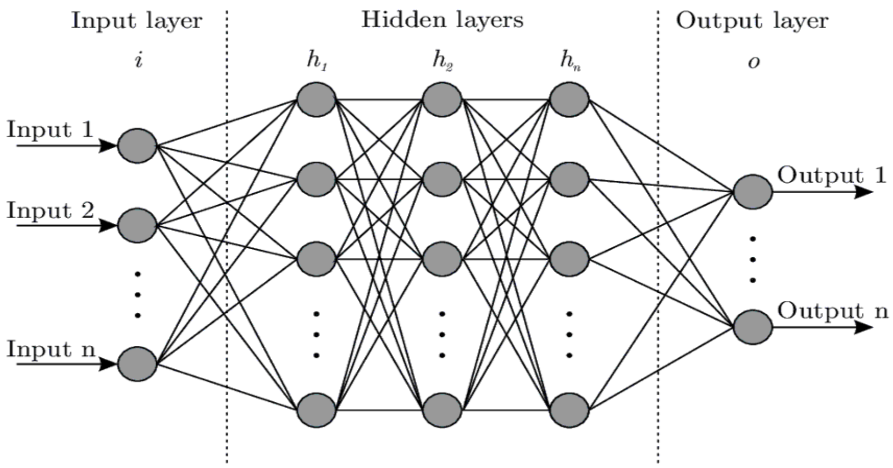

Figure 2. Simple neural network as feed-forward

3. Results and discussion

3.1. WQI (WQI) calculations

In this research, in order to assess the Tigris River, the weighted arithmetic method was used to calculate WQI. Fourteen raw water parameters represent the data used during a period from 2012 and 2019. These parameters were studied according to their human consumption suitability compared with the recommended standards of drinking WQ by the Iraqi Standard Organization (ISO/417-2001).

Table 3 shows the calculations sample of WQI for at Al-Karkh station, which is located in the northern part of Baghdad city. Thus, the river's WQ is classified as poor to pollute for drinking purposes.

Table 3. WQI calculations for Al-Karkh station.

Parameter	Measured value	Si	Wi	Qi	Wi*Qi	WQI
Tur.(NTU)	46.667	5	0.05	933.34	49.915	**59.00**
Alk.(mg/l)	132.667	500	0.00	26.53	0.014	
T.H (mg/l) as CaCO3	291.333	500	0.00	58.27	0.031	
Ca $^{+2}$(mg/l)	66.833	50	0.01	133.67	0.715	
Cl^{-}(mg/l)	53	250	0.00	21.20	0.023	
Mg $^{+2}$(mg/l)	28.917	50	0.01	57.83	0.309	
pH	7.743	7.5	0.04	148.60	5.298	
EC(µS/cm)	774.167	2000	0.00	38.71	0.005	
SO4(mg/l)	150.667	250	0.00	60.27	0.064	
TDS(mg/l)	504.167	1000	0.00	50.42	0.013	
NO2(mg/l)	0.004	3	0.09	0.13	0.012	
NO3(mg/l)	0.785	50	0.01	1.57	0.008	
NH3(mg/l)	0.014	0.5	0.53	2.80	1.497	
PO4^{-3}(mg/l)	0.041	1	0.27	4.10	1.096	
Sum			**1.00**		**59.002**	

3.2. Selection of ANN as parameters of input

The main issue in network as neural is the input parameters selection. Thus, abundant input variables consideration must be taken into consideration if the structure of ANN has been utilized for providing operative results and better understand the difficulties. The variables as input utilized in the current work are Ca, TDS, TH, Cl, Mg, pH, SO_4^{-2}, EC, NO_3, PO_4, NO_2, NH_3, Alkalinity and Turbidity, as exposed in **Figure 3**. Such parameters are of imperative impact on ANN presentation and render ANN to work efficiently.

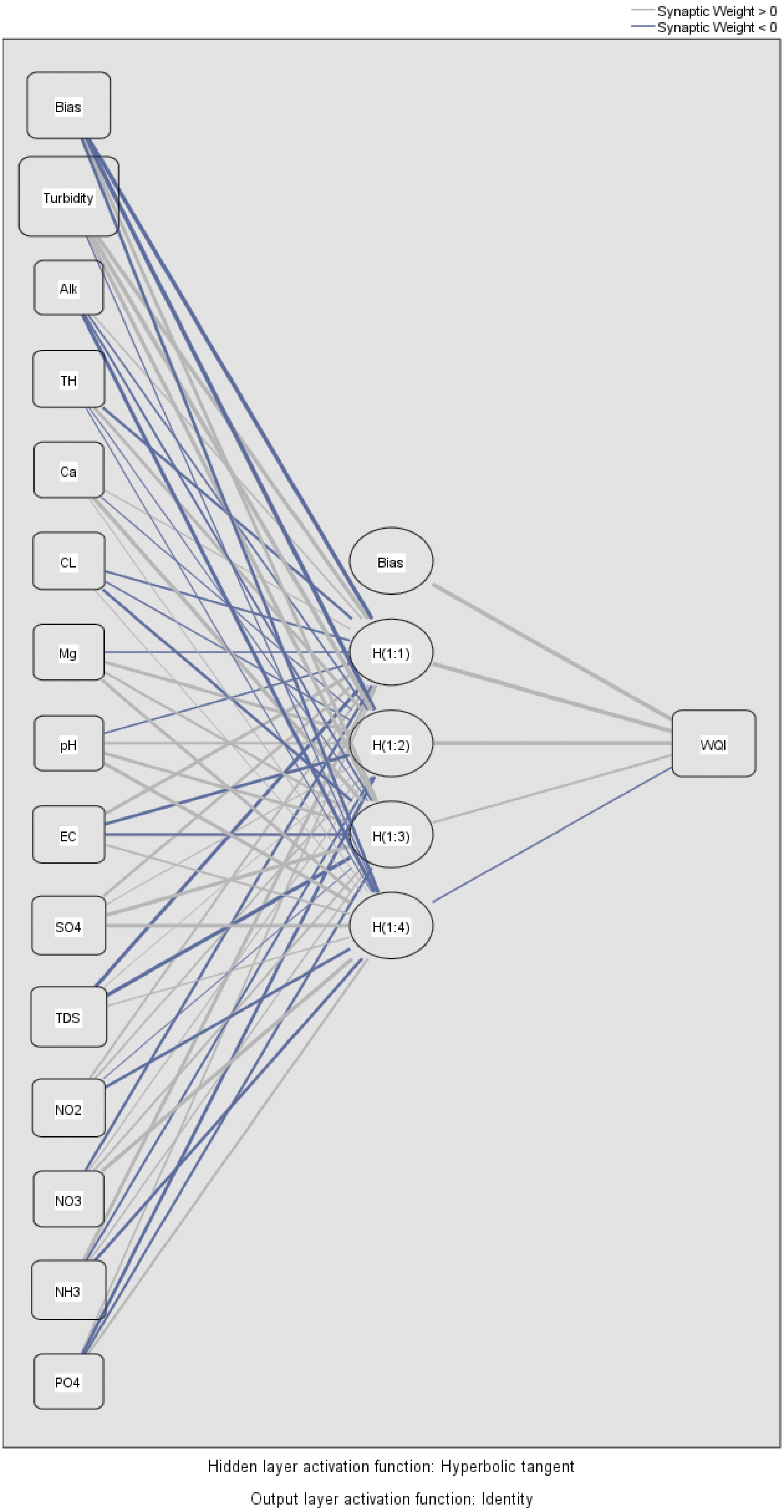

Figure 3. Inputs parameters for ANN

For expecting the outcome data from the input one, the networks as neural might be utilized relying on simulating the human nervous time function. For obtaining convergence, the information as input and output should be normalized.

3.3. Model formulation

To decrease the complexity, the networks as neural are utilized for composing the neurons being synthetic that join and variation in varied layers. The connection weights are definite via reducing the error among the output expected values and the output actual ones under experimental data. The model processing was elected as the inputs vary for the training to 70%, for the testing 20% and for the holdout 10% as exposed in Table 4.

Table 4. Case Processing Summary

		N	Percent
Sample	Training	42	77.8%
	Testing	7	13.0%
	Holdout	5	9.3%
Valid		54	100.0%
Excluded		0	
Total		54	

The neural network consists of a list of values being measured in the characteristics of raw water as a set data. For finding a model set of parameters which ables the model with an offered function from with the effectual performance, numerous training in ANN was organized with anticipated output and input relation. In a single set, the readings are joined for examining the developing possibility of network as model being neural to predicte the WQI. The ANN model function in **Equation (6)** with the determination coefficient (R^2) was 97.7 %. The findings revealed that TDS and Turbidity have additional influence on predicting the WQI than other parameters, as shown in **Figure 4,** and these results support the conclusions of previous researchers such as [2]. Equation (6) reflects the fitting model line so it is able to utilize for whichever point to identify the predicted WQI value depending on the other parameters.

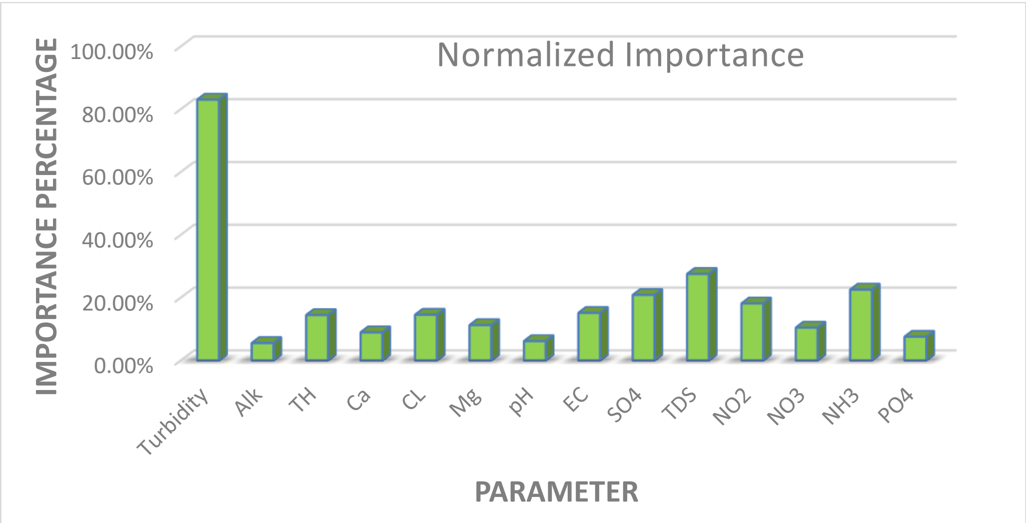

Figure 4. ANN independent variable importance

For expecting the outcome data from the input one, the networks as neural might be utilized depending on mimic’s human nervous time function. The detailed parameters of the proposed model are illustrated in **Table 5** to estimate ANN output and hidden layers.

Table 5. Hidden and output layers prediction parameters

Predictor		Predicted				
		Hidden Layer 1				Output Layer
		H(1:1)	H(1:2)	H(1:3)	H(1:4)	WQI
Input Layer	(Bias)	-.675-	-1.024-	.383	-.292-	
	Turbidity	.551	1.479	.480	-.091-	
	Alk	.116	-.119-	-.140-	-.400-	
	TH	-.214-	.358	-.062-	-.074-	
	Ca	.097	-.080-	.504	.049	
	CL	-.127-	-.098-	-.251-	.022	
	Mg	-.121-	.318	.209	.347	
	pH	-.121-	.181	.313	.425	
	EC	.376	-.289-	-.222-	.159	
	SO4	.259	.086	.474	.427	
	TDS	-.386-	.012	-.436-	.106	
	NO2	.175	.122	-.044-	-.266-	
	NO3	-.244-	.091	.167	.496	
	NH3	.397	-.172-	.110	-.285-	
	PO4	.125	-.314-	-.185-	.195	
Hidden Layer 1	(Bias)					.778
	H(1:1)					.925
	H(1:2)					.868
	H(1:3)					.182
	H(1:4)					-.110-

Since: Bias is the element being constant, H (1:1) is the 1st hidden layer, H (1:2) is the 2nd hidden layer, H (1:3) is the 3rd hidden layer, H (1:4) is the 4th hidden layer.

4. Conclusion and recommendations

WQ conditions have been identified and compared by WQI, which can be used as an environmental indicator to evaluate the management activities of WQ, to improve understanding of WQ issues, and the need for preventive measures. Analysis of the WQI along nine stations from upstream to downstream of Tigris River within Baghdad city revealed that the WQ (during the study period) is unsuitable for drinking purposes. It was indicated that the Tigris River WQ is generally "polluted," which reflects the effect of pollution due to domestic and industrial effluents along the Tigris River. The (ANN) application revealed the influential of turbidity role and TDS on WQ deterioration because of its high concentrations in the river, which are more than the allowable limits. Therefore, the outcomes attained throughout the current work offered a perfect WQ view and displayed a severe Tigris River water pollution problem. Activate all laws and special legislations for stopping all irregular discharges from some stations that are mainly designed to discharge stormwater. However, the irregular agencies turned it into the output of industrial wastewater and untreated sewage directly to the river.

Declaration of competing interest

The authors declare that they have no any known financial or non-financial competing interests in any material discussed in this paper.

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