Tigris River Water Quality Quantifying Using the Iraq Water Quality Index (IraqWQI) and Some Statistical Techniques

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Abstract

Evaluation of water quality is important for the management of water resources. The current study is focused on water quality data monitoring analysis. of the Tigris River in Iraq by the application of the principal component analysis (PCA), cluster analysis (CA), and water quality index (WQI). Twelve water quality parameters were taken from 14 stations along the river are Ca^{+2}, Mg^{+2}, Na^{+1}, K^{+1}, Cl^{-1}, SO_4^{-2}, HCO_3^{-1}, NO_3^{-1}, TH, TDS, BOD_5, and EC to apply the PCA and CA. The results show that the mean of all the variables was under the boundaries. except for EC, Ca^{+2}, Mg^{+2}, $SO_4^{-2,}$ and TH. EC is the essential element impacting the consistency of the river water. The PCA has one major component which accounts for 97% of variance from various sources of pollution. The CA divided the river into three regions of sampling stations with similar water quality, the best in the north, and the worst in the far south. In this paper, the computer-automated tool (IraqWQI) was presented and evaluated, which has been developed by authors to classify and measure the quality of Iraqi surface water. The proposed index is of hundred degrees and includes six variables for drinking water quality are Cl^{-1}, TH, TDS, COD, DO, and total coliform (TC) according to the Iraqi specifications. The result of the IraqWQI application showed decreasing in the water quality of the river and the suitability for drinking toward the south of the country. The best value of the index was (81.48, Good) in Fishkhabour during winter, and the worst value was (46.23, Bad) in Qurnah during summer. The study showed that the use of statistical technologies and WQI as useful instruments for the management, control, and protection of surface water has been effective and significant

1. Introduction

The surface water quality, including rivers, deplies for normal processes (weathering of soil, erosion, and rainfalls, etc.), human acts (agricultural, urban, and industrial activities). Rivers are very vulnerable bodies of water to contamination due to their simple openness to industrial, domestic, and agricultural discharges (Ewaid, and Abed, 2017). The second-largest in Iraq is the Tigris River; owing to its rich soil and abundance of water, the basin is a region that is densely inhabited (Varol et al. 2012). The river water is used for irrigation, manufacturing, domestic and acts as a receiver of industrial and municipal wastewater, and the quality of river water has declined as a result during the recent several decades (Rabee et al. 2011).

A vast volume of chemical, physical and biological data are used for water quality assessment using a descriptive approach which does not aid decision making., and the analysis of water quality data using these basic methods, become more complicated as the number of parameters increases (Ling et al. 2017; Wong, et. al., 2020).

Statistical approaches such as multivariate and WQI methods are required to obtain suitable outcomes; these methods provide greater opportunities to help the decision-making process and be effective for environmental quality assessment (Zafar *et al.* 2018; Patil, et. al., 2020; Wong, et. al., 2020).

The principal component analysis (PCA), cluster analysis (CA), and water quality index (WQI) goals are to better interpret the broad data from several variables and to identify the factors that cause water content differences, and to provide a valued tool for developing appropriate efficient water quality conservation plans (Herojeet et al. 2017).

Water quality indices are important to convert the long, multi-parameter water analysis reports into a single number or word. This, in turn, easy to understand and useful for comparing the water quality of the various sources and for tracking changes in the water quality of the source as a function of time and other factors of influence (Abbasi and Abbasi, 2012).

Chabuk, et. al., 2020 studied the WQI along the Tigris River using the Weighted Arithmetic Method. They selected 12 parameters that were measured at 14 stations. The results showed that the water quality index was classified as good quality, although the WQI values of stations along the Tigris River showed in the degradation of water quality of river from upstream at Fishkhabour until Shuhada Bridge, Baghdad. The WQI values indicated the degradation of the Tigris River and rated as a poor water quality starting from Aziziyah to the last station in the south of Iraq at the Qurnah, Basrah.

Another study using the WQI method of the Tigris River water in Baghdad city through measuring 18 parameters at 10 stations found that it was inadequate for main uses (drinking, irrigation, and industrial) (Flaieh et al., 2014). The WQI model was adopted by Kamil, (2009) to evaluate the water quality of the Tigris River from upstream of the river in Iraq (Feeshkhabour) to Qurnah, Basrah (downstream of the river) through measuring eight parameters (pH, TDS, EC, Ca, total hardness, Cl, SO4, SAR, and BOD) from thirteen stations during 2007–2008. The results showed that the categories of (90–100) and (65–89) were classified for drinking use, while the categories of (65–89), (35–64), and (11–34) were classified for irrigation use, the categories of (35–64) and (11–34) were classified for industrial use (Kamil, 2009). The water quality of the Tigris River within Baghdad (capital of Iraq) was studied by Alobaidy et. al. (2010) by selecting 13 parameters (pH, Ca, Mg, Cl, SO4, TDS, Alkalinity, Turbidity, Total Hardness, NH3, F, Al, and Fe) from 2002 to 2008, the study showed that the water quality in north Baghdad was poor, while midpart and downstream of the river was poor and very poor.

Another variety of Tigris River hydrochemistry studies have been performed (Sulaymon, et. al., 2009; Al-Ansari & Knutsson, 2014; Alobaidy, et. al., 2015; Abdulwahab & Rabee, 2015; Omar, 2017; Ewaid et al., 2020a). These studies demonstrated important spatial and temporal shifts in the river parameters; thus, it is important for continuous monitoring to clarify the key changes and the cause of these variations using appropriate technologies and Approaches (Ewaid, et al., 2018).

The current study aims to apply two statistical techniques (PCA and CA) for the identification by the water management authority and society of the important paramètres of water quality that cause pollution. Also, a software named the Iraq Water Quality Index (IraqWQI) for assessing surface water quality for drinking demand was developed and applied to all Tigris River from north to south Iraq as a case study. To develop this proposed new WQI, the Iraqi specifications for drinking water (COQS, 2009), and the World Health Organization (WHO) were adopted (Cotruvo, 2017).

2. Data And Methods

2.1 The Study Area

Iraq is part of the Middle East, it occupies an area of 433,970 km^2, has around 39 million inhabitants, and it is well known for its two major rivers the Euphrates and Tigris (Sissakian et al., 2014), (Figure 1).

The Tigris River rises in the south-eastern part of Turkey on the southern slopes of the Taurus Mountain range and drains an area of 472,606 km^2 shared by Turkey, Syria, Iran, and Iraq. The total length of the river from its sources to its meeting with the Euphrates in Qurnah to form Shatt Al-Arab is 1900 km, of which about 1415 km are inside Iraqi lands, about 58% of the basin lies in Iraq (Saleh, 2010).

The Tigris River in Turkish territory consists of five tributaries; these tributaries pass over rocky lands of various types and are a major source of many types of salts and minerals. In Iraq, the river has five main tributaries; called Fishkhabour, Greater Zab, Lesser Zab, Adhaim, and Diyala, in addition to tens of sub-tributaries (Al-Ansari, 2013; Ewaid et al., 2019a). The Tigris River is exposed to erosion like the rest of the rivers of the world, especially in the twisting areas of the river, and the depth of the riverbed changes, and the main course of the river is altered by the hydrological and hydraulic variables (Muratoglu, 2019; Ewaid et al., 2019b). The construction of dams on the tributaries of the Tigris River by the Turkish and Iranian governments reduced the amount of water and negatively affected its quality (Ewaid, 2018; Ewaid et al., 2020 b).

To track and monitor the water quality of the Tigris River, the National Center of Water Resources Management of the Iraqi Ministry of Water Resources (NCWRM) for many years, has been developing a surveillance scheme for the water of the Tigris River. The trained staff of the laboratories in the NCWRM collect and analyze the water samples by the standard methods of Rice *et al.* (2017) within the nonstop monitoring program throughout the study year at the 14 positions on the river (NCWRM, 2017, Chabuk, et al., 2020). The 14 stations are Fishkhabour, Mosul Dam, Mosul, Shraqat, Tikrit, Samarra, Tarmiyah, Muthanna Bridge, Shuhada Bridge, Aziziyah, Kut, Ali Garbi, Amarah, and Qurnah (Figure 1).

2.2 Data pretreatment and analysis

In this study, the two 2017 seasons dry (summer and autumn) and wet (winter and spring) monitoring dataset obtained from the NCWRM has been tested by some statistical techniques using twelve water quality parameters i.e. calcium (Ca^{+2}), magnesium (Mg^{+2}), chloride (Cl-1), electrical conductivity (EC), total dissolved solids (TDS), sulfate (SO4-2), nitrate (NO_3^{-1}), biochemical oxygen demand (BOD_5), sodium (Na^{+1}), potassium (K^{+1}), total hardness (TH) and bicarbonate (HCO_3).

For descriptive and predictive data processing, the statistical program package SPSS 25 for Windows was used. All 12 variables have been standardized to achieve normality and retrieve the influence of variables with very high or very small variance values (Cronk, 2017).

To measure the goodness of the right data to the distribution the experiment Kolmogorov-Smirnow (K-S) was used. All the values of variables had a normal distribution of 95 percent assurance according to the K-S measure (Allen et al., 2018).

2.3 The Principal Component Analysis (PCA)

In this empirical approach, all datasets and generating variables can be defined by the most relevant parameters (Bouguerne et al. 2017). Factors with > 1 variance are used since any factor will describe more variance than any variable (Khaledian, *et al*, 2018). The PCA explains data sets and the reduction of data and provides a distinction between water variables without modifying the original data (Zheng *et al*. 2015). The normalized variables were derived in this study from the important PCs and minimized the effect of parameters of limited significance by using varimax rotation to extract the eigenvalues from the correlation matrix (Bhardwaj et al. 2010).

Bartlett's and Kaiser-Meyer-Olkin (KMO) checking was used to validate data fitness for PCA. The KMO can sample and reveals how much variation the causal factors create (Field, 2005). The high KMO value (close to 1) shows the utility of the PCA. The sphericity test from Bartlett explores the identity of the correlation matrix and the link between the variants. In this study, KMO = 0.675 and 0.702 for dry and wet season respectively, the significance level is (0 < 0.05) reveals the essential relationships between variables (Table 3).

Fig. 1. Iraq map displaying the Tigris River sample stations (Chabuk, et al., 2020).

2.4 Cluster Analysis (CA)

Cluster analysis is a multivariate statistical analysis methodology that classifies all dissimilar objects into separate classes with an unsupervised pattern based on their characteristics. High internal (within the group) homogeneity and external (among the groups), in the resulting groups of objects, heterogeneity should be observed (Huang et al., 2010; Salwan et al., 2019).

Cluster analysis was used here to examine the dataset to define the spatial similarity of the water quality of river stations. The hierarchical CA achieved on the standardized dataset using the Pearson correlation technique as a similarity measure using linkage distance by showing an illustrated dendrogram (Zhao et al., 2011; Varol et al., 2012).

2.5 The Iraqi Water Quality Index (IraqWQI)

The IraqWQI was developed using these four steps (Ewaid et al., 2020a).

1. Selection the suitable parameters.

2. Weight assignment for the selected parameters.

3. Sub-indexes' functions development using the Iraqi specifications.

4. Formation of the final equation of the index by aggregation of the sub-indices.

The authors' experiences, information from previous studies, two statistical methods (the PCA and the modified Delphi method in the survey of expert opinions) were used in the first and second steps.

Based on the foregoing, the index is based on six important water variables according to the Iraqi standard, the final list of parameters from which the index was derived was COD, DO, TC, TDS, TH, and Cl^-. Accordingly, the final formula for the Iraqi Water Quality Index was as follows: (Ewaid et al., 2020a).

$$\text{Iraq WQI} = [(-0.019\ TDS + 84.587) \times 0.2] + [-0.006\ TC + 86.231) \times 0.2] + [10\ DO \times 0.2] + [(-0.119\ TH + 113.68) \times 0.15] + [-5.886\ COD + 99.846) \times 0.1] + [(-0.12\ Cl + 106.58) \times 0.15] \quad (1)$$

2.5.1 The specification of the IraqWQI V.1 software

The Iraqi water quality index (IraqWQI V.1) is computer software for evaluating the surface water quality for drinking purpose-designed and programmed using the C Sharp programming language with XAML and Xamarin languages in both versions (Windows and Android). It contains a simple user interface to enter the data and calculate the results (Figures 2 and 3). The program contains a studio that connects the user to the program's social networking sites for help or view details of the authors. The design of the program is based on a kind of artificial intelligence to perform the job on behalf of the user.

The IraqWQI is developed to classify the river's water into five categories, viz. Very good (90-100), Good (70-90), Acceptable 50-70, Bad 20-50, and Very bad (0-20) (Ewaid et al., 2020a).

The IraqWQI V.1 user-friendly software was developed based on the Iraqi specifications for drinking water and includes features that help researchers, specialists, organizations, and ministries to set up their water assessment and propose management methods. The authors provide free access to the software, the Android free version is available on the Google Play market under the name (IraqWQI) https://play.google.com/store/apps/details?id=com.companyname.project_iraqwqi&hl=en and the Windows version is available here:

http://water2irrigation.net/download.php?fbclid=IwAR3mxg3Gk1MyqSEqOOZ4HF3KdK6iM8c2No9RtDAhFFuXpHCrMwN4gQAN8dc

This index will be of help to researchers and state departments concerned with the quality of the Iraqi surface water and its suitability for drinking and is an alternative to foreign models or indices designed for the waters of other countries. The index is characterized by a simple and easy-to-use interface. Figure (2) and (3) show the program interface in Windows computers and Android phones. This application has been developed to save time and avoid errors related to manual calculations.

2.5.2 How to use the IraqWQI

After installing and running the application, the user interface for calculating the quality index pops up. It consists of a menu to calculate the Iraq water quality index (IraqWQI). The user must have raw data on water quality parameters in mg/l for chemical parameters and the most probable number per 100 ml (MPN/100 mL) unit for the total coliform. Once the raw data entered for the parameters, the "Calculate" button in Windows and "Results" in Android allow us to immediately calculate the numerical value and the class matching the interpretation of this numerical value. The "Remove" button allows the user to clean up the operation previously performed and repeat the data entry. The "Exit" button allows the user to exit the application. Figure (2) and (3) show the different functionalities of the application.

Figure 2. The Windows start and main menu of the graphic user interface of the IraqWQI for entering, calculating, and saving results.

Figure 3. The Android icon and main menu of the user interface of the IraqWQI for entering and calculating the results.

3. Results And Discussion

The general state of the river

Table (1) and Table (1) present informative statistics with the range, minimum, mean, standard

error (SE), standard deviation (SD), and variation values for 2017 of the 12 physiochemical parameters.

Table 1. Descriptive statistics of the year 2017 Tigris River data (dry season).

Table 2. Descriptive statistics of the year 2017 Tigris River data (wet season).

The physicochemical parameters of the river water (TH, Ca^{+2}, Cl^{-1}, Mg^{+2}, EC, SO_4^{-2}, K^{+1}, NO_3^{-1}, BOD_5, Na+1, HCO3-1, and TDS) were analyzed to provide a better understanding of water quality and to differentiate between parameters that reduce the quality of water. The mean parameter values were compared with the Iraqi drinking norms in this analysis (COQS, 2009).

The findings showed that the water parameters were following the standards except for Mg^{+2}, TH, and Ca^{+2}, which were continuously more than the criteria, and occasionally the EC and $SO4^{-2}$ do (Tables 1 and 2).

The values of EC and TH parameters seem to be important to the water quality of the river especially in the middle and south of the country. The Tigris River has a real shortage of water and annual fluctuations in water amount and quality; this is because of climate alteration and the numerous dams constructed by neighboring states and the river do not follow the pattern of river's annual discharge. Water comes from north reservoirs in summer and autumn (dry seasons), packed with organic dark materials, which alter the quality of the water (Al-Sharqi, 2020).

3.1 The Principal Component Analysis (PCA)

In this analysis, the PCA is determined for the 12 variables of the 14 river sampling stations in 2017

to determine the main variables of water quality with the highest degree of importance of their values. Eigenvalues of 1.0 or more are treated as significant (Table 3 and Figure 4) (Bhardwaj *et al.* 2010) and used to assess the important parameters in the river water (Khaledian, *et al,* 2018).

From the gained PCA data (for both seasons); one component was extracted, explaining 97% of the total variation that helps to explain the outcomes and detect causes of water quality contamination. Table (3) and Figure (4) contain the eigenvalues and loadings of the PC showing the total variance.

The rotation, which increased the factor number, is essential to explain the same variance quantity in the original dataset, here, only one component was extracted, and the solution cannot be rotated (Bhardwaj *et al.* 2010).

The extracted PC explained 97% of the variance and loaded heavily on all the 12 variables, it is a result of the point and the hydro-geochemical processes of non-point source pollution and soil mineralization.

The Cl^{-1}, TH, and Mg^{+2} clarify the influence of point pollution and the chemistry of the river water (Zhang *et al,* 2018). The BOD_5, Na^{+1}, and TDS represent the role of the non-point source of biological pollution from agricultural zones and point's source of pollution from local sewage (Bouguerne *et al*. 2017). The rest variables represent the runoff the domestic sewage and the influence of the geological constituents of soil (Barakat *et al*, 2016; Bouguerne *et al*. 2017).

Table 3. Loadings of the 12 variables on one significant PC in the Component Matrix and the Kaiser–Meyer–Olkin (KMO) and Bartlett's Test, (for both 2017 seasons).

The KMO and Bartlett's Test

Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization. One principal component was extracted.

Figure 4. Scree plot of the Eigenvalue of the extracted component.

3.2 Hierarchical Cluster Analysis (HCA)

The HCA gathered sampling stations in the river into 3 clusters of similar water quality features (there is no significant difference between the dry season and the wet season). Figure (5) illustrates the dendrogram output by using Ward's linkage method and square Euclidean distances.

Cluster 1 (stations 1, 2, 3, and 4), Cluster 2 (stations 5, 6, 7, 8, 9, 10, and 11), and Cluster 3 (stations 12, 13, and 14) correspond to the relatively low pollution, moderate pollution, and high pollution regions respectively from north of the country to south.

In Cluster 1, which contains relatively less polluted sites (Feeshkhabour, Mosul Dam, Mosul, and Shraqat stations), this could be accredited to the fact that fewer human activities were taking place at stations upstream the river; they are far from the discharge of effluent. The river's water here is close to its springs in the mountains, and there are no big cities that drain their waste into the river.

Cluster 2 is made up of moderately polluted sites (the seven stations; Tikrit, Samarra, Tarmiyah, Muthanna Bridge, Shuhada Bridge, Aziziyah, and Kut) are located in the middle of the country, the river here characterized by agricultural fields on both sides, incidence under the influence of the human activity of many towns as the untreated domestic wastewater is added directly to the river.

Cluster 3 contains the last three southern stations (Ali Garbi, Amarah, and Qurnah) which are located downstream the river where the river region characterized by a significant reduction in water level, high population density, under the influence of agricultural drainage projects as well as high evaporation that increases salinity and pollutants.

Figure 5. The CA Dendrogram of the study stations on the river (the dry season).

3.3 Application of the IraqWQI V.1 software

In this study, to ensure the validity of the proposed IraqWQI, it was applied to estimate the two season's water quality of 14 sites on Tigris from north to south. The data of these sampling locations are taken from the National Center of Water Resources Management of the Iraqi Ministry of Water Resources (NCWRM, 2017, Chabuk, et al., 2020); the total coliform values were assumed to be zero due to the unavailability of data, the COD values calculated by this equation: BOD/COD = 0.40 (Lee and Nikraz, 2015; Lee et al., 2016), (Table 4 and 5).

It is observed from Tables 4 and 5 that the IraqWQI values are gradually descending as we head downstream. In the dry season, three regions can be distinguished on the river, in which the index values of water quality converge. The northern region includes the first four stations, where the values of the index were (74.94, 73.81, 72.32, and 71.20 respectively) in the category "Good".

The second region includes eight stations with the value of index ranging between 68.28 and 51.60 in the category "Acceptable". There are two stations in the south of the country with the value of the index of 48.28 and 43.55 in the category "Bad".

In the wet season, the river's water quality improves a little, so the number of stations in the north becomes six stations and the index value varies between 81.48 and 71.62 in the category "Good".

Next, come seven stations with an index value of between 68.28 and 51.60 in the category "Acceptable". Qurnah is the last station in the south with an index value of 46.23 in the category "Bad". Sure enough, that the river water in all regions needs a traditional purification treatment (sedimentation, filtration, and disinfection) to make it drinkable.

The WQI reached its maximum in the north sampling points during the wet season when the flow of the river is high. The values of the WQI in these points are the highest because there is no more pollution on the river. The values of the water quality parameters in this area never exceed the maximal except the values for TH.

The index smaller values were recorded in the south during the dry season when the flow of the river water was low, the values of the dissolved oxygen are low, and the values of Cl^{-1}, TH, TDS, COD, and TC are high. It can be seen that the values of all parameters except for dissolved oxygen increase as we head south, indicating the presence of more organic and mineral materials. The COD values are an important indicator of the efficiency of municipal wastewater treatment plants existent along the river.

Iraq currently faces three forms of water quality problems, the first is the scarcity of water, the second is salinity and the third is the accumulation of contaminants in water linked to municipal, industrial and agricultural activities (Rahi and Halihan, 2018).

Water quality depletion is further exacerbated by drought events and is a significant contributor to agricultural land desertification (Al-Shujairi et al., 2015).

As the water flows downstream, the salinity of the Tigris River worsens because of local geological features, city waste disposal to the river, and agricultural irrigation and drainage activities (Rahi, 2018).

Table 4. The IraqWQI values of the 14 stations along the Tigris River during the dry season.

Table 5. The IraqWQI values of the 14 stations along the Tigris River during the wet season. All parameters in mg/l except for the total coliform (TC) in (MPN/100 mL unit.

From the above results, we notice a congruence between the cluster analysis and the IraqWQI in classifying the water quality of the river stations. Cluster analysis divides the river into three groups of stations with similar water quality, the index divides the stations on the river into three categories: ”Good”, “Acceptable” and “Bad” of the five categories of the index: “Very good”, “Good, “Acceptable”, “Bad”, and “Very bad”.

In the north of the country, the water is “Good” because it has not yet passed through sources of pollution such as large cities and industrial areas, as well as the riverbed is stony and erosion is little (Shihab and Al-Rawi, 2005).

When the river leaves the mountainous region and enters the plains region in the center and south of the country, the water quality according to the index turns into “Acceptable” and in the far south to “Bad”, because the river passes through large cities such as Mosul and Baghdad and passes through a loose plain where erosion occurs frequently (Abbas, 2013).

In the far south, according to the index, the water quality becomes “Bad” in the dry and wet season, due to the combination of agricultural, industrial, and human pollution factors. The increase in evaporation due to the high temperature also helps to increase pollutants, salinity, and dissolved solids (Al-Ansari et al., 2018).

4. Conclusion

Some important statistical techniques were applied in this analysis to determine the complicated data on water quality along the River Tigris. The heavy load of all twelve PCA variables showed the inputs of pollutants. This research would help the monitoring of essential parameters in the river route and support the use of techniques according to the measured parameters. Therefore, for the development of the river scheme, the managing establishments should reflect the results of PCA, CA, and the IraqWQI for a complete assessment of the river ecology.

The use of a water quality index based on the Iraqi legislation is of great help to water resource managers. This computer application represents a key tool for public and private water resource managers, to determine the status of water intended for drinking.

Declarations

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Data availability: The datasets used and/or analysed during the current study available from the corresponding author on reasonable request.

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Tables

Table 1. Descriptive statistics of the year 2017 Tigris River data (dry season).

	Range	Min	Max	Mean	Std. Error	Std. Dev.	Variance	Iraqi Standard
Ca^{+2}	43.00	79.00	122.00	102.35	3.42	12.79	163.78	50
Mg^{+2}	56.00	54.00	110.00	80.35	4.51	16.89	285.47	50
Na^{+1}	156.00	34.00	190.00	97.57	12.09	45.24	2046.72	200
K^{+1}	3.10	5.10	8.20	6.62	0.24	0.92	0.85	-
Cl^{-1}	337.00	33.00	370.00	155.00	29.86	111.74	12486.76	250
SO_4^{-2}	170.00	360.00	530.00	457.07	12.83	48.03	2306.99	250
HCO_3^{-1}	30.00	164.00	194.00	182.00	2.77	10.37	107.69	-
TH	587.00	726.00	1313.00	986.87	47.87	179.11	32081.76	500
TDS	947.00	438.00	1385.00	833.42	78.19	292.58	85604.11	1000
BOD_5	3.90	3.20	7.10	4.52	0.30	1.149	1.32	5
NO_3^{-1}	11.40	5.90	17.30	10.21	0.96	3.59	12.94	50
EC	1457.00	674.00	2131.00	1282.2	120.29	450.11	202603.1	1000

Note All parameters in mg/l except for EC in (μS/cm) unit.

Table 2. Descriptive statistics of the year 2017 Tigris River data (wet season).

	Range	Min.	Max.	Mean	Std. Error	Std. Dev.	Variance	Iraqi Standard
Ca^{+2}	35.00	75.00	110.00	93.57	2.64	9.91	98.26	50
Mg^{+2}	45.00	50.00	95.00	72.28	3.78	14.14	200.06	50
Na^{+1}	140.00	30.00	170.00	87.35	11.12	41.62	1732.70	200
K^{+1}	3.10	5.30	8.40	6.85	0.24	0.92	0.86	-
Cl^{-1}	328.00	32.00	360.00	148.14	28.82	107.86	11635.82	250
SO_4^{-2}	164.00	353.00	517.00	446.57	12.31	46.06	2121.80	250
HCO_3^{-1}	30.00	168.00	198.00	184.71	2.77	10.36	107.45	-
TH	555.00	712.00	1267.00	955.21	44.75	167.43	28036.02	500
TDS	951.00	443.00	1394.00	843.35	77.94	291.64	85057.63	1000
BOD_5	3.80	3.10	6.90	4.40	0.30	1.12	1.27	5
NO_3^{-1}	11.40	5.70	17.10	10.01	.96	3.62	13.15	50
EC	1463.00	682.00	2145.00	1297.60	119.92	448.72	201356.26	1000

Note All parameters in mg/l except for EC in (μS/cm) unit.

Table 3. Loadings of the 12 variables on one significant PC in the Component Matrix and the Kaiser–Meyer–Olkin (KMO) and Bartlett's Test, (for both 2017 seasons).

Variables	Principal Component
TH	0.999
Na^{+1}	0.995
Mg^{+2}	0.993
NO_3^{-1}	0.993
TDS	0.989
EC	0.989
Cl^{-1}	0.987
K^{+1}	0.986
BOD_5	0.986
Ca^{+2}	0.977
HCO_3^{-1}	-0.970-
SO_4^{-2}	0.956

The KMO and Bartlett's Test

		Dry Season	Wet Season
KMO Measure of Sampling Adequacy.		0.675	0.702
Bartlett's Test of Sphericity	Approx. Chi-Square	646.715	614.214
	df	66	66
	Sig.	0.000	0.000

Table 4. The IraqWQI values of the 14 stations along the Tigris River during the dry season.

Stations		Cl-1	TH	TDS	COD	DO	TC	IraqWQI	
1.	Feeshkhabour	33	726	438	4.8	9	0	74.94	Good
2.	Mosul Dam	39	777	490	4.95	8	0	73.81	Good
3.	Mosul	54	822	560	5.25	8	0	72.32	Good
4.	Shraqat	66	852	634	5.4	8	0	71.20	Good
5.	Tikrit	78	875	710	5.4	7	0	68.28	Acceptable
6.	Samarra	92	912	720	5.85	7	0	67.07	Acceptable
7.	Tarmiyah	110	942	755	6.3	7	0	65.81	Acceptable
8.	Muthanna Bridge	128	974	790	6.75	6	0	62.52	Acceptable
9.	Shuhada Bridge	158	1012	844	6.9	6	0	61.01	Acceptable
10.	Aziziyah	190	1056	890	7.5	6	0	59.12	Acceptable
11.	Kut	230	1115	952	7.8	5	0	54.93	Acceptable
12.	Ali Garbi	284	1185	1152	8.4	5	0	51.60	Acceptable
13.	Amarah	338	1255	1348	9	5	0	48.28	Bad
14.	Qurnah	370	1313	1385	10.65	4	0	43.55	Bad

Note All parameters in mg/l except for the total coliform (TC) in (MPN/100 mL unit.

Table 5. The IraqWQI values of the 14 stations along the Tigris River during the wet season. All parameters in mg/l except for the total coliform (TC) in (MPN/100 mL unit.

Stations		Cl-1	TH	TDS	COD	DO	TC	IraqWQI	
1.	Feeshkhabour	32	712	443	4.65	11	0	81.48	Good
2.	Mosul Dam	38	762	500	4.8	11	0	80.16	Good
3.	Mosul	52	804	575	5.1	10	0	76.71	Good
4.	Shraqat	64	831	650	5.25	10	0	75.62	Good
5.	Tikrit	74	855	725	5.25	9	0	72.74	Good
6.	Samarra	88	888	730	5.7	9	0	71.62	Good
7.	Tarmiyah	105	908	764	6.15	8	0	68.57	Acceptable
8.	Muthanna Bridge	120	941	800	6.45	8	0	67.31	Acceptable
9.	Shuhada Bridge	145	972	850	6.75	7	0	64.02	Acceptable
10.	Aziziyah	180	1014	900	7.2	7	0	62.18	Acceptable
11.	Kut	220	1072	960	7.65	6	0	57.94	Acceptable
12.	Ali Garbi	270	1136	1160	8.25	6	0	54.78	Acceptable
13.	Amarah	326	1211	1356	8.65	6	0	51.54	Acceptable
14.	Qurnah	360	1267	1394	10.35	5	0	46.23	Bad

Note All parameters in mg/l except for the total coliform (TC) in (MPN/100 mL unit.

Figures

Figure 1

Iraq map displaying the Tigris River sample stations (Chabuk, et al., 2020).

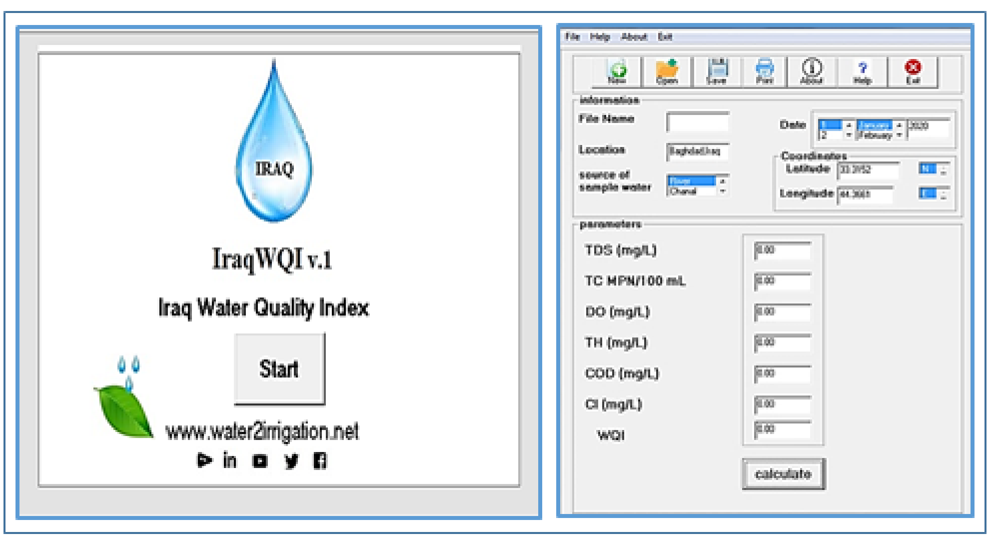

Figure 2

The Windows start and main menu of the graphic user interface of the IraqWQI for entering, calculating, and saving results.

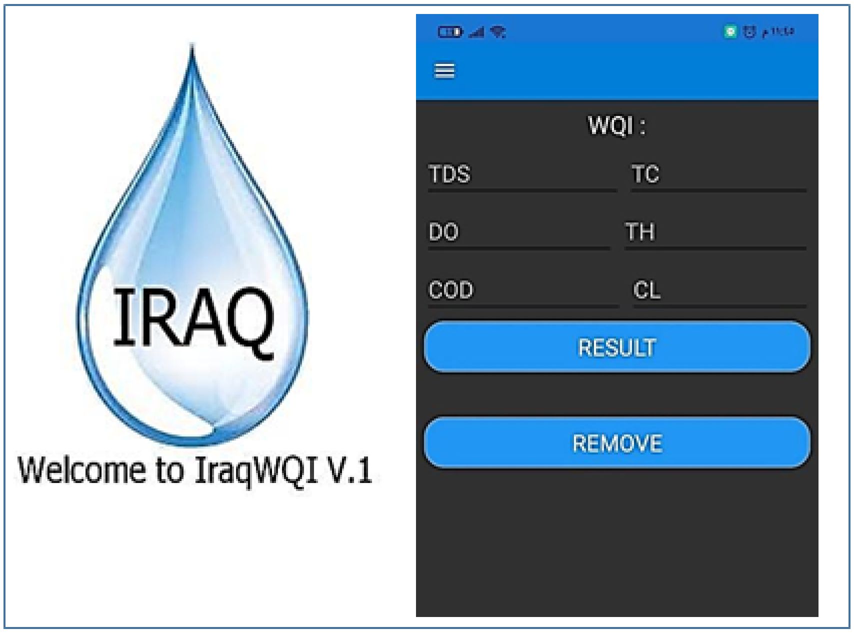

Figure 3

The Android icon and main menu of the user interface of the IraqWQI for entering and calculating the results.

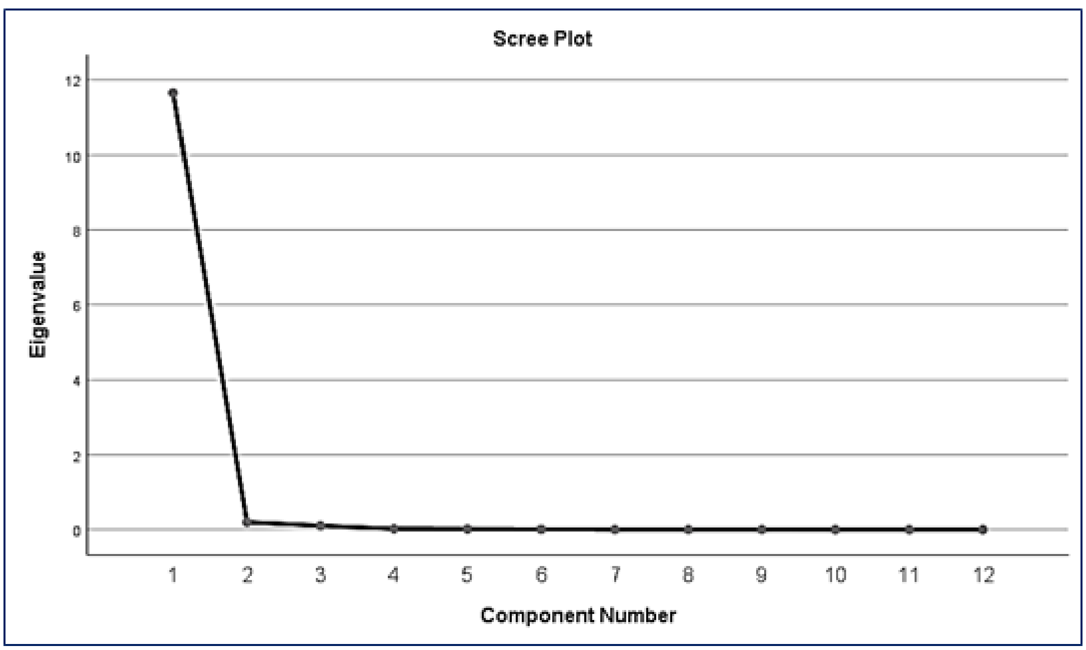

Figure 4

Scree plot of the Eigenvalue of the extracted component.

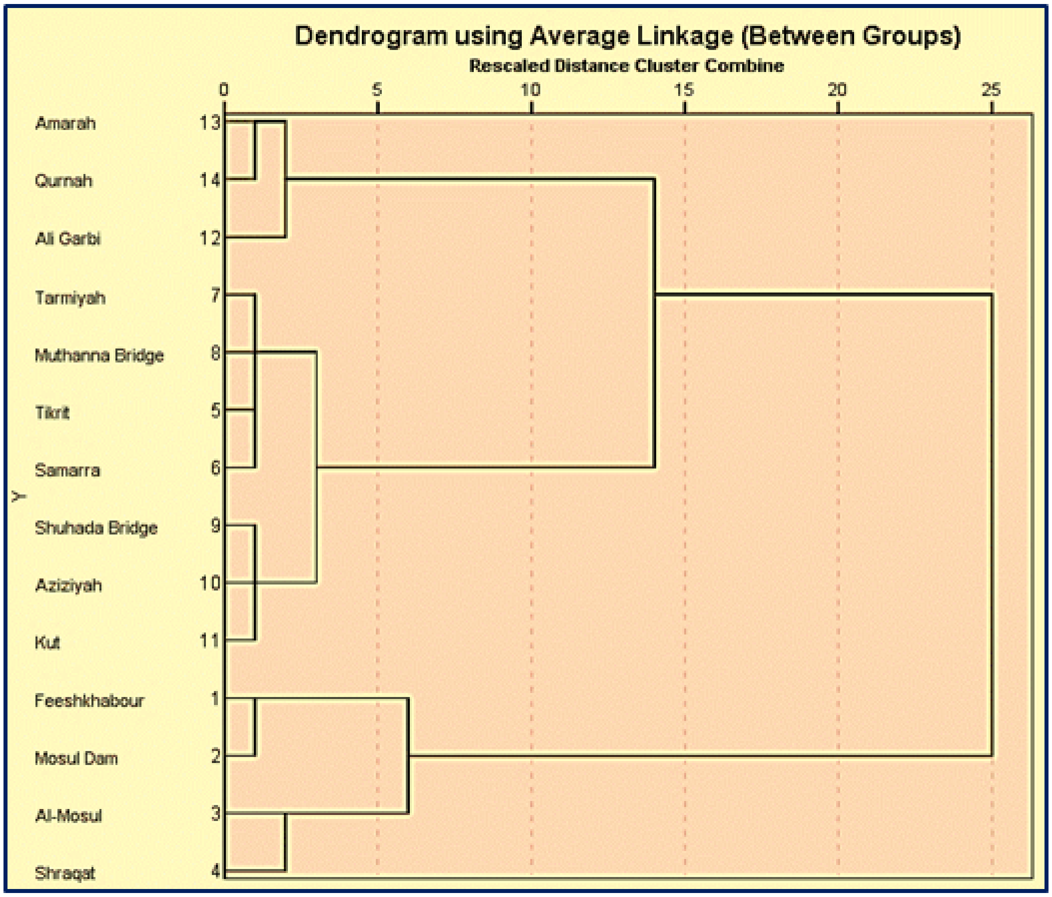

Figure 5

The CA Dendrogram of the study stations on the river (the dry season).