ISSN: 2277-9655
Scientific Journal Impact Factor: 3.449
(ISRA), Impact Factor: 1.852

IJESRT
INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY

Assessing Tigris River Water Quality in Baghdad City Using Water Quality Index and Multivariate Statistical Analysis

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Abstract

This study assesses spatial and long temporal variations in water quality over the years 2008-2011 for Tigris River by: use of a water quality index (WQI), and multivariate statistical methods namely: principal component analysis and factor analysis (PCA/FA) to extract the parameters that are most important in assessing variations of river water quality, and cluster analysis (CA) to parameters responsible to temporal and spatial variations , for 18 physiochemical pollution data sets :pH value, Electrical conductivity (EC), Total suspended solids (TSS), Temperature (T), Turbidity (Tur), Total alkalinity(TA), Total hardness (TH), Calcium(Ca^{+2}), Magnesium (Mg^{+2}), Sulfate($SO4^{-2}$), Total solids(TS) ,Iron(Fe^{+2}), Aluminum(Al^{+3}), Nitrite(NO_2^{-1}), Nitrate(NO_3^{-1}), Ammonia(NH_3), Silica(Si), and Orthophosphate$(PO4)^{-3}$, from the intake of 8 water treatment sampling sites on the river. WQI on a rating scale range 50 >WQI>300, is 192, indicating poor water quality, not safe for drinking, industrial and crop uses. (PCA/FA) total variance for the rotation sums of squared loadings gives70.742% for 4 components, and 52.186% cumulative for 2 factor components. CA analysis dendrogram gives 3 clusters based on 8 WTPs as: Cluster 1 (Alrashed,Alwahda),cluster2(cluster1,Al-Karkh,East-Tigrus,Al-athba),cluster3(cluster1,cluster2,Al-Karama,Al-Qadsiya,Al-Dora), and 3 clusters based on the 20 physical and chemical data sets parameters : Cluster 1(,TS, EC, SO_4^{-2} , Mg^{+2}, Ca^{+2}, TH), cluster2(cluster1, TA, pH, NO_3^{-1}, Si), cluster3(cluster1,cluster2,Tur, Fe, NO_2^{-1}, PO_4^{-2},TSS,NH_3^{+1},Al^{+3})

Keywords: water quality index, multivariate analysis, Tigris River, principal component analysis, factor analysis, and cluster analysis.

Introduction

The surface water quality is a matter of serious concern today. Rivers due to their role in carrying off the municipal and industrial wastewater and run-off from agricultural land in their vast drainage basins are among the most vulnerable water bodies to pollution **Singh, et al., 2005**. Flow in rivers is a function of many factors including precipitation, surface runoff, interflow, groundwater flow and pumped inflow and outflow.

Physico-chemical properties determination for stream water monitoring is necessary to evaluate contamination level in surface water, with increasing overpopulation, urbanization and different anthropogenic activities, there has been a rapid increase in domestic and industrial effluent discharge into streams and rivers, leading to increase pollution load **Sekabira, et al.,2010.** Water Quality Index (WQI) is one of the most effective tools to communicate information on the quality of water to the concern of citizens and policy makers. It becomes an important parameter for the assessment and management of surface water as a synthetic indicator. The concept of WQI is based on the comparison of the water quality parameters with respective regulatory standards and gives a single value to the water quality of a source, which translates the list of constituents and their concentrations present in a sample **Khudair, 2013; Khan et al., 2003; House, 1989.**

Factor analysis (FA), which includes principal component analysis (PCA) is a very powerful technique applied to reduce the dimensionality of a data set consisting of a large number of inter-related variables, while remaining as much as possible the

ISSN: 2277-9655
Scientific Journal Impact Factor: 3.449
(ISRA), Impact Factor: 1.852

variability present in data set. This reduction is achieved by transforming the data set into a new set of variables, the principal components (PCs), which are orthogonal (non-correlated), and are arranged in decreasing order of importance **Panda, et al., 2006.** Principal component analysis provides information on the most meaningful parameters, which describe whole data set rendering data reduction with minimum loss of original information **Singh, et al., 2004.** PCA has allowed the explaining of related parameters by only one factor **Boyacıo˘glu, and Boyacıo˘glu, 2006; Kannel, et al., 2007; Kottı, et al., 2005; Kowalkowski, et al., 2006; Sengörür, and ˙Isa, 2001; Singh, et al., 2004** and exposing of the important factor responsible for overall changes in river water quality **Ouyang, 2005; Ouyang, et al., 2006.**

Multiple regression analysis MRA examines the relation between a single dependent variable and a set of independent variables to best represent the relation in the population and to determine the most meaningful parameters responsible for water quality. **Amiri and Nakane, 2009; Sliva, and Williams, 2001; Wang, 2001; Singh, et al., 2005.**

CA comprises a series of multivariate methods, which is used to group the object based on the similar characteristics. The objects grouping into a cluster possess high homogeneity within cluster and high heterogeneity between clusters. The levels of the similarity at which observations are merged are used to construct dendrogram **Lokhande, et al., 2008.** The dendrogram provides a visual summary of clustering process, presenting a picture of groups and their proximity, with a dramatic reduction in dimensionality of the original data.

The objective of this study is to provide information on the physicochemical characteristics of Tigris River water quality within Baghdad city, and the impacts of unregulated waste discharge on the quality of the river as well as to discuss its suitability for human consumption based on computed water quality index values (WQI). A large data matrix, obtained during 4-years (2008-2011) monitoring program, is subjected to PCA/FA, MRA and CA techniques, to study and demonstrate the application of the data reduction techniques. The (PCA/FA) evaluates the importance of various water quality parameters, and (CA) identifies and evaluates similarities and dissimilarities between sampling sites of water treatment plants and water quality parameters. Hierarchical cluster analysis was performed using Ward's method. Squared Euclidean distance was used as a measure of distance, which is one of the most commonly adopted measures .The Ward method, uses an intra cluster variation to form clusters, and the clusters are formed by maximizing the homogeneity within each cluster.

Materials and methods

Study Area

Along the Tigris River near Baghdad, there exist eight water treatment plants. The most recent one is Al-Karkh water treatment plant, was start operating at the beginning of 1980. At that time and before, the Tigris water quality was relatively good. Hence, those treatment plants were designed according to this with the conventional treatment concept of water treatment, i.e., with no special treatment units. From that time up to now, the water quality of Tigris River had deteriorated because of the reduction of water quantities due to the construction of dams in Turkey, climate changes, and irregular and illegal discharges of waste water to the river upstream of Baghdad. Hence, it is important for both of the operation and modification of those treatment plants, to account for the raw water quality change. Prediction models for the raw water quality parameters will be useful for this operation and modification, to produce water with the desired drinking water quality. The study area covers the Tigris River at Baghdad city, which is considered as a meandering river in Baghdad. The length of Tigris River through Baghdad city is about (67.09) km, and the river velocity varies between (1.42) m/sec at high water level and (0.45) m/sec at low water level, **Abu-Hamdeh, 2000.** The Tigris River at Baghdad city represents the main source for different uses, such as: Supply source for many water treatment plants , irrigation of large agricultural areas , and supply source for industrial plants. Eight main water treatment plants were exist, that draw raw water from the river, Karkh, Sharq Dijlah, Karama, Wathba, Qadisiya, Dora,Wahda , and Rasheed water treatment plants, as shown in **Fig. (1)**. Several types of sources of pollutants are taken into consideration as follows: Treated domestic waste water (municipal and inter-municipal waste water treatment plants as well as septic tank), untreated waste water (raw waste water from sewer networks and directly from house hold), treated industrial waste water (private and public waste water treatment plants), untreated industrial waste water, farming, and agriculture practices. Many drains and ground water flow into the river represent other sources of pollution, which increase the possibility of river pollution, **Abu-Hamdeh, 2000.**

ISSN: 2277-9655
Scientific Journal Impact Factor: 3.449
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Table (1) shows the distance of each plant from the reference point and the distance of each plant from the other.

For calculating the Water Quality Index, a set of eighteen water quality parameters have been selected based on both importance and availability of data from each station.
The overall Water Quality Index (WQI) was calculated using the Weighted Arithmetic Index method given by **(Cude, 2001)**. The quality rating scale for each parameter (q_i) was calculated by using **Eq. (1)**:

$$q_i = \left(\frac{C_i}{S_i}\right) \times 100 \qquad (1)$$

A quality rating scale (q_i) for each parameter is assigned by dividing its observed concentration (C_i) in each water sample by its respective standard value (S_i) and the result is multiplied by 100. Relative weight (w_i) was calculated by a value inversely proportional to the recommended standard value (S_i) of the corresponding parameter using **Eq. (2)**:

$$w_i = \frac{1}{S_i} \qquad (2)$$

The overall Water Quality Index (WQI) was calculated by aggregating the quality rating scale (q_i) with the unit weight (w_i) linearly in **Eq. (3)** as follows:

$$WQI = \left(\sum_{i=1}^{n} w_i \times q_i\right) \qquad (3)$$

Generally, WQI is to be discussed for a specific and intended use of water. In this study the WQI for drinking purposes is considered a permissible WQI if its value is 100 using **Eq. (4):**

$$\text{Over all WQI} = \frac{\left(\sum_{i=1}^{n} w_i \times q_i\right)}{\sum w_i} \qquad (4)$$

The data used to calibrate and validate the multivariate analysis models were collected from Baghdad Water Authority. In each station, data were collected from raw water (river water near intakes of water treatment plants). In addition, the flow of the river and the distances between those treatment plants were taken from **(Al-Suhaili, 2008).**
SPSS© v.20, and Microsoft Office Excel© 2007, software packages were used to implement all the mathematical and multivariate statistical analyses.

Results and discussion

Water Quality Index (WQI) In this study, the water quality index (WQI) of the Tigris river within Baghdad city has been calculated using the weighted arithmetic index method for seventeen parameters of the raw water that were studied with respect to their suitability for human consumption compared with the standards of drinking water quality recommended by the World Health Organization **WHO, 2004.**
The overall WQI of all the samples taken were calculated according to the procedure explained in **Eqs. 1, 2, 3, and 4** and the results are presented in **Table 2**. **Table 3** shows the classification of water quality based on WQI value and distribution of the water samples according to their respective quality group. Based on the WQI value, water is categorized in to five groups ranging from excellent water to water unsuitable for drinking.
The computed annual overall WQI for all samples from 2008 to 2011 was **192**, which implies that the water is generally "poor quality". The result obtained from this study indicates that the overall WQI of Tigris river water is not within the permissible limits for drinking water (100) for the entire samples taken, thereby signifying contamination. The high value of WQI obtained is as a result of the high concentrations of turbidity, total hardness TH, electrical conductivity EC, and total solids TDS in the water and can be attributed to the various human activities taking place at the river bank.
Identical findings were reached by **Al-Suhaili and Nasser, 2008**, but it is hard to make a comparison in WQI values obtained as they used a different procedure in the determination of WQI. **Hameed, et al., 2010** also indicated WQI was good at the north of Baghdad in 2002 to 2004 but was poor in 2006 to 2008. At the south region it was very poor to unsuitable for the same years. They concluded the effect of dryness in the area in the last three years might be behind the clearly observed depletion of WQI, especially in the upstream stations where there is no high intervention between the effects of dryness and those of human activities. So, all WQI values indicate that the water of Tigris River is unsuitable for drinking purposes.

Factor Analysis/Principal Component Analysis (FA/PCA)
Before the applying of the multivariate statistical techniques, experimental data were normalized within the range 0.1 to 0.9 in order to avoid misclassification due to wide differences in data dimensionality, tends

ISSN: 2277-9655
Scientific Journal Impact Factor: 3.449
(ISRA), Impact Factor: 1.852

to minimize the influence of difference of variance of variables and eliminates the influence of different units of measurement and renders the data dimensionless **Eq. 5 Dogan et al., 2009**.

$$x_i = 0.8\frac{(x - x_{min})}{(x_{max} - x_{min})} + 0.1 \qquad (5)$$

Correlation matrix of the PCA **Table 4**, shows the correlation between particular parameters: Turbidity is correlated negatively with TH ,Ca^{+2} ,Mg^{+2} ,pH ,Cond , Sulfate, and TS, and positively with TSS ,Fe^{+2}, Nitrate ,Nitrite ,and Si. TH is correlated negatively with Temp, Tur, TSS, Fe^{+2}, Al^{+3}, Nitrate, Si, and positively with Ca^{+2} ,Mg^{+2} ,conductivity ,sulfate ,and TS. TSS is negatively correlated with Fe, Al^{+3}, Nitrate, Ammonia, orthophosphate, Sulfate, EC, Mg, Ca, and total hardness, and positively with Tur, alkalinity, TS, and Si. According to the eigenvalues-one criterion **Kowalkowski et al., 2006,** only the four first eigenvalues were taken into account (eigenvalues >1) **(Fig2)**; the remainder principal components (PC) were eliminated .The cumulative variance for the first four principal components is 70.742% of the total variance of the original dataset **Table 5**.

FA follows PCA. The main purpose of FA is to reduce the contribution of less significant variables to simplify even more of the data structure coming from PCA. This purpose can be achieved by rotating the axis defined by PCA, according to well established rules, and constructing new variables, also called varifactors (VF) or loadings **Boyacıo and Glu, 2006**.

The first four PC components were rotated according to Varimax rotation in order to make interpretation easier **Table 6**. Consequently, the first two principal components (loadings) can be considered significant in the analysis, especially the particular parameters having communality scores of 0.60 and above, that contributing to the variability in the component, by following the criteria of **Kowalkowski et al., 2006.** For the first loading component the significant parameters were: TH, Ca, sulf, cond, TS and Mg with positive relation, while in the second, nitrate, nitrite, TSS. Fe, Alkalinity, and tur, are significant parameters with a positive relation; while sulfate and TH shows a negative correlation coefficient Therefore factor analysis of the present data set further reduced the contribution of less significant variables obtained from PCA.

Multiple Regression Analysis MRA

MRA analysis was performed to examine the most water quality affecting dependent variables which are; Turbidity, TH, and TSS, and the remaining set of the independent variables respectively, to best fit and represent the relation between them. Eqs (6-8)

Turbidity= -0.574+0.428 TSS- 0.261 S – 0.167 T – 0.157 Alkalinity + 0.159 Nitrite – 0.179 Mg + 0.161 Ca -0.067 Al (6)

TH = - 0.003 + 0.598 Ca + 0.27 Mg +0.248 TS – 0.065 Fe – 0.077 Alkalinity + 0.064 Nitrate + 0.0035 pH – 0.30 T- 0.042 P (7)

TSS = 0.429 + 0.494 Tur +0.24 Nitrate + 0.367 Fe + 0.176 Nitrite + 0.171 Silica + 0.113 P (8)

Cluster Analysis CA for Sites and Variables Similarity

The similarity between sites and similarities between variables were obtained through cluster analysis using Wards method (linkage between groups) with Euclidian distance as a similarity measure and were amalgamated into dendrogram plots respectively.

CA performed to find out the similarity groups between the sampling stations, produced a dendrogram (Fig. 3), grouping all the eight WTTPs sampling stations into three statistically meaningful clusters, at a level of 5 for the rescaled distance cluster combine (squared Euelidean distance) which are: Cluster 1(Alrashed, Alwahda),cluster2(cluster1,Al-Karkh,East-Tigrus,Al-Wathba),cluster3(cluster1,cluster2,Al-Karama,Al-Qadsiya,Al-Dora). Also performing CA based on the 18 physical and chemical data sets parameters, gives 3 clusters at a level of 5 for the rescaled distance cluster combine (squared Euelidean distance) (Fig 4) which are: Cluster 1(,TS, EC, SO4 , Mg^{+2}, Ca^{+2}, TH), cluster2(cluster1, TA, pH, $NO3^{-1}$, Si), cluster3(cluster1,cluster2,Tur, Fe^{+2}, $NO2^{-1}$, PO4,TSS,NH3,Al) respectively.

The dendrogram **Fig. 3**, from the site analysis there are similarity associations between Cluster 1, Cluster 2 and Cluster 3 corresponded to relatively low pollution, moderate pollution and high pollution regions respectively. The water quality differences in the clusters reflect difference in morphology and anthropogenic pollution. The water quality in sites 3, 4, and1 was found to be only moderately polluted because its location is near municipal and industrial effluents not meeting the discharge standards. The improved water quality at sampling sites 7, 8, 2, 6, and5 revealed the self purification and assimilating capacity of the river. The deterioration in water quality in downstream at site 1 signified severe pollution because of pollutions from domestic wastewater, agricultural run-off and industrial effluents located in Baghdad city.

The dendrogram **Fig.4** , showed the similarity degree between studied variables in which three clusters were formed. First group linked TS, EC, SO_4^{-2}, Mg^{+2} ,Ca^{+2}, and TH. These ions suggest the association with a combination of various hydrogeochemical processes. The Second group association between TA, pH, NO3, and Si were obtained, which are associated with a combination of various hydrogeochemical processes, and then augmentation of more mineralized water. While, third group consists of association between turbidity, Fe^{+2}, NO_2, PO_4, TSS, NH3, and Al^{+3}. is an indication of man- made pollution due to domestic, agricultural, and industrial waste.

For rapid water quality assessment studies, only a representative site from each cluster (not all monitoring sites) can be used. This reduces the number of analysis and the cost of the risk assessment procedure **Simeonov et al., 2003**.

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ISSN: 2277-9655
Scientific Journal Impact Factor: 3.449
(ISRA), Impact Factor: 1.852

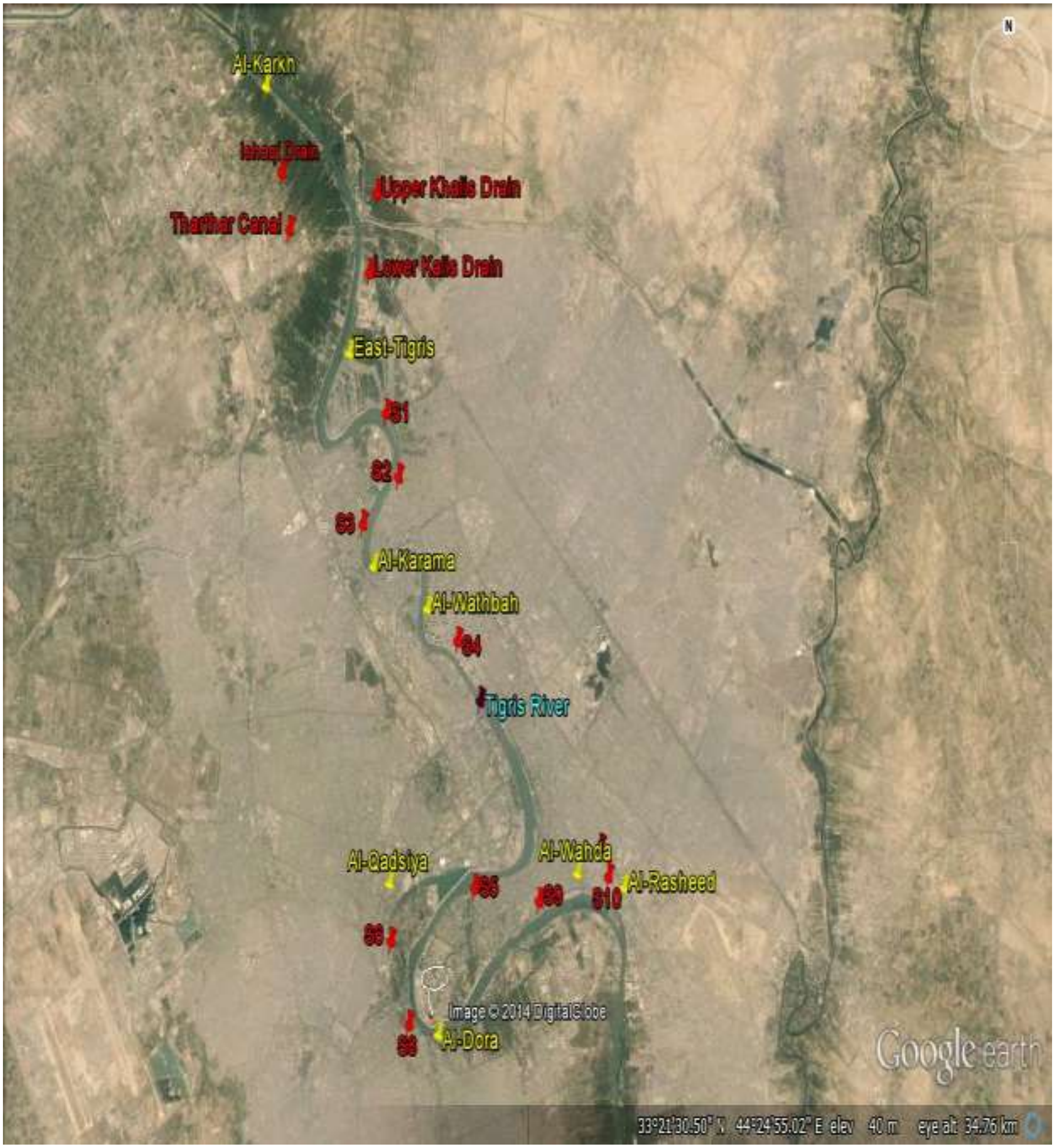

Figure 1. Conventional water treatment plants and main sources of pollutions in Tigris River at Baghdad S1, S2, S4, S5, S7= rainfall and wastewater network, S3= overflow from Abdulmusan Alkadimi sewerage, S6= overflow from Al Saidya sewerage, S8= Dora electric power plant, S9= vegetable oils factory, S10 middle zone electric power plant

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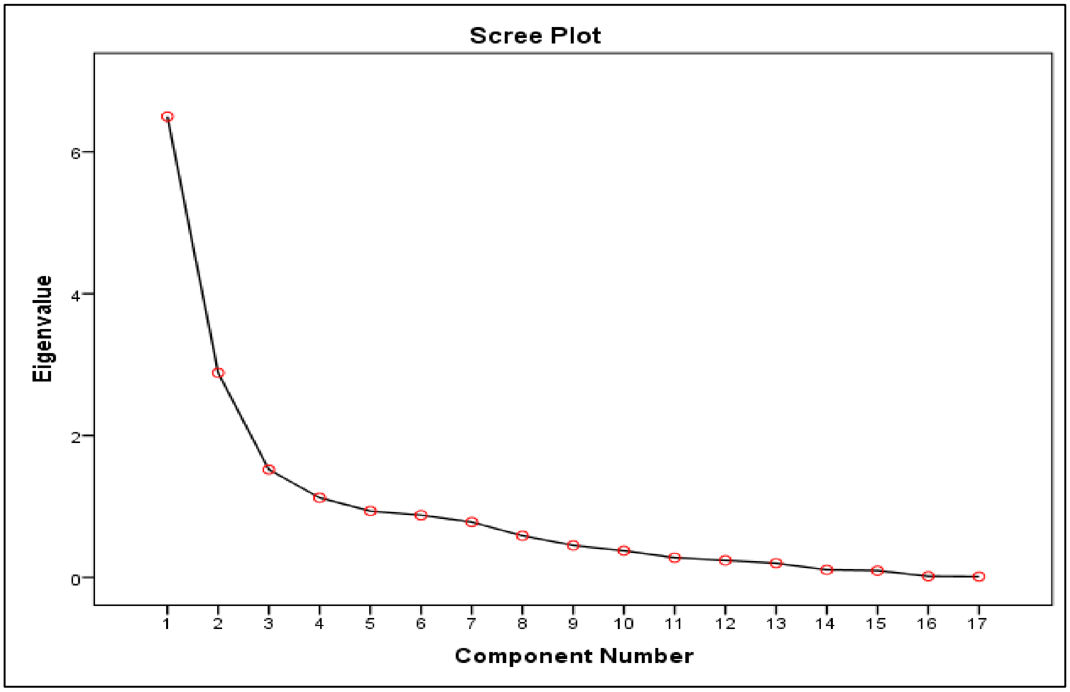

Figure 2. Eigenvalues Scree Plot.

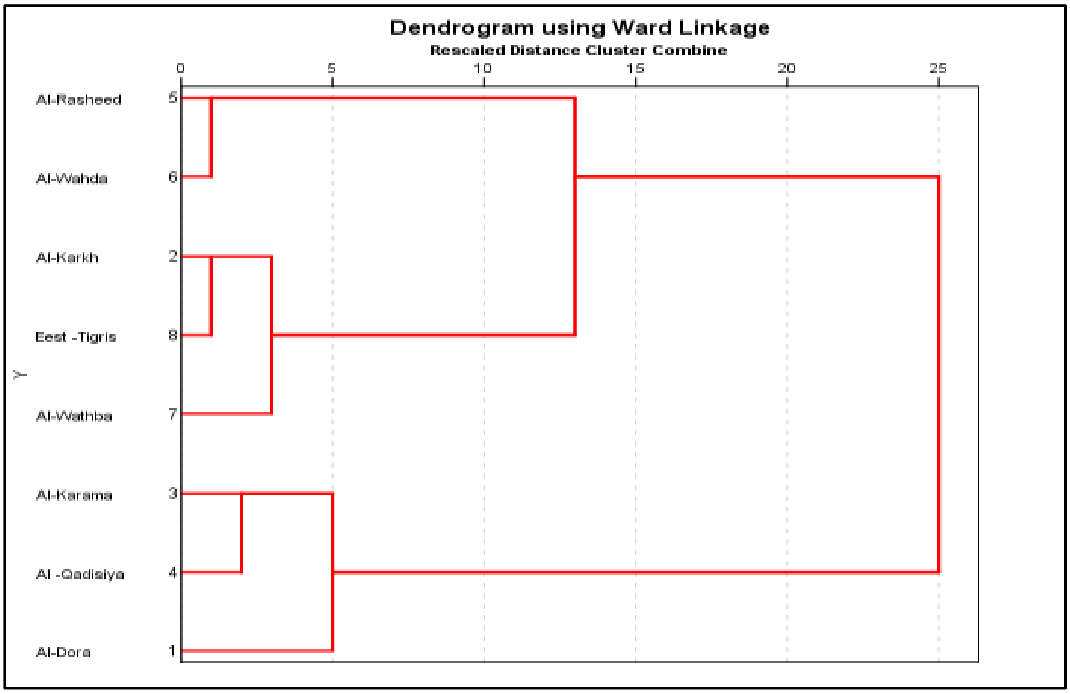

Figure 3. Dendrogram of cluster analysis for water quality parameters according to WTTPs of Tigris River.

ISSN: 2277-9655
Scientific Journal Impact Factor: 3.449
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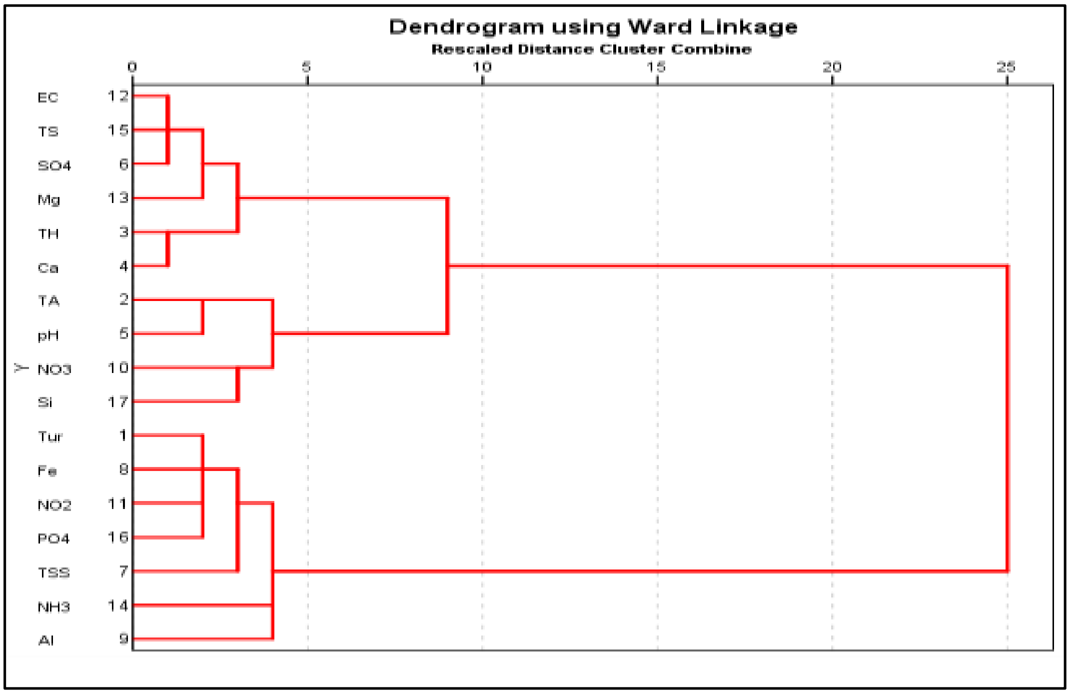

Figure 4. Dendrogram of cluster analysis for sampling stations according to water quality parameters of Tigris River.

Table 1. The distances between water treatment plants (Abu-Hamdeh, 2000).

Plants	Distance from reference point (km)	Distance from each other's (km)	Operating capacity Million L/day	Source of pollution
Al-Karkh WTP	0	0	1365	Salinity of Al-Adhaim river
Sharq Dijlah WTP	30	30	540	Al-Therthar Tigris canal,Al-Ishaki &Al-Khalis drainage canals,Tagi gas factory, wool washing and drying factory
Al-Karama WTP	40.76	10.76	200	Ramadan textile ,14 July factories, Iraqi textile co., combined sewer input 1.5km upstream
Al-Wathba WTP	43.47	2.71	60	Storm water sewer input T1
Al-Qadisiya WTP	55.02	11.55	135	City hospital, Al Khaeer river input
Al-Dora WTP	58.78	3.76	105	Combined sewer input(PN) 1.7 km upstream, Dora power plant,Saidia sewage plant

ISSN: 2277-9655
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Al-Wahda WTP	64.15	5.37	50	Storm water
Al-Rasheed WTP	67.09	2.94	45	Storm water sewer input(TS1) .95 km upstream, Dora refinery, vegetable oil factory detergent factory, Baghdad cement factory

Table 2. Computed WQI values for Tigris River within Baghdad city from 2008-2011

Test Type	Minimum	Maximum	Average Ci	Si	wi	qi	WQI
Temperature	10	33.5	22.42	20	0.050	112.10	5.605
Turbidity	6.5	2015.	124.09	5	0.200	2481.93	496.387
Alkalinity	97.5	177	143.57	150	0.010	95.72	0.638
T.Hardness	225	564	338.38	500	0.002	67.68	0.135
Calcium	55.5	172	90.99	200	0.005	45.49	0.227
Magnesium	17	45.5	28.74	150	0.007	19.16	0.127
PH	7.5	8.25	7.9483	7.5	0.133	105.98	14.130
Conductivity	530	1369	887.41	250	0.004	354.97	1.419
Sulfate	75	420	209.41	400	0.003	52.36	0.131
Total Solids	340	910	578.33	1500	0.001	38.55	0.026
SS	8	1009	133.52	133	0.007	100.39	0.755
Iron as Fe	0.05	27.555	1.611	0.3	3.333	537.14	1790.466
Aluminium	0.01	0.09	0.018	0.01	100	185.35	18535.16
Nitrite	0.001	0.1005	0.008	3	0.333	0.28	0.093
Nitrate	0.16	2.1	0.72	50	0.020	1.44	0.029
Ammonia	0.01	0.9	0.14	0.2	5	71.36	356.803
Silica	0.85	8	3.94	4	0.250	98.64	24.662
Orthophosphate	0.01	0.93	0.05	1	1	5.79	5.792
					110.35	**4374.35**	**21232.58**
					overall WQI		**192**

Table 3. Water quality classification based on WQI value (House, 1989, Ramakrishniah et. Al..2009).

No.	WQI value	Water quality classification
1	**<50**	**Excellent**
2	**50-100**	**Good water**
3	**100-200**	**Poor water**
4	**200-300**	**Very poor water**
5	**>300**	**Water unsuitable for drinking**

ISSN: 2277-9655
Scientific Journal Impact Factor: 3.449
(ISRA), Impact Factor: 1.852

Table 4. Correlation matrix of the PCA

	T	Tur	TH	TA	Ca^{+2}	Mg^{+2}	pH	EC	$(SO4)^{-2}$	TS	TSS	Fe^{+2}	Al^{+3}	NO^{-2}	NO^{-3}	NH_3	Si	$(PO_4)^{-3}$
T	1																	
Tur	-.17	1																
TH	-.41	-.25	1															
TA	-.24	.29	-.35	1														
Ca^{+2}	-.36	-.22	.96	-.39	1													
Mg^{+2}	-.45	-.27	.77	-.03	.66	1												
pH	-.04	-.18	.17	-.03	.13	.2	1											
EC	-.38	-.28	.95	-.31	.91	.77	.16	1										
$(SO_4)^{-2}$	-.30	-.38	.90	-.41	.89	.68	.19	.9	1									
TS	-.37	-.26	.93	-.30	.88	.73	.15	.97	-.1	1								
TSS	-.08	.70	-.25	.40	-.23	-.18	-.15	-.23	-.3	.89	1							
Fe^{+2}	.09	.43	-.32	.37	-.28	-.19	-.1	-.29	-.2	-.34	-.22	1						
Al^{+3}	.20	.05	-.24	.01	-.18	-.31	-.17	-.2	-.1	-.3	-.29	.56	1					
NO^{-2}	-.22	.31	.12	.28	.1	.07	-.17	.15	-.2	-.25	-.26	.12	.01	1				
NO^{-3}	-.20	.56	-.28	.6	-.29	-.12	-.08	-.29	-.2	-.01	.18	.37	.16	.08	1			
NH_3	-.09	.01	.27	.2	.26	.18	-.11	.29	.9	-.42	-.26	.64	.44	.18	.36	1		
Si	.26	.38	-.43	.19	-.41	-.44	.02	-.38	.5	.2	.3	.09	.01	-.05	.53	.01	1	
$(PO_4)^{-3}$	-.1	.02	.15	-.01	.21	.04	.02	.14	-.1	-.4	-.32	.45	.33	.05	.07	.42	-.28	1

ISSN: 2277-9655
Scientific Journal Impact Factor: 3.449
(ISRA), Impact Factor: 1.852

Table 5. Total Variance Explained

Component Number		Initial Eigenvalues			Extraction Sums of Squared Loadings (PCA)			Extraction Sums of Squared Loadings (FA)		
		Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	$(PO_4)^{-3}$	6.497	38.215	38.215	6.497	38.215	38.215	5.565	32.737	32.737
2	Si	2.885	16.971	55.186	2.885	16.971	55.186	3.816	22.449	52.186
3	NH_3	1.520	8.942	64.128	1.520	8.942	64.128			
4	TH	1.124	6.614	70.742	1.124	6.614	70.742			
5	NO^{-3}	.936	5.506	76.248						
6	NO^{-2}	.878	5.167	81.415						
7	Ca^{+2}	.781	4.594	86.008						
8	pH	.588	3.461	89.470						
9	$(SO_4)^{-2}$	.452	2.659	92.128						
10	EC	.377	2.219	94.347						
11	TS	.279	1.642	95.989						
12	TSS	.241	1.420	97.409						
13	Fe^{+2}	.203	1.192	98.601						
14	Al^{+3}	.109	.638	99.239						
15	Mg^{+2}	.097	.573	99.812						
16	TA	.018	.106	99.918						
17	Tur	.014	.082	100.000						

ISSN: 2277-9655
Scientific Journal Impact Factor: 3.449
(ISRA), Impact Factor: 1.852

Table 6 PCA components and FA loadings

	PCA components [a]				FA loadings [b]	
	1	**2**	**3**	**4**	**1**	**2**
$(PO_4)^{-3}$	.172	.215	-.579	-.148	.258	.098
Si	-.567	.152	.454	.221	-.411	.419
NH_3	.242	.518	-.545	-.245	.471	.323
TH	.933	.267	.113	.110	.940	-.244
NO^{-3}	-.521	.617	.228	-.033	-.135	.796
NO^{-2}	-.020	.729	-.338	.025	.353	.638
Ca^{+2}	.900	.254	.055	.195	.904	-.238
pH	.213	-.124	.420	-.474	.121	-.215
$(SO_4)^{-2}$	.930	.109	.098	.096	.856	-.378
EC	.921	.287	.123	.108	.939	-.221
TS	.898	.307	.145	.102	.929	-.191
TSS	-.496	.688	.166	.188	-.078	.845
Fe^{+2}	-.479	.447	.190	-.042	-.186	.629
Al^{+3}	-.275	-.046	-.379	.473	-.260	.100
Mg^{+2}	.749	.278	.218	-.237	.787	-.141
TA	-.462	.474	-.003	-.544	-.157	.643
Tur	-.496	.563	.151	.271	-.141	.737

a-Extraction Method: Principal Component Analysis , 4 components extracted.

b-Extraction Method: Principal Component Analysis, Rotation Method: Varimax with Kaiser Normalization , Rotation converged in 3 iterations

Nomenclature	
MRA	Multiple Regression Analysis
q_i	the quality of the ith parameter
w_i	the unit weight of the ith parameter.
n	number of the parameters considered
x_i	normalized value of a certain parameter
x	is the measured value for this parameter
xmin	Minimum values
xmax	Maximum values