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Determination of Pollution's Sources for some Raw Water Supplies at Basrah Governorate

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Abstract - In Iraq, water resources suffered from salinity, declining in flow rate and pollution. Recently, these problems have reached critical point where people in Basrah governorate depended on desalinized water. Therefore, the objective of this research is evaluating seasonal water quality of some raw water supplies in Basrah governorate using Principal Component and Factor Analyses (PCA/FA). Raw water samples had been collected from nine water supplies (Braadhyia; Garma; Shatt Al-Arab; Mhejran; Hamdan balad; Hamdan bridge; Jubaila; Maqal and Zubair) for analyzing fourteen parameters along the period from January 2017 to December 2020. We used varimax as a rotation method for interpreting the results of PCA/FA. Depending or scree plots, we extract three factors for winter, summer and autumn and two factors for spring only. Rotated factors are named as follows: The first factor represents pollution with sea water due to reduction in river discharge which allowed a salt-water wedge to penetrate into the Shatt Al-Arab River. The second factor represents pollution with biotic and a biotic particulate. Water temperature contributes in variance of the third factor for Summer and Autumn seasons which reflects disturbance of climate conditions. pH contributes in variance of the third factor for Summer season only which considers as an important factor for efficiency of both coagulation and chlorination. The alkalinity contributes in variance of the third factor for Winter and Autumn seasons.

تحديد مصادر التلوث لبعض إمدادات المياه الخام في محافظة البصرة، العراق

ايناس قاسم محمد و آمال موسى عيسى و لمى جاسم العنبر
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المستخلص – عانت الموارد المائية في العراق من الملوحة وانخفاض معدل التدفق والتلوث. في الآونة الأخيرة، وصلت هذه المشاكل إلى نقطة حرجة حيث اعتمد الناس في محافظة البصرة على المياه المحلاة. لذلك، فإن الهدف من هذا البحث هو تقييم جودة المياه الموسمية لبعض إمدادات المياه الخام في محافظة البصرة باستخدام المكونات الرئيسية وتحليلات العوامل .(PCA/FA) وتم جمع عينات من المياه الخام من تسعة إمدادات للمياه (براضعية ؛ كرمة ؛ شط العرب ؛ ومهيجران ؛ وحمدان بلد ؛ وجسر حمدان ؛ الجبيلة ؛ معقل والزبير) لتحليل أربعة عشر معامل على طول الفترة من كانون الثاني 2017 إلى كانون الاول 2020. استخدمنا varimax كطريقة دوران لتفسير نتائج .PCA/FA اعتمادًا على قطع الأراضي، نستخرج ثلاثة عوامل للشتاء والصيف والخريف وعاملين للربيع فقط. وتسمى العوامل الدوارة على النحو التالي: يمثل العامل الأول التلوث بمياه البحر بسبب انخفاض تصريف الأنهار مما سمح لإسفين المياه المالحة بالتوغل في نهر شط العرب. العامل الثاني يمثل التلوث بالجسيمات الحيوية واللاحيوية. تساهم درجة حرارة الماء في تباين العامل الثالث لموسمي الصيف والخريف مما يعكس اضطراب الظروف المناخية. يساهم الأس الهيدروجيني في تباين العامل الثالث لموسم الصيف فقط والذي يعتبر عاملاً مهمًا لكفاءة كل من التخثر والكلورة. تساهم القلوية في تباين العامل الثالث لموسمي الشتاء والخريف. يجب أن يكون معروفًا بحساب كميات الشب وغيرها من أدوات التخثر التي يجب إضافتها في معالجة المياه.

كلمات مفتاحية: مصدر إمدادات المياه – التلوث، PCA/FA.

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Introduction

Water is a secret of life for all living organisms on earth's surface. It forms more than 90% of body's fluids. Global populations continue to rise, leading to consume large volumes of water in varied activities. Most of these activities lead to high levels of pollution. In developing countries, majority of wastes are discharged into water bodies without adequate treatments. Recently, there are several epidemics of water borne diseases in developing countries such as cholera and dysentery. Such epidemics threat human health and life (Rwoo *et al.*, 2016). Pollution of water resources becomes a global issue. In addition to human activities, climate change observed worldwide has a significant effect on quality of water resources and their possible future availability (Rehana and Mujumdar, 2011; Abbas *et al.,* 2016).

Due to spatial and temporal variations in water quality, which are often difficult to interpret, a monitoring program providing a representative and reliable estimation of the quality of surface waters is necessary (Pejman *et al.,* 2009). Monitoring of water quality requires big database comprising many variables measured at long time periods and finds the appropriate approach for analyzing and interpreting them. Practically, the multivariate statistical techniques, such as cluster analysis (CA), principal component analysis (PCA) and factor analysis (FA), provide a simple and suitable approach in monitoring water quality deterioration (Härdle and Simar, 2003; Maestre and Pitt 2005; Mustapha and Nabegu, 2011). The principal component analysis and factor analysis (PCA/FA) are the main multivariate statistical approaches applied to understand much larger sets of variables by reducing the overall variables set to a smaller one of factors or components contain majority of data variance. Such approach facilitates the identification of possible factors that influence water quality and can aid in the reliable management of water resources (Thareja *et al.*, 2011). Also, this approach is useful in verifying temporal and spatial variations caused by natural and anthropogenic factors linked to seasonality (Pejman *et al*., 2009; Zare Garizi *et al.*, 2011).

In Iraq, water resources suffered from water shortage, salinity, declining in flow rate and pollution (HRW, 2019 and IOM, 2019). Iraq needs more water than what it gets now due to the increase in population. In recent years, these problems have reached critical point where people in most of the Basrah governorate depended on desalinized water even for their animals. Many farmers have deserted their lands due to the lack of fresh water especially in the Faw peninsula and on the banks of the Shatt Al-Arab estuary (Fawzin and Mahdi, 2014).

Several researchers have applied various statistical methods to determine the water quality of rivers and water supplies (Rwoo *et al.*, 2016; Shekha, 2016; Sentas *et al.*, 2018; Hamed, 2019; Ewaid *et al.*, 2020). The objective of this research is evaluating seasonal water quality of raw water supplies in Basrah governorate using the multivariate statistical analysis approach (PCA/FA).

Materials and Methods:

Raw water samples had been collected from nine water supplies (Braadhyia; Garma; Shatt Al-Arab; Mhejran; Hamdan balad; Hamdan bridge; Jubaila; Maqal and Zubair) lied at Basrah governorate for forty-two months only along the period from January 2017 to December 2020 as shown in Figure 1. Fourteen physico-chemical tests of water samples had been conducted by Central Laboratory of Basrah's water supplies located at Braadhyia locality according to (Baird, *et al.*, 2017), as shown in Table 1 below:

Table 1. Physico-Chemical Analyses of Raw Water Samples

Parameter	Abbreviation	Procedure
Temperature	Tem.	pH meter
Turbidity NTU	Tur.	Nephelometry
pH	-	
Electrical Conductivity Ohm^{-1}	EC	Portable multimeter
Total Alkalinity mg\L	Alk	Titration with Diluted Sulfuric Acid
Total Hardness mg\L	Th	Titration with Na2EDTA
Calcium Ion mg\L	Ca^{+2}	Titration with Na2EDTA
Magnesium Ion mg\L	Mg^{+2}	Titration with Na2EDTA
Chloride Ion mg\L	Cl^{-}	Titration with AgNO3
Sulfate mg\L	SO_4^{-2}	Gravimetry
Total Dissolved Solids mg\L	TDS	Portable multimeter
Total Suspended Solids mg\L	TSS	Gravimetry
Sodium Ion mg\L	Na^{+}	Flame photometer
Potassium Ion mg\L	K^{+}	Flame photometer

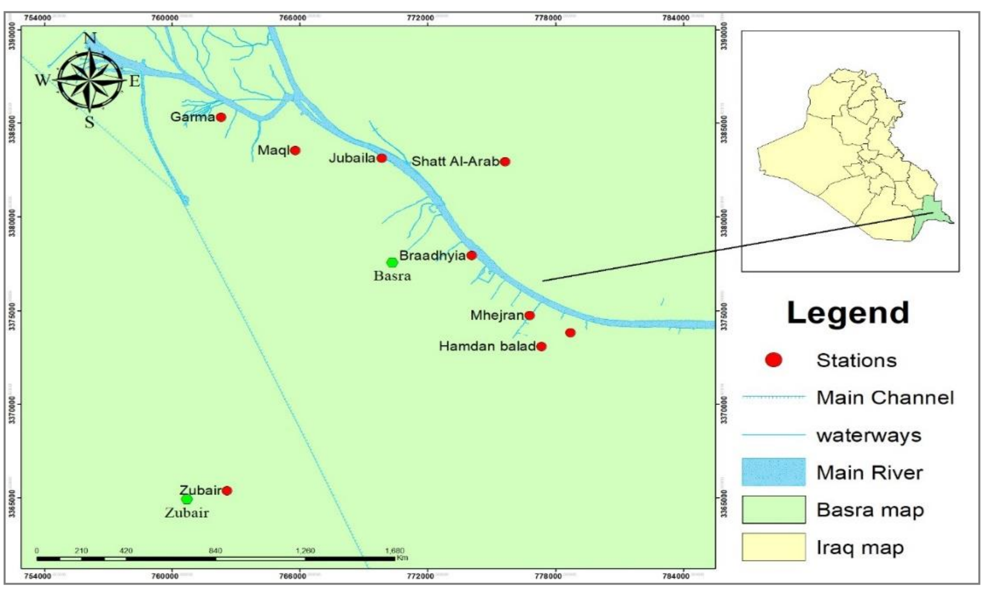

Figure1. Location map for Basrah Governorate, Southern Iraq

The multivariate PCA has been widely applied in statistical assessment of water quality. PCA is used to reduce a set of original variables and to extract a small number of latent factors or principal components for analyzing relationships among the observed variables without any loss in the information of whole data (Rosha and Kaur, 2017). In the present study, the PCA was performed on SPSS (Statistical Package for the Social Sciences) software, version 21, IBM SPSS Inc.

In order to distinguish the variations of each parameter for a given season, the data were divided into four databases. Winter (November and December), Spring (March and April) March, Summer (May to August) and Autumn (September to October). Therefore, four seasonal separated PCA/FA were performed. Each PCA/FA analysis comprised nine Tables. they are: 1) Descriptive Analyses; 2) Correlation Matrix; 3) Kaiser-Meyer-Olkin and Bartlett's Tests; 4) Communalities; 5) Total Variance Explained; 6) Component Matrix; 7) Reproduced Correlations; 8) Rotated Component Matrix; and 9) Component transformation Matrix and two figures They are: Scree plot and Component Plot in Rotated Space. Because of impossible listing all Tables and Figures in our research, we chose some of them and the remaining ones are mentioned in results and discussion.

Results and Discussion:

Principal Component Analysis (PCA):

Shatt Al-Arab River represents the life's artery in Basrah governorate because it supplies majority of water supplies. It formed by merging of Tigris and Euphrates Rivers at Qurna District northern of Basrah then it flows into Arabian Gulf (Al-Asadi and Alhello, 2019).

In the present study, PCA/FA used an extraction method and Varimax with Kaiser Normalization as a rotation method for interpretation the results of fourteen raw water supplies in Basrah governorate. The descriptive analysis is shown in Table 2 while both Kaiser-Meyer-Olkin (KMO) and Bartlett's tests are shown in Table 3. According to Sarstedt and Mooi (2019), The KMO values for four seasons indicate that have a middling value (i.e. 0.70-0.79) in Winter and Meritorious values (i.e. 0.80-0.89) in other three seasons and the p values of Bartlett’s test of sphericity were significant (i.e. < 0.001) for all seasons which indicate that can be continued and achieved PCA/FA analysis.

The scree plot helps to choose the factors or components and understand the basic data structure. In scree plot, eigen values drop sharply at the beginning but then they gradually approach zero after a certain point. The eigen values represent the variance not expressed in percentage which plotted against a certain number of components equal to the number of variables but we choose only the components whose their eigen values are greater than one (Maestre and Pitt 2005; Baran and Warry, 2008; Mustapha and Nabegu, 2011; Mohanty and Nayaka, 2017). The present study, extracts three factors for Winter, Summer and Autumn and two factors for Spring only as shown in Figure 2.

Table 2. Descriptive Analysis of Raw Water Supplies' in Basrah Governorate.

	Winter				Spring				Summer				Autumn			
	Min.	Max.	St.Dev.	N.	Min.	Max.	St.Dev.	N.	Min.	Max.	St.Dev.	N.	Min.	Max.	St.Dev.	N.
Tem.	19.2	91.0	4.01	324	14.4	27.5	1.32	120	21.8	34.2	1.64	279	24.0	32.1	1.68	132
Tur.	1.2	40.7	5.52	324	3.0	32.3	5.29	120	0.7	90.0	7.98	279	2.9	60.4	8.05	132
pH	7.09	8.30	0.21	324	7.10	7.96	0.16	120	7.03	8.02	0.15	279	6.97	8.12	.2158	132
EC.	1197	27558	4420.07	324	1088	14890	2218.08	120	865	30384	6715.72	279	945	34030	8716.78	132
Alk.	96	284	22.30	324	100	296	25.69	120	90	260	24.49	279	104	246	20.65	132
Th.	416	3592	564.98	324	385	2720	359.86	120	303	4632	841.52	279	320	4860	1070.63	132
Ca	83	736	113.52	324	78	550	72.66	119	62	928	168.72	279	67	976	213.05	132
Mg	47	428	68.63	324	46	328	43.64	120	36	564	102.37	279	37	590	131.29	132
Cl	140	8300	1365.70	324	136	3700	588.49	120	112	8750	2059.53	279	127	9950	2725.21	132
SO4	250	3416	561.33	324	217	2568	363.46	120	137	4449	833.39	279	156	3977	849.35	124
TDS.	728	18486	2978.08	324	672	9864	1454.74	120	522	20618	4510.42	279	584	22954	5945.73	131
TSS	10	296	38.35	324	26	168	29.28	120	10	280	32.78	278	2	288	43.04	132
Na	80	5437	897.82	324	86	2514	399.19	120	59	5770	1358.58	279	70	6547	1789.46	132
K	3.8	21.3	3.57	324	4.0	22.0	3.304	120	2.5	50.0	8.01	279	4.0	28.0	4.96	132

Table 3. Kaiser-Meyer-Olkin (KMO) and Bartlett's Test

	Winter	Spring	Summer	August
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.	0.79	0.82	0.85	0.81
Approx. Chi-Square	18025.73	5648.84	15773.84	7462.72
Bartlett's Test of Sphericity df	91	91	91	91
Sig	0.000	0.000	0.000	0.000

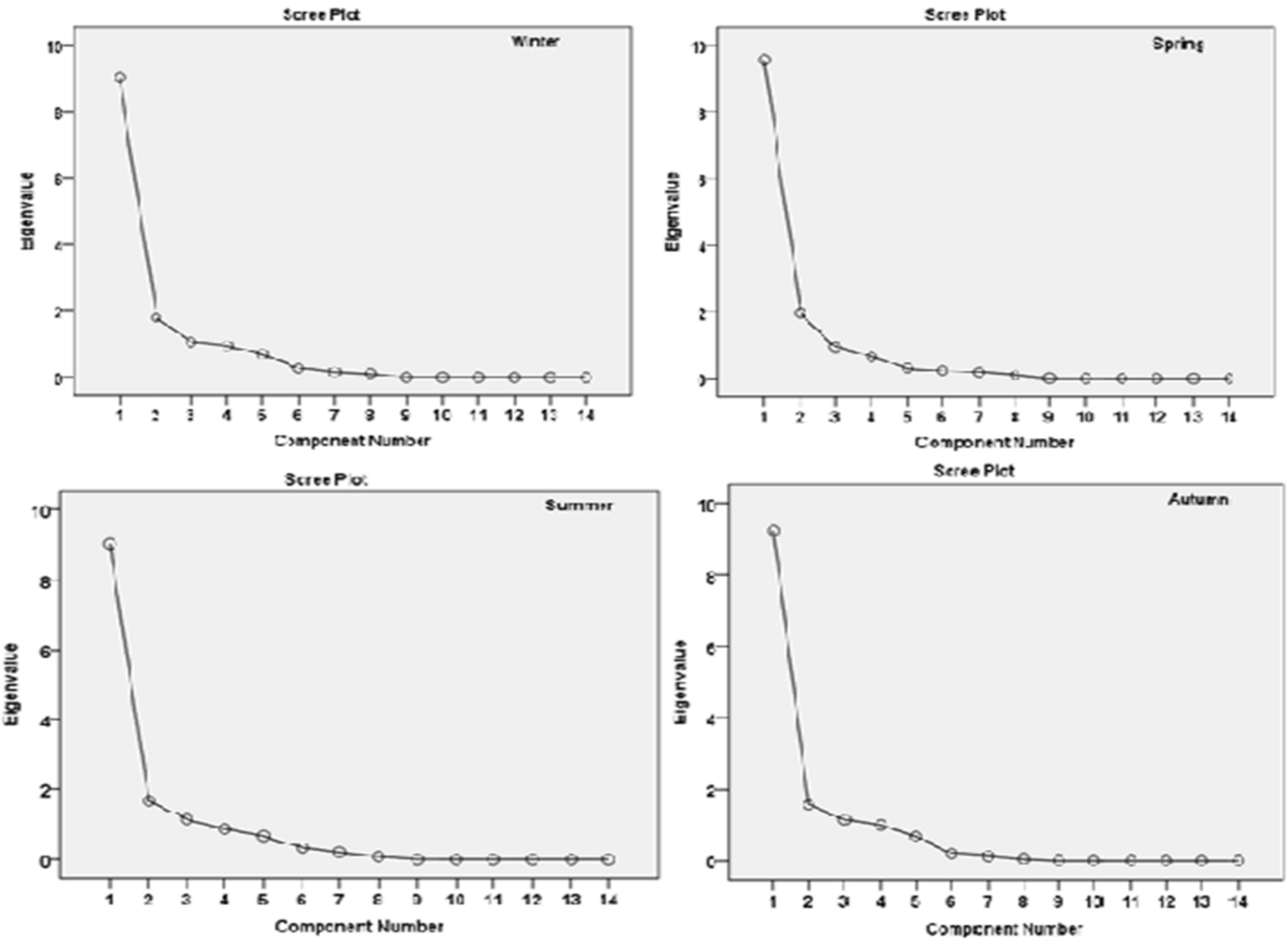

Figure 2. Seasonal Scree Plot of Raw Water Supplies in Basrah Governorate.

According to EC (2008), the sums of squared loadings for all variables belonging to a certain factor represents the eigen value (numerical value of variance) or the explained variance (percentage of variance) of that factor. Only eigen values > 1 are extracted and rotated and in our present study, the explained variance of rotated factors are as follow:

Factor loadings of Winter season are partitioned into three factors whose their total variance are 61.24 %, 14.05 % and 9.44 % for factor one, factor two and factor three respectively and the total cumulative variance is 84.75 % (Table 3). Factor loadings of Spring season are partitioned into two factors whose their variance are 68.21 % and 14.11 % for factor one and factor two respectively and the total cumulative variance is 82.32 % (Table 4). Factor loadings of Summer are partitioned into three factors whose their total variance are 64.23 %, 12.01 % and 8.34 % for factor one, factor two and factor three respectively and the total cumulative variance is 84.59 % (Table 5). Finally, Factor loadings of Autumn season are partitioned into three factors whose their total variance are 60.34 %, 13.58 % and 11.48 % for factor one, factor two and factor three respectively and the total cumulative variance is 85.41 % (Table 6).

These extracted factors are tested using reproduced correlations in order to assess the analysis goodness-of-fit (i.e. to what extent are the factors able to explain the observed correlations between the variables). According to reproduced correlations, the percentage of residual which computed between observed and reproduced correlations are 20 % , 9 % , 10 % and 14 % for Winter, Spring, Summer and Autumn seasons respectively. They are below 50 % indicating a good model fit conducted by PCA/FA analysis capable of providing a very accurate summary of the relationships in the data. Another support for goodness-of-fit of PCA/FA analysis is the total extracted variance (percentage of cumulative as shown in Table 3, 4, 5 and 6) which explains over than 80 % for all seasons (EC, 2008; Sarstedt and Mooi, 2019).

The purpose of rotation of the extracted factors is the interpretation of the finding of PCA/FA analysis (Härdle and Simar, 2003) which is considered as an complicated and multi-steps procedure and their results are interpreted depending upon the knowledge of the researchers in their environment (Rosha and Kaur, 2017). In our present study we proposed that the factors which represent pollution's sources are independent from each other's or in other words, the factors are orthogonally to each other's therefore we rotated them by certain angles using varimax method according to Sarstedt and Mooi (2019). Multivariate statistical procedure represented by PCA/FA analysis visualized results of varimax rotation both arithmetically and graphically. In arithmetical procedure, numerical correlation between a factor and a variable after rotation is called factor loading and the correlation values ranged from -1 to +1 (Mohanty and Nayaka, 2017). While in graphical procedure, the variables are expressed as vectors or geometric shapes on ordination plot (Baran and Warry, 2008).

Factor loadings are classified into strong, moderate and weak, corresponding to absolute loading values of > 0.75, 0.75-0.50 and 0.50-0.30 respectively (Pejman *et al.,* 2009; Zare Garizi *et al.,* 2011). In our present study, Rotated factor loadings are displayed arithmetically in table 3,4,5 and 6 for Winter, Spring, Summer and Autumn respectively and all variables which have factor loading greater than 0.6 are highlighted in yellow color while they displayed graphically in figure 2,3,4 and 5 and also. All variables which have factor loading greater than 0.6 are encircled in red color (Alkhawaja *et al.,* 2020). We can name these factors depending on the degree of correlation between the variable and its factors after rotation as follows:

Factor one represents pollution with sea water (i.e. Arabian Gulf). The correlated between most cationic and anionic variables and factor one plus high total variance of factor one reflects deterioration in freshness of Shatt Al-Arab River due to reduction in river discharge which allowed a salt-water wedge to penetrate into the Shatt Al-Arab River. However intrusion of Persian Gulf water into Shatt Al-Arab estuary disrupts its ecology (Partow, 2001 and HWR, 2019).

Factor two represents pollution with biotic (such phytoplankton and suspended bacteria) and abiotic particulates (such as suspended clay, silt and fine divided colloidal materials). Turbidity of water is defined as the cloudiness of water caused by suspended materials, obtained by measuring its light scattering ability while total suspended solids are defined as residue left after the evaporation and subsequent drying of a known volume of sample in oven at specific temperature (Baird, *et al.,* 2017). The desirable level of water turbidity, recommended by Iraqi guideline value (2001) is 5 NUT. Turbidity values higher than 5 NUT might correlate with increasing pathogenic microorganisms, including coliform bacteria (Mustapha and Nabegu, 2011).

Water temperature contributes in variance of the third factor for Summer and Autumn seasons which reflects disturbance of climate conditions in Basrah. In southern part of Iraq, climate is considered continental, subtropical and semi-arid type (Fawzin and Mahdi, 2014).

pH contributes in variance of the third factor for Summer season only. pH is an essential parameter that is often employed to test water quality. In the present study, the pH values of water samples ranged from 6.97 in Autumn season to 8.30 in Winter season and they do not exceed Iraqi standard values ranged from 6.5 to 8.5. pH values of most rivers are slightly basic due to prevalence of bicarbonates and carbonates of alkali and alkaline earth metals. pH governed largely by the equilibrium of carbon dioxide, bicarbonate and carbonate and also, it may be influenced by humic substances, by changes in the carbonate equilibriums due to the bioactivity of plants and in some cases by hydrolysable salts (AWWA, 1964 and Baird, *et al.*, 2017). According to Mohammed (2021), pH variations of Iraqi rivers are probably due to geological conditions of water. Alum is used in Iraq for coagulation and it is most effective when the pH range is between 5.5 to 8.0. Also. The pH of water is an important factor for chlorination efficiency. Chlorine is mostly used in the disinfection of Iraqi drinking water supplies (Eassa and Mahmood, 2012).

The alkalinity contributes in variance of the third factor for Winter and Autumn seasons. The alkalinity of water is its capacity to neutralize acid. Total alkalinity is resulted from bicarbonate (HCO_3^-) and carbonate (CO_3^{-2}) salts in addition to free hydroxyl ion (OH^-) depending on pH value, at pH 7, total alkalinity is due to HCO_3^- and CO_3^{-2}, OH^- is too low to make any significant contribution to the total alkalinity. While at pH 8.3 the whole total alkalinity is bicarbonate alkalinity (Bartram and Balance, 1999). During coagulation process, alum reacts and consumes water alkalinity at a rate of 0.45 mg/L alkalinity for each 1 mg/L of added alum. Therefore, the alkalinity of water must be known to calculate the quantities of chemicals (i.e alum and other coagulant aids such as lime and soda ash) to be added in treating the water (Cheremisinoff, 2002). In the present study, minimum values of total alkalinity are below Iraqi standard value of 120 mg/l as $CaCO_3$ while maximum values of total alkalinity exceed the Iraqi standard value for all seasons.

Table 3. Factor loading, eigen value, Variance and Cumulative for Winter Season after Varimax Rotation.

	Factors		
	F1	**F2**	**F3**
Tem	-0.22	-0.29	0.53
Tur	-0.17	0.92	-0.01
pH	-0.41	0.15	-0.42
EC	0.98	-0.11	0.10
Alk	0.34	0.23	0.76
Th	0.98	-0.09	0.11
Ca	0.98	-0.09	0.11
Mg	0.98	-0.086	0.11
Cl	0.97	-0.13	0.08
SO4	0.98	-0.09	0.11
TDS	0.98	-0.12	0.09
TSS	-0.17	0.93	-0.08
Na	0.97	-0.127	0.09
K	0.75	0.003	0.46
Eigen value	8.57	1.96	1.32
Variance %	61.24	14.05	9.44
Cumulative %	61.24	75.30	84.75

Table 4. Factor loading, eigen value, Variance and Cumulative for Spring season after Varimax Rotation.

	Factors	
	F1	**F2**
Tem	-0.10	0.39
Tur	0.13	0.92
pH	-0.62	-0.12
EC	0.99	0.01
Alk	0.83	0.22
Th	0.97	-0.14
Ca	0.97	-0.13
Mg	0.97	-0.14
Cl	0.98	0.06
SO4	0.97	-0.12
TDS	0.99	-0.01
Tss	0.09	0.91
Na	0.98	0.06
K	0.90	0.11
Eigen value	9.54	1.97
Variance %	68.21	14.11
Cumulative %	68.21	82.32

Table 5. Factor loading, eigen value, Variance and Cumulative for Summer season after Varimax Rotation.

	Factors		
	F1	**F2**	**F3**
Tem	0.22	-+0.001	0.65
Tur	-0.02	0.92	0.01
pH	-0.22	0.02	0.76
EC	0.20	0.01	-0.004
Alk	0.52	0.16	-0.40
Th	0.99	0.01	-0.06
Ca	0.99	0.01	-0.06
Mg	0.99	0.01	-0.06
Cl	0.99	0.01	0.02
SO4	0.99	0.01	-0.06
TDS	0.20	0.01	0.001
Tss	0.04	0.90	-0.02
Na	0.99	0.01	0.02
K	0.89	0.01	-0.02
Eigen value	8.99	1.68	1.16
Variance %	64.23	12.01	8.34
Cumulative %	64.23	76.24	84.59

Table 6. Factor loading, eigen value, Variance and Cumulative for Autumn season after Varimax Rotation.

	Factors		
	F1	**F2**	**F3**
Tem	-0.12	-0.08	0.72
Tur	-0.14	0.94	0.01
pH	-0.41	0.13	-0.53
EC	0.97	-0.15	0.14
Alk	0.31	0.11	0.60
Th	0.98	-0.12	0.16
Ca	0.98	-0.12	0.16
Mg	0.98	-0.13	0.15
Cl	0.97	-0.16	0.12
SO4	0.98	-0.13	0.16
TDS	0.97	-0.15	0.13
Tss	-0.23	0.90	-0.11
Na	0.97	-0.16	0.12
K	0.72	-0.13	0.52
Eigen value	8.44	1.90	1.60
Variance %	60.34	13.58	11.48
Cumulative %	60.34	73.92	85.41

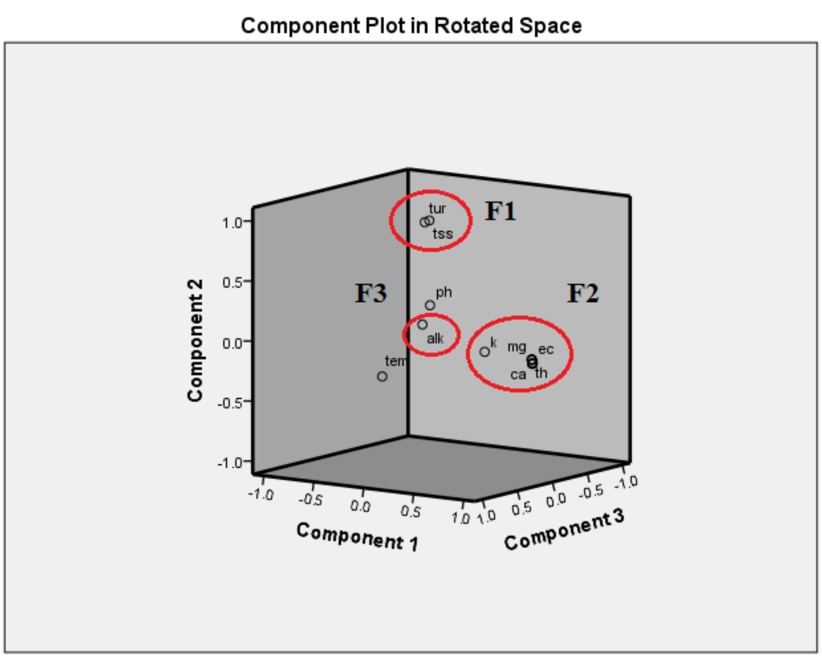

Figure 1. Factor Loading Plot for Winter Season after Varimax Rotation.

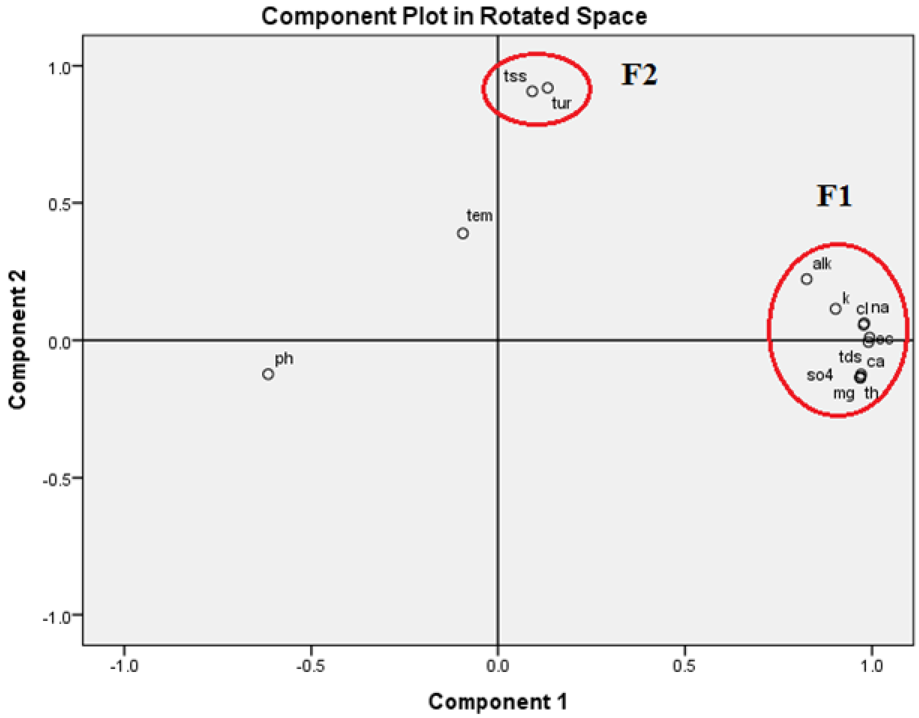

Figure 2. Factor Loadings Plot for Spring Season after Varimax Rotation.

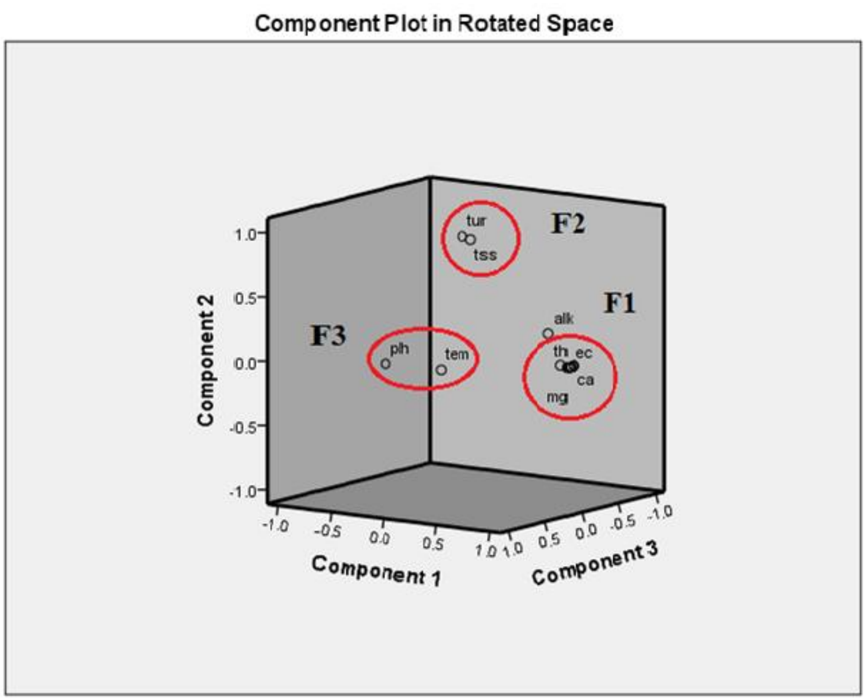

Figure 3. Factor Loadings for Summer Season after Varimax Rotation.

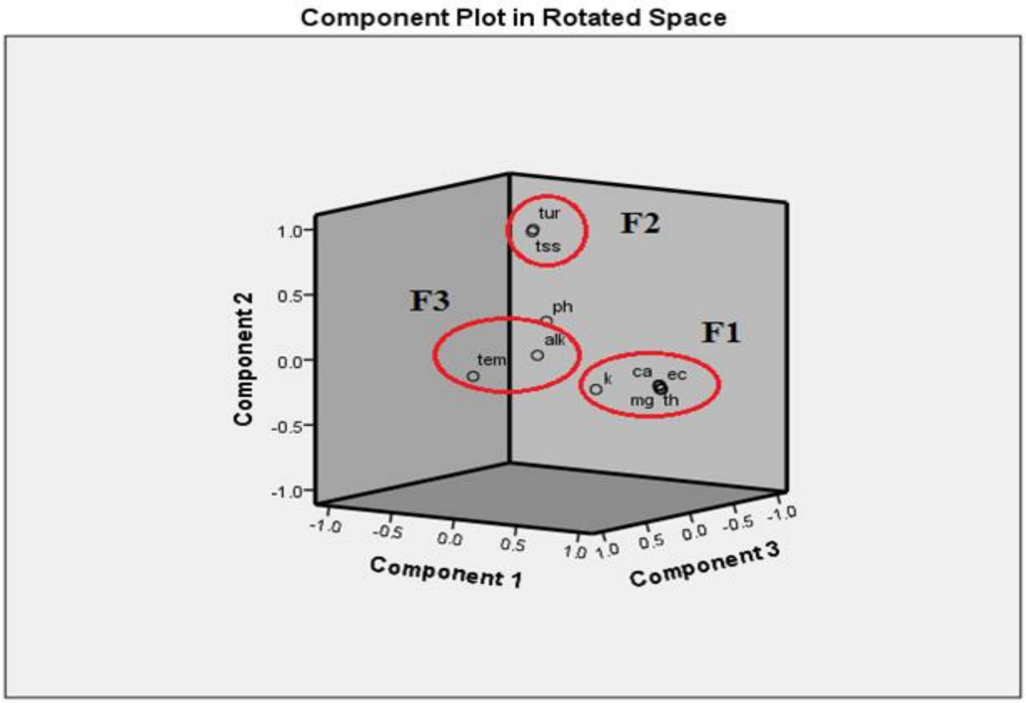

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Figure 4. Factor Loadings for Autumn Season after Varimax Rotation.

Conclusion

The present study conducted there are three factors for Winter, Summer and Autumn and two factors for Spring only. Rotated factors are named as follows: The first factor represents pollution with sea water due to reduction in river discharge which allowed a salt-water wedge to penetrate into the Shatt Al-Arab River. The second factor represents pollution with biotic and a biotic particulates. Water temperature contributes in variance of the third factor for Summer and Autumn seasons which reflects disturbance of climate conditions. pH contributes in variance of the third factor for Summer season only which considers as an important factor for efficiency of both coagulation and chlorination. The alkalinity contributes in variance of the third factor for Winter and Autumn seasons. It must be known to calculate the quantities of alum and other coagulant aids to be added in water treatment

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