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Evaluation of Water Quality for Greater Zab River by Principal Component Analysis/ Factor Analysis

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Abstract

This study was conducted to determining the variable effects on water quality of Greater Zab River in Erbil province, Iraq, using multivariate statistical analysis. Seventeen variables were monitored in four sampling sites during one year (from May 2012 to April 2013). The dataset were treated using principal component analysis (PCA)/ factor analysis (FA), cluster analysis (CA) to the most important factors affecting water quality, sources of pollution and suitability of water for drinking consumption and irrigation. Six factors were identified as responsible for the data structure explaining 73.5% of the total variance in the dataset and are conditionally named, hydrochemical from weathering, mineral salts and domestic wastes. CA showed two different groups of similarity between sampling sites, in which site 2 was more contaminated than other studied sites. Their pH and TDS values were found in agreement for drinking and irrigation purposes with drinking water quality standard for Iraq, WHO, and Richards standards. SAR contents were low and maximum value was observed at site 2 and all sites classified as S1 type (low salinity) water quality. While, sulfate concentration exceeding permissible level according to water quality standard for Iraqi standard for drinking water, and irrigation purposes Richards standards. Generally, results of most water quality parameters revealed that Greater Zab River were within permissible level for drinking water consumption, while it regarded as safe water type for all kinds of crops.

Key words: Drinking water, irrigation water quality standard, Greater Zab River, multivariate statistics.

تقيم نوعية المياه في نـهر الزاب الأعلى بطريقة تحليل المكونات الرئيسة

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الخلاصة

أجريت هذه الدراسة لمعرفة تأثيرات العوامل البيئية على نوعية المياه في نهر الزاب الاعلى في محافظة أربيل، بأستعمال التحليل الاحصائي متعدد العوامل. تم تحليل سبعة عشر عاملا لنماذج عينات المياه جمعت شهريا (مايس 2012 الى نيسان 2013) من اربعة مواقع على طول مجرى السفلي للنهر. أستعملت تحليل المكونات الرئيسة و التحلبل العنقودي لتحديد أهم العوامل المؤثرة على نوعية المياه، مصادر التلوث، ملائمة المياه لأغراض الشرب والري. أعتمادا على تحليل المكونات الرئيسة، شخصت ستة مكونات مسؤولة عن 73.5% من التغايرات في نوعية المياه، وتكون متأثرة بالعوامل المتعلقة بالكيمياوية المياه الناتجة من التعرية

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والاملاح المعدنية، وفضلات المنزلية. أشار التحليل العنقودي لأغلب العوامل المدروسة إلى تكوين مجموعتين متميزتين من التشابه بين المواقع المدروسة، وفيها الموقع الثاني كانت أكثر تلوثا من بقية المواقع. حسب نتائج pH و المواد الكلية الذائبة فأن المياه تقع ضمن المعايير العراقية، WHO و ريتشارد لغرض الشرب. محتوى SAR كانت منخفضة وأعلى قيمة سجلت في الموقع الثاني، وكل المواقع صنفت كنوعية منخفضة الملوحة. أما تركيز الكبريتات تجاوز كل المعايير المذكورة سابقا لغرض الشرب. عموما، كل العوامل المدروسة تقع ضمن المعايير المسموح بها لغرض الشرب، بينما تعتبر المياه آمنة لارواء جميع أنواع المحاصيل.

Introduction

Water is a common chemical substance that is essential for the survival of all known forms of life [1]. A river is a system comprising both the main course and the tributaries, carrying the one-way flow of a significant load of matter in dissolved and particulate phases from both natural and anthropogenic sources. The quality of a river at any point reflects several major influences, including the lithology of the basin, atmospheric inputs, climatic conditions and anthropogenic inputs [2]. Anthropogenic influences (urban, industrial and agricultural activities, increasing consumption of water resources) as well as natural processes (changes in precipitation inputs, erosion, weathering of crustal materials) degrade surface waters and impair their use for drinking, industrial, agricultural, recreation or other purposes [3].

Principal Component Analysis (PCA)/ and Factor Analysis (PFA) are multivariate statistical techniques used to identify important components or factors that explain most of the variances of a system. They are designed to reduce the number of variables to a small number of indices (i.e., principal components or factors) while attempting to preserve the relationships present in the original data. The problems of indicator parameter or import monitoring station identification, data reduction and interpretation, and characteristics change in water quality parameters can be approached persuading the PCA and PFA methods [4].

In recent years, the PCA have been applied to many environmental issues in northern Iraq, for evaluating water quality of different water bodies, rivers, wastewater, reservoir, and seasonal, spatial and anthropogenic influences have been evidenced [5, 6].

Many studies have been conducted on Greater Zab River monitoring and its suitability for different purposes [7-12].

The aims of this study was to assess levels of physico- chemical parameters in order to determine the source of pollutants and on quality of water in Greater Zab river by using multivariate statistical methods, as well as, to evaluate their suitability for drinking consumption and irrigation purposes according to Iraqi standard for drinking [13], WHO [14], and Richards standards [15].

Materials and Methods

Study area

Greater Zab River is one of the main Tigris river tributaries, it flows 390km downstream of its original source from Turkey [16]. The Greater Zab River is the most prominent Tigris river tributaries that contribute the largest flow volume to the Tigris River. The Greater Zab supplies the Tigris River with an average annual flow volume of 12.7 billion cubic meter (measured at Eski Kalak near Khabat subdistrict). During their flows providing water supply for irrigation, drinking, fishing, recreation, and waste disposal for several settlement along its course [17]. The climate is characterized by dry and warm summers and cold winters. Precipitation occurs mainly in winter and spring. The average annual precipitation in the khabat (site 2) is about 288mm.

Sample collection

During this study samples were collected in four sites; the first was located near Kawergosk village (agriculture activities is dominant near this sites) and second site was located at Khabat subdistrict (higher populated and wastewater discharge near this site), third Chamadbz village about 10 Km from site two, and site four near Gaetel village, last two sites also dominated by agriculture activities Figure-1. Generally, the width, and depth of river near studied sites was 40 to 60m and 2-4m respectively. The collected samples were stored in acid- cleaned, polyethylene plastic bottles.

Analysis of water samples were carried out immediately after collection samples were stored in a refrigerator at 4ºC prior to analysis. Standard techniques were used [18] to analyze different physico-chemical parameters: pH, electrical conductivity in field by using (pH meter Philips 4014 and EC meter Philips 4025 respectively), total dissolved solids (TDS, evaporation at 180 ºC), total hardness, calcium and magnesium (EDTA titrimetric method), Cl (argentometric method), SO_4^{-2} (turbidimetric method), HCO_3 (titrimetric method), Na^+ and K^+ (flame photometric method), trace metals (Cd, Pb, Cu and Zn) by (Atomic absorption spectroscopy Philips Sp9) after concentrating 1L of samples (with addition of HNO_3).
Sodicity, including the following parameters Na% and SAR were calculated according to the formulas given by [19] as follow:

$$Sodium\ percentage\ Na\% = \frac{Na * 100}{Na + K + Mg + Ca}$$

$$Sodium\ Adsorption\ Ratio\ (SAR) = \frac{\sqrt{Ca+Mg}}{2}$$

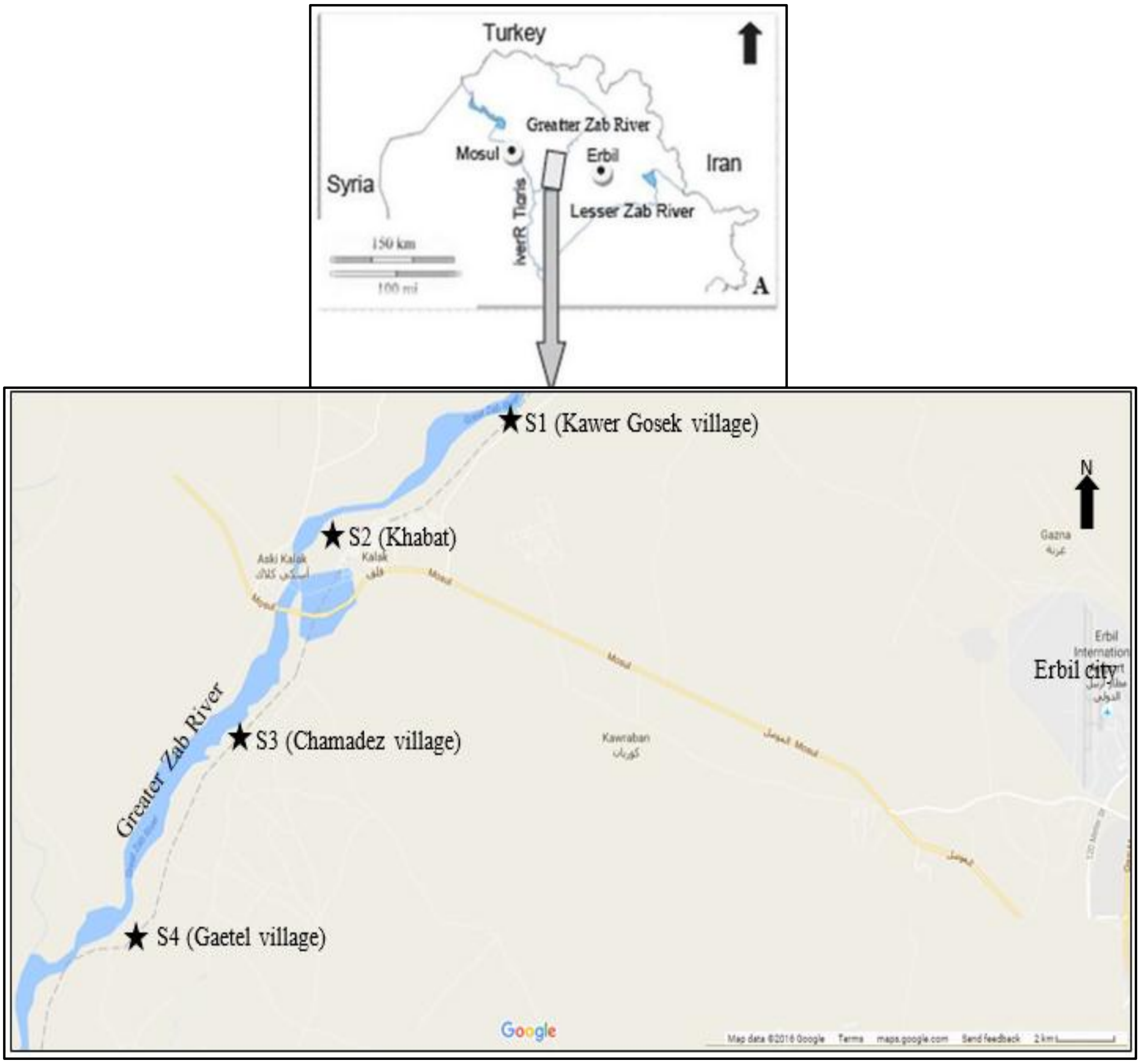

Figure 1- Map showing northern part of Iraq, and sampling sites on distal part of Greater Zab River.

Multivariate statistical methods

All mathematical and statistical computations were made using Microsoft Office Excell 2007 and SPSS 22.

Principal Component Analysis/ Factor Analysis

PCA is designed to transform the original variables into new, uncorrelated variables (axes), called the principal components, which are linear combinations of the original variables. The new axes lie along the directions of maximum variance. PCA provides an objective way of finding indices of this type [20]. PC provides information on the most meaningful parameters, which describes a whole data set affording data reduction with minimum loss of original information [21].

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). PC is a linear combination of observable water quality variables, whereas VF can include unobservable, hypothetical, latent variables [22]. PCA of the normalized variables was performed to extract significant PCs and to further reduce the contribution of variables with minor significance; these PCs were subjected to varimax rotation (raw) generating VFs [23]. As a result, a small number of factors will usually account for approximately the same amount of information's as do the much larger set of original observations [24, 25].

Cluster analysis

Cluster analysis is a group of multivariate techniques whose primary purpose is to assemble objects based on the characteristics they possess [26]. The Euclidean distance usually gives the similarity between two samples and a distance can be represented by the difference between analytical values from the samples [27]. In this study, hierarchical agglomerative CA was performed on the normalized data set by means of the Ward’s method, using squared Euclidean distances as a measure of similarity [28].

Analysis of Variance (ANOVA)

ANOVA was employed to determining whether groups of variables have the same means on data that are continuous or normally distributed and with homogenous variance.

Correlation analysis

Pearson correlation's was adopted to analyses the relationship between physic- chemical characteristics of the river water.

Results and Discussion

The analyzed physico-chemical parameters of water of Greater Zab River were presented in Table- 1.The examined surface waters were in the alkaline pH range without remarkable variations, but with a trend to increase during winter months (December to February) in all monitoring sites, in which pH values exceed 8 in most cases. This may be attributed to erosion of carbonate ions from soils. The pH value ranged from 7.25 to 8.54 with highest mean value 7.92 observed in site 3, which was within the recommended range for drinking water quality standard [13, 14] and for irrigation purposes according to [19]. [11, 12, 17] recorded similar trend of pH values in different branches of Greater Zab River where geological formation of the area, which composed mainly of $CaCO_3$ is main factors affecting this parameter.

Total dissolved solids measure the quantity of various inorganic salts dissolved in water. High levels of TDS content indicates poor water quality and vice versa [29]. TDS value ranged from 162.1 to 434.8 $mg.l^{-1}$, with highest mean value 284.3 $mg.l^{-1}$ recorded in site 2. The concentration of TDS is within Iraqi standard for drinking water quality [13, 14], while it regarded as none restricted type of water on using irrigation crops [19]. Similar trend of results were obtained by [6, 16] at the monitored river.

Electrical conductivity (EC) is measurement for the ability of water to conduct an electrical current. The ability is a result of the presence of ions in water such as CO_3, HCO_3, Cl^-, SO_4^{-2}, Na^+, K^+, Ca^{+2}, Mg^{+2} [30]. Generally, low EC value was recorded during May to November then increases in EC content were observed during December to March Figure-2. Phiri et al. [31] commented that the higher values in the rainy season could be due to surface runoff from the surrounding areas that might have brought in ionic substances such as nitrates, chlorides and phosphates from fertilizers. Higher EC and other measured ions from site 2 related to discharging domestic effluents from surrounding settlements into this site. Shekha [32] stated that relative high ranges of EC value in the sewage water may be related to nature of municipality pollutants, industrial wastes and land use activities in the area. Most of EC values are below maximum permissible limits for drinking water (400 µs. cm^{-1}) according to [33], while only 37.5% of total sample exceed this limits. On the other hand, water quality classified as moderate type C2 for irrigation purposes [19]. Similar trend of results were observed by [5, 6, 16].

Sodium adsorption ratio (SAR) is an index of the potential of water to induced sodic soil conditions, and is calculated for Na^{+}, Ca^{+2} and Mg^{+2} concentrations in the water. The determination of the SAR value can be used to characterize the problems caused by sodium [34]. SAR values of Greater Zab River were ranging from 0.03 to 1.74 $Meq.l^{-1}$, with the mean value of 0.532 $Meq.l^{-1}$. Higher SAR values were recorded in site 2 than other sites. Statistically, there is a significant difference ($P \le 0.05$) between site 2 and other sites, which may be related to domestic effluent discharged to it, [12, 32] have reviewed that high SAR is attributed to considerable load of cations from untreated sewage from nearby villages. According to the classification of irrigation water based on SAR it classified as S1 (low salinity).The values of SAR and EC of the GZR were plotted in the US salinity laboratory diagram for irrigation water it regarded as C2- S1 zone of salinity which considered as medium salinity type based on EC- SAR content according to [15] Figure- 3.

Sodium is an alkali metal, which reacts with water to form highly soluble positively charged sodium ions. Metabolically, Na^{+} interacts with K^{+}, and they are the most important extracellular and intracellular cations respectively, and vital to all living organisms [30]. Low concentration of Na^{+} and K^{+} were recorded in all monitored sites, with mean values (2.26, 10.43, 2.89, 2.63 $mg.l^{-1}$) and (0.136, 0.21, 0.134, 0.154 $mg.l^{-1}$) for Na^{+} and K^{+} respectively.

High Na^{+} content were observed in site 2 than other sites. Aziz [16] observed high Na^{+} content in sewagewater discharged into Greater Zab River which originated from anthropogenic activities. Statistically, there is a significant difference ($P \le 0.05$) between site 2 and other sites. Na^{+} and K^{+} were within the recommended range for Iraqi standard for drinking water prescribed by [14].

Chlorides occur in all natural waters in widely varying concentration. The chloride content normally increases as the mineral content increases [35]. The Cl^{-} concentration ranged from 11.4 to 36.96 $mg.l^{-1}$ with mean values 13.88, 20.71, 14.38, 14.92 $mg.l^{-1}$ respectively for monitored sites. Chloride content of water for all monitored sites, is associated from dissolution of chloride from catchment area, except from site 2 results from sewagewater disposal. Cl^{-} value was within desirable range for drinking water quality according to [13, 14]. Meanwhile, it can be considered as weak water type (< 70$mg.l^{-1}$) and which is suitable for almost all plants irrigation [34] Table- 2.

Hardness of water is an important consideration in determining the suitability of water for domestic and industrial uses. The hardness of water reflects the nature of the geological formations with which it has been in contact [36]. Hardness values ranged from 136 to 292 $mg.l^{-1}$ as $CaCO_3$ with mean value 209 $mg.l^{-1}$. These results are within the recommended range for drinking water quality standard according to Iraqi standard [13, 14]. Greater Zab River water classified as hard water according to [36] that regarded water quality as hard within (150- 300 $mg.l^{-1}$). Human activities and the nature of geological formations of the area, through which the river flows, are the main reasons for the higher values of water hardness [37]. The results obtained by [11] showed that total hardness values were often higher than the minimal permissible level recommended by the WHO for drinking water.

Calcium and magnesium ions present in all natural waters and often cited as the cause of hardness [38].

The mean concentration of Ca^{+2} and Mg^{+2} for monitoring sites were 103, 119.5, 109.6 and 100.9 $mg.l^{-1}$ as $CaCO_3$ respectively, and 116.5, 104, 95.5 and 93.6 $mg.l^{-1}$ respectively for Mg^{+2}. Both ions were within the recommended range with Iraqi standard for drinking water [13, 14]. Lower results for calcium concentration were obtained in same monitored river by [11, 17].

Highest sodium percent (Na %) was recorded in site 2 which was ranged from 40.4 to 68.5%, while minimum value 3.7% was found in site 3. Statistically, there is a significant difference ($P \le 0.05$) between site 2 and other sites. According to [39] the monitoring river classified as good type water for irrigation purposes. This result agreed with that obtained by [12] during their investigation on some branches of Greater Zab River, they attributed high Na% in site affected by sewagewater disposal which contain high cations content.

Alkalinity of water is a measure of its capacity to neutralized acids. Bicarbonates represent the major form of alkalinity [40]. Gradually trend of decrease in bicarbonate ion observed from upstream to downstream with mean values of 186.6, 184.5, 168, 162.9 mg.l^{-1} as $CaCO_3$ respectively for monitoring sites. According to Iraqi standard for drinking water [13] it exceeding permissible range (170 mg.l^{-1}) in sites 1 and 2 for drinking water standard.

Generally, sulfate concentration exceeding permissible range for Iraqi standard for drinking water [13, 14] in all monitoring sites, with highest mean value 1235.8 mg.l^{-1} in site 2, which may be attributed to domestic effluent discharged into the river near this site. Shekha et al. [41] stated that high sulfate content of sewage water it may be due to biodegradation of organic matter. The mean SO_4^{-2} values were 19.84, 25.76, 19.1, 19.47 Meq.l^{-1}, and according to [19] the mean value in site 2 exceeding permissible level (0- 20 Meq.l^{-1}) for irrigation purposes.

The mean concentrations of ions in Greater Zab River were noticed in the order: SO_4^{-2}> Cl^-> Mg^{+2}> Ca^{+2}>HCO_3^-> Na^+>K^+.

Table 1- Physical-chemical properties of Greater Zab River, data represented as mean± S.E. with minimum and maximum values, during studied period.

Variables	Sites				Drinking water quality standards	
	1	2	3	4	Iraqi standard 1986 [13]	WHO 2011 [14]
pH	7.89± 0.063 7.53- 8.18	7.84± 0.077 7.27- 8.30	7.92± 0.091 7.25- 8.43	7.91± 0.087 7.36- 8.54	6.5-8.5	6.5- 9.5
TDS (mg.l^{-1})	256.47± 21.7 163.9- 434.8	284.3± 15.79 196.8- 372.9	253.3± 19.5 162.1- 396.4	313.3± 54.64 205.2- 892.4	600	1000
EC(µS.cm^{-1}) (at 25ºC)	369 ± 27.59 227.6- 556.1	437.2± 34.9 280.3- 652.4	378.6± 30.23 271- 560.95	372.97± 28.98 264.3- 551.2		
SAR (Meq.l^{-1})	0.261± 0.026 0.140- 0.400	1.189± 0.116 0.520- 1.740	0.365± 0.098 0.030- 0.950	0.342± 0.077 0.040- 0.960		
Na^+ (mg.l^{-1})	2.267± 0.224 1.50- 3.80	10.43± 1.137 4.52- 17.05	2.89± 0.77 0.340- 8.70	2.63± 0.494 0.340- 5.90		200
K^+ (mg.l^{-1})	0.136± 0.035 0.030- 0.490	0.210± 0.026 0.06- 0.360	0.134± 0.016 0.03- 0.210	0.154± 0.027 0.030- 0.390		
Cl^- (mg.l^{-1})	13.88± 0.71 11.40- 18.98	20.71± 1.55 16.0- 36.96	14.38± 0.51 11.5- 17.98	14.92± 0.640 11.98- 19.98	200	250
Total hardness (mg $CaCO_3$.l^{-1})	211.16± 10.3 140.0- 262.0	223.5± 12.02 136.0- 278.0	205.1± 47.46 120.0- 292.0	196.3± 12.7 110.0- 244.0	500	200
Ca^{+2} (mg $CaCO_3$.l^{-1})	103± 9.69 20- 150	119.5± 14.77 22- 194	109.6± 12.14 18- 152	100.9± 10.32 40- 158	200	
Mg^{+2} (mg $CaCO_3$.l^{-1})	116.5± 13.86 47- 200	104± 13.29 46- 180	95.5± 9.32 54- 140	93.6± 9.64 47- 160	50	
Na%	25.17± 2.200 11.99- 38.07	58.89± 2.549 40.40- 68.54	28.46± 5.907 3.720- 62.08	29.07± 4.959 5.880- 62.88		
HCO_3^- (mg $CaCO_3$.l^{-1})	186.6± 12.87 104- 270	184.5± 10.58 110- 240	168± 7.84 118- 204	162.9± 9.44 114- 198	170	
SO_4^{-2} (Meq.l^{-1})	19.84± 2.500 3.750- 30.36	25.74± 3.120 6.880- 41.67	19.08± 2.404 2.080- 29.17	19.47± 2.436 2.080- 29.17	200	250
Cd (µg.l^{-1})	12.46± 2.656 0.00- 18.690	11.68± 3.070 0.00- 28.040	17.13± 2.529 0.00- 28.040	10.12± 3.140 0.00- 28.040	5	3 or less 1
Pb (µg.l^{-1})	178.2± 13.46 0.00- 1650.0	61.03± 12.85 0.00- 120.59	45.83± 15.04 0.00- 179.41	61.27± 10.49 0.00- 120.59	50	10
Cu (µg.l^{-1})	9.345± 2.817 0.00- 18.690	7.788± 2.778 0.00- 18.690	9.346± 2.817 0.00- 18.690	7.788± 2.778 0.00- 18.690	1	2
Zn (µg.l^{-1})	19.23± 10.04 0.00- 76.920	19.23± 10.04 0.00- 76.920	19.23± 10.04 0.00- 76.920	12.82± 8.643 0.00- 76.920	1	3

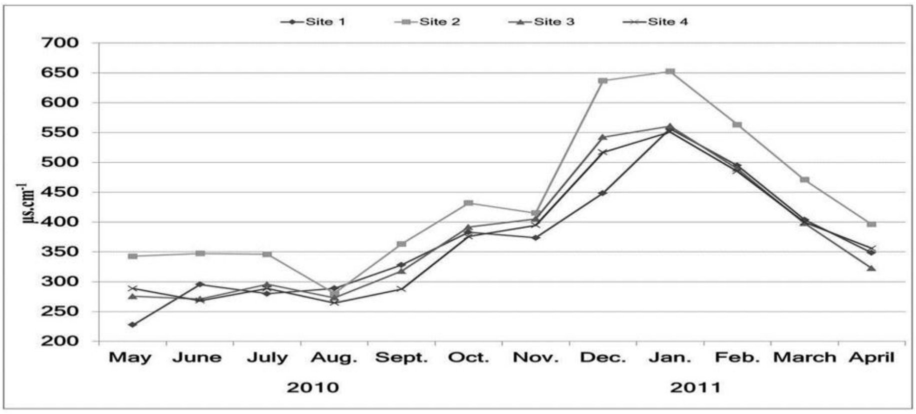

Figure 2- Variation of electrical conductivity (μs.cm^{-1}) in the monitored sites of Greater Zab River.

The heavy metals in river water show similar behavior to that of the major element. The mean value of heavy metals in Greater Zab River was 16.16, 87.5, 13.63 1nd 17.63 μg.l^{-1} for Cd, Pb, Cu and Zn respectively. Both Cd and Pb were exceeding permissible level for drinking water quality standard for Iraqi [13, 14]. While, Cu and Zn values were within the permissible level. The inputs of Pb into the environment are from sewage effluent, runoff of wastes and atmospheric deposition [42]. The heavy metals dominance content was in the following sequences: Pb> Zn> Cd> Cu.

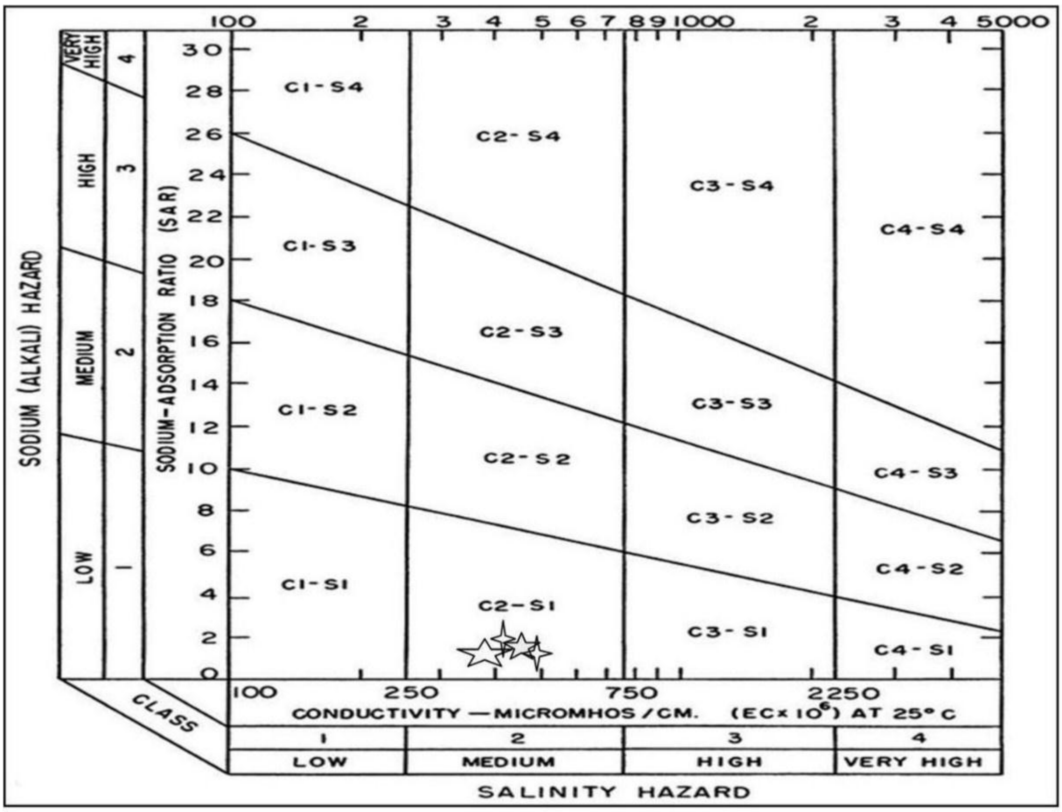

Figure 3- Classification of water for irrigation. Circles denoted the chemical data of the water sampling sites depending on mean value.

Table 2- Water quality of Greater Zab River for irrigation purposes.

Parameters	Potential irrigation problems	Water quality type
EC	None restricted to use for crops irrigation	Good
TDS	None restricted to use for crops irrigation	Good
Specific ion toxicity		
EC versus SAR	Slight to moderate to use	Good
Na^+ %	Good to permissible	
HCO_3		Good
pH		Good
SO_4^{-2}	62.5% of samples exceed permissible level for irrigation purposes	
Cl^-	Suitable for almost all plants	Good

Correlation analysis

Commotional relations in water show that pH has significant correlation ($P\leq 0.05$) with EC, hardness, Mg^{+2}, SO_4^{-2} and negative correlation with TDS and HCO_3^-. EC has significant correlation ($P\leq 0.01$) with hardness, Na^+, K^+, HCO_3^-, Ca^{+2}, Mg^{+2} and SO_4^{-2}. This represent the main constitutes of water conductance [38]. Hardness has high significant correlation with HCO_3^-, Ca^{+2}, Mg^{+2} and SO_4^{-2} Figures- 4a and 4b, which related to temporary hardness in water [2]. Na^+ has high significant correlation ($P\leq 0.01$) with K^+, Ca^{+2}, Cl^-, Na%, SAR and SO_4^{-2} Figures- 4c and 4d. K^+ has high significant correlation ($P\leq 0.01$) with SAR, and moderate significant correlation with HCO_3^- and Ca^{+2}. While, for HCO_3^- high significant correlation were obtain with Ca^{+2} and Mg^{+2}. On the other hand, Ca^{+2} have significant correlation with SO_4^{-2}. The catchment area is mainly consisting of carbonate and $CaSO_4$ [43]. Also, Cl^- has high significant correlation to Na% and SAR

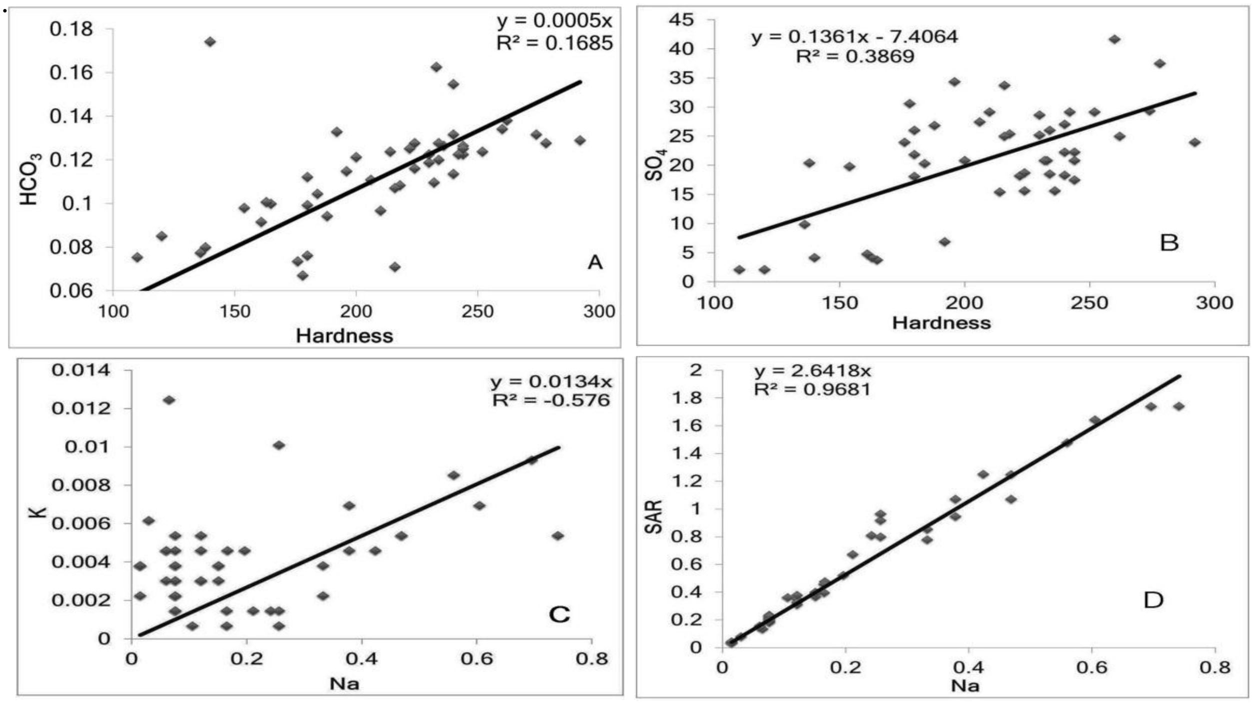

Figure 4- The relationship between variables in monitored sites.

Factor analysis

The data obtained from the laboratory analysis used as variables inputs for PCA/ FA, for water samples described by seventeen physic- chemical parameters, prior to analysis the data were standardized to produce a normally distribution of all variables, since water quality parameters had different magnitudes and scales of measurements [44]. The factor loading was classified as per [45] who categorized the factor loading values of >0.75 as "strong", of 0.75- 0.5 as "moderate" and of 0.5- 0.4 as "weak". Six factor with eigenvalues > 1 were extracted that account for more than 73.5% of the total variance in the data set Table- 3. The first factor accounts for 22.29% of the total variance and contains EC, hardness and HCO_3^- with strong positive loading, while Ca^{+2}, K^+ and SO_4^{-2} associated with moderate positive loading. This indicated temporary hardness ions. The concentration of hardness, HCO_3^-, Ca^{+2} and SO_4^{-2} ions suggests the most of the hardness in the water is temporary [2, 46]. Also it contains hydrochemical variables originating from weathering process and an agricultural source of SO_4^{-2} in surrounding farm lands is possible [47, 48]. Second factor explains 20.2% of the total variance and is strongly loading with SAR, Na and Na%, with moderately positive loading of Cl^-. This salinity type component may be interpreted as representing influences from mineral salts and domestic wastes Figure- 5. Third factor explains 8.9% of total variance with strong positive loading for Mg^{+2} and negative moderate loading for Ca^{+2} Figure- 6. Hama Saeed et al. [49] found higher Mg^{+2} concentration in Greater Zab River than Ca^{+2} and return the reason to nature of sedimentary rock and to deposition of Ca^{+2} ions due to high pH value.

Factor four accounts for 8% with moderate positive loading to pH and negative moderate loading to TDS.

This may be related to role of pH in precipitation of ions into water bottom. The factor five accounts for 7.3% of total variance and contributed to Cd, Zn and SO_4^{-2} with moderate positive loading. This may be attributed to geochemical influences and weathering factor [50]. Six factor explains 6.7% of total variance with moderate positive loading for Cu, Zn and negative moderate loading for Pb. This may be related to municipal wastes, geology of the river and catchment area [51, 52]. The analyzed results revealed that FA/ PCA can serve as important means to identify the main factor affecting water quality [53].

Table 3- Eigen value and percentage of variance explained by each of the six factor loading values for water quality variables of Greater Zab River.

	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6
Eigenvalue	3.789	3.435	1.520	1.361	1.242	1.152
% total variance explained	22.29	20.207	8.943	8.005	7.303	6.778
% cumulative variance	22.29	42.497	51.440	59.445	66.748	73.527
Rotated factor correlation coefficients						
pH	0.348	-0.080	0.194	0.578	-0.071	-0.063
EC	0.874	0.125	0.077	0.013	-0.010	0.045
TDS	-0.095	0.160	0.078	-0.702	-0.043	-0.022
Total hardness	0.838	0.013	0.227	0.262	0.182	-0.068
Na^+	0.262	0.919	-0.109	-0.093	-0.108	0.005
K^+	0.533	0.221	0.063	-0.498	0.033	-0.077
HCO_3^-	0.750	-0.076	-0.004	0.080	-0.233	0.074
Ca^{+2}	0.678	0.139	-0.600	0.101	0.123	-0.133
Mg^{+2}	0.320	-0.189	0.864	0.067	0.012	0.074
SO_4^{-2}	0.524	0.081	0.294	0.312	0.515	-0.215
Cl^-	0.024	0.689	0.358	-0.029	0.327	-0.197
Na%	-0.188	0.876	-0.130	-0.125	-0.174	0.119
SAR	0.117	0.930	-0.173	-0.146	-0.136	0.045
Cd	-0.095	-0.233	-0.045	-0.130	0.744	-0.061
Pb	-0.048	0.051	0.199	0.380	0.007	-0.545
Cu	-0.078	0.075	0.290	0.068	-0.145	0.723
Zn	0.042	0.028	-0.078	0.270	0.557	0.583

Cluster analysis

Cluster analysis can be used as an important tool for analyzing water quality data [54-56] to understand the relationship among sites and variables. The results of CA shown in Figure- 7, it was found the similarity groups between the sampling sites.

All sampling sites on the Greater Zab River were grouped into two clusters. First cluster formed by sites 1, 3 and 4, which comprises relatively unpolluted water types by domestic and industrial wastewater. While cluster 2 represent the site 2 which is polluted by domestic wastewater. These clusters of sampling sites indicated that each cluster had a water quality of its own characteristics which was different from the other cluster. The CA results revealed that this approach was useful in offering reliable classification of surface waters in the whole region and optimizing the design of a future spatial sampling strategy. This can be said for quick spatial assessments of water quality, one site sampled in cluster 2 are sufficient to determine the water quality of the entire network.

On the other hand, based on physico- chemical variables two clusters were identified Figure- 8. CA showed the association of (HCO_3^-, Ca^{+2}, Mg^{+2}, K^+, Na, Cl^-, SAR, Cu and Zn) in the first cluster. While, second cluster consists of two subgroups in which the association obtained between TDS, EC and hardness in first one. Second subgroup consists of the association between pH, SO_4^{-2}, Na%, Cd and Pb in the second one.

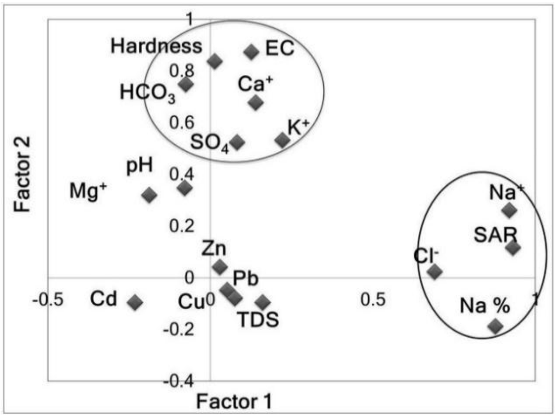

Figure 5- Factor analysis scatterplot for water quality variables of Greater Zab River.

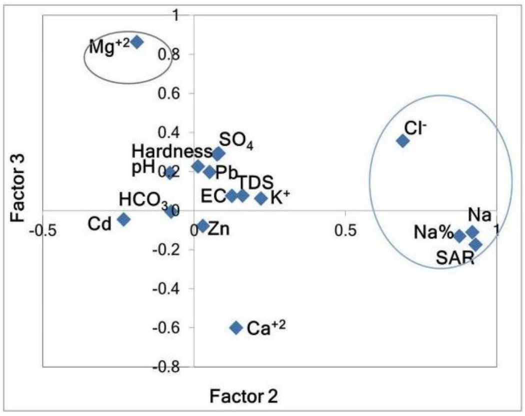

Figure 6- Factor analysis scatterplot for water quality variables of Greater Zab

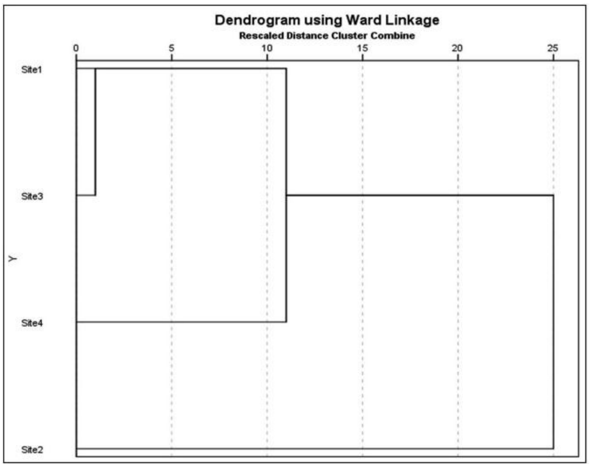

Figure 7- Similarity dendogram among water quality variables for Greater Zab River from cluster analysis.

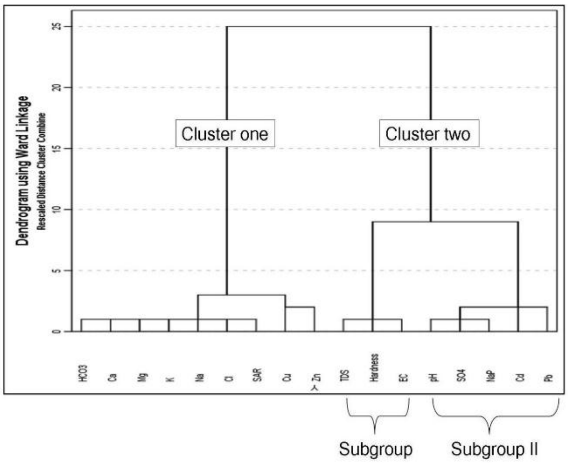

Figure 8- Similarity dendogram among studied sites of Greater Zab River from cluster

Conclusions

From above results of this research it can be concluded that the US Salinity diagram the water regarded as medium salinity type it falls in the zone of a moderate salinity hazard (C2) and a low sodium hazard (S1) type for irrigation purpose. The studied water samples classified as hard water. High sulfate content was observed in all studied sites especially site 2. Arrangement of ions were noticed in order: SO_4^{-2}> Cl^-> Mg^{+2}> Ca^{+2}>HCO^{3-}> Na^+>K^+. Both Cd and Pb concentration exceeding drinking water standards.

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