ASSESSMENT OF MONTHLY VARIATION OF TWO WATER BODIES IN ERBIL GOVERNORATE.

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ABSTRACT

The present study was conducted on Erbil wastewater channel and Greater Zab River. Seven sites were selected, three of them from polluted channel and four from the Greater Zab River. Water samples for chemical and biological analysis were collected monthly from May 2006 to April 2007.

Factor analysis (Principal component analysis) revealed six significant main components which represented by more than 64.5% of the total variance, in which explained by 26.13%, 15.73%, 11.92%, 8.33%, 7.36% and 5.85% respectively, it revealed that sewagewater from Erbil city and agricultural activities a round polluted channel were the major source of pollutant in the channel, whereas, for the Greater Zab river the seven PCs, of the total variance, were 23%, 14.63%, 10%, 8.96%, 7.73%, 6.55%, and 6.24% respectively, with 77.14% of a cumulative variance, in which Greater Zab river was polluted by effluent of polluted channel, agricultural activities and mineral erosion through rainfall.

KEY WORDS: Principal component analysis**,** Erbil wastewater channel, Greater Zab River, Water pollution.

INTRODUCTION

Water is essential for maintaining, an adequate food supply and a productive environment for the human population, animals, plants and microbes worldwide (Cunningham and Saigo, 2001). Population and economics grow, accompanied by increased water use, will not only severely reduce water availability per person but also create stress biodiversity in entire global ecosystem (Graham *etal.*, 2006).

Surface water bodies deteriorate by wastewater (point source), irrigated drainage and runoff (non-point source). Impacts depend on the extent that wastewater has been in contact with soil, on water quality body, and their use, as well as on the hydraulic retention time within the ecosystems (Jimenz, 2006).

Self purification capacity of streams can compensate to a certain extent of pollution. Ecosystem function can be affected by enhanced pollution stress caused by effluents (Hynes, 1960; Allan, 1995). Degree of impairment caused by effluent wastewater depends on the river size; rate of flow and the ratio of river water to effluent discharge (Spanhoff *etal.*, 2007).

The polluted surface water cannot achieve a balance ecosystem. A balance ecosystem means that living things and the environment interact for beneficial use to one another (Akbulut *etal.*, 2010; Ricklets and Miller, 2000). According to (Kiely, 1997) domestic sewage discharge may change the organism population in quality and quantity.

The aims of the present investigation on Greater Zab River and raw wastewater of Erbil channel was to evaluate physico-chemical and biological properties of both studied water ecosystems.

MATERIALS AND METHODS

Description of studied sites:

Erbil city (locally Hawler) is a capital of Iraqi Kurdistan region, with population nearly 1 million inhabitants (ESD, 2009). Erbil sewer system has been constructed for storm water and in most cases domestic sewers are connected illegally with storm sewer, both (combined storm water and sanitary sewer) form Erbil wastewater channel with a length exceeded 50km, extend from southwest of the city to the Greater Zab River. During flowing the channel passes through vast farmlands, orchards and several villages. At Gameshtapa village, the channel confluent with Greater Zab River (Figure 1).

Sample collection and analysis:

From May 2006 to April 2007 monthly water samples were collected from seven sites, three of them located on wastewater channel of Erbil city and four on Greater Zab River for chemical and biological analysis from surface water (30-40cm depth) using pre-washed polyethylene bottle (5 Liters) by water sample twice before filling.

Zooplankton samples were collected with clean bucket. Sixty liters of water sample passed through plankton net (55 µm mesh size), concentrated sample were fixed with 5% formalin in the field and preserved with 70% ethanol in the laboratory. The most zooplankton (Rotifera, Cladocera, Copepod and Nematoda group) were identified and counted, according to (Edmonson, 1959; Scourfield and Harding, 1966; Smith, 2001). The results expressed as individual.m^{-3} (Arimoro *etal*., 2007).

Laboratory analyses include some physical and chemical parameters: pH was measured by pH meter (Philips PW 9420); conductivity by conductivity meter (WTW D 8120); turbidity by turbidity meter (Nr 1420). While chemical measurement were analyzed according to (APHA, 1998) as follows: Dissolved Oxygen and BOD_5 using azide modification method; Chemical Oxygen Demand was determined after oxidation of organic matter by strong acid with $K_2Cr_2O_7$ at 148 ^oC; reactive phosphate using phosphomolybdate- ascorbic acid reduction procedure; total phosphate using persulphate digestion method; ammonia using indophenols' blue method; nitrate using Cadmium-copper reduction method; nitrite using azo- dye method, as well as total dissolved nitrogen using potassium persulphate ($K_2S_2O_8$) as described in (Bmatram and Balance, 1996).

Principal component analysis (PCA) was used after Log10(x+1) data transformation to meet assumption of normality and homogeneity of variances, choosing the axes rotation option. Eigenvalue >1 was used as the criterion to determine the appropriate number of principal components (PCs) (Ouyang *etal*., 2006).

RESULTS AND DISCUSSION

Characterization of changes in surface water quality is an important aspect for evaluating the potential impact of natural or anthropogenic point and non-point sources of pollution on ecosystem health (Cunningham and Saigo, 2001). In a principal component analysis (PCA), the number of components is equal to the number of variables (Fataei, 2011). Eigenvalues were normally used to determine the number of principal components (PCs) that can be retained for further study. A scree plot for the eigenvalues obtained in this study showed a pronounced change of slope after the sixth eigenvalue, for Erbil wastewater channel, and seventh eigenvalue for Greater Zab River (Figure 2 and 3). The six PCs for Erbil wastewater channel had eigenvalues greater than or closer to unity and represented by 26.13%, 15.73%, 11.92%, 8.33%, 7.36% and 5.85% of the total variances of information contained in the original dataset respectively. The six PCs together accounted for about 75.33% of the total variance and the rest of the 12 components only accounted for about 24.67% (Table 1), while for the Greater Zab River the seven PCs, of the total variance represented by, were 23%, 14.63%, 10%, 8.96%, 7.73%, 6.55%, and 6.24% respectively, with 77.14% of a cumulative variance (Table 2). Therefore, the discussion is focused only on the first six PCs and seven PCs for Erbil wastewater channel and Greater Zab River respectively.

The first six factors account for three-quarters of the total water quality variation in Erbil wastewater channel (Table 1). PC_1 explained 26.13% of the total variance was highly participated by TDN, PO_4, TDP, NO_3, NH_4, temperature and Rotifera. The largest source of variation (26.13%) can be interpreted as a pollution by organic matter of the anthropogenic source in which the high levels of these organic related parameter (TDN, NO_3, NH_4, TDP, PO_4) decomposed and consumed large amount of DO creating anaerobic conditions, for this the NO_2 converts to ammonium (Liu *etal*., 2011; Dong *etal*., 2010), whereas, DO, EC, and Nematoda had negative contribution to this component. PC_2 contained 15.73% of the variance and included Cladocera, Copepoda and NO_2. While, NH_4 had a negative contribution. The positive load effect of temperature and negative of DO attributed to the relation of solubility of gases in water which decreases with the increasing temperature (Best and Ross,1977). In addition, rotifer can be considered as a pollution indicator species preference existing organic matter source in their habitat (Altindag, 2000). Meanwhile in PC_3 positive organic correlated parameter were (BOD_5 and COD). Furthermore, DO was the most important parameter in contribution to water quality variation in Erbil wastewater channel, although the organic related parameters were positively correlated and DO was negatively correlated seasonal variations with water quality. The third component of Erbil wastewater samples represented by organic related parameters (BOD_5 and COD) low level of DO, was attributed to the oxygen consumed by decomposition of organic matter, in addition to preventing light penetration to water column by turbidity that led to a decrease of photosynthesis rate and oxygen production in water body (Banerji, 1997). PC_4 (8.33% of variance) had high and positive load of turbidity, EC, NO_3 and Nematoda, in addition to a negative load of COD and temperature. PC_4, turbidity and EC may be used as an indicator of storm water runoff, while nutrient related variables (NO_3, NO_2, PO_4) can be used as an indicator of wastewater and land application discharges (Pejman *etal*., 2009; Sekabira *etal*., 2010). PC_5 represented by 7.36% of variance and was positively participated by NO_2, DO, pH and Rotifera, with negative load for Nematoda, which may be attributed to productivity rate which caused O_2 production and elevation of pH value with an increase of rotifer densities. (Bonachela *etal*., 2007) concluded that high DO must be attributed to high photosynthetic activity, favored by nutrient availability and optimal temperature conditions. (Feike etal., 2007) stated that the optimum of rotifers corresponded well with high pH values and low water temperature. Finally, PC_6 (5.85% of variance) was participated by COD and Rotifera. The first three components PC_1, PC_2 and PC_2, PC_3 used for graphical representations, explained a lesser amount of variance (Figures 4 and 5).

As shown in Table (2), seven components were retained. In the first component PC_1 with 23% of total variance represented by only four parameters (i.e., EC, DO, Rotifera and Nematoda) were identified as the most important parameters and positively contributed to water quality variation in Greater Zab River, meanwhile, the other four parameters (i.e. temperature, TDN, BOD_5 and COD) were negatively contributed. The first component elevation of DO content may be attributed to the river of high flow rate, that caused an increase of the mineral related parameters of River (EC) in addition to DO content, with the decrease of organic related parameters in the same component (Igbinosa *etal*., 2009; Venkatesharaju *etal*., 2010). PC_2 contained 14.63% of the variance and included TDP, PO_4, turbidity and Cladocera, whereas, TDN had a negative contribution to this component. PC_3 (10% of variance) had a positive load of TDN, BOD_5, Copepoda, Rotifera and Cladocera, as well as, turbidity had a negative correlation. Water temperature had an obvious effect on microorganisms metabolic activity, and any decrease of temperature was coincided with less decomposes of organic matter parameters (TDN, BOD_5 and COD) (Hammer, 1996). Additional inputs from point sources of Erbil wastewater channel to Zab River appeared in the second component (At- Tamir and Al-Sanjari, 2007), the third component accounted for 10% of the total quality variability, and these results were graphically represented in Figures 6 and 7. Moreover, PC_4 explained 8.96% of the total variance and was positively related to NO_2 and negatively to pH and BOD_5. Meanwhile, PC_4 (8.96 of variance) including pH and BOD_5 had a negative contribution whereas; NO_2 has a positive contribution. This can be explained by a presence of dissolved organic matter discharged from urban wastewater consists mainly of carbohydrate, proteins and lipids which, as the amount of available DO decreases, led to decomposition of these organic matters causing a decrease of water pH values. Also reduction of DO content appeared from converting NO_3 to NO_2 (Li *etal*., 2009; Jianqin *etal*., 2010). Also, PC_5 accounted for 7.73% of the total variance with COD and Nematoda were positively involved in water quality variations. Moreover, additional inputs of organic related parameters revealed from PC_5 (7.73% of variance) with COD and nematode were positively involved in water quality variations. (Mohammed, 1980) returned high nematode densities in polluted channel in Baghdad area to high organic matter content. PC_6 (6.55% of variance) were found to be positively related by NH_4 and negatively related by DO and Cladocera. Finally, PC_7 contained 6.24% of the total variance which was participated by NO_3 and TDN parameters were positively correlated. Furthermore, denitrification can be regarded as a process which cause to increase NH_4 concentration with a reduction of DO content as shown in PC_6 (Kiely, 1997). Finally, the last component, explained 6.24% of the total variance was participated by NO_3 and TDN parameters were positively correlated. (Zeng and Rasmussen, 2005) stated that (NOx, TDN and PO_4) may represent the relative abundance of limiting nutrients.

Generally, the most important water quality parameters for Erbil wastewater channel can be represented by organic related parameters that had a high positive contribution in this study including TDN, PO_4, TDP, temperature, Cladocera and copepod, while DO and NH_4 negatively correlated to water quality.

Although, EC, DO, TDP and PO_4 were the most important parameters for Greater Zab River, they had a positive correlation contribution, whereas, temperature and TDN were negatively correlated with water quality

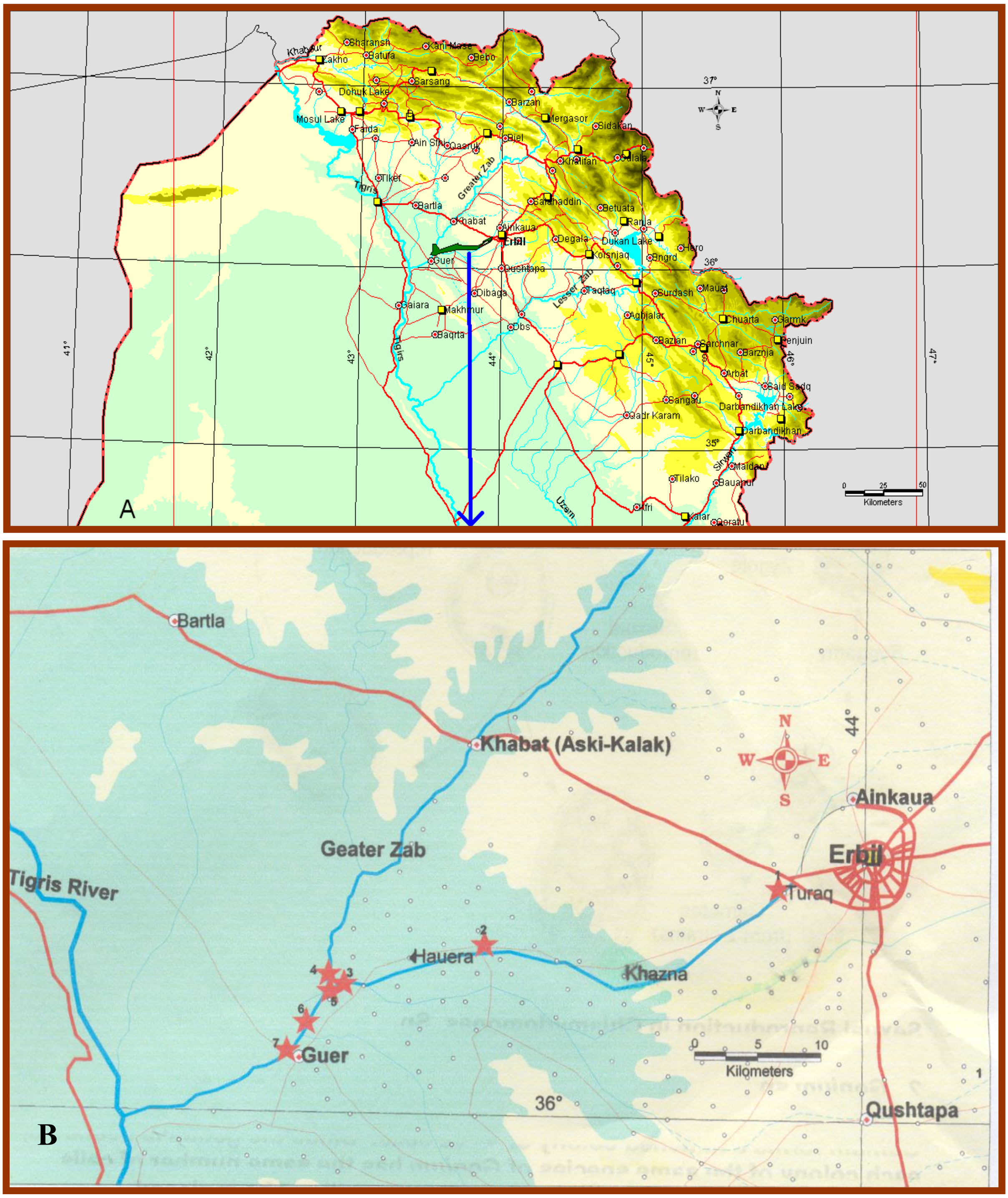

Figure (1): Map of:

A- Northern part of Iraq.

B- Studied sites.

Table (1): Eigenvalue and percentage of variance explained by each of the six principal components (PCs) for Erbil wastewater channel studied variables.

Principal Component	PC1	PC2	PC3	PC4	PC5	PC6
Eigenvalue	**4.705**	**2.832**	**2.146**	**1.499**	**1.326**	**1.053**
% total variance explained	**26.13**	**15.73**	**11.92**	**8.330**	**7.365**	**5.850**
% cumulative variance	**26.13**	**41.87**	**53.79**	**62.12**	**69.48**	**75.33**
Rotated factor correlation coefficients						
TDN	**0.922**	**0.027**	**-0.046**	**0.087**	**0.071**	**-0.137**
PO_4	**0.903**	**-0.052**	**-0.015**	**-0.105**	**0.064**	**0.078**
TDP	**0.873**	**-0.117**	**-0.050**	**0.087**	**0.034**	**0.214**
Temperature	**0.804**	**0.023**	**0.227**	**-0.337**	**0.170**	**0.116**
Rotifera	**0.491**	**0.270**	**0.185**	**-0.176**	**0.457**	**0.343**
Cladocera	**-0.079**	**0.812**	**-0.095**	**-0.228**	**0.037**	**-0.103**
Copepoda	**0.211**	**0.808**	**-0.047**	**0.155**	**-0.023**	**0.065**
NO_2	**-0.060**	**0.606**	**-0.121**	**0.216**	**0.365**	**-0.008**
NH_4	**0.413**	**-0.596**	**-0.173**	**0.168**	**0.075**	**0.092**
Turbidity	**0.070**	**0.089**	**0.891**	**0.302**	**0.034**	**0.006**
BOD_5	**-0.146**	**-0.241**	**0.753**	**-0.291**	**-0.029**	**-0.073**
DO	**-0.495**	**0.219**	**-0.536**	**0.246**	**0.496**	**-0.085**
EC	**-0.422**	**-0.151**	**0.060**	**0.679**	**-0.037**	**0.044**
NO_3	**0.433**	**0.247**	**0.039**	**0.641**	**0.099**	**-0.098**
COD	**0.160**	**0.187**	**0.388**	**-0.518**	**-0.238**	**0.393**
pH	**0.076**	**0.032**	**-0.093**	**0.184**	**0.787**	**-0.021**
Nematoda	**-0.357**	**-0.010**	**-0.120**	**0.376**	**-0.651**	**0.118**

Table (2): Eigenvalue and percentage of variance explained by each of the seven principal components (PCs) for Greater Zab River studied variables.

Principal Component	PC_1	PC_2	PC_3	PC_4	PC_5	PC_6	PC_7
Eigenvalue	4.141	2.635	1.800	1.613	1.392	1.180	1.125
% total variance explained	23.00	14.63	10.00	8.963	7.734	6.557	6.248
% cumulative variance	23.00	37.64	47.64	56.60	64.33	70.89	77.14
Rotated factor correlation coefficients							
EC	0.899	0.113	0.045	0.061	-0.009	0.127	0.083
Temperature	-0.878	-0.197	0.269	-0.090	0.096	0.066	-0.062
DO	0.818	-0.034	0.025	-0.078	-0.116	-0.306	-0.156
TDP	0.010	0.883	-0.032	0.258	-0.160	-0.004	0.058
PO_4	0.177	0.870	0.103	0.167	0.011	0.068	0.063
Turbidity	-0.005	0.635	-0.613	-0.084	0.253	0.024	-0.078
TDN	-0.466	-0.513	0.302	0.112	0.02	0.157	0.462
Copepoda	-0.121	0.080	0.789	-0.188	0.213	-0.041	-0.116
Rotifera	0.574	-0.118	0.618	0.051	-0.255	-0.148	-0.096
pH	0.152	-0.167	0.039	-0.769	-0.024	-0.025	0.143
NO_2	0.273	0.119	-0.079	0.714	0.181	0.048	0.002
BOD_5	-0.295	0.007	0.463	-0.520	0.118	0.225	0.094
COD	-0.351	-0.103	0.051	0.054	0.779	-0.030	-0.046
Nematoda	0.588	0.091	0.089	0.122	0.599	0.131	0.084
NH_4	-0.056	0.242	0.120	0.064	0.181	0.791	-0.116
Cladocera	0.097	0.311	0.300	0.162	0.235	-0.687	-0.074
NO_3	0.066	0.064	-0.133	-0.142	-0.011	-0.099	0.921

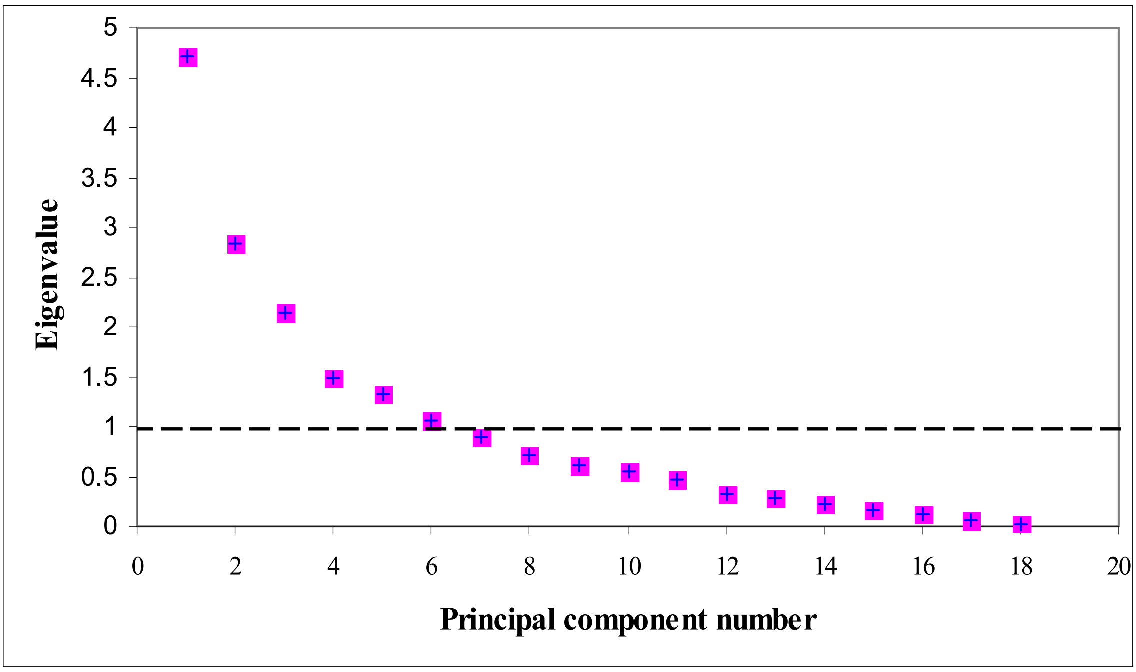

Figure (2):- Scree plot of the eigenvalue of principal component in Erbil wastewater channel variables.

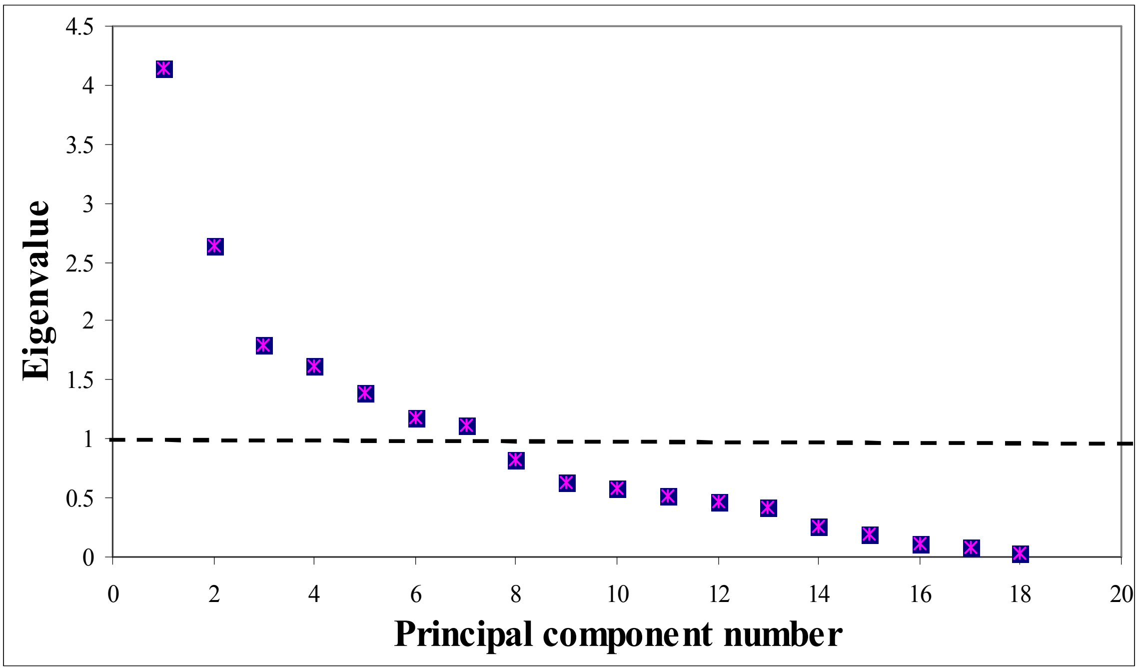

Figure (3):- Scree plot of the eigenvalue of principal component in Greater Zab River variables.

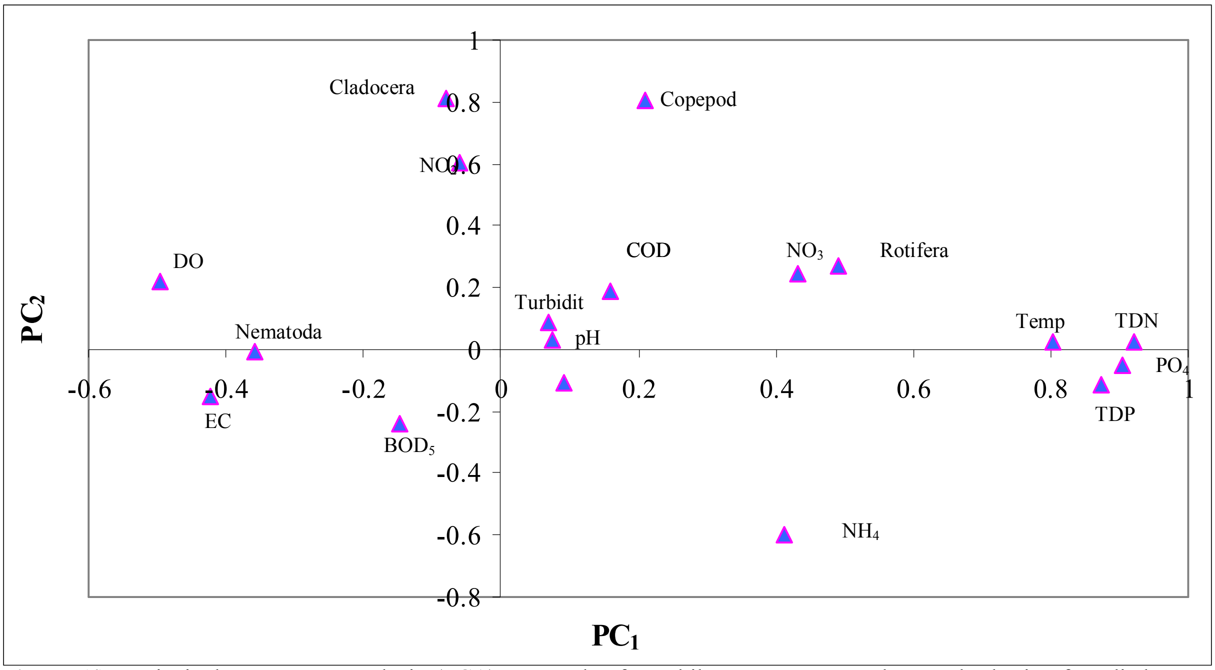

Figure (4):- Principal component analysis (PCA) scatterplot for Erbil wastewater samples on the basis of studied water variable characteristics.

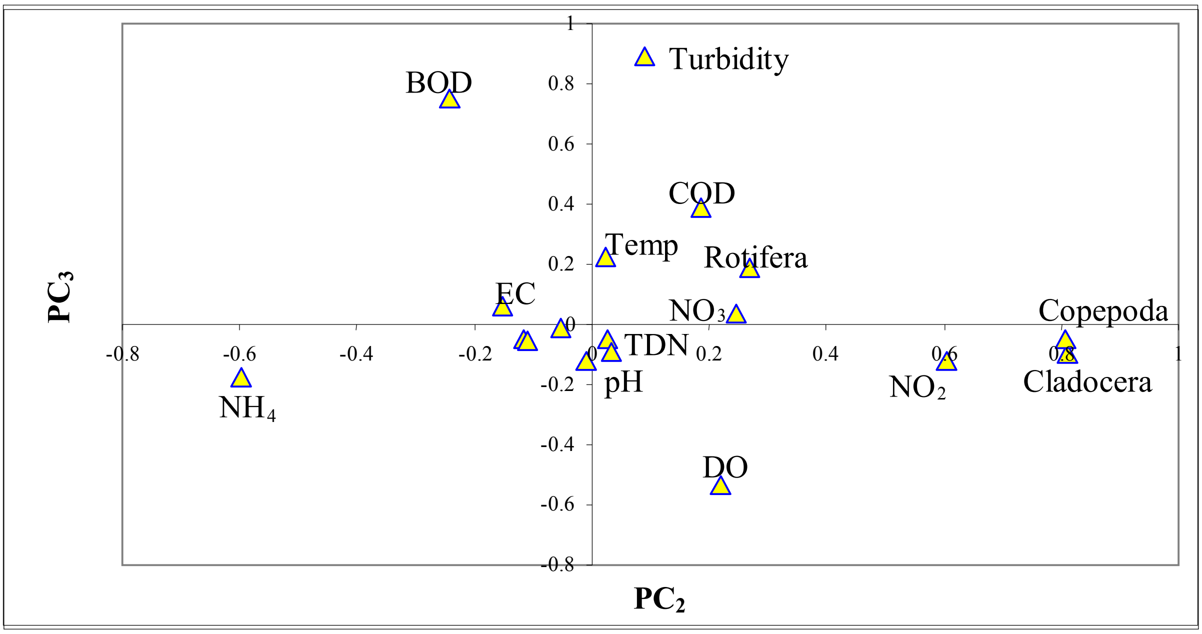

Figure (5):- Principal component analysis (PCA) scatterplot for Erbil wastewater samples on the basis of studied water variable characteristics.

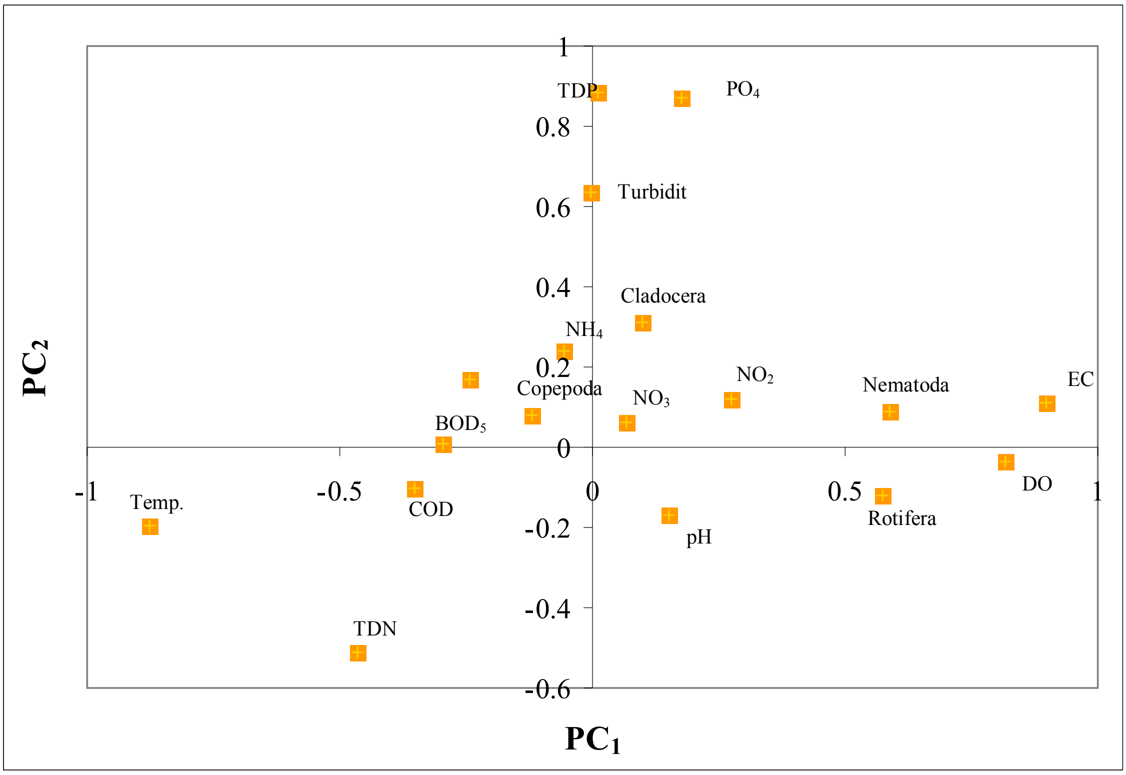

Figure (6):- Principal component analysis (PCA) scatterplot for Greater Zab river samples on the basis of studied water variable characteristics.

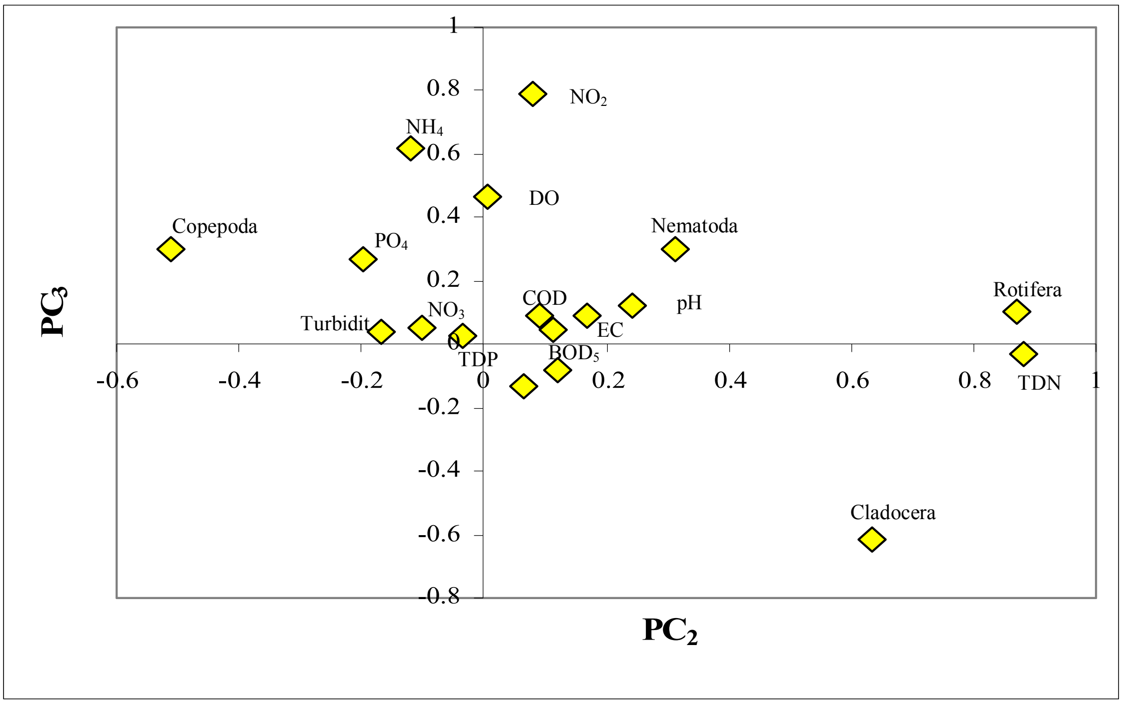

Figure (7):- Principal component analysis (PCA) scatterplot for Greater Zab River samples on the basis of studied water variable characteristics.

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تقيم تغايرات الشهرية لنوعية المياه جسمين مائيين في محافظة أربيل.

الخلاصة:

تضمن البحث الحالي دراسة العوامل الفيزياوية- الكيمياوية و البايولوجية لسبع مواقع مختارة , يقع ثلاثة منها على قناة مياه المجاري أربيل وأربع على نهر الزاب الاعلى. جمعت نماذج المياه شهرياًإبتداءً من ايار 2006 وحتى نيسان 2007.

نتائج تحليل مكونات الرئيسة (PCA) بينت أن عدد المكونات المعنوية كان ستة وقد تمثلت بقيمة أكثر من 64.5% من قيمة الكلية للمتغيرات وبقيم 8.33% ,7.36%,5.85% بلغت 26.13% ,15.73% ,11.92%, على التوالي. وظهرت بأن مصادر الرئيسية لتلوث مياه قناة أربيل كانت مياه الصرف الصحي لمدينة أربيل و النشاطات الزراعية حول القناة. بينما تحليل PCA لمياه نهر الزاب الاعلى بينت أن عدد المكونات المعنوية كان سبعة تمثلت بالقيم 23%, 14.63%, 10%, 8.96%, 7.73%, 6.55% و 6.24% على التوالي, وبقيمة كلية للمتغيرات أكثر من 77.14%. حيث ان نوعية مياه النهر تأثرت بالملوثات من فضلات قناة أربيل و النشاطات الزراعية , أضافة الى أنجراف المواد بفعل مياه الامطار.

هەڵسەنگاندنی گۆرانکاری مانگانە لە جۆریەتی ئاوی دوو جۆر ئاو لە پارێزگای هەولێر.

كورتی:

لەم لێکۆلینەوەدا هەندیك سیفاتي فیزیاوي ,کیمیاوي هەروەها بایولۆجي لەحەوت وێستگە دیاری کراو بۆ ئەم توێژینەوە کە سێ یان بەدرێژایی کەنالی ئاوەرۆی هەولێر وچوار وێستگە لەسەر رووباری زێ ی گەورە بوو. نمونەکان وەرگیران بە شێوەیەکی مانگانە لە دەستپێکی مانگی ئازاری 2006 بۆ نیسانی 2007.

ئەنجامی شیکاری پێکهاتە سەرەکی PCA شەش پێکهاتە مەعنەوی وە بەکۆی زیاتر لە 64.5٪ لە بەهای گشتی گۆراوەکان وەبە بەهایەکان 26.13٪, 15.73٪, 11.92٪, 8.33٪, 7.73٪ و 5.85٪ بوو یەك بەدوای یەك بۆ ئاوی ئاوەرۆی شاری هەولێر بەدەست کەوت. دەرکەوتووە کە جۆریەني ئاوي کەنالی ئاوەرۆی شاری هەولێر پیس بووە بە پاشەرۆی مالان و چالاکیە کشتوکالیەکانی دەوروبەری کەنالەکە. بەلام ئەنجامی PCA حەوت پێکهاتە مەعنەوی بۆ رووباری زێ ی گەورە بە دەست کەوت وەببەهای 23٪, 14.63٪, 10٪, 8.96٪, 7.73٪, 6.55٪ و 6.24٪ بوو یەك بەدوای یەك وە بە کۆی گشتی گۆراوەکان زیاتر لە 77.14٪. بەپشت بەستن بە ئەنجامەکاني PCA دەرکەوتووە کە جۆریەني ئاوي زێ ی گەورە هەستیارە بە کاریگەرەکاني ئاوی ئاوەرۆی شاری هەولێر, هەروەها بۆ کاریکەري کشتوکالێ وداماڵیني خاك بە هۆی ئاوی باران دەگەرێتەوە.