Environmetric Techniques for Water Quality: A Case Study of Al-Gharraf River in Thi Qar Province, Iraq

Mudhar H. Gatea, Ammar S. Dawood*, Haleem K. Hussain

Civil Engineering Department, College of Engineering, University of Basrah, Basrah, Iraq

mudhar.hasan@gmail.com, * ammars.dawood@yahoo.com, haleem.albremani@gmail.com

Abstract: The most beneficial strategy of reporting the water quality condition of a river is the classification of data based on water quality, to manage water pollution in supervised areas. The current environmetric research combined with the explanation the monitoring data from the Al-Gharraf River in Thi Qar province. Twenty variables for water quality are measured to estimate and classify the water quality of the Al-Gharraf river at two sampling sites. In this study, factor analysis (FA) and cluster analysis (CA) have been applied to determine the characteristics quality of water, to get the source inputs-elements of water quality, and to estimate the pattern of water quality and its spatial in this area. The results of PCA for the region under study indicated that the first four components from the data sets of principal component analysis (PCA) recorded 92.7% of the total variance. This research confirmed that the use of the multivariate statistical methods is an effective tool for the river-water category. Hence, it is suggested to comprise the data that are environmetric data counseling as a useful operation for assessment of water quality data.

Keywords**:** water quality, cluster analysis, principal component analysis, Al-Gharraf River.

1) *Introduction*

Rivers play a part that is crucial in transporting domestic and industrial wastewater as well as the surface run-off of agricultural areas and tend to be one of the most vulnerable waters to pollutants [1-3]. The system of rivers is carry a load that is significant of materials in its dissolved and particulate stages in one direction from different sources that are natural and anthropogenic [4]. Presently, all around the world, great environmental interest is the contamination of surface water with physical, chemical and biological pollutants by some activities such as anthropogenic tasks [5-7]. As previously mentioned, the continual discharge of some wastewaters like domestic and industrial types as well as the effect of climate on the in-season surface run-off all have actually an impact on the river water quality and discharge. The land use changes, human activities, and utilization of chemicals in agricultural are the most factors that have a major impact on surface water quality [8,9].

As ended up being discussed earlier, the evaluation of water quality is determined based on its chemical, biological and physical parameters that are prepared making use of descriptive statistics and both of univariate and multivariate techniques [10,11].

Some particular problems were noticed in the monitoring of water quality, which are the difficulty linked with analyzing a large number of assessed variables and its large variability because of natural and anthropogenic effects [12,13].

The organic pollutants influence Al-Gharraf River basin. These pollutants coming from the effluents such as the industrial wastewater and the excess of nutrients caused by the agricultural runoff. For effective water resources management, the water quality classification is starting to become a concern for useful management possibilities [14]. As a result, the water quality classification of rivers is a valuable method of stating the condition of water quality in addition to identify more techniques that are significant for controlling water contamination in monitored areas [14].

Environmetric methods such as factor analysis (FA), cluster analysis (CA), and regression analysis, should be implemented to assess the data framework and to categorize and the data-sets model as well as to present time patterns with pollution [15]. The most typical methods of multivariate analysis, which are unsupervised, used for classification are principal component analysis (PCA) and CA [14]. Recently, CA and PCA arise trusted when observing the interpretation units of complex-data to much had better assess the quality of water and other range of environmental concerns. These environmental problems like an evaluation of pollution resources, chemical material types concerning hydrological situations, and examining the trends (spatial and temporal) of water quality [16-21]. CA is a technique that its objective is to determine the normal groupings within the group of data [22]. It is utilized to classify entities with same characteristics. CA splits the big number of elements into a smaller number of homogeneous sets as stated by their correlation framework [23].

FA tries to explain the correlations between the findings when it comes to the elements, which are underlying which are usually not directly [24]. The effective use of PCA together with CA has offered a practical way that is beneficial for the management of water resources and control of pollution. PCA and CA have the ability of detection the possible aspects brought on some activities like the natural and anthropogenic strategies that manipulate the water systems [20]. PCA and CA have been utilized effectively in hydrochemistry for several years. They enable acquiring hidden information through the data go about the impacts which can be possible from the ecosystem regarding the water quality and provide greater possibilities for administrators in terms of assisting the process that is decision-making [25].

In the present study, the monitoring of water quality parameters was carried out by two monitoring stations in the area under investigation along one year [26]. The goals behind this research are to evaluate the physicochemical parameters of the studied river based on its water quality by using PCA and CA multivariate technique. The multivariate statistical techniques are practiced to the river water quality data set to find out the group monitoring stations for the study area. The other objective is to evaluate the important information from the similarity and dissimilarities between the two monitoring stations and further to be sure the influence associated with the sources' pollution regarding the water quality variables.

2) *Materials and Methods*

2.1) Study Area

The Al-Gharraf River in Thi Qar province shows the study area. The Al-Gharraf River has a total drainage area of approximately 435000 x 106 m^2 from its starts in Kut regulator to its ends in Al-Hammar marsh [27]. The total length of the River from its start to its end is about 230 km, and it is the longest river in Thi Qar province. This river is the main source of water for domestic use and a source of irrigation in this catchment area. The Al-Gharraf River has 52 canals with 968 irrigation ditches bifurcate from the main River that used for irrigation of 700,000 hectares [27]. Furthermore, fast industrialization and population growth in the last few decades have formulated an excessive concern on the ecological situations in the region. The described study area is shown in Fig.1. The geographical position of the river is longitude 45º47'25"E, and latitude 32º31'55"N. The climate of the study area is characterized by cold and wet in winter and hot and dry summer, and it's classified as semi-arid area.

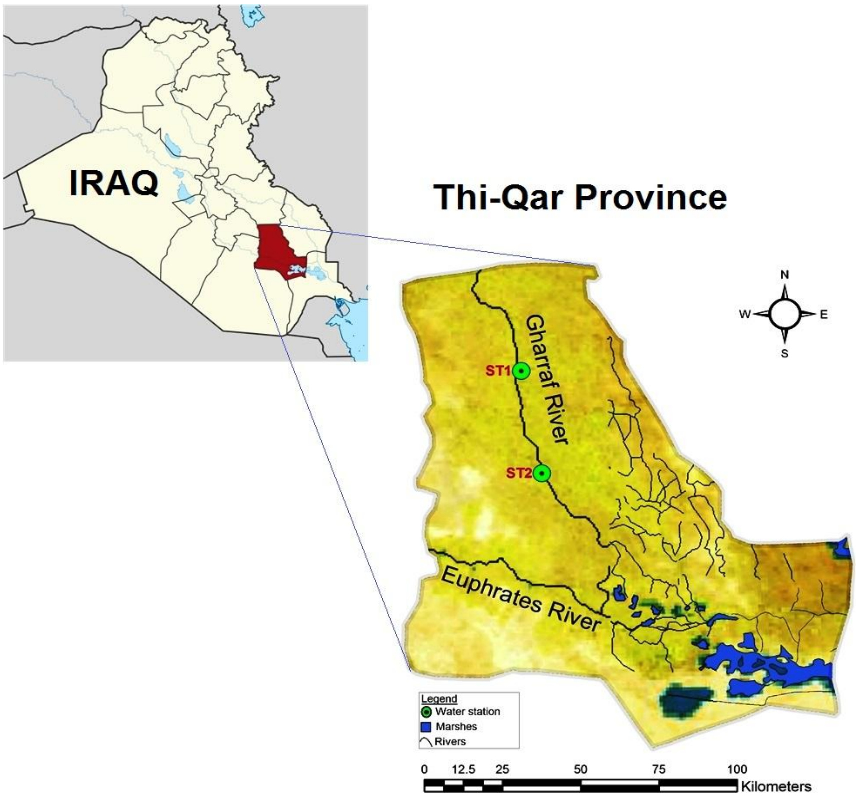

Fig**.1. The study area show Al-Gharraf River in Thi Qar province**

2.2) Raw Data

The two monitoring stations (Fig. 1) lies on the main River basin. The first monitoring station (ST1) is located in the Ar Rifa'i city with geographical position of longitude 46º06'53.9"E, and latitude 31º41'21.6"N. The second monitoring station (ST2) is located in the Ash Shatrah city with an estimate distance of 40 Km from the first station. The geographical position of the second station is longitude 46º06'53.9"E, and latitude 31º41'21.6"N.

The recorded data set contains the time of one year (summer 2014 to spring 2015) and is collected seasonally for a purpose of calculation of the water quality index in the studied area [26]. The data set includes twenty water quality parameters: water temperature (T), pH, chemical oxygen demand (COD), biochemical oxygen demand (BOD_5), dissolved oxygen (DO), total dissolved solids (TDS), electrical conductivity (EC), bicarbonates (HCO_3^-), total hardness (TH), total alkalinity (TA), calcium (Ca^{2+}), magnesium (Mg^{2+}), potassium (K^+), sodium (Na^+), sulfate (SO_4^{2-}), phosphate (PO_4), and fecal coliform bacteria (E-coli). The data matrix applied for categorization has 2 X 20 dimensions (i.e. two monitoring stations by seventeen-water quality parameters).

3) *Environmental Techniques*

One of the multivariate statistical method used in this study is the PCA, which is configured to convert the complexness of the input variables that have a large quantity of information towards principal components (PC) that are new uncorrelated variables. These new variables are linearly combined with the original parameters (ie. variables) [20]. Additionally, it meant to have a better interpretation of original parameters.

CA is a pattern that is an unsupervised technique which is unearths the innate framework or underlying behavior of an information set without the need of a priori assumption regarding the data, to categorize the system's objects into groups or clusters considering their similarity or nearness [28]. Thereafter the CA results reveal high uniformity between the cluster and high heterogeneousness among clusters [29].

The method of grouping the clusters consecutive is called Hierarchical clustering (HC) which is the more common approach called dendrogram. In the dendrogram, the grouped clusters typically started with the most set that have similar objects and then developed higher clusters step-by-step. The dendrogram introducing the groups' map with reducing the dimensionality from the original data used with a visual overview of the processes of clustering. The Euclidean distance, which is used as measure of similarity. It gives the similarity from both the samples by representing the variation amongst its analytical values. In this method, the analysis of variance is utilized to measure the distances between the clusters. This method used for any two clusters by trying to reduce the sum of squares that can be create at each step [1,21,30].

The raw data sets of Al-Gharraf river water quality (twenty variables) are clarified by using three multivariate statistical techniques: Fa, CA, and PCA. In this research, a measure of similarity used the hierarchical CA by made use of Ward's method with squared Euclidean distances [31].

4) *Results*

The descriptive statistics recorded from the data-set are displayed in Table 1. The temperature of water samples in the study location varies from 8.10 to 28.30 ºC with mean value of 21.83 ºC. pH value of the water samples in the region varies from 6.80 to 8.45 with the mean pH value of 7.44. Dissolved oxygen (DO) concentration is a very important factor for aquatic life in rivers and lakes. DO ranges from 1.06 to 8.40 mg/l, mean concentration of DO was found to be 4.24 mg/l.

The measured concentration of biochemical oxygen demand (BOD_5) in the water samples ranges from 1.23 to 3.05 mg/l, with mean value was found to be 2.10 mg/l. The concentration of chemical oxygen demand (COD), in water samples ranges from 6.90 to 30.90 mg/l, the mean of the COD concentration was 15.82 mg/l. The electrical conductivity (EC) of the water samples varies from 674 to 1406 µS/cm, the mean EC concentration had been discovered to be 1156.13 µS/cm implies the water samples had considerably salinity nature. To find the suitability of water for drinking purpose, the measurement of total dissolved solids (TDS) must be carry out for water samples, and hence it is an important parameter for identifying the usage of water. The TDS concentrations varies from 336 to 798 mg/l, the mean TDS value was noticed to be 590.01 mg/l suggesting well for drinking target.

The turbidity (TU) measurement is a useful test for check the water's clean. The TU concentration in the water samples varies from 3.11 to 6.70 NTU, the mean value of TU was 5.07 NTU indicating well for drinking usage. The concentration of total hardness (TH) in the water samples ranges from 367 to 579 mg/l and mean value of TH is 468.88 mg/l. The measured of bicarbonate concentration in the water samples ranges from 342 to 605 mg/l, the mean value was found to be 453.25 mg/l. The concentration of total alkalinity (TA) in study area varies from 191 to 301 mg/l, the mean value was found to be 229.38 mg/l and its value was above the allowable limit.

Calcium (Ca) concentration in the water samples ranges from 52.03 to 175.00 mg/l, the mean value of Ca was 108.63 mg/l that not goes beyond the permitted limit (150 mg/l) and all water samples fall in acceptable with limits, which are allowable. The concentration magnesium ion (Mg) in the water samples varies from 36.06 to 131.00 mg/l and the mean value of Mg concentration was 70.38 mg/l not surpass the particular level that is allowable and there are a greatest water samples fall in the drinkable, permitted limit. The sodium (Na) concentration in the water samples ranges from 93 to 179 mg/l and mean value of Na concentration is 136.5 mg/l it does not surpass potable limit. Potassium (K) concentration varies from 3.30 to 13.37 mg/l, the mean value of K was 7.81 mg/l, it not exceeds above the potable type. The concentration chloride (Cl) ion of water samples in the study area ranges from

118 to 292 mg/l, the mean value was founded to be 194.38 mg/l and it exceeds above the suitable limit of potable type.

Table 1. Descriptive statistics for the data of water quality variables [26]

Variable	Unit	Mean	Median	Minimum	Maximum	Variance	Std. deviation	Skewness
T	° C	21.83	25.20	8.10	28.30	64.05	8.00	-1.32
pH	mg/l	7.44	7.20	6.80	8.45	0.44	0.67	0.93
DO	mg/l	4.24	3.70	1.06	8.40	8.39	2.90	0.34
BOD_5	mg/l	2.10	2.32	1.23	3.05	0.43	0.66	-0.16
COD	mg/l	15.82	13.90	6.90	30.90	75.14	8.67	0.99
EC	µS/cm	1156.13	1220.00	674.00	1406.00	59394.70	243.71	-1.17
TU	NTU	5.07	5.04	3.11	6.70	1.85	1.36	-0.29
TDS	mg/l	590.01	616.50	336.00	798.00	26855.01	163.87	-0.40
TH	mg/l	468.88	471.00	367.00	579.00	6312.13	79.45	0.11
HCO_3	mg/l	453.25	422.00	342.00	605.00	10507.93	102.51	0.68
TA	mg/l	229.38	202.50	191.00	301.00	2094.27	45.76	1.05
Ca	mg/l	108.63	108.00	52.03	175.00	1869.21	43.23	0.18
Mg	mg/l	70.38	57.00	36.06	131.00	1352.25	36.77	1.18
Cl	mg/l	194.38	185.00	118.00	292.00	4699.13	68.55	0.50
Na	mg/l	137.13	136.50	93.00	179.00	1113.55	33.37	-0.03
K	mg/l	7.81	7.44	3.30	13.37	15.83	3.98	0.19
PO_4	mg/l	0.20	0.13	0.06	0.40	0.02	0.15	0.59
NO_3	mg/l	2.54	2.33	1.35	4.10	1.35	1.16	0.20
SO_4	mg/l	242.63	214.50	204.00	399.00	4331.98	65.82	2.42
Ecoli	cfu/100ml	176.25	227.50	51.00	286.00	10379.36	101.88	-0.49

The phosphate (PO_4) concentration of water samples in the study region varies from 0.06 to 0.40 mg/l, the mean value was noticed to be 0.20 mg/l and it is within the allowable limit. Nitrate (NO_3) is another measure used as pollution indication. The measured NO_3 of water samples varies from 1.35 to 4.10 mg/l, the mean value was 2.54 mg/l does not exceed the drinkable limit. The sulfate (SO_4) concentration of water samples of the study area ranges from 204 to 399 mg/l, the mean value was noticed to be 242.63 mg/l and it is above the allowable limit.

For a better illustration of cations and anions dominance, the box plot is used for the representation [32,33]. In this study, the box plots has been utilized to symbolize the dominance of temporal concentration for major ions (Fig.2). In this plot, Specifies the top and bottom quarter of the data above and below the rectangle box. The interior line of the box signifies the median value whereas the box-sizing shows the spread of the central value [33]. According to Figure 2, the plot explains the water samples in the study area were dominated by the order of HCO_3>SO_4>Cl>NO_3>PO_4 for anions, and Na>Ca>Mg> K in cations. Furthermore, the plot shows variation that is remarkable for the median, mean and the standard deviation values of water quality parameters revealing that the study location is varied of process influenced the water for a variety of complicated contamination source.

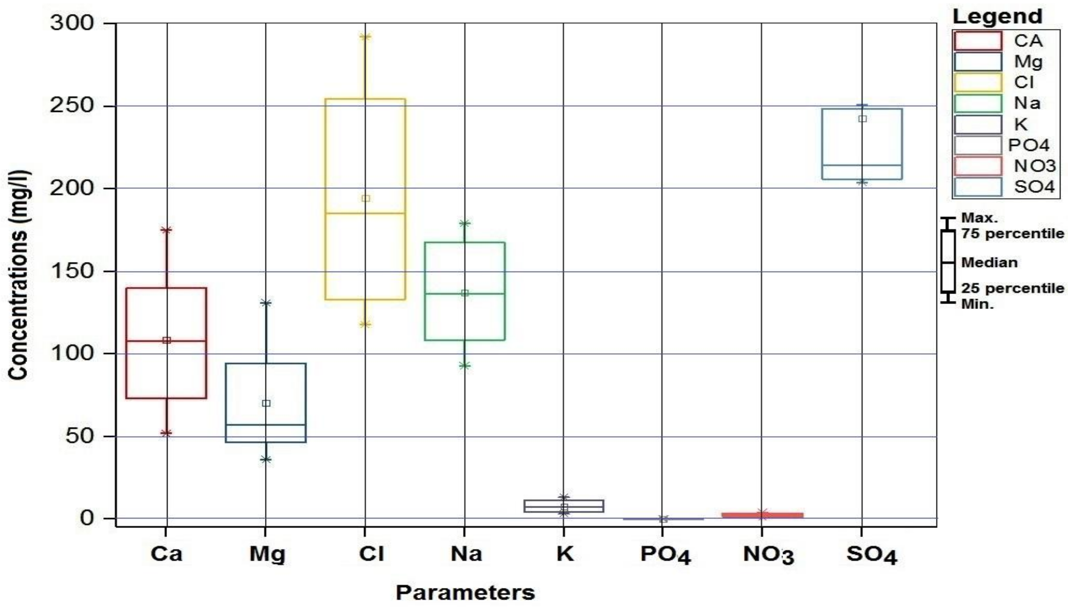

Fig.2. Box plot for chemical water quality variables.

The FA results for the data-set of chemical parameters that obtained from two sites along one year including eigenvalues, matrix of factor-loading, values of total and cumulative variance are displayed in Table 2. Figure 3 presents scree plot and its cumulative variance proportion of principal components.

In the current research, twenty variables (all the examined parameters) were utilized to discover the efficient varactors. The categorized method of the factor loadings based on the loading values is regarded as weak (0.30–0.50) moderate (0.50–0.75) and, strong (>0.75) [34]. The evaluation process for analyzing the principal components is taken as a criterion when the Eigenvalues was higher than one. As mention before, the analyzing the principal components were employed to explain the sources of variance in the data sets and based on table 2, four factors (4 PCs) explained 92.7 % of the total variance.

As a result of the factors that had been shown, and considering the factor loadings and hydrochemical aspects, it is recommended that, PC1 shows a weakly correlated as shown by the presence of EC, DO, K, PO_4, and NO_3. This first factor explored 38 % of the variance. PC_2 is also weakly correlated with Tu, COD, TH, and Na. Factor loadings for PC_3 were 0.344 and 0.305 for T and Ta varabiles, respectively. In addition, it has an inversely weakly correlated as shown by the presence of Ca and Mg. Factor loadings for PC_4were inversely weakly correlated with BOD_5, Cl, and SO_4.

Cluster analysis was implemented using Minitab software ver.18 on the score of principal components of the water quality parameters respectively, to determine the spatial similarity and dissimilarity in the recorded data sets from the monitoring stations that distributed in the main river under-investigated. Dendograms in cluster analysis produce a helpful graphical tool for finding the number of clusters typically explain the hidden process that causes spatial variation

The dendogram that produced from tree clustering is shown in Figure 4. Based on Clustering analysis results, two statistically appreciable clusters were formed: Cluster 1 matched to T, E-coli, K, NO_3, PO_4, COD, Ca, Na, and TDS, where were identified as the main polluted parameters in the investigated location. Cluster 2 matched to pH, TA, HCO_3, EC, BOD_5, DO, TU, Na, TH, Cl and SO4, where were determined as the biological pollutants of the investigated location.

Table 2. The matrix of factor-loading and the total variance.

Variable	PC1	PC2	PC3	PC4
T	-0.143	-0.266	0.344	0.041
pH	0.247	-0.219	0.261	-0.036
DO	0.325	0.157	-0.077	0.116
BOD	0.169	-0.121	0.242	-0.486
COD	-0.22	-0.305	-0.144	-0.021
EC	0.304	-0.153	-0.056	-0.065
TU	-0.013	0.361	0.223	0.094
TDS	0.191	-0.229	-0.249	0.191
TH	0.102	0.388	-0.05	-0.053
HCO_3	0.316	-0.101	0.202	0.045
TA	0.205	-0.239	0.305	-0.046
CA	0.033	-0.21	-0.449	0.025
Mg	-0.083	-0.275	-0.367	-0.061
Cl	-0.137	0.123	-0.03	-0.63
Na	0.014	0.394	-0.087	0.114
K	-0.346	-0.016	0.133	-0.082
PO_4	-0.317	0.052	0.132	0.167
NO_3	-0.35	-0.047	-0.068	-0.004
SO_4	0.106	0.132	-0.258	-0.486
E-coli	-0.273	-0.113	0.163	-0.076
Eigenvalue	7.5903	6.018	3.4749	1.4436
Proportion	38	30.1	17.4	7.2
Cumulative	38	68.1	85.5	92.7

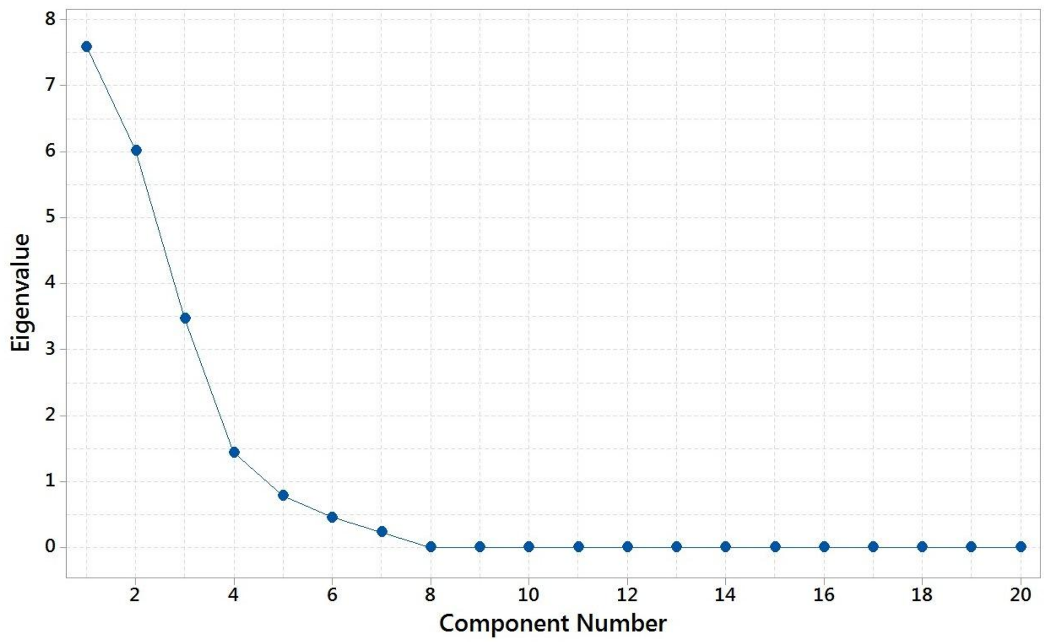

Fig.3 Scree plot of FA for the data-set in the study region

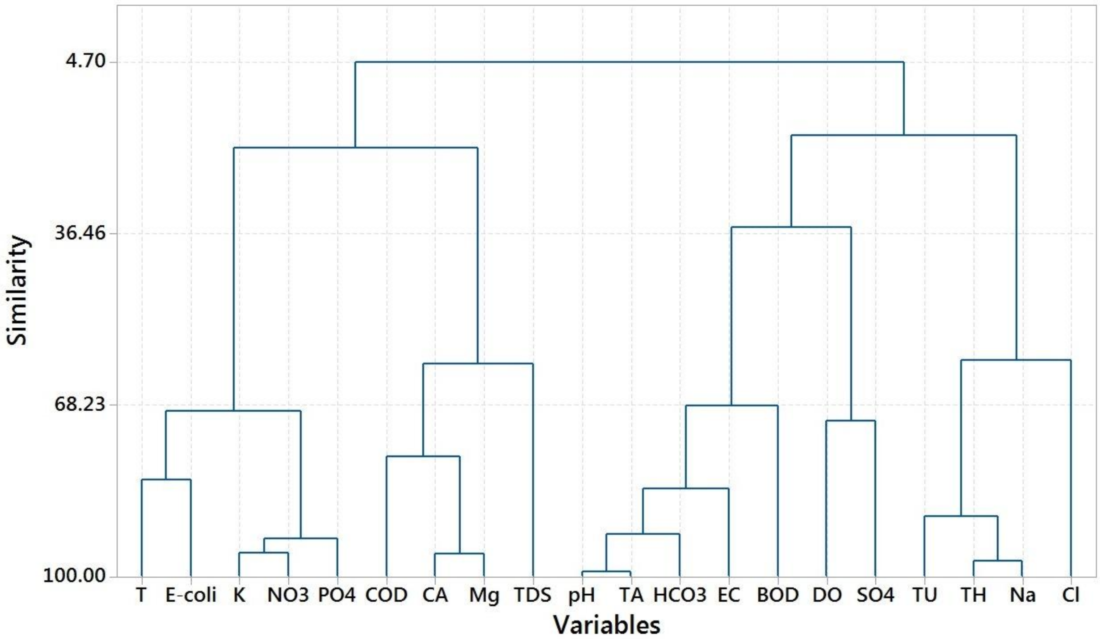

Fig.4 Dendogram diagram of factor analysis for the data set in the study region.

5) *Conclusion*

In this research environmetric methods particularly factor and cluster analyses (PCA and CA) were applied to the data set recorded by the mointoring stations located in the Al-Gharraf River. The target of applying these multivariate statistical methods were to categorize the two monitoring locations into classes of similar water quality characteristics depending on twenty selected water quality parameters in the study region. FA was applied also to demonstrate the correlations involving observations with regards to the hidden factors that are not exclusively observable.

The results from PCA and CA sorted the two monitoring stations into four clusters depending on similarities of the characteristics in water quality. Results presented that, FA were able to explain around 92.7 % of the total variance. It is concluded that the water quality variables can be grouped under two main clusters. Hence, the results from this paper recommend that both CA and PCA techniques are helpful tools to assist in water resources management and in water quality determination.

6) *References*

[1] Singh KP, Malik A, Mohan D, Sinba, S. Multivariate statistical techniques for the evaluation of spatial and temporal variations in water quality of Gomi River (India)- a case study. *Water Res 2004*; 38: 3980-3992.

[2] Singh KP, Malik A, Sinha S. Water quality assessment and apportionment of pollution sources of Gomti river (India) using multivariate statistical techniques- a case study. *Anal Chim Acta* 2005; 538: 355-374.

[3] Wang XL, Lu YL, Han JY, He, GZ, Wang, TY. Identification of anthropogenic influences on water quality of rivers in Taihu watershed. *J Environ Sci-China 2007*; 19: 475-481.

[4] Zhang ZI, Tao F, Du J, Shi P, Yu D, Meng Y,Sun Y.Surface water quality and its control in a river with intensive human impacts-a case study of the Xiangjiang River, *China. Environ Manage 2010*; 91(12):2483-2490.

[5] May AM, Mutasem E, Mark DS, John, NL. Factors influencing development of management strategies for the Abou Ali River in Lebanon. *Sci Total Environ 2006*; 362: 15-30.

[6] Noori R, Sabahi MS, Karbassi AR, Baghvand, A, Taati Zadeh, H. Multivariate statistical analysis of surface water quality based on correlations and variations in the data set. *Desalination, doi:10.1016/j.desal.2010.04.053.*

[7] Ouyang Y, Nkedi-Kizza P, Wu QT, Shinde D, Huang, CH. Assessment of seasonal variations in surface water quality. *Water Res 2006*; 40: 3800-38 10.

[8] Zhang QL, Shi XZ, Huang B, Yu DS, Öbornc I, Blombäckc K, Wang HJ, Pagella TF, Sinclair FL. Surface water quality of factory-based and vegetable-based peri-urban areas in the Yangtze River delta region, *China. Catena 2007*; 69 (1): 57–64.

[9] Hussain M, Ahmed SM, Abderrahman W. Cluster analysis and quality assessment of logged water at an irrigation project, *eastern Saudi Arabia. Journal of Environmental Management 2008*; 86:297–307.

[10] Sargaonkar, A., & Deshpande, V. Development of an overall index of pollution for surface water based on a general classification scheme in Indian context. *Environmental Monitoring and Assessment2003*;89, 43–67.

[11] Lopez, F. J. S., Garcia, M. D. G., Vidal, J. L. M., Aguilera, P. A., & Frenich, A. G. Assessment of metal contamination in Doñana National Park (Spain) using Crayfish (Procamburus clarkii). *Environmental Monitoring and Assesment2004*; 93, 17–29.

[12] Saffran, K. Canadian water quality guidelines for the protection of aquatic life, CCME water quality Index 1,0, *User`s manual. Excerpt from Publication no.1299, 2001; ISBN* 1-896997-34-1.

[13] Simeonov, V., Einax, J. W., Stanimirova, I., & Kraft, J. Environmetric modeling and interpretation of river water monitoring data. *Analytical and Bioanalytical Chemistry2002*; 374, 898–905.

[14] Kannel PR, Lee S, Kanel SR, Khan SP. Chemometric application in classification and assessment of monitoring locations of an urban river system. *Analytica Chimica Acta 2007*; 582(2): 390-399.

[15] Simeonov, V., Sarbu, C., Massart, D. C., & Tsakovski, S. Danube River water data modelling by multivariate data analysis. *Microchimica Acta2001*; 137, 243–248.

[16] Bouza-Deaño R, Ternero-Rodríguez M, Fernández-Espinosa AJ. Trend study and assessment of surface water quality in the Ebro River (Spain). *J Hydrol 2008*; 361: 227-239.

[17] Omo-Irabor OO, Olobaniyi SB, Oduyemi K, Akunna, J. Surface and ground water quality assessment using mutivariate analytical methods: a case study of the Western Niger Delta, Nigeria. *Phys Chem Earth 2008*; 33: 663-673.

[18] Ouyang Y. Evaluation of river water quality monitoring stations by principal component analysis. *Water Res 2005*; 39: 2621-2635.

[19] Parinet B, Lhote A, Legube B. Principal component analysis: an appropriate tool for water quality evaluation and managementapplication to a tropical lake system. *Ecol Model 2004*; 178: 295-311.

[20] Shrestha S, Kazama F. Assessment of surface water quality using multivariate statistical techniques: a case study of the Fuji river basin, *Japan. Environ Modell Softw 2007*; 22: 464-475.

[21] Wu ML, Wang YS, Sun CC, Wang, HL, Dong, JD, Yin, JP, et al. Identification of coastal water quality by statistical analysis mthods in Daya Bay, *South China Sea. Mar Pollut Bull 2010*; 60: 852-860

[21] Yeung, I. M. H. Multivariate analysis of the Hong Kong Victoria Harbour water quality data. *Environmental Monitoring and Assessment1999*; 59, 331–342.

[23] Zeng, X., & Rasmussen, T. C. Multivariate statistical characterization of water quality in Lake Lanier, Georgia, USA. *Journal of Environmental Quality 2005*; 34, 1980–1991.

[24] Yu, S., Shang, J., Zhao, J., & Guo, H. Factor analysis and dynamics of water quality of the Songhua River Northeast China. *Water, Air, and Soil Polution 2005;* 144, 159–169.

[25] Kotti, M. E., Vlessidis, A. G., Thanasoulias, N. C., & Evmiridis, N. P. Assessment of river water quality in Northwestern Greece. *Water Resources Management2005*; 19, 77–94.

[26] Al-Tamimi M. M. Evaluation of the validity of The AL-Gharraf- River Water Southern of Iraq for various uses by using the Water Quality Index *(Canadian Model), Ph.D. thesis, University of Thi-Qar.2016*.

[27] Ewaid, S. H. Water quality evaluation of Al-Gharraf river by two water quality indices. *Applied Water Science2017*; 7(7), 3759-3765.

[28] Vega M, Parda R, Barrada E, Deban, L. Assessment of seasona and polluting effects on the quality of river water by exploratory data analysis. *Water Res 1998*; 32: 3581-3592.

[29] Kazi TG, Arain MB, Jamali MK, Jalbani, N, Afridi, HI, Sarfraz, RA., et al. Assessment of water quality of polluted lake using multivariate statistical techniques: *A case study. Ecotox Environ Safe 2009*; 72: 301-309.

[30] Simeonov V, Statis J A, Samara C, Zachariadis, G., Voutsa, D., Anthemidis, A., et al. Assessment of the surface water quality in Northern Greece. *Water Res 2003*; 37: 4119-4124.

[31] Zhaoa Y, Xia XH, Yang ZF, Wang F. Assessment of water quality in Baiyangdian Lake using multivariate statistical techniques. *Procedia Environmental Sciences 2012*; 13: 1213 – 1226.

[32] Taheri TA, Voudouris KS Groundwater quality in the semi- arid region of the Chahardouly basin, West Iran. Hydrol Process 22:*2008*; 16 : 3066–3078.

[33] Srinivasamoorthy K, Gopinath M, Chidambaram S, Vasanthavigar M, Sarma VS Hydrochemical characterization and quality appraisal of groundwater from Pungar sub basin, Tamilnadu, India. *Journal of King Saud University-Science 26, no. 1 2014*; 37-52.[34] Liu CW, Lin KH, Kuo YM Application of factor analysis in the assessment of ground water quality in a Back foot disease area in Taiwan. *Science of the Total Environment 313, 2003*; (1–3):77–89.