THE EFFECT OF THE DISCHARGE OF WASTE WATER FROM THE CITY ON THE PHYSICO-CHEMICAL WATER QUALITY IN THE DAM OF WADI EL ARAB, EASTERN ALGERIA

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Abstract
Multivariate statistical techniques such as cluster analysis, principal component analysis, and factor analysis and time series analysis were used to evaluate temporal variations in surface water in the Baber watershed. A total of 21 samples (7 from each city) were collected on which eleven phys-chemical parameters were determined. The salinity of the samples brought from the Eastern part (S1) are found to have high TDS values, while part (S2) to the west display low TDS and in the dam (S3) TDS values are intermediate on average. The water type in S1 is SO4-Na, in S2 it is HCO3-Ca-Mg and SO4-Ca-Mg which is the characteristic facies of mixed water in the dam. In the cluster analysis (R-mode), seven variables were classified into two clusters controlled by SO4 and in Q-mode, 21 samples are grouped into 3 groups coinciding with the station S1, S2 and S3. Factor analysis indicates two factors, which explained 87% of the total variance in water quality data set. Two factors, which are salinization and sulfates explaine 73% and 14% of the total variance respectively. Time series analysis showed that Ca, Mg, Na, Cl and SO4 have very similar trend with TDS and K have similar pattern as NO3. It suggests that five components control TDS evolution. K and NO3 represent a negative correlation with TDS, it resulted from the human activity as fertilizer and domestic sewages are thrown to the tributaries of Wadi Arab. This study illustrates the benefit of multivariate statistical techniques for interpreting complex data sets in the analysis of spatial and temporal variations in surface water quality.

Key words: Hydrochemical, Statistical techniques, Time series, Salinity, Surface water, Dam, Algeria.

1. INTRODUCTION

The objective of the present work is to characterize the chemistry of surface water and determine the origin of the chemical elements present by using the multivariate statistical techniques and time series analysis. The investigated area is located in the South-East of Algeria. Most of inhabitants (more than 20,000 inhabitants) are concentered in the town of Baber.

2. Materials and Methods

2.1. Study area

The study area is located at the downstream of the Wadi (River) Arab. The area of the watershed is 567 km^2, Babar dam with a capacity of 54 Mm^3 is built to impound the Wadi waters. (Figure 1).

2.2. Physicochemical analysis and methodology

Monthly surface water was sampled from Wadi Arab and Babar dam, from October 2007 to April 2008 at three stations. The station 1 (S1) and station 2 (S2) are located downstream of urban and industrial discharges and station 3 (S3) is located at the lake of the dam. Figure 1. Total 21 samples (7 from each station) were collected. Samples were analyzed for the major ions. The physico-chemical data that were analyzed are pH, temperature of water (T), Total dissolved solids (TDS), calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^+), potassium (K^+), chloride (Cl^-), sulfate (SO_4^{2-}), bicarbonates (HCO_3^-), nitrate (NO_3^-). Table 1. This was achieved using standard methods suggested by the American Public Health Association (APHA 2005).The respective ionic balance is generally around 5%. All the statistical computations were made using Excel 2010 (Microsoft Office ®) and STATISTICA 6 (StatSoft, Inc. ®).

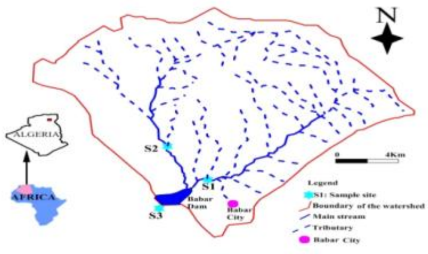

Figure 1. Map of situation of Babar area.

3. Results and Discussion

Eleven physic-chemical parameters were determined during this study Table 1. During the study period, the change in water temperature is similar in the three stations and is largely influenced by the general climate of the region. The low temperatures coincide with the cold period and high temperatures coincide with the warm periods. pH value of water samples varied from 7.4 to 8.9 indicating that water is slightly alkaline in nature. pH values of the station S2 are greater than those of the other two stations in association with the presence of carbonate formations which are in this part of the field. It is known that the process of buffering calcite and dolomite, are dominant for the pH range 6.5 to 7.5 (Geller et al. 2000). For the salinity, the S1 with high TDS (2837.1±285.3 mg/l), S2 with low TDS (917±201.5 mg/l) and S3 with intermediate and average TDS (1557.1±295mg/l) thus salinity may be classified in the following order S1>S3>S2. Higher concentration of TDS observed in S1 and S3, due to the impact of solubility of evaporate element as gypsum, anhydrite and halite (Nas and Berktay 2010, Pacini et al. 2013). High concentrations of evaporite elements (Na, K, Cl and SO4) are recorded at S1 with 908, 7.7, 293.2 and 966.1 respectively. This is mainly due to the presence of evaporate formations in the area. Another reason for the increase of Na, Cl and SO4 concentration is related with the effluents input from the industrial and urban sector (Kura et al. 2014). It is also noteworthy that the S3 waters are strongly influenced by those of S1. The Ca and Mg content are greater in S1; this is in connection with the dissolution of gypsum and epsomite. As against the HCO3 concentration which is higher in S2 due to dissolution of carbonates formations. The variation of the concentration of NO3 appears to be similar in the three stations. However we note that the high values are recorded in periods of drought while low concentrations recorded during floods (Sæbo 1991).

In this case study, environmental techniques and time series analysis were used to evaluate temporal variations in surface water in the Baber watershed. The sources of water pollution in the Baber watershed could more probably be derived from industrial and urban wastewater, irrigation activity and mineral weathering. The application of Piper diagram for water surface in the region can show three chemical facies. The water type in S1 is SO4-Na for S1, in S2 is HCO3-Ca-Mg and is SO4-Ca-Mg water in the dam. These water types are, in fact, a reflection of the predominant influence of gypsum, anhydrite and halite in the Eastern part of study area. The predominant influence of carbonate material is in the western part of study area and mixed water in the dam. In the cluster analysis (R-mode) seven variables were classified into two clusters controlled by SO4. These groups are: cluster 1 with evaporate elements: Na, Cl and K, cluster 2 with carbonate elements: Ca, Mg and HCO3. In Q-mode, 21 samples were classified into three groups. The first group is made up by the samples belonging to the station S1. Second group 2 is represented by the samples belonging to the station S2. The third group is made up by the samples belonging to the station S3. In PCA, the two main principal components explain 87.2% of the total variance. Time series analysis also provided the same results. The autocorrelation shows that TDS, Ca, Mg, Na, K, Cl and HCO3 have a strong linear interrelationship, and they are subjected to periodically changing sources. In fact, NO3 and SO4 are affected by anthropogenic sources, urban action and geological condition. Spectral density functions of Ca, Mg, Na, Cl and HCO3 has almost similar trend with TDS. It suggests that TDS was affected by these elements and that TDS plays a more vital role on the surface water quality. But the multiple peaks of the spectral density functions of pH, K, SO4 and NO3 resulted from the human activity, fertilizer and domestic sewage. The cross-correlations of Ca, Mg, Na, Cl and SO4 have very similar trend with TDS and K have similar pattern as NO3. It suggests that five components are the controlling factors of the TDS. K and NO3 represent a negative correlation with TDS, it resulted from the human activity, fertilizer and domestic sewage inputs from the tributaries of Wadi Arab. The results of this study clearly demonstrate the usefulness of the multivariate statistical analysis in hydrochemistry.

Table 1. Range, mean, standard deviation (SD), of water quality parameters of the Babar dam during 2007–2008.

	T	pH	TDS	Ca	Mg	Na	K	CL	SO4	HCO3	NO3
Station				**S 1 (n=7)**							
Min	3.7	7.6	2320.0	224.4	148.9	811.9	6.7	255.6	880.0	190.3	50.0
Mean	10.9	7.9	2837.1	261.5	168.3	908.0	7.7	293.2	966.1	216.6	81.4
Max	20.5	8.1	3200.0	284.6	194.6	1019.0	9.6	308.9	998.0	262.3	120.0
SD	5,5	0.2	285.3	20.3	17.2	73.0	0.9	16.9	41.3	23.5	27.0
Cv(%)	51	3	10	7	10	8	11	6	4	10	33
Station				**S2 (n=7)**							
Min	3.0	7.5	700.0	92.1	55.2	53.3	3.8	35.3	32.5	229.4	5.0
Mean	10.7	7.9	917.1	110.7	72.5	66.2	5.7	57.8	38.9	262.3	10.1
Max	20.6	8.3	1250.0	149.7	104.4	80.8	7.0	71.0	46.0	298.9	16.0
SD	6.0	0.2	210.5	18.6	15.1	11.4	1.1	12.2	4.4	26.3	3.9
Cv(%)	56	3	22	17	21	17	18	21	11	10	38
Station					**S3 (n=7)**						
Min	4.0	7.4	1000.0	120.2	71.9	490.6	6.9	113.6	650.0	222.0	10.0
Mean	10.9	7.8	1557.1	147.4	93.2	574.0	7.6	158.4	726.3	303.1	42.9
Max	20.6	8.1	1890.0	176.4	117.1	679.8	8.1	205.9	770.0	384.3	90.0
SD	57.0	0.3	295.0	18.1	16.8	60.5	0.5	30.8	40.7	47.2	24.9
Cv(%)	52	3	19	12	18	11	7	19	6	16	58
					Total (n=21)						
Min	3.0	7.4	700.0	92.1	55.2	53.3	3.8	35.3	32.5	190.3	5.0
Mean	10.8	7.8	1770.4	173.2	111.3	516.1	6.9	169.8	577.1	260.6	44.8
Max	20.6	8.3	3200.0	284.6	194.6	1019.0	9.6	308.9	998.0	384.3	120.0
SD	5.9	0.2	862.2	68.6	45.4	359.1	1.3	101.2	404.1	50.2	36.9
Cv(%)	54	3	48	39	40	69	18	59	70	19	82

All values are in mg/l except pH and T (°C).