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Assessment of surface water quality using multivariate statistical techniques: El Abid River, Middle Atlas, Morocco as a case study

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ABSTRACT

This study aims at assessing the spatial water quality variation and to determine the main contamination sources in the El Abid River as well as its main tributary Ahençal River. The water quality data were monitored for 16 parameters at 33 different sites. The used parameters were temp, pH, electrical conductivity (EC), turbidity, total hardness, dissolved oxygen, sodium (Na^+), potassium (K^+), calcium (Ca^{2+}), magnesium (Mg^{2+}), chloride (Cl^-), bicarbonate (HCO_3^-), sulfate (SO_4^{2-}), nitrite (NO_2^-), nitrate (NO_3^-), and ammonia (NH_4^+). This case study reports different multivariate statistical techniques such as Pearson's correlation, principal component analysis (PCA), and cluster analysis. The results have demonstrated that in downstream stations part of El Abid River, the water quality parameters were near or over Moroccan water standards. The PCA supported in extracting and recognizing the factors that are responsible for river water quality variance. Four factors that are responsible for 78% of the total variance in water quality of the river are identified. This suggests that the variations in water compounds concentration are mainly related to point source contamination (domestic wastewater), non-point source as natural processes (weathering of soil and rock). The CA classified the 33 monitoring sites into three differentiated clusters that showed relatively few spatial change in surface water quality. The results of this work can be used to decrease the number of samples to be analyzed, and to identify the pollution sources, as well as to better comprehend the spatial variations for effective river water-quality management.

Keywords: El Abid basin; Water surface; Water quality; Multivariate statistical techniques; Pearson's correlation; Principal component analysis (PCA); Cluster analysis (CA)

1. Introduction

Water is an essential resource and a vital component of life for human beings, plants, and animals. Its quality provides significant information about the available resources for supporting life in the ecosystem [1]. This resource is most readily available in rivers which have always played an important role in supplying freshwater for human consumption, agricultural needs, industrial and recreational purposes [2]. Rivers play also a major role in assimilation or carrying off the municipal and industrial wastewater and run-off from agricultural land. The quality and the composition of water from rivers depends on natural factors such as precipitation, geology, climate conditions, topography, and weathered products basin and especially the availability of easily soluble minerals such as calcite ($Ca–HCO_3$ dominant), halite (Na–Cl dominant), and gypsum ($Ca–SO_4$ dominant) [3–6], as well as the anthropogenic inputs which comprise urban and industrial wastewater and run-off from agricultural land. Nyenje et al. [7] pointed out that anthropogenic inputs are the major sources of the nutrients found in surface water bodies. Thus, increasing surface water pollution has been

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an issue of worldwide environmental concern. It causes not only deterioration of water quality but also threatens human health, balance of the aquatic ecosystem, economic development, and social prosperity [8].

Therefore, it becomes imperative to prevent and control the surface of water from pollution and to ascertain the water river quality based on the physicochemical analysis in order to undertake that the water satisfies certain quality standards as suggested by various national and international agencies and for effective management [9]. In addition, another approach seems important which can couple with the physicochemical analysis for more and appropriate interpretation. Many reports have shown that the application of different multivariate statistical techniques such as cluster analysis (CA), principal component analysis (PCA), factor analysis (FA) and discriminate analysis (DA) has helped to treat a large volume of spatial and temporal data from a variety of monitoring sites, to identify possible sources that influence water systems, and have offered a valuable tool in the reliable management of water resources as well as rapid solution to pollution issues [10–17].

Many studies have been carried out that are related to multivariate statistical methods around the world. In Morocco, a few authors have assessed the surface water quality of Oum Er Rbia River and his tributaries [18–20] and a few works were conducted using multivariate statistical techniques. Recently, Barakat et al. [18] used multivariate statistical techniques including Pearson's correlation, PCA, and CA to assess surface water quality of the Oum Er Rbia River.

Morocco is highly vulnerable to drought. According to the FAO [21], Morocco would be one of the countries affected by water scarcity, such a situation is difficult for the population and, inter alia, agriculture. In addition to their significant decline as a result of agricultural over exploitation, the quality of water reserves is greatly impacted by the anthropogenic activities such as the use of pesticides, fertilizers, and organic amendments [19,22,23], and the waste and wastewater discharge. In this study, we have focused on El Abid River and its tributary, Ahençal River, crosscutting the mountainous areas where agriculture and livestock are the main occupations of the people. These rivers constitute the major source of domestic water supply for the neighboring population and Beni Mellal and Azilal provinces, but at the same time, they receive back untreated domestic wastewater from many settlements and agricultural run-off. Hotels installed on the bank of Bin El Ouidane dam and washing of clothes constitute other point sources of wastewater. Therefore, possible deterioration of water quality can be happening especially in the downstream part which suffers from a general lack of equipment.

The objective of the present study is to analyze physicochemical parameters of river water quality from El Abid River and Ahençal River using Pearson's correlation, PCA and CA multivariate techniques, to determine the similarities and differences between the monitoring stations, and identify the contamination that affects water quality and their potential sources.

2. Materials and methods

2.1. Study area

The El Abid River, a major tributary of the Oum Er Rbia River, is located in the center of northern part in Morocco (Fig. 1), in Khenifra-Beni-Mellal region and Azilal province.

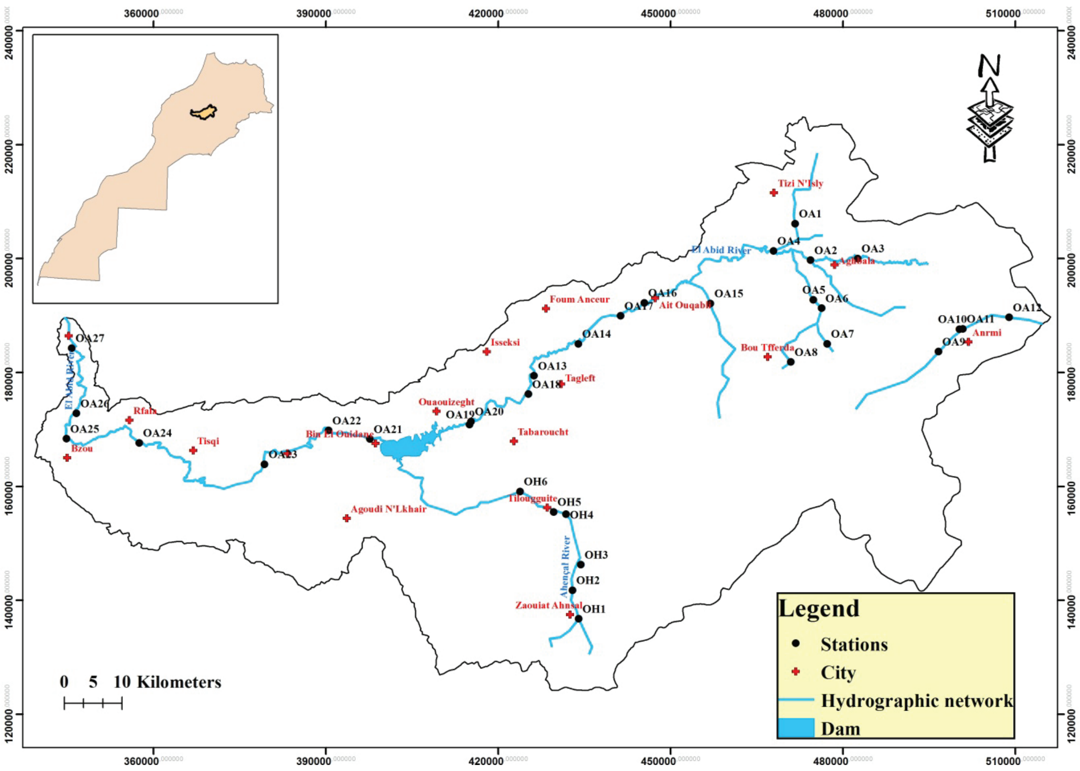

Fig. 1. El Abid basin river and water quality stations.

The upper part of the study area is characterized by a semi-arid climate, and concentration of rainfall in autumn and winter, high evaporation and high average temperatures with high monthly and daily amplitude. The minimum temperature is –5°C recorded in January while the maximum is 34.9°C in August.

The geological features of the study area exhibit limestone, marl and clay outcrops which the ages spread between the mesozoïc and the quaternary [24]. The El Abid basin is a mountainous region characterized by meadows, pastures, and cattle rearing. Frequency and intensity of inundations in recent decades have grown in the study area in a remarkable way due to heavy rain intensity, land use variation (urbanization, vegetal cover, deforestation) and rugged topography that is characterized by high slope [25]. Karaoui et al. [25] have reported that from the year 2013, the land use/cover in the Alfet River basin (El Abid River tributary) began to deteriorate and this degradation is generally followed by a very significant increase of precipitation flow peak and inundation intensity and subsequently the fatal damages.

2.2. Sampling and analysis

A refined observation network was designed to measure multiple parameters in different stations at key points throughout the villages crossing the El Abid River and Ahençal River in the wet season. 33 samples are sampled in bottles pre-rinsed with the effluent water, conserved at 4°C, transported in cooler boxes and then analyzed after 24 h. Stations OA1 to OA27 are located in El Abid River; OH1 to OH6 are situated in Ahençal River. 33 monitoring stations altogether are shown in the map below (Fig. 1). The data sets that comprise 16 water quality parameters which include the temperature (T), pH, electrical conductivity (EC), and total hardness (TH) were recorded in situ using a thermos-scientific portable multiparameter meter. Turbidity (NTU) was determined by turbidimeter; chloride (Cl^-), dissolved oxygen (DO), calcium (Ca^{2+}), magnesium (Mg^{2+}), and bicarbonate (HCO_3^-), were determined by volumetric titrimetry, and sulfate (SO_4^{2-}) was analyzed by spectrophotometry using the turbidimetric method. Sodium (Na^+) and potassium (K^+) were measured using BWB flame photometer. Nitrite (NO_2), nitrate (NO_3), and ammonium (NH_4) were estimated by a spectrophotometric technique. All the water quality parameters are expressed in mg/L, except pH, EC (µs/cm), and temperature (°C).

All samples were analyzed in the Georesources and Environment laboratory of the Faculty of Science and Techniques, Beni Mellal, and the laboratory of the National Office of Electricity and Water (ONEE), Morocco. The physicochemical analysis was performed following the standard methods [26]. All statistical computations in this study were implemented using Microsoft Excel 2007 and IBM SPSS 21 to prepare the correlation matrix of the surface water parameters.

2.3. Statistical procedures

The obtained data were subjected to multivariate analyses techniques in order to facilitate consistent evaluation of the multiple variables, through Pearson's correlation, PCA, CA. Pearson's correlation is a commonly used measure and to assess the relationship between two variables. It is a simple measure to exhibit how well one variable predicts the other. A coefficient correlation (r) of +1 indicates that two variables are perfectly related in a positive linear sense, but $r = -1$ indicates a negative linear correlation. However, no relationship between two variables exists if $r = 0$. Thus, two variables have a positive correlation coefficient infer that they have a common source, while a negative correlation coefficient indicates different source [27,28]. Further, to examine the suitability of the data for PCA, Kaiser-Meyer-Olkin (KMO) and Bartlett's test was performed [6]. KMO is a measure of sampling adequacy that indicates the proportion of variance, that is, which might be caused by underlying factors. The high value (close to 1) generally indicates that PCA analysis may be useful, which is the case in this study (i.e., KMO = 0.742). Bartlett's test of sphericity indicates whether the correlation matrix is an identity matrix, which would indicate that variables are unrelated. The significance level which is 0 in this study (less than 0.05) indicates that there are significant relationships among variables.

2.4. Principal component analysis (PCA)

PCA is a pattern recognition technique that attempts to interpret the variance within a large set of intercorrelated variables by converting them into a smaller set of independent variables [16]. It provides information on the most significant parameters used to describe the entire data set, data reduction, and to summarize the statistical correlation among constituents in the water with a minimum loss of original information [29–31]. PCA has been used on a correlation matrix of rearranged data to explain the structure of the underlying dataset and to identify the unobservable, latent pollution sources.

2.5. Cluster analysis

CA is a group of multivariate techniques whose primary purpose is to assemble objects based on the characteristics they possess [6,32]. It provides intuitive similarity relationships between any one sample and the entire data set and is typically illustrated by a dendrogram [6,13,33]. The resulting clusters of objects should then exhibit high internal (within-cluster) homogeneity and high external (between clusters) heterogeneity [6,13,16]. We employed in this study hierarchical CA on standardized data using Ward's method with squared Euclidean distance as a measure of similarity [6,9,32,34].

3. Results and discussion

3.1. Water quality evaluation

The summary of the maximum, minimum, mean, standard deviation of measured variables in the river water samples stations and the [35] are provided in Table 1. Pearson's correlation coefficient (r) gives an idea about the possible relationships between variables. Table 2 presents the values of Pearson's correlation coefficient matrix of variables at all sampling stations.

Water temperature is one of the most important factors which influence the aquatic ecology [36]. The recorder values

Table 1
Statistical descriptive for the parameters analyzed at all stations

	Minimum	Maximum	Mean	Standard deviation	Morrocan standards
Temperature	11.5	24.9	17.52	3.71	20
pH	7.5	8.2	7.87	0.16	6.5–8.5
EC	260	770	444.06	145.87	2,700
TH	188	642	346.30	118.87	300
Turbidity	5	1,000	522.33	446.19	5
DO	4.8	8.88	7.11	1.12	5–8
Na^+	5.6	100.8	35.90	27.45	
K^+	1.58	3.66	2.34	0.51	
Ca^{2+}	40.3	153	78.53	27.73	100
Mg^{2+}	34.41	120.65	61.69	22.92	
HCO_3^-	0	280.6	191.91	89.59	
Cl^-	2.84	205.9	52.33	44.92	
SO_4^{2-}	28.93	83.6	55.41	14.02	
NO_2^-	0.006	0.048	0.02	0.01	0.5
NO_3^-	0	0.171	0.05	0.03	50
NH_4^+	0.01	0.282	0.06	0.05	0.5

range from 11.5 to 24.9 with an average of 17.52. It remains at optimum level and was well within the safe limit of Moroccan standards. Temperature presents a significant positive correlation with EC (r = 0.639), TH (r = 0.688), Na^+ (r = 0.718), Ca^{2+} (r = 0.722), Mg^{2+} (r = 0.595), Cl^-(r = 0.690), HCO_3^- (r = 0.561), and NO_2^- (r = 0.576) and negative correlation with DO (r = –0.646).

All of the analyzed water samples have neutral pH values between 7.5 and 8.2 indicating alkaline nature. It was positively correlated with SO_4^{2-}.

The electrical conductivity (EC) is an index that represents the concentration of soluble salts in water. Ca^{2+}, Mg^{2+}, Cl^-, Na^+, and SO_4^{2-} are the main elements that cause the salinity [37]. Water electrical conductivity measurements changed from 260 to 770 μS/cm with mean values of 444.06 μS/cm. The level of EC is low with slightly highest values in downstream of El Abid River but it remains within the recommended range of Moroccan standards. E.C. showed significant positively correlated with T (r =0 .639), TH (r = 0.920), Na^+ (r = 0.884), Ca^{2+} (r = 0.859), Mg^{2+} (r = 0.958), and Cl^- (r = 0.825) but negatively correlated with DO (r = –0.303).

The TH is caused by the presence of too many minerals primarily soluble salts of calcium and magnesium. It was found to be in the range of 188 to 642 mg/L with mean values of 346.3 mg/L. The highest value is recorded in over than 57% of the samples especially in the downstream part of Al Abid River where TH exceeds the Moroccan standards fixed at 300 mg/L while Ahençal river shows normal values and therefore a good quality of water. There was a positive correlation between TH and EC (r = 0.920), T (r = 0.688), Na^+ (r = 0.872), Ca^{2+} (r = 0.863), Mg^{2+} (r = 0.902) and Cl^- (r = 0.875), and negative correlation with DO (r = –0.433).

Calcium and magnesium content range from 40.3 to 153 mg/L and Mg^+ ranges from 34.41 to 120.65 mg/L with mean values of 78.53 and 61.69 mg/L, respectively. Ca^{2+} values indicate that the water samples ranked as slightly high and exceeds the acceptable limit fixed at 100 (Moroccan standards) in OA5, OA8, and OA24 to OA27. The measured Ca concentration showed significant positive correlation with EC (r = 0.859), T (r = 0.722), TH (r = 0.863), Na^+ (r = 0.957), Mg^{2+} (r = 0.790), Cl^- (r = 0.927), and NO_2^- (r = 0.579) and negative correlation with DO (r = –0.519) while, Mg showed significant positive correlation with EC (r = 0.958), T (r = 0.595), TH (r = 0.902), Na^+ (r = 0.814), Ca^{2+}(r = 0.790), and Cl^- (r = 0.807). This indicates that Ca^{2+} and Mg^{2+} are likely due to the leaching of minerals from the basin rock.

Turbidity is a measure of the relative clarity or cloudiness of water [38,39]. It may result from mobilization of particulate matter such as sediments, mineral precipitates, biomass and his occurrence may be permanent or seasonal [40]. The turbidity concentration shows a wide range between 5 and 1,000 NTU. The very lower values were recorded in River Ahençal and the downstream of El Abid River after Bin El Ouidane dam. The highest values were recorded in El Abid River.

Most of the samples (over 75%) are far from the maximum permissible limits of Moroccan Standards fixed at 5 NTU. The turbidity in our case study comes from the adjacent outcrops and then it is a consequence of marl and chalk particles or of insoluble precipitations moved during rainfall and storms, and then responsible from siltation problem which suffers El Abid dam. No apparent correlation between turbidity and other parameters.

DO content is an essential parameter that maintains the equilibrium of aquatic ecosystems and the most sensitive parameters indicating organic pollution. The samples show values between 4.8 and 8.88 mg/L with a mean value of 7.11 mg/L qualifying the water quality as quality good to excellent mainly in Ahençal River. Spatially, lower values were observed at a downstream station where the small settlement was widespread, due to local domestic wastewater especially with the lack of an appropriate equipment. In correlation matrix, it was found that DO was negatively correlated to T (r = –0.646), Ca^{2+} (r = –0.519), HCO_3^- (r = –0.494), Cl^- (r = –0.454) and NO_2^- (r = –0.567).

Table 2
Correlation matrix of water quality parameters (Pearson correlation coefficients [r^2])

	T	pH	EC	TH	Turbidity	DO	Na^+	K^+	Ca^{2+}	Mg^{2+}	HCO_3^-	Cl^-	SO_4^{2-}	NO_2^-	NO_3^-	NH_4^+
T	1.000															
pH	0.096	1.000														
EC	**0.639**	0.248	1.000													
TH	**0.688**	0.160	**0.920**	1.000												
Turbidity	0.233	–0.021	–0.028	0.024	1.000											
DO	**–0.646**	0.130	**–0.303**	**–0.433**	–0.310	1.000										
Na^+	**0.718**	0.170	**0.884**	**0.872**	0.042	–0.390	1.000									
K^+	0.213	0.276	0.050	0.014	0.453	–0.290	0.087	1.000								
Ca^{2+}	**0.722**	0.084	**0.859**	**0.863**	0.051	**–0.519**	**0.957**	0.071	1.000							
Mg^{2+}	**0.595**	0.214	**0.958**	**0.902**	–0.048	–0.296	**0.814**	0.001	**0.790**	1.000						
HCO_3^-	**0.561**	0.379	0.290	0.314	0.482	**–0.494**	0.224	0.355	0.266	0.266	1.000					
Cl^-	**0.690**	0.126	**0.825**	**0.875**	0.078	**–0.454**	**0.942**	0.028	**0.927**	**0.807**	0.236	1.000				
SO_4^{2-}	0.147	**0.528**	–0.072	–0.100	0.017	–0.001	–0.025	0.283	–0.084	–0.122	0.342	–0.070	1.000			
NO_2^-	**0.576**	–0.056	0.395	0.422	0.211	**–0.567**	**0.551**	0.149	**0.579**	0.335	0.341	0.479	0.004	1.000		
NO_3^-	0.396	0.353	0.333	0.374	0.342	–0.214	0.326	0.246	0.289	0.364	0.413	0.433	0.059	–0.041	1.000	
NH_4^+	0.119	0.110	–0.167	0.044	0.316	–0.279	–0.052	0.501	–0.100	–0.180	0.198	–0.058	0.048	0.109	0.183	1.000

Sodium values indicate that Na^+ range from 5.6 to 100.8 mg/L with mean values of 35.9. It shows low values which tend to increase in downstream from OA20 to OA27 but they remain under the limit recommended, while the potassium indicates very low values which varied between 1.58 and 3.66 mg/L with a mean value of 2.34 mg/L. Sodium must have entered the water system through natural sources including weathering of feldspars (albite), leaching of clay minerals [41,42] and rainwater [43]. Na showed the positive correlation with T (r = 0.718), EC (r = 0.884), TH (r = 0.872), Ca^{2+} (r = 0.957), Mg^{2+} (r = 0.814), Cl^- (r = 0.942), and NO_2^- (r = 0.551), whereas K present positive correlation only with NH_4^+ (r = 0.501). Based on the mean values of the chemical parameters, the cations were in the order of abundance as $Ca^{2+} > Mg^{2+} > Na^+ > K^+$.

The anions geochemistry (HCO_3^-, SO_4^{2-}, Cl^-, NO_3^-, and NO_2^-) revealed large variations along the watercourse. The HCO_3^- was at the range from 0 to 280.6 mg/L with mean value of 191.91. It showed a positive correlation with T (r = 0.561) and negative correlation with DO (r = –0.494). The SO_4^{2-} changed from 28.93 to 83.6 mg/L and Cl^- ranges from 2.84 to 205.9 mg/L with averages of 55.41 and 52.33 mg/L, respectively. The measured SO_4^{2-} concentration showed positive correlation with pH (r = 0.528), while the measured Cl^- showed significant positive correlation with T (r = 0.690), EC (r = 0.825), TH (r = 0.875), Na^+ (r = 0.942), Ca^{2+} (r = 0.927), and Mg^{2+} (r = 0.807) and negative correlation with DO (r = –0.454). NO_3^- ranges from 0 to 0.171 mg/L with an average of 0.05 mg/L, there was no correlation either positive or negative with any variable. The average concentration of NO_2^- in this study was from 0.006 to 0.048 mg/L while NH_4^+ ranges from 0.01 to 0.282 mg/L. The anions reveal order of abundance as $HCO_3^- > SO_4^{2-} > Cl^- > NO_3^- > NO_2^-$. No apparent correlation between NH_4^+ and other variables. There was a positive correlation between NO_2^- and T (r = 0.576), Ca^{2+}(r = 0.579), and Na^+ (r = 0.551) and negative correlation with DO (r = –0.567).

3.2. Spatial similarity and site grouping

CA was used to detect the similarity groups between the sampling sites. It yielded a dendrogram, grouping all 33 sampling sites of the basin into three clusters (Fig. 2). The stations in each group have similar water contamination types, greatness [18] and natural background of the water quality characteristics [44].

Cluster 1 included stations OH1, OH2, OH3, OH4, OH5, OH6, OA1, OA7, OA8, OA9, OA12, OA19, OA20, OA21, OA22, and OA23. This cluster comprises all Ahençal river samples (OH1 to OH6), stations located in the upstream part of El Abid River (OA1, OA7, OA8, OA9, and OA12) and stations situated around the dam (OA19, OA20, OA21, OA22, and OA23). In this cluster, the Bin El Ouidane dam play a role of dilution and self-purification capability. The Cluster 2 consisted of stations OA2, OA3, OA4, OA10, OA11, OA13, OA14, OA15, OA16, OA17, and OA18. These two clusters 1 and 2 correspond to the good quality of water, this could be accredited to the fact that fewer human activities were taking place. Cluster 3 is a small cluster comprising the stations OA5 and OA6 that are sampled in N'ait Ouhssaine watercourse (a tributary of El Abid River) which situated in the upstream part of El Abid River while OA24, OA25, OA26, and OA27 that are located just downstream of the El Abid River. This cluster recorded high values in all monitoring parameters even they are still under the recommended limits of Moroccan Standards. It corresponds to a moderate water contamination cluster. Important anthropogenic sources can be detected and were spotting on a field in this river section (Cluster 3). This part of river received domestic wastewater effluents discharged directly into the watercourse and via their tributaries. Stations of all clusters receive pollutants from non-point sources, that is, mostly from domestic and animal waste, manure, soil leaching, and runoff [18].

The results indicate that the CA technique is useful in offering a reliable classification of surface waters and it will provide more insights on the design of sampling and monitoring network for effective management of reservoir water quality [45]. There are other reports [9,13,16,46,47] where a similar approach has successfully been applied to water quality programs.

3.3. Source identification of monitored variable/data structure determination and source identification

PCA was performed on the normalized data set to compare the compositional pattern between the water samples and to identify the factors influencing each one [45]. Thus the scree plot was used to identify the number of PCs to be retained. An eigenvalue of 1 or greater is considered significant [6] while variables with eigenvalues lower than 1, were removed due to their low significance [48]. In the present study, the scree plot (Fig. 3) showed a pronounced change of slope after the fourth eigenvalue; four components were retained. Liu et al. [49] classified the factor loadings as 'strong', 'moderate', and 'weak' where the absolute loading values are greater than 0.75, between 0.75 and 0.50 and between 0.50 and 0.30, respectively. Loadings of four retained PCs are expressed in Table 3.

The first factor (PC1), accounting 39.75% of the total variance, showed a high positive loading of EC, TH, Na^+, Ca^{2+}, Mg^{2+}, and Cl^-, moderate positive loading of T and weak negative loading of DO. This factor can be interpreted as a mineral component of the river water and points to a common origin for these minerals, likely from the dissolution of limestone and gypsum soils [50]. The second factor (PC2) explained 16.02% of the total variance and had a strong positive loading on turbidity, moderate positive loading on K^+, NH_4^+, NO_3^-, and HCO_3^- and weak negative loading on DO. This represented the stream input, surface runoff, and soil erosion in the basin and K^+ could come from livestock excrement [51].

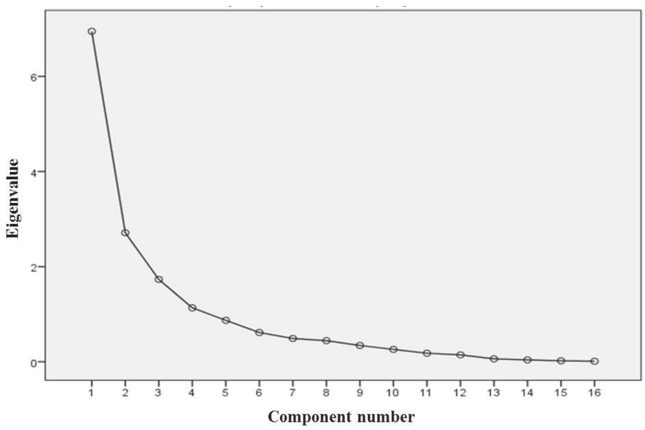

Fig. 3. Scree plot of the eigenvalues.

Table 3
Loading of experimental variables (16) on principal components for the whole datasets

	PC1	PC2	PC3	PC4
EC	**0.953**	–0.060	0.092	0.040
TH	**0.942**	0.064	–0.006	0.098
Mg^{2+}	**0.938**	–0.062	0.039	–0.026
Cl–	**0.932**	0.060	–0.024	0.145
Na^+	**0.929**	0.004	0.049	0.212
Ca^{2+}	**0.910**	0.011	–0.018	0.307
T	0.686	0.306	0.160	0.439
Turbidity	–0.001	**0.788**	–0.075	0.101
NH_4^+	–0.134	0.700	–0.011	0.060
K^+	–0.014	0.692	0.299	0.088
NO_3^-	0.475	0.563	0.132	–0.444
HCO_3^-	0.265	0.555	0.464	0.253
SO_4^-	–0.137	0.035	**0.891**	0.146
pH	0.205	0.114	**0.811**	–0.327
NO_2^-	0.391	0.129	0.010	**0.776**
DO	–0.358	–0.460	0.075	–0.629
Eigenvalues	6.361	2.565	1.825	1.774
% of variance	39.755	16.028	11.406	11.086
% Cumulative	39.755	55.783	67.189	78.275

Note: Bold values represent significant correlation.

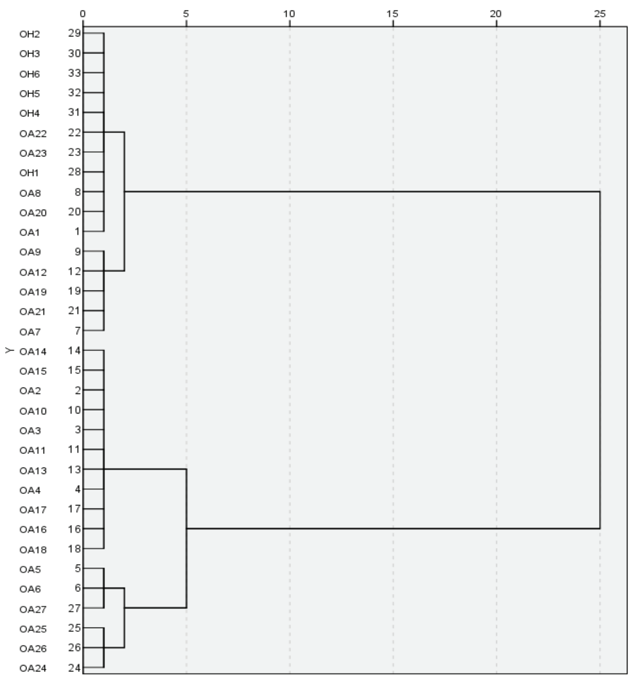

Fig. 2. Dendrogram based on hierarchical clustering (wards method) for complete stations.

The studied rivers and especially El Abid River receive a large amount of debris due to continuous erosion of soil from the river watersheds and of the Atlas Mountain [18].

The third factor (PC3), which described 11.4% of the total variance, had strong positive loading on pH and SO_4^- and weak positive loadings on HCO_3^-. It can be due to the anaerobic conditions in the river and the signature of livestock excrement.

The fourth factor (PC4) explaining 11.06% of the total variance and had strong positive loading on NO_2^-, moderate negative loading on DO and weak negative loading on NO_3^-. This factor represents anthropogenic pollution sources such as domestic waste.

It should be noted that further DO was negatively correlated to all variables, it represents also a negative loading with PC1, PC2, and PC4. Patel and Vaghani [52] conclude in Par River Valsad, Gujarat, India, that from correlation analysis the negative relationship of DO with the other parameters reveals the high organic pollution with anthropogenic activities in the river basin. Therefore, this represents a serious threat to the ecosystem. The similar observation was found by Chow et al. [45] in Fei-Tsui Reservoir basin. Taiwan when VF2 (rotated PCs) has a negative loading on DO in the winter unlike other seasons and they suggest that seasonal variation in water quality parameters has occurred in the reservoir water system. These PCA analyses identified the potential contamination sources of El Abid and Ahençal Rivers. This contamination is due to a mixed source including natural processes and anthropogenic activities. The discharging untreated rural waste into surface water system constitutes the major point anthropogenic contamination source. The non-point source which also contributes immensely to water contamination is manure and livestock.

4. Conclusion

This study was conducted to assess the water quality of the El Abid River and its tributaries and to identify the sources of contamination. Multivariate statistics including Pearson's correlation, PCA and CA were employed to evaluate spatial variations of surface river water quality data. According to the obtained physicochemical results, some variables at downstream stations showed concentrations exceed those recommended by the guide levels allowed by the Moroccan Standards concerning the quality of river water. This indicated that the river water is affected in the downstream part. The PCA helped in identifying the factors and sources responsible for water quality variations. Variable factors obtained indicate that the parameters responsible for water quality variations are mainly related to natural process (soluble salts and the erosion from upland areas during rainfall events) and the contribution of the anthropogenic sources (domestic wastewater). CA grouped the 33 sampling sites into three clusters of similar characteristics pertaining to water quality characteristics. Extracted grouping information can be of use in reducing the number of sampling sites on the river without missing much information, losing time and it can reduce the associated costs. The results of this study could assist decision-makers in assessing the water quality level via practical pollution indicators. It could also provide a reliable guideline for selecting the priorities of possible controlling measures in the sustainable management of reservoir water quality.

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