Multivariate Analysis to Assess the Quality of Irrigation Water in a Semi-Arid Region of North West of Algeria : Case of Ghrib Dam

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Abstract

Dams are critical to agriculture, industry, and the needs of humans and wildlife. This study evaluates the water quality of the Ghrib dam in north west of Algeria, using Irrigation Water Quality Index (IWQI), sodium absorption rates (SAR) and multivariate statistical methods (Clustering and principal component analysis). The study concerns the analysis of physical and chemical parameters (pH, EC, O_2, TUR, Ca, Mg, HCO_3, Na, K, BOD, DCO, Cl^-, PO_4, SO_3. NH_4 et NO_3) which were measured at twelve selected points along the dam over 8 periods (dry and wet periods) using standard methods.

Irrigation Water Quality Index values in the dam were found to be between 41 and 59, according to classifications for different water uses, values below 60 indicate that water is of poor quality for irrigation and treatment is recommended to make dam water more suitable for irrigation.

The results of water analysis in our study area reveal the presence of acute pollution which is certainly caused by direct releases of either industrial or domestic origin, and we note that this pollution remains variable depending on the collection periods. Also, Chloride-calcium and sulfate facies are the most dominant in sampling periods for dam water, resulting in poor water quality for irrigation. In addition, water is, therefore, highly mineralized and is likely to be suitable for irrigation of certain species (cucumbers...) that are well tolerant to salt and on well-drained and leached soils.

1. Introduction

The Earth's Critical Zone (CZ) is defined by the thin layer of the Earth's surface and its environment that extends vertically between the top of the vegetation canopy (or atmosphere-vegetation interface) and the bottom of the alteration zone (or freshwater-bed substrate interface) (National Research Council, 2001) and horizontally encompasses nested basins associated with the surface and sub-surface structure that develop at geological time scales (Brooks et al., 2015). The TZ provides all the vital resources on which life originates, evolves, and thrives (Merhabi et al., 2019). Understanding the functioning of the Critical Zone is an increasingly important issue raised by the public and the scientific community (Banwart et al., 2013), especially at a time when the Critical Zone is continuously disrupted by socio-economic development, rapid human population growth, intensive land use, global environmental changes and expanding consumption patterns (IPCC, 2013).

Water, a vital commodity on earth and a component of this critical land area, is a recyclable resource. However, it must be managed and protected because of its vulnerability to overexploitation and pollution (Osuolal and Okoh, 2017). Water pollution is a physical, chemical, biological, or bacteriological degradation of its natural qualities, it disturbs the living conditions of aquatic flora and fauna. Several agricultural fields have also been destroyed because of the use of polluted water from the wadis for irrigation (Debieche, 2002). This pollution in developing countries is often due to anthropogenic activities due to uncontrollable urbanization (Youmbi et al., 2013) with the often lack of adequate treatment of the wastewater generated and their direct discharge into the natural environment.

Water quality used for irrigation is an essential parameter for crop yields, maintenance of soil productivity and environmental protection. Thus, the physical and chemical properties of the soil, such as its structure (aggregate stability) and permeability, are very sensitive to the type of potentially tradable ions present in irrigation waters. Irrigation water quality can be better determined by chemical analysis in the laboratory.

The low quality of irrigation water is characterized by a reduction of dissolved oxygen, a lower transparency, a high electric conductivity, a high alkalinity, a water temperature increase, and high levels of total dissolved solids (Al Hadrami, 2013). The irrigation water quality index (IWQI) represents a gathering of individual water parameters that are expressed in a single numerical expression to judge the use of water for irrigation purposes (Noori et al., 2019).

Therefore, irrigation water contains several dissolved salts (Machael, 1985; Allen and MacAdam, 2020; Kurunc et al., 2020). The characteristics and amount of these dissolved salts depend on the water source and its chemical composition. The most ordinarily dissolved ions in water are calcium (Ca^{2+}), sodium (Na^+), magnesium (Mg^{2+}), sulfate ($SO4_2^-$), nitrate (NO_3^-), chloride (Cl^-) and bicarbonates (HCO_3^-). The proportion and concentration of these dissolved ions are used to determine the suitability of water for irrigation (Ajayi and Nduru, 1990; Perez, 2011; Sarkar and Islam, 2019).

Water irrigation quality for agricultural use is determined based on its impact on crop yield (quality and quantity), as well as its impact on soil physiochemical properties (FAO, 1985). Most soil problems (e.g., salinity, sodicity, contamination, and restricted infiltration) are due to the use of low-quality water for irrigation (US Salinity Laboratory, 1954).

Indeed, the irrigation perimeter of Upper Cheliff and its plains, which are part of the northern part of the Cheliff watershed in northern Algeria and which are supplied with water mainly from dams, are among the twenty-five (25) large perimeters that total an area equipped with more than 200,000 ha, as well as nearly 164,000 ha (79%) irrigable (ONID, 2012). According to the Ministry of Water Resources (2019), the annual need for irrigation water by 2030 will have to be 8.3 billion m^3 for a population of around 50 million people, compared to 6.8 billion m^3 currently (Hallouz et al., 2021).

The quality of irrigation water in this region has deteriorated in recent years due to uncontrolled urban discharges, the intensive use of chemical fertilizers in agriculture and its disorganized exploitation. These elements modify the chemistry of the water and make it unfit for the desired uses.

The study objective was to assess the irrigation water quality of the Ghrib dam at twelve locations during the rainy season (before irrigation season). Therefore, multivariate statistical methods such as Principal Component Analysis (PCA) and Hierarchical Cluster Analysis (HCA) are used in numerous studies to identify potential pollutants (Gholami and Srikantaswamy, 2009; Fan et al., 2010; Massoud, 2012; Lin et al., 2017; Misaghi et al., 2017; Zamani-Ahmad mahmoodi et al., 2017). PCA is a multivariate statistical technique, and in the cases where large amount of data is available, it is a suitable means to decrease the data (Noori et al., 2009, 2010). In addition, HCA is one of the multivariate statistical techniques used to determine relative similarity in the homogeneity of measured parameters (Shrestha and Kazama, 2007; Fathi et al., 2018). In the present study, the water quality of the Ghrib dam has been evaluated using SAR, IWQI, HCA, and PCA in selected sampling points.

The IWQI is clearly a useful tool to evaluate water quality given a criterion for surface water classification (Swamee and Tyagi, 2000; Cude, 2001; Nagel et al., 2001; Liou et al., 2003; De La Mora-Orozco et al., 2017).

2. Materials And Methods

2.1. Study area

The Cheliff Valley, crossed by the Wadi Cheliff, is in the northern part of the Cheliff watershed, which occupies 22% of the area of Northern Algeria (ONID, 2006).

The perimeter of Upper Cheliff is both the oldest and most extensive of the Algerian irrigable perimeters. Created in 1941, it is 40 km as the crow flies from the sea. It stretches along the Wadi Cheliff valley on the right and left banks from the city of Djendel in the east to the city of El Attaf in the west, a length of about 75 km (Fig. 1). The average width of the perimeter is 8 km. The Wadi Cheliff, over a length of 730 km, is the main adductor carrying water released from the dams towards the perimeter (Hallouz et al., 2021).

The Cheliff-Ghrib wadi watershed, with an area of 1378 km^2, is elongated in the axis of the mainstream and is characterized by strong relief because the specific gradient is between 250 and 500 m. The Chorfa Wadi, on which the Ghrib Dam is located, is a tributary of the Cheliff Wadi, its outlet is about 20 km southwest of the Medea wilaya. Indeed, this basin has a relief that reaches an altitude of 1500 meters, while the lowest point is at the outlet with an altitude of 400 meters. Geographically, the topography and relief of the plain are very varied by the resulting combination of two factors (altitude and slope) and presents steep slopes from the upstream Djendel region to Khemis Miliana and downstream from Aribs. The wadi feeding the Ghrib dam is the Cheliff wadi which originates in Djebel Ammour in the Saharan Atlas near Aflou, it is the only Algerian river which, taking its source in the Saharan Atlas, flows into the Mediterranean (Monographie du Barrage, 1965). The Ghrib dam was built in 1927 and was put into water in 1939; with an initial capacity of 280 Mm^3 and ensures the irrigation of the upper Cheliff plain (Merili et Belouazani, 2016).

The Cheliff Ghrib Wadi watershed is part of the Cheliff Wadi Basin. It is located 100 km south-west of Algiers, between 2–25' and 3–45' of east longitude and between 35–45' and 36 – 00' from the northern altitude. It drains an area of 1405 km^2 and a perimeter of 177.9 km. The Wadi Cheliff Ghrib covers 69.95 km following a South-East orientation to the West of the watershed, the relief reaches an altitude of 1284 meters, while the lowest point is at the outlet with an altitude of 351 meters. Administratively, the Ghrib sub-basin is part of two wilayas Médéa and Ain Defla (Fig. 1).

The Ghrib Dam was commissioned in 1939 with an initial capacity of 280 Mm^3. It is designed for different uses (Drinking Water Supply, irrigation). Its total capacity is currently 116.32 Mm^3.

The Ghrib sub-basin is characterized by a diversified relief. In the south and east, we find mountains that exceed 1000 m in altitude. In the center of the watershed are valleys, they are characterized by the lowest altitude of the basin of 350.7 m, with very low slopes to the west (Cheridi and Djebouri, 2016).

The Ghrib dam is in a region of Helvetian age lands, constituted by an alternation of sandstone and marl. The general dip, which is that of the Miocene sea beaches, is directed from South to North, it is therefore unfavorable for the establishment of a stop to the water thrusts. The thickness of the various banks is very variable. Thus, some sandstone horizons, such as the sandstone called superior according to a denomination of building site, has a sufficient power to receive the works of the dams on almost all their height (Fig. 2).

However, some of the highly continuous marl levels are only a few centimeters thick, but this is enough to create an autonomous aquifer level.

The waterproofing of the reservoir around the dam is provided by the upper marl, the middle sandstone which has been cemented over a large area and the so-called lower marl whose thickness is quite large. As for the basin itself, it belongs largely to the Cretaceous period and comprises a predominance of marl and shale, thus impermeable rocks.

The tectonic structure plays a major role in the morphology of this region. To the allochthonous corresponds high peaks but with a rather soft relief and anarchic architecture. However, to the Cretaceous native corresponds reliefs generally oriented East-west, parallel to the axis and tectonic folds, this set is dominated by the western ending of the Bibans whose flysch mass culminates at 1249 m. Only the Wadi Seghouane valley is oriented north-south, constituting an excellent passageway for the great Algiers-Laghouat road ((Cheridi and Djebouri, 2016).

To the east of Berrouaghia, a topographical depression corresponding to the marls of the Late Cretaceous separates the Bibans from the southern Tellian zone and facilitates communications in the eastern direction. The quaternary is quite reduced. Apart from some scree veneers on the slopes, it is essentially made up of fine alluvial filling in the wadi beds, with locally remains of older terraces testifying to a resumption of current erosion (Mokhtari 2017).

The Miocene outcropping in the northern part of the sheet constitutes the southern edge of the large Medea basin, which extends to the west by the Cheliff basin and to the east towards Bouira.

An Oligocene series of the same facies as that known further east on the Souagui sheet at Draâ el Mensdjel, where coarse oyster sandstones, gray sandy marls, and detrital limestones, attributed to the Oligocene, are observed over several hundred meters.

The Tellian slicks, generally devoid of any vegetation, oppose the Cretaceous of the Biban. This one is unevenly covered with different species (Mokhtari, 2017):

-The Albian flysch corresponds to a vegetation where thorny trees and holm oaks dominate, accompanied by rare cork oaks;

- On the Cenomanian marls, forming the depression of Berrouaghia, vines and some cereals are grown;

On the marly series of the Senonian grows, where it has not been destroyed by goats and sheep or by fire during the war, a thin pine forest.

- Aleppo pines and junipers cover most of the Cretaceous zone where only meager cereal crops are found in the clearings or in the narrow valley of the Cheliff.

- On the other hand, in the rest of the country, if the sandstone massifs only support scattered bushes, the marly depressions and the large alluvial valleys are covered by rich cereal crops (wheat and barley).

The Ghrib Dam is arguably the most visited of the large reservoirs that Algeria has built in a quarter of a century (ANBT, 2014). It is in the Cheliff Valley 07 km upstream from the center of Wadi Chorfa, 45km from Khemis Miliana, 30km south-west of Medea and 150km west of Algiers.

The climate, in the study region, is Mediterranean type, it is characterized by hot and dry summers. Autumns and springs can be very rainy. Annual rainfall is around 800mm and is concentrated over a few months (Bourdelle 1995). Temperatures average from 21 to 25 degrees Celsius in June and August and 7 degrees Celsius to 8 degrees Celsius in January and December (Merili et Belouazni, 2016).

In addition, a long period of drought hit the study area over six months, from May to October during the period 2000–2014 (ANRH, 2014).

2.2. Field sampling and Analytical procedures

Within the framework of monitoring the state of the quality of irrigation water at the Ghrib dam, two water withdrawal campaigns were carried out. The first one was carried out on January 30, 2016 (before the irrigation campaign: wet season) and the second one on May 2, 2016 (during the irrigation campaign: dry season), these withdrawals were carried out manually. For this reason, six (06) points were chosen for our samples. The sampling steps directly influence the quality of the results obtained. Elementary precautions are therefore necessary to minimize the risks associated with contamination and to enable the integrity of the samples to be maintained. Water sampling can be carried out in several ways depending on the size of the watercourse and the accessibility of the site, in the case of dams and wadis. Ideally, the sample should be taken in the center of the watercourse at a depth of 15 to 150 cm and in such a way as to avoid the effects of the edge (oxygenation too close to the surface, suspension of solid matter too close to the bottom...), facing the water current. This is called point sampling (AQUA-REF, 2011).

The 2016 samples were collected and analyzed by us; they are distributed as follows (Fig. 3):

1st campaign (January 30th, 2016):

- (P1) sampling at the entrance of the basin of the dam, (P2): in the middle of the basin, (P3): at the level of the Chorfa wadi (exit of the dam).

2nd campaign (May 2nd, 2016):

- (P4) sampling at the entrance of the basin of the dam, (P5): in the middle of the basin, (P6): at the level of the Chorfa wadi (exit of the dam).

But the samples P7, P8, P9, P10, P11 and P12, they were collected and analyzed by ANRH and ANBT (Fig. 3).

One-liter polypropylene bottles were used for water sample collection. Prior to sample collection, all bottles were washed with very dilute hydrochloric acid followed by demineralized water. All samples were collected from the middle point of the river and a depth of 15 to 150 cm from the water surface. Before taking final water samples, the bottles were rinsed several times with the water sample to be collected. The sample bottles were then sealed & labeled with date immediately and transported to the laboratory and preserved in refrigerator (4°C) prior to processing and analysis. Samples were preserved and analyzed according to standard methods. The pH, electrical conductivity and dissolved oxygen were measured in situ (on site) using a multi-parameter instrument. The parameters were analyzed in the laboratory of ADE-Ain Defla (Algérienne Des Eaux). Indeed, these parameters are very sensitive to environmental conditions and are likely to vary in significant proportions if they are not measured in situ (Rodier, 2009).

All the water quality parameters were analyzed according to the standard methods. The following 16 parameters (Table 1) were quantified in the laboratory: alkalinity (HCO_3), Tur., NO_3, SO_4, NH_4, PO_4, Cl^-, Ca^{2+}, Mg^{2+}, Na^+, K, BOD, and DCO. The parameters used for the IWQI were selected for their importance for irrigation and regional crops.

Table 1
Measurement methods for the water quality parameters.

N	Parameter	Unit	Method	Site
1	BOD	mg l^{-1}	Azide modification at 20 _C (5 D)	in situ
2	pH	mg l^{-1}	WTW portable multi-meter 340i	Laboratory
3	DO	NTU	WTW portable multi-meter 340i	in situ
4	Tur.	mg l^{-1}	Turbidimetric	in situ
5	PO_4	mg l^{-1}	Molybdate ascorbic acid method	Laboratory
6	NO_3	mg l^{-1}	Silver nitrate titration method	Laboratory
7	Cl^-	dS m^{-1}	Argentometric titration	Laboratory
8	EC	mg l^{-1}	WTW portable multi-meter 340i	Laboratory
9	Alkalinity (HCO_3)	mg l^{-1}	Titration method	in situ
10	Ca	mg l^{-1}	Titration	Laboratory
11	Mg	mg l^{-1}	Titration	Laboratory
12	Na	mg l^{-1}	Photometry—flame emission	Laboratory
13	K	mg l^{-1}	Photometry—flame emission	Laboratory
14	NH_4	mg l^{-1}	Nessler is reagent spectrophotometry	Laboratory
15	SO_4	mg l^{-1}	Spectrophotometric	Laboratory
16	DCO	mg l^{-1}	Spectrophotometric	Laboratory

2.3. Obtaining the sodium content of mixtures

The danger of alkalisation is expressed by the SAR value, which is expressed as follows : Ca^{2+}, Mg^{2+} and Na^+ are expressed in mmg.L-1. The SAR does not take into account changes in the Ca^{2+} content of soil water caused by precipitation or dissolution during or after irrigation. Sodium, which is an important factor in salinity, remains constantly soluble and in equilibrium with exchangeable sodium. External agents have little influence on the dissolution or precipitation of sodium, whether it is concentrated by plant samples between two irrigations, diluted by applied water or leached by drainage (Benkhelifa et al., 2008).

The quantities involved are determined by the relationship: $2[Na]^2 + SAR^2. [Na] - SAR^2.[C] = 0$, derived from SAR expressions and saline concentration [C] :

$$SAR = \frac{[Na^+]}{\sqrt{\frac{[Ca^{++}]+[Mg^{++}]}{2}}}; 2[C](\mathrm{meq}.l^{-1}) = [Na^+](meq.l^{-1}) + [Ca^{++}](meq.l^{-1}) \quad \text{......(1)}$$

2.4. Calculation of the IWQI

The Irrigation Water Quality Index (IWQI) is a numeric expression used to evaluate the quality of a given water body meant to be easily understood by managers from many countries (Ionus, 2010). This index was for the first time used to highlight the physical-chemical changes that may occur during the year on the flowing water quality (House and Ellis, 1987; House, 1990; Andreea-Mihaela, 2018).

The IWQI was established in three steps the first of which was to normalize individual values used to design the index (De La Mora-Orozco et al., 2017). This was done to establish a correspondence of the results obtained for each parameter with a variable scale of 0 to 100 based on the maximum values established in official standards (De La Mora-Orozco et al., 2017). A value of 100% indicates optimal natural conditions, while 50% indicates significant constraints in water use. Tables 2 and 3 present the parameters used to calculate the IWQI with their corresponding normalizations (Conesa, 1995). The second step in determining the IWQI was to assign numerical weights to the parameters, which were established according to their importance in normal criteria of quality (De La Mora-Orozco et al., 2017). Table 4 shows the assigned weights.

The third step was calculating the IWQI by applying the following Equation (Léon-Vizcaíno, 1991):

$$IWQI = \sum_{i=1}^{n} \frac{\sum_{i=1}^{n} W_i Q_i}{\sum_{i=1}^{n} W_i} \quad \text{......(2)}$$

Where Qi is the parameter value (%), and Wi is the weight given to each parameter. The results were interpreted according to the intervals, where 4 of the categories of the IWQI are as follows: 0 to 39% indicates highly contaminated water; 40–59% poor water quality, 60–90% good quality, and 90–100% excellent quality (Léon-Vizcaíno, 1991).

Table 2. Normalization of individual values.

Parameters	pH $ds.m^{-1}$	EC $mg. l^{-1}$	DO $mg. l^{-1}$	HCO_3 $mg. l^{-1}$	CL^- $mg. l^{-1}$	NO_3 $mg. l^{-1}$	SO_4 $mg. l^{-1}$	Ca $mg. l^{-1}$	Mg $mg. l^{-1}$	Na $mg. l^{-1}$	K $mg. l^{-1}$	Value %
	1/14	>16.00	0	>1.500	>400	>55	>250	>250	>50	>90	>35	0
	2/13	12	1	1	350	50	225	225	45	80	30	10
	3/12	8	2	800	300	45	200	200	40	70	25	20
	4/11	5	3	600	250	40	175	175	35	60	20	30
Analytical value	5/10	3	3.5	500	200	35	150	150	30	50	15	40
	6/9.5	2.5	4	400	150	30	130	120	24	40	10	50
	6.5	2	5	300	100	25	100	100	20	30	8	60
	9	1.5	6	200	50	20	75	75	15	20	6	70
	8.5	1.25	6.5	100	25	10	50	50	10	10	4	80
	8	1	7	50	10	5	25	25	5	5	2	90
	7	<750	7.5	<25	<10	<5	<10	<20	<5	<5	<1	100

Table 3. Weight given to the parameters in calculating the Irrigation water quality index (IWQI).

Parameter	Weight (Wi)
pH	2
EC	3
DO	1
HCO_3	3
Cl^-	3
NO_3	1
SO_4	5
Ca	2
Mg	3
Na	5
K	5

The Irrigation Water Quality Index uses a scale from 0 to 100 to rate the quality of the water, with 100 being the highest possible score. Once the overall IWQI score is known, it can be compared against the following scale to determine how healthy the water is on a given day.

Water supplies with ratings falling in the good or excellent range would be able to support a high diversity of aquatic life. In addition, the water would also be suitable for all forms of recreation, including those involving direct contact with the water. Water supplies achieving only an average rating generally have less diversity of aquatic organisms and frequently have increased algae growth.

Water supplies falling into the fair range are only able to support a low diversity of aquatic life and are probably experiencing problems with pollution. Water supplies that fall into the poor category may only be able to support a limited number of aquatic life forms, and it is expected that these waters have abundant quality problems. A water supply with a poor-quality rating would not normally be considered acceptable for activities involving direct contact with the water (Fathi et al., 2018).

2.5. Statistical study

The statistical software XL-STAT Version 2014.5.03 (https://www.xlstat.com) was used for statistical analysis. Principal Component Analysis (PCA) and Hierarchical Cluster Analysis (HCA) are used in this study to identify potential pollutants According to Singh et al., (2004), PCA delivers strategies on spatial and temporal distribution of resultant factors.

The Principal Component Analysis (PCA) and the Hierarchical Cluster Analysis (HCA) allow to study the phenomena at the origin of the mineralization of waters, the grouping of waters and to identify the factors responsible of these groupings.

a/ Principal component analysis (PCA)

Perhaps the oldest multivariate method, was introduced by Pierson for the first time in 1901 and later by Hotelling (1933). The main idea in PCA is to reduce the dimensions of the data that feature a relatively high correlation in terms of modulus. To reduce dimensions, data are converted into new variables that are PCs or indicators independent from one another. The process is carried out in such a way that the first several indicators incorporate a large part of the variation in the entire data. The changes are larger in the first indicator than the second one, and in the second indicator more than the third, and so on (Johnson and Hanson 1995). Instead of making direct use of the input variables, they can be converted to PCs that can be subsequently applied as the throughputs. Input variables are offered with the least loss of the principal components (Johnson and Hanson 1995; Biazar et al., 2020). The correlation matrix between the different variables has been established.

The central idea of principal component analysis (PCA) is to reduce the dimensionality of a dataset consisting of many interrelated variables while maximizing the variation present in the data. PCA provides information on the most meaningful parameters which describe the whole data set, data reduction and to summarize the statistical correlation among constituents in water with minimum loss of original information (Saluja and Garg, 2015).

b/ Hierarchical Cluster Analysis

Hierarchical Cluster Analysis is a group of multivariate techniques whose primary purpose is to assemble objects based on their characteristics (Simeonova et al., 2003). The results of CA help to interpret the data and examine patterns. Two common methods for cluster analysis are: Hierarchical and Non-hierarchical cluster analysis. In this study, Hierarchical CA was performed on the standardized dataset using Ward's method with squared Euclidean distance as a measure of similarity. This method uses analysis of variance approach to evaluate the distances between clusters, attempting to minimize the sum of squares of any two clusters that can be formed at each step. Standardization of the data values minimizes the influence of differing variances and eliminates the influence of different units of measurement (Simeonova et al., 2003). Dendrogram provides a visual summary of the clustering processes, presenting a picture of the groups and their proximity, with a dramatic reduction in the dimensionality of the original data (Saluja and Garg, 2015).

3. Results And Discussion

3.1. Irrigation water quality parameters

The concentration of all physicochemical parameters of water in the study area are presented in the table4.

Water temperature is one of the most important factors in aquatic environment since it regulates physicochemical as well as biological activities (Kumar and Siddiqui, 1997). Minimum and maximum surface water temperatures at the Ghrib Dam are observed during January and September respectively (table 4). The water temperature of the dam is affected by the change in season and temperature fluctuations. pH is inseparable from temperature values, dissolved oxygen, and electrical conductivity, because during the day the intense absorption of CO_2 leads to an evolution of pH and precipitation of carbonates (Arrignon,1991, El Houati et al., 2013). The pH values range from 8.49 (P1) to 8.37 (P3) during January 2016 and between 8.13 (P5) and 6.23 (P4) during May 2016 and from 8.3 (P7) to 7.8 (P11) during April 2017 and April 2018 respectively (Table 4). The observed values indicate that the pH is slightly alkaline neutral at all points of the sample, this is due to the presence of carbonates that allow to buffer the water that flows towards the dam, pH values are, therefore, acceptable for irrigation as they meet FAO standards (6 à 8,5. Electrical conductivity is proportional to the amount of dissolved ionizable salts and is a bio-indicator of the degree of water mineralization (Nisbet and Verneaux 1970). The more the conductivity of water the lesser is its resistance to electric flow thereby indicating higher concentration of dissolved salts and higher trophic status of the system (Kumar and Siddiqui, 1997). The results show that the values of electrical conductivity fluctuate between 2.75 to 3.80 ds/m for the waters of January 2016 and 2.74 to 3.20 ds/m for the waters of the second campaign, between 2.4 and 2.2 ds/m during April and September 2017 respectively and between 2.5 and 2 ds/m during February and May 2018, which does not meet the standards demanded by FAO. These values indicate a strong mineralization of the waters in the Ghrib Dam. This excess mineralization is due to contact with rocks during the water path through the various geological formations of the Ghrib Dam.

Tableau 4. Descriptive statistics of Dam water parameters in comparison with FAO (1996)

Statistique	Unit	SAMPLE 1 (P1, P2, P3)				SAMPLE 2 (P4, P5, P6)				SAMPLE 7	SAMPLE 8	SAMPLE 9	SAMPLE 10	SAMPL 11
		Min	Max	Mean	SD	Min	Max	Mean	SD					
HCO_3^-	mmg.L^{-1}	93	152	107.8	28.17	155	178.6	158.6	10.56	212	202	216	216	218
NH_4^+	mmg.L^{-1}	0.144	0.239	0.203	0.052	0.02	0.24	0.17	0.12	1	0.58	0.3	0.38	0.4
EC	dS.m^{-1}	2.75	3.8	3.3	0.42	2.74	3.2	2.93	0.11	2.4	2.2	2.5	2.2	2.4
Ca^{2+}	mmg.L^{-1}	188.58	322	249.8	40.08	162	243	200.4	32.73	136	126	116	117	138
Cl^-	mmg.L^{-1}	270.03	280	268.2	13.66	197	240	218.65	20.26	322	290	320	360	315
BOD	mmg.L^{-1}	4	14	7.33	4.93	3	4	2.67	0.58	5.1	4.4	3	1.1	1.1
DCO	mmg.L^{-1}	18	28	21	5.57	24	28	24.33	2.52	34	19	15.1	9.0	20
Mg^{2+}	mmg.L^{-1}	43	114	77.64	36.16	66	205	128.48	68.21	82	242	74	73	86
NO_3^-	mmg.L^{-1}	0.86	1.84	1.26	0.49	1.32	3.48	2.46	1.12	3.85	10.42	0.6	0.16	0
DO	mmg.L^{-1}	10.92	11.59	11	0.18	9.27	9.48	9.25	0.09	10.06	8.40	10.2	10.73	9.95
PO_4^{3-}	mmg.L^{-1}	0.352	0.507	0.406	0.09	0	0.5	0.17	0.29	0.474	0.1	0.12	0.2	0.1
K^+	mmg.L^{-1}	5.65	7.62	6.57	0.9	6.98	7.90	7.9	0.48	5.6	6.1	4.2	5	7.2
SAR	Meq.L^{-1}	0.006	0.05	0.026	0.018	0.05	0.02	0.042	0.003	0.021	0.018	0.023	0.024	0.022
Na^+	mmg.L^{-1}	0.75	3.55	2.22	1.5	2.57	3.27	2.8	0.41	2.27	2.42	2.25	2.40	2.2
SO_4^{2-}	mmg.L^{-1}	154	275	202	65.35	108	134	119	12.43	472	488	540	520	475
Tur.	NTU	9.92	10.33	10.04	0.18	5.02	11	6.39	3.35	5	12.3	3.4	5	4
pH	-	8.54	8.74	8.46	0.08	6.44	8.35	7.33	0.98	8.3	7.95	8.2	8.2	7.8

Dissolved oxygen is one of the most important parameters in assessing the quality of water, which affects the survival and distribution of flora and fauna. Oxygen content is important for direct need of many organisms and affects solubility of many nutrients and therefore, productivity of aquatic ecosystem (Wetzel, 1983). Variations in dissolved oxygen are related to several factors, mainly temperature and salinity (Lacaze 1996). Low concentration promotes the development of algae and parasites, which are responsible for the presence of toxic substances. Based on the results, the observed values of dissolved oxygen range from 10.92 to 11.59 mmg.L^{-1} for the 1st campaign and 9.27 to 9.48 mmg.L^{-1} for the 2nd campaign. Also, for the year 2017, the value of dissolved oxygen was between 8.40 mmg.L-1 during the month of September 2017 and 10.06 mmg.L-1 during the month of April 2017, while the values oscillated between 7.85 mmg.L^{-1} (month of May) and 10.73 mmg.L^{-1} (month of March) in 2018. It noticed that the values of dissolved Oxygen of the 2nd campaign, April 2017, and March 2018are low (below 10 mmg.L-1 minimum acceptable value) which shows the presence of organic pollution. These values are low compared to the 1st campaign (January 2016), September 2017 et May 2018, this is due to the decrease in flow and the increase in temperature, therefore the dilution process at the Ghrib Dam is decreasing. These values of dissolved oxygen make the water of the Ghrib Dam of poor quality. Overall, the closer the concentration of dissolved oxygen is to saturation, the greater the river's ability to absorb pollution (Rodier et al., 2009).

Biological oxygen demand (BOD), an organic pollution criterion based on the amount of oxygen consumed at 20°C, is considered as an important parameter in an aquatic ecosystem to establish the status of organic pollution (Jain, Dhanija, (2000). Adakole (2000) categorized water based on BOD levels into unpolluted (BOD < 1.00 mmg.L^{-1}), moderately polluted (2–9 mmg.L^{-1}) and heavily polluted (BOD > 10 mmg.L^{-1}). The BOD levels in all Ghrib dam during study period fluctuated between 1 and 7.33 mmg.L^{-1} indicating that the lake is moderately polluted. BOD values range from 4 mmg.L^{-1} to 14 mmg.L^{-1} for the first campaign, from 3 to 4 mmg.L^{-1} for the 2nd campaign, from 4.4mmg.L^{-1} to 5.1mmg.L^{-1} for April and September 2017 and from 1mmg.L-1 in mars

2018 to 4.2mmg.L^{-1} in May 2018, which may be due to the small amount of organic matter available in the medium. The BOD, in the study, area indicates that the waters of Ghrib Dam are moderately polluted according to the classification of Adakole (2000), but during the 1st sampling campaign, the BOD was 14mmg.L^{-1} which shows that the waters during this period are severely polluted. This may be due to input of organic wastes and enhanced bacterial activity (Prasannakumari et al., 2003). Chemical oxygen Demand (COD) determines the amount of oxygen required for chemical oxidation of most organic matter and oxidizable inorganic substances with the help of strong chemical oxidant. Based on the results obtained, the variation in the concentration of DCO at the level of the campaigns is from 18 to 28 mmg.L^{-1} for the first campaign and 24 to 28 mmg.L^{-1} for the 2nd campaign, from 19 to 34mmg.L-1 for September and April2017 respectively and from 9 to 20mmg.L^{-1} for mars and April 2018 respectively, which is explained by the fact that the amount of oxygen provided by the oxidation of organic matter is therefore low biodegradability.The higher levels may be due to higher decomposition activities and lower water levels. Similar trends have been observed in several studies (Hallouz et al., 2014; Touhari et al., 2018). On the other hand, the highest values probably correspond to a high content of organic matter that has a biodegradable character, and therefore has degraded in this environment. Finally, these values do not meet FAO standards. Sulphate plays an important role in soft water systems where complex metal ions prevent reacting with other substances (Wetzel, 1983). The main source of sulphates is runoff from catchment area rich in mineral and organic Sulphur. The sulphate values recorded in the waters of these campaigns vary from point to point, they are moderately high by FAO standards, this is due to the nature of the rocks crossed during their displacement. Indeed, crops like sugar cane requires higher sulfate concentrations (94 kg. ha^{-1}) than other crops (corn: 47 kg. ha^{-1}, rice: 20 kg. ha^{-1}) (Schueneman, 2001; De La Mora-Orozco et al., 2017). Sulphate can be naturally occurring from gypsum or pyrite, of industrial origin or from agricultural processing products with gypsum land, or from runoff or infiltration into gypsum fields. They are also the result of the activity of certain bacteria (chlorothiobacteria, rhodothiobacteria, etc.).

The presence of nitrate nitrogen in lakes is governed by the activity of nitrifying bacteria on nitrogen source of domestic or agricultural origin. The most widespread contaminants are nitrogen compounds in sub-surface areas, mainly originated from decaying organic matter, leakage of septic tanks, sewage wastes, and fertilizers, as well as the infiltration of nitrate with the leaching water (Sirajudeen and Mubashir, 2013; Adam Khalifa et al., 2019). Nitrates stimulate the development of aquatic flora and increase the productivity of a lake ecosystem (Arrignon, 1976). Ganapati (1960) pointed out that concentration of NO3−N > 150 µgL-1 is an indicative of eutrophication. The concentration of nitrogen in water is quite high, due to equilibrium with nitrogen in the atmosphere. Based on the results, a remarkable variation exists between nitrate values for the campaigns from 0.86 to 1.84 mmg.L^{-1} for the first campaign, 1.32 to 3.48 mmg.L^{-1} for the 2nd campaign, 3.85 to 10.42 mmg.L^{-1} for the 3rd campaign (April and September 2017) and from 0 to 7.84 mmg.L^{-1} for the last campaign (April and May 2018), this variation is mainly due to leaching of agricultural land by runoff, this was observed during the period of the 1st campaign. In the end, nitrate values remain below the allowable values given by FAO standards, except for September 2017, which shows a value above the FAO standard.

Among nutrients, the importance of phosphates in water bodies is well studied (Vollenweider, 1968); Vaithiyanathan and Subramanian, 1993). Niswander and Mitsch (1995) pointed out that the addition of phosphate to water brings about eutrophication by increasing the bacterial content, increase in oxygen demand, and increase in production of growth factors for algae thus resulting in increased algal growth. Phosphate is essential for the development of suspended micro-algae and the results obtained show low values than those given by the FAO standards, where the presence of excess phosphorus can provoke the proliferation of plants. This parameter informs us about the degradation that is due to eutrophication. High concentrations of chloride (Cl^-) gives a salty taste to water (Adam Khalifa et al., 2019). The chloride dosing results show that the values of the first campaign range from 270.03 to 280 mg.L^{-1}, from 197 to 240 mg.L^{-1} for the second campaign, 290 mmg.L^{-1} to 322 mmg.L^{-1} for the 3rd campaign (2017) and from 271 mmg.L^{-1} to 360 mmg.L^{-1} for the last campaign (2018). These values are in accordance with FAO standards. Then, the chloride levels of the water are extremely variable and are mainly related to the nature of the land crossed. Sodium can come from several origins, namely: the decomposition of mineral salts such as silicates, the leaching of NaCl-rich geological formations from saltwater in the slicks, and the discharge of industrial and domestic wastewater. Indeed, for all samples, sodium concentrations are low for all samples with values ranging from 0.75 to 3.55 mg.L^{-1} for the first campaign, from 2.57 to 3.27 mg.L^{-1} for the second campaign, from 2.27 to 2.42 mg.L^{-1} for the 3rd campaign and from 2.19 to 2.40 mmg.L^{-1} for the last samples, these values are in line with FAO standards. Like sodium, potassium is also a naturally occurring element. Potassium levels were high during all samples. Low potassium concentrations lead to lower growth rate and photosynthesis of blue-green algae and increased respiration (Wetzel, 1983). The variation in potassium values between the two companions varies from 5.65 to 7.62 mg.L^{-1} for the first companion, from 6.98 to 7.9 mg.L^{-1} for the 2nd campaign., from 5.6 to 6.1 mg.L^{-1} for the 3rd campaign and from 4.2 to 7.2 mg.L^{-1} for last campaign. Potassium values remain high by input to FAO standards. Potassium can come from fertilizers, clays, and volcanic rocks and from industrial origin. Also, calcium and magnesium are often present in significant concentrations of natural water and are directly related to hardness (Adam Khalifa et al., 2019). The results obtained show that the waters of the Ghrib Dam are rich in calcium at all sampling points, these values are between 188.58 and 322 mg.L^{-1} for the waters of the first campaign, vary between 162 and 243 mg.L^{-1} for the second campaign, from 126 to 136 mg.L^{-1} for the 3rd campaign and from 116 to 162 mg.L^{-1} for the last sampling points. These variations in calcium levels remain in line with FAO standards. Le magnésium affiche des valeurs supérieures à la norme FAO pour l'ensemble des échantillons. For all samples, the bicarbonate concentrations ($HCO^-{}_3$) decrease, this applies to all samples with values ranging from 93 and 152 mg.L^{-1} for the first campaign, 155 to 178.6 mg.L^{-1} for the second campaign, 202 to 212 mg.L^{-1} for the 3rd campaign and from 142 to 218 mg.L^{-1} for the last campaign. These values are high but remain in line with FAO standards, this increase is probably related to the increase in pH. On the other hand, magnesium levels vary from season to season, both surface and depth. The level of Mg^+ for the waters of the first campaign varies between 43 and 114 mg.L^{-1}, for the second campaign, it varies from 66 to 205 mg.L^{-1}, for the 3rd campaign, the values of magnesium are from 82 to 242 mg.L^{-1} and from 19 to 86 mg.L^{-1} for the last sampling points. These values remain moderately high by FAO standards, this is due to a mineral origin, the main source is the mineral complex of sedimentary rocks and to the terrain crossed. Ammonia nitrogen is present in two forms in solution, ammonia NH_3 and ammonium NH_4, whose relative proportions depend on pH and temperature. Ammonium is often dominant; therefore, this term is used to design ammonia nitrogen (Aminot and Chaussepied, 1983). In an oxidizing medium, ammonium turns into nitrites and then nitrates, which induces oxygen consumption (Gaujous, 1995). Based on the results obtained, there is a remarkable variation between the values of the Ammonia Nitrogen for all campaigns. The values obtained are low and do not meet FAO standards, or this water ranks in the wrong class. Turbidity reflects the presence of suspended particles in water (organic debris, clays, microscopic organisms, etc.). It is important to know the content of turbidity when considering treating water because it facilitates the development of germs that indicate contamination, reduces the effectiveness of disinfectants, and increases chlorine consumption while decreasing its effectiveness. (Miquel, 2003). The results obtained revealed that turbidity is slightly variable for all campaigns during the analysis period, these values are between 9.92 and 10.33 NTU for the waters of the first campaign, they are, therefore, murky waters and this is due to the presence of finely divided suspended matter: clays, silt, and organic matter. As for the 2nd campaign, the values oscillate 5.02 and 11 NTU which indicates that this water is slightly cloudy, so presence of some particles suspended. During the months of September 2017 and May 2018, turbidity increased dramatically, reaching the values of 12.3 and 17.1 NTU respectively. In addition, the values of the 1st campaign as well as those of September 2017 and May 2018 remain higher compared to the waters of the other campaigns, this is due to the difference in the harvest dates, during the 1st period, the flow was abundant due to heavy rains during January 2016, September 2017, and May 2018 (which correspond to 88mm, 36mm and 58mm respectively) but during the other campaigns, the flow was zero.

Finally, in this study, the variation in Sodium Absorption Rates (SAR) values was 0.006 to 0.05 meq.L^{-1} for the first campaign, which means that there was dilution during that month of January 2016 since the amount of rain during that month was 88mm. On the other hand, the values of the other campaigns ranged from 0.010 to 0.025 meq.L^{-1}, the latter do not meet FAO standards, which proves that this water has a high salinity.

3.2. Hydro-geochemical facies

Piper's diagrams are composed of two ternary diagrams in which the proportions in cations and anions are carried over. The third diagram takes a synthesis of the previous two and allows to quickly characterize the water analyzed. The figure below (Fig. 4) shows the Piper diagram and the types of water found in the Ghrib Dam.

The results of the chemical analyses of the waters of the Ghrib dam for the 1st campaign (January 2016), the 2nd campaign (May 2016), the 3rd campaign (April and September 2017) and the last campaign (from February to May 2018) were plotted on the Piper diagram in order to determine the chemical trends of the waters (Fig. 4). Indeed, the results reveal that these waters are, essentially, chloride-calcium and sulfate waters.

Examination of the levels of major elements shows that mineralization is governed by calcium and magnesium for cations and chlorides and sulphates for anions. The problem with Piper diagrams is that they show relative proportions. Therefore, two points with concentrations of strongly different major elements can occupy the same place in the graph if the proportions are the same, which seems to be the case here. This problem has led us to look for other methods of interpretation such as the PCA (Principal Component Analysis) or the HCA (Hierarchical Cluster Analysis) which are addressed in the following.

3.3. Statistical analysis

3.3.1. Pearson’s Correlation Coefficient among Parameters

The correlations among water quality variables can reveal several important hydrochemical relationships (Wu et al., 2014). The Pearson’s correlation matrices were applied to identify the relationship between the variables. Correlation matrix of the 18 measured parameters was computed and presented in Table 5. Pearson’s correlation value ranges between 0 (in the case of no correlation) and 1 (when the correlation is perfect). Samples having a correlation coefficient greater than 0.7 are strongly correlated. The loading values are classified according to Liu *et al.* (2003); the absolute loading values of > 0.75, 0.75 – 0.50, and 0.50 – 0.30 are classified as strong, moderate, and weak, respectively. From the correlation matrix, many of the physicochemical parameters showed strong correlations with each other, indicating the close association of these parameters with each other. Results of correlation analysis showed that the high positive correlations between EC and Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, Cl^{-}, HCO_3^{-}, SO_4^{2-}, and PO_4^{3-} was observed, and this reflects the great contribution of these ions in water salinity (Jahin et al., 2020). In addition, significant positive correlation of EC with NO_3^{-} indicates relative lower contribution in water salinity (Table….). High significant positive correlations observed among Na+, K+, Ca^{2+}, Mg^{2+}, Cl^{-}, SAR, and SO_4^{2-} demonstrate that these six constituents form the majority of soluble salts in waters. This also reflects the natural composition dominating surface water in the studied area (Chapman, 1996). The NO_3^{-} showed a strongly negative correlation with DO, moderate significant positive correlation with Turbidity (TUR), but weak significant positive correlations with Mg^{2+}, EC, and Cl^{-}. Furthermore, PO_4^{3-} showed a significant positive correlation with pH, DO, and Ca^{2+}, but weak significant negative correlations with Mg^{2+}. The water temperature (T) had shown moderate significant and positive correlation between sulfate, NO_3^{-}, and Mg^{2+}, and a negative high correlation with DO. The Turbidity had shown a weak significant and positive correlation with K^{+} and BOD. Lastly, NH_4^{+} had shown a significant and negative correlation with BOD (Table 5). Also, pH has a significant negative correlation with most of the physicochemical parameters. Despite being a very effective tool, correlation analysis could only indicate the general insight into water-rock interactions [(Adam Khalifa et al., 2019).

Table 5
Pearson correlations of the physicochemical variables

Var.	pH	EC	DO	TUR	Cl^-	HCO_3^-	Ca^+	Mg^+	Na^+	K^+	NO_3^-	PO_4^-	SO_4^-	BOD	DCO	S
pH	1															
EC	0.183	1														
DO	0.418	-0.224	1													
TUR	0.206	-0.145	-0.400	1												
Cl^-	0.570	0.812	0.304	-0.203	1											
HCO_3^-	-0.145	0.784	-0.200	-0.500	0.560	1										
Ca^+	-0.093	0.774	0.364	0.170	0.796	-0.682	1									
Mg^+	-0.328	0.797	-0.314	0.106	0.799	0.228	0.800	1								
Na^+	-0.416	0.868	-0.118	-0.068	0.801	0.151	0.848	0.811	1							
K^+	-0.256	-0.794	-0.286	0.467	0.762	-0.501	0.797	0.802	0.775	1						
NO_3^-	-0.061	0.343	-0.773	0.579	0.313	0.017	-0.208	0.318	-0.062	0.126	1					
PO_4^-	0.444	0.743	0.494	0.201	0.097	-0.293	0.331	0.139	0.032	-0.041	-0.313	1				
SO_4^{2-}	0.277	0.967	-0.160	-0.031	0.856	0.639	0.768	-0.164	0.773	0.759	0.258	-0.240	1			
BOD	0.364	-0.308	0.330	0.353	-0.134	-0.350	0.698	-0.061	0.183	0.024	0.044	0.368	-0.289	1		
DCO	-0.190	-0.276	-0.105	0.009	-0.436	-0.063	0.334	0.194	0.392	0.376	0.078	0.388	-0.436	0.421	1	
SAR	-0.453	-0.503	-0.074	-0.157	-0.647	-0.160	0.236	0.233	0.848	0.570	-0.211	0.015	-0.636	-0.039	0.335	1
NH_4^+	0.162	0.648	-0.061	-0.241	0.551	0.511	-0.465	0.029	-0.182	-0.363	0.343	0.063	0.588	-0.483	0.239	-0
T(°C)	-0.417	0.279	-0.801	0.103	-0.150	0.436	-0.406	0.591	0.193	0.263	0.718	-0.410	0.158	-0.321	0.191	0.

Values in bold are different from 0 at a significance level alpha = 0.05

3.3.2. Principal Component Analysis (PCA)

For the meaningful interpretation of all the data collected from the chemical analysis of the waters, we used the method of Principal Component Analysis (PCA) which allows to establish correlations between the different variables and to specify the relationships between the chemical variables. This method provides information on the most meaningful parameters which describe complete dataset allowing data reduction with minimum loss of original information (Helena et al., 2000, Singh et al., 2004).

The objective of this analysis is to describe or classify the data, to allow the interpretation of the hydrochemical functioning of the dam waters. A principal component analysis was carried out in order to complete the hydrochemical study.

Principal component analysis (PCA) is a method of reducing the number of variables to allow their geometric representation. This reduction is only possible if the initial variables are not independent and have non-zero correlation coefficients (Faye et al., 2020).

To identify the important water quality parameters and their controlling mechanisms, PCA is executed on 18 variables including T, EC, pH, DO, Turbidity, major ions (Ca^{2+}, Mg^{2+}, Na^+, K^+, NH_4^+, Cl^-, NO_3^-, $SO_4^-$and PO_4^-), SAR, alkalinity, BOD and COD of the 12 different sampling sites which shows the major variables governing water physiochemical properties of the Ghrib dam.

3.3.3. Multivariate statistical analyses

Based on the Eigen values results, 4 factors explaining 78.96% of the variance or information contained in the original data set were retained. The factors correspond to the Eigen values (5.88, 4.02, 2.38, 1.93) respectively and are sufficient to give a good idea of the data structure. Any factor with an Eigen value greater than 1 is considered significant. The Eigen values for different factors, percentage variance, cumulative percentage variance and component loadings (unrotated and varimax rotated) are summarized in Table 6. The first component represented 32.69% of the variance with an eigenvalue of 5.88. It included the most significant variables controlling the water chemistry in the studied area, i.e., EC, Ca^{2+}, Mg^{2+}, Na^+, K^+, Cl^-, SO_4^{2-}, PO_4^{3-}, SAR, and NH_4^+. As these parameters were well-correlated (Table 6). The second component represented 22.33% of the variance with an eigenvalue of 4.02. This component was dominated by trace elements of natural origin, including pH, DO, and T. The third component was dominated by variables Turbidity and NO_3^-.This third component represented 13.24% of the variance with an eigen value of 2.38. The fourth component accounted for 10.70% of the total variance with an eigenvalue of 1.93. It was dominated by well-correlated three variables, i.e., NH_4^+, BOD, and DCO.

Tableau 6. Varimax rotated component matrix for water quality parameters.

	PC1	PC2	PC3	PC4
Eigenvalue	5.88	4.02	2.38	1.926
Variance, (%)	32.69	22.33	13.24	10.70
Cumulative, %	32.69	55.01	68.26	78.96
Indicator	**Eigenvectors**			
pH	0.28	**-0.65**	0.41	0.19
EC	0.94	0.14	-0.02	0.13
DO	-0.11	**-0.87**	-0.33	0.19
TUR	-0.21	0.11	**0.86**	-0.06
Cl^-	**0.88**	-0.39	-0.03	0.16
HCO_3^-	**0.72**	0.33	-0.44	0.27
Ca^+	**-0.80**	-0.32	0.15	-0.01
Mg^+	**-0.60**	0.48	-0.02	0.38
Na^+	**-0.54**	0.42	-0.41	0.41
K^+	**-0.70**	0.37	0.13	-0.11
NO_3^-	0.19	0.63	**0.70**	0.03
PO_4^-	**-0.63**	-0.48	0.14	0.42
SO_4^-	**0.96**	0.00	0.11	-0.01
BOD	-0.34	-0.38	0.42	**0.59**
DCO	-0.44	0.22	0.05	**0.70**
SAR	-0.67	0.35	-0.49	0.11
NH_4^+	0.64	0.13	0.08	**0.52**
T	0.21	0.91	0.15	0.11

Bold-face numbers indicates highly loaded variables.

The quality of irrigation water is highly variable depending upon both the type and the quantity of the salts dissolved in it. These salts originate from natural (i.e., weathering of rocks and soil) and anthropological (i.e., domestic, and industrial discharges) sources and once introduced, they follow the flow path of the water. It is commonly accepted that the problems originating from irrigation water quality vary in type and severity as a function of numerous factors including the type of the soil and the crop, the climate of the area as well as the farmer who utilizes the water. Nevertheless, there is now a common understanding that these problems can be categorized into the following major groups: (a) salinity hazard, (b) infiltration and permeability problems, (c) Specific ion toxicity and (d) miscellaneous problems (Simsek and Gunduz, 2007; Rasul and Hassan, 2013).

3.3.4. Hierarchical cluster analysis

The hierarchical cluster analysis HCA aims to classify objects into groups based on the similarity between samples with respect to the physicochemical elements (Noshadi and Ghafourian 2016). (Fig. 4). Hierarchical clustering of all sampling sites using Ward's method with squared Euclidean distance resulted in dendrogram consisting of four statistically significant clusters (Fig. 3): cluster 1 (P1, P2, P3), cluster 2 (P4, P5, P6), cluster 3 (P7, P9, P10, P11) and cluster 4 (P8, P12). The result of cluster analysis has revealed different water quality exists in different zones of the lake depending upon their proximity to the water source. The agglomeration of these sites into different clusters may be due to the different environmental conditions they are exposed to. It is evident that the CA is advantageous in offering reliable classification of sampling sites and will support designing a more precise sampling strategy for future monitoring programs. The obtained results reinforce those already achieved through PCA.

3.4. Assessment of water quality using IWQI and SAR

The results of Table 7 demonstrated that IWQI in this section of the Ghrib dam decreases from downstream to upstream. Indeed, the IWQI values were less than 59 units for all sampling sites and in May 2018 (41 units). According to the classifications for the different uses of water, values below 60 indicate that the water is of poor quality for irrigation. Nevertheless, it is recommended that more data be obtained over several years to confirm the effect of environmental conditions on water quality at Ghrib Dam. It should be noted that several authors have reported the polluting effect of rain and climatic conditions on the dynamics and water quality of rivers and reservoirs (Roselli et al., 2009; Razmkhah et al., 2010; González-Ortegón, 2010; Chilundo, 2008; De La Mora-Orozco, 2017). However, rainy season runoff can introduce pollutants such as nitrogen and phosphorus, which contribute to the flowering of water hyacinths. Water treatment is recommended to make dam water more suitable for irrigation.

Added to these results, the variation in SAR values was 0.006 to 0.05 meq.L^{-1} for the 1st companion, which means that there was dilution during this month of January 2016 since the amount of rain during that month was > 70mm.

On the other hand, the values of the 2nd campaign ranged from 0.05 to 0.019 meq.L^{-1}, the latter do not meet FAO standards, which proves that there is a high salinity. SAR values in the third campaign ranged from 0.021 in April 2017 to 0.018 in September 2017 and during the last campaign, the SAR values were between 0.022 in April 2018 and 0.023 in February and May 2018. Based on the results, the waters of the Ghrib Dam have a poor chemical quality.

Table 7
IWQI values from the Ghrib dam reservoir in all sampling

Date	Sampling	IWQI values
January 30th, 2016	P1	55
	P2	55
	P3	53
May 2nd, 2016	P4	59
	P5	59
	P6	59
April, 2017	P7	50
Sept. 2017	P8	55
Feb. 2018	P9	59
March, 2018	P10	58
April, 2018	P11	59
May, 2018	P12	41

There were no significant differences in IWQI values among the sampling sites during all campaigns along the dam over the study year (Table 7). According to the classifications for the different water uses, values below 60 indicate that the water requires treatment before use for irrigation or other purposes. However, the campaigns of 2016 and 2017 observe a quality index below 60%, which makes these waters of poor quality. We hypothesize that this improvement is the result of the rainy season in this particular year of study (2016, 2017).

It should also be noted that the campaigns of May 2017 and February and April 2018 have given values of IWQI equal to 59 units, these values indicate that we are in the presence of poor water quality, this is probably due to climatic conditions during this period, where rainfall of 57mm, 101 mm and 192mm were recorded during the months of May 2017 and February and April 2018 respectively. It should be noted that several authors have reported the polluting effect of rain and climatic conditions on the dynamics and water quality of rivers and reservoirs (Roselli et al., 2009; Razmkhah et al., 2010; González-Ortegón, 2010 ; Chilundo, 2008 ; De La Mora-Orozco, 2017).

Also, the minimum value of this quality index was recorded during the month of May 2018 although during this period a rainfall of 56mm was observed, and it was, also, the irrigation season of the perimeter (beginning April 1st of each year). This explains that the rainy season runoff can introduce pollutants such as nitrogen and phosphorous, which contribute to the blooming of water hyacinths. Water treatment is recommended to make dam waters more fit for irrigation or other purposes.

In the end, the values of the physical and chemical analyses of the Ghrib dam waters, intended for irrigation of farms and compared to the guide values (FAO) led to the following results:

- The waters of our study region have low alkalinity, as well as high mineralization for all sampling points.

- The indicators of pollution reveal the presence of acute pollution which is certainly caused by direct releases of either industrial or domestic origin, and this pollution remains variable depending on the sampling periods.

- Chloride-calcium and sulfate facies are the most dominant in the two harvest periods during all sampling periods for dam waters, resulting in poor water quality for irrigation. In addition, water is, therefore, highly mineralized and is likely to be suitable for irrigation of certain species (cucumbers...) that are well tolerant to salt and on well-drained and leached soils.

4. Conclusion

The results of the physical and chemical analyses of the waters of the Ghrib Dam, intended for irrigation of farms and compared to the guide values (FAO) showed that these waters have low alkalinity, as well as high mineralization for all sampling points.

The indicators of pollution reveal the presence of acute pollution which is certainly caused by direct releases of either industrial or domestic origin, and it's noted that this pollution remains variable depending on the collection periods.

Chloride-calcium and sulfate facies are the most dominant in all sampling periods during the sampling campaigns for dam water, resulting in poor water quality for irrigation.

IWQI values were less than 60 units for all sampling sites. According to the classifications for the different uses of water, values below 60 indicate that the water is of poor quality for irrigation.

The IWQI index in this study showed significant temporal differentiation clearly marking seasonal variation. Thus, the level of deterioration becomes high during the wet winter period (February) and is linked to the decrease in the flow of the Chorfa wadi while the flow of effluents loaded with domestic and industrial wastewater from the various urban centers remains low. Similarly, and during the 2nd and last campaigns (May 2016 and 2018: beginning of the irrigation campaign) the development of agriculture and the high contribution of runoff and leaching of soils mainly downstream at the level of agricultural land (Djendel plain) increase the deterioration of water quality both in the wadi and in the dam. Therefore, priority must be given to reducing these sources of pollution in order to protect water resources and improve water quality in the watershed. To do this, policy makers will have to install wastewater treatment plants and conduct awareness campaigns with farmers for the rationed use of fertilizers. Based on these results; the waters of the Ghrib dam for irrigation, in general, are of poor quality.

In perspective, the assessment of water quality at the Ghrib Dam could incorporate other complementary parameters such as microbiological parameters in addition to physical-chemical parameters and heavy metals in IWQI calculations and water quality monitoring.

Declarations

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References

1. Abdel-Fattah, M.K., Abd-Elmabod, S.K., Aldosari, A.A., Elrys, A.S., Mohamed, E.S., (2020). Multivariate Analysis for Assessing Irrigation Water Quality: A Case Study of the Bahr Mouise Canal, Eastern Nile Delta. Water **2020**, 12, 2537. https://doi.org/10.3390/w12092537.
2. Adakole JA., (2000). The effect of domestic, agricultural and industrial effluents on the water quality and biota of Bindare stream, Zaria, Nigeria. Ph.D. Thesis, Department of Biological Sciences, Ahmadu Bello University, Zaria, Nigeria. 2000,256.
3. Adam Khalifa Mohamed, Liu Dan, Song Kai, Mohamed A. A. Mohamed, Elsiddig Aldaw and Basheer A. Elubid (2019). Hydrochemical Analysis and Fuzzy Logic Method for Evaluation of Groundwater Quality in the North Chengdu Plain, China. International Journal of Environmental Research and Public Health, Int. J. Environ. Res. Public Health 2019, 16, 302, doi:10.3390/ijerph16030302 www.mdpi.com/journal/ijerph.
4. Agence Nationale des Barrages et Transferts (ANBT, 2014). Rapport Annuel D'activité sur L'état des Barrages Algériens, ANBT: Kouba, Algeria, 2014. (In French).
5. Ajayi, F., Nduru, M., Oningue, A. (1990). Halting the salt that kills crops. Afr. Farmer 1990, 4, 10–12.
6. Al Hadrami, S.N. Preparation, Characterization and Catalytic Activity Study of Transition Metal Doped Porous -Alumina. Master Thesis, United Arab Emirates University, Abu Dhabi, United Arab Emirates, January (2013). Available online: https://core.ac.uk/download/pdf/230628289.pdf (accessed on 12 June 2020).
7. Allen, L.N., MacAdam, J.W. (2020). Irrigation and Water Management. Forages Sci. Grassl. Agric. 2020, 2, 497–513.
8. Aminot A., M.Chaussepied (1983). Manuel des analyses chimiques en milieu marin.CNEXO.
9. Andreea-Mihaela Dunca (2018). Water Pollution and Water Quality Assessment of Major Transboundary Rivers from Banat (Romania). Hindawi Journal of Chemistry Volume 2018, Article ID 9073763, 8 pages https://doi.org/10.1155/2018/9073763.
10. Arrignon J., (1976). *Aménagement écologique et piscicole des eaux douces.* Gauthier-Villard, Paris, 329 p.
11. Arrignon. J, (1991). Aménagement écologiques et piscicoles des eaux douces, 4éme édition Gauthier Villars, 631 p.
12. Banwart, S.A., Chorover, J., Gaillardet, J., Sparks, D., White, T., Anderson, S., Aufdenkampe, A., Bernasconi, S., Brantley, S.L, Chadwick, O., Dietrich, W.E., Duffy, C., Goldhaber, M., Lehnert, K., Nikolaidis, N.P, and Ragnarsdottir, K.., (2013). Sustaining Earth's Critical Zone Basic Science and Interdisciplinary Solutions for Global Challenges. The University of Sheffield, United Kingdom.
13. Benkhelifa m., Daoud y., Belkhodja m. et Tessier d., (2008). Effets de la salinite et de la sodicite sur la conductivite hydraulique saturee de melanges de sable et d'argile. Conference paper. Université Abdel Hamid Ibn Badis, Mostaganem. https://www.researchgate.net/publication/274387476.
14. Biazar Seyed Mostafa & Rahmani Vahid & Isazadeh Mohammad & Kisi Ozgur & Dinpashoh Yagob (2020). New input selection procedure for machine learning methods in estimating daily global solar radiation. Arabian Journal of Geosciences (2020) 13:431, https://doi.org/10.1007/s12517-020-05437-0.

15. Brooks P.D., Chorover J., Fan Y., Godsey S.E., Maxwell R.M., Mc Namara J.P., T.C., (2015). Hydrological partitioning in the critical zone: Recent advances and opportunities for developing transferable understanding of water cycle dynamics. *Water Resources Research.* 6973–6987. https://doi.org/10.1002/2015WR017039.Received.
16. Chapman, D., (1996). Water Quality Assessments - a Guide to Use of Biota, Sediments and Water in Environmental Monitoring. Chapman & Hall, University Press, Cambridge, Great Britain.
17. Cheridi Lounis et djebouri Tassadit (2016). Simulation unidimensionnelle du transport solide avec HEC-RAS 4.1.0 : Application au sous bassin de l'oued Cheliff-Ghrib. Mémoire de Master, université Mouloud MAMMERI, Tizi-Ouzou, Algérie, 94p.
18. Chilundo, M., Kelderman, P., Ókeeffe, J.H. (2008). Design of a water quality monitoring network for the Limpopo River Basin in Mozambique. Phys. Chem. Earth Parts A/B/C 2008, 33, 655–665.
19. Cude, C.G., (2001). Oregon water quality index: A tool for evaluating water quality management effectiveness.J. Am. Water Resour. Assoc. 2001, 37, 125–137.
20. Debieche T.H., (2002). Evolution de la qualité des eaux (salinité, azote et métaux lourds) sous l'effet de la pollution saline, agricole et industrielle. Application à la basse plaine de la Seybouse. Thèse de doctorat. Ecole doctorale Homme, Environnement, Santé. Science de la terre.
21. De La Mora-Orozco Celia, Flores-Lopez Hugo, Rubio-Arias Hector, Chavez-Duran Alvaro and Ochoa-Rivero Jesus (2017). Developing a Water Quality Index (WQI) for an Irrigation Dam. Int. J. Environ. Res. Public Health 2017, 14, 439, doi:10.3390/ijerph14050439 www.mdpi.com/journal/ijerph.
22. Ehsan Fathi. Rasool Zamani-Ahmadmahmoodi . Rafat Zare-Bidaki (2018). Water quality evaluation using water quality index and multivariate methods, Beheshtabad River, Iran. Applied Water Science (2018) 8:210, https://doi.org/10.1007/s13201-018-0859-7
23. El Haouati H., M. Guechaoui, K. Djermane, C. Chaabat Dis et A. Arab, (2013). Etude préliminaire physico-chimique des eaux du barrage Gargar (w. Relizane). Proceeding du Séminaire International sur l'Hydrogéologie et l'Environnement SIHE 2013 Ouargla.
24. Fan X, Cui B, Zhao H et al (2010). Assessment of river water quality in Pearl River Delta using multivariate statistical techniques. Procedia Environ Sci 2:1220–1234.
25. FAO, (1996). La qualité d'eau dans l'irrigation, Bulletin n°29 de l'Organisation Mondiale pour l'Alimentation et l'Agriculture.
26. Fathi, E., Zamani-Ahmadmahmoodi, R. & Zare-Bidaki, R., (2018). Water quality evaluation using water quality index and multivariate methods, Beheshtabad River, Iran. *Appl Water Sci* **8,** 210 (2018). https://doi.org/10.1007/s13201-018-0859-7.
27. Food and Agriculture Organization (FAO), (1985). Soil Survey Investigation for Irrigation. Soil Bulletin 42, Food and Agriculture Organization of the United Nations: Rome, Italy, 1985.
28. Ganapati SV. Ecology of tropical waters, (1960). Proceedings of Symposium on Algalogy, ICAR, New Delhi. 1960,204-218.
29. Gaujous. D, (1995). La pollution des milieux aquatiques. Aide mémoire 2éme édition Paris. 217 p.
30. Gholami S, Srikantaswamy S (2009). Statistical multivariate analysis in the assessment of river water quality in the vicinity of KRS Dam, Karnataka, India. Nat Resour Res 18:235–247.
31. González-Ortegón, E., Subida, M.D., Cuesta, J.A., Arias, A.M., Fernández-Delgado, C., Drake, P., (2010). The impact of extreme turbidity events on the nursery function of a temperate European estuary with regulated freshwater inflow. Estuar. Coast. Shelf Sci. 2010, 87, 311–324.
32. Guide des prescriptions techniques pour la surveillance physico-chimique des milieux aquatiques Rapport AQUAREF (2011) – 6 p + manuel d'utilisation du guide.
33. Faye Cheikh, Wade Cheikh Tidiane, Demba Dione Ibrahima (2020). A dissymmetry in the figures related to the covid-19 pandemic in the world: what factors explain the difference between Africa and the rest of the world? doi: https://doi.org/10.1101/2020.05.17.20104687.
34. Hallouz, F., Meddi, M., Bouchali H. et Boudani S., (2014). Study of the quality of surface waters of the watershed of High Cheliff (North West Algeria).4th Asia Africa Resource Mineral Conference – Algiers October 13-16th 2014.
35. Hallouz Faiza, Meddi Mohamed, Mahé Gil, Ali Rahmani Salaheddine, Chebana Fateh, (2020). Statistical study of rainfall and sediment transport in the North west of Algeria. 3rd Conference of the Arabian Journal of Geosciences (CAJG), held online, on 2–5 November 2020.
36. Hallouz Faiza, Meddi Mohamed, Cherfaoui Hamid, Hallouz Mohamed, Ali Rahmani Salaheddine, (2021). Irrigation efficiency in the Large Irrigated Perimeters: Case of Upper Cheliff perimeter (northwestern Algeria) (in press).
37. Helena B, Pardo R, Vega M, Barrado E, Fernández JM, Fernández L., (2000). Temporal evolution of groundwater composition in an alluvial aquifer (Pisuerga River, Spain) by principal component analysis. Water Research. 2000, 34:807-816.
38. Hotelling, H. (1933). Analysis of a complex of statistical variables into principal components. Journal of educational psychology 24, 417–441.
39. House M. A. and J. B. Ellis (1987). The development of water quality indices for operational management, *Water Science and Technology*, vol. 19, no. 9, pp. 145–154, 1987. View at: Google Scholar.
40. House M. A., (1990). Water quality indices as indicators of ecosystem change, *Environmental Modeling & Assessment*, vol. 15, no. 3, pp. 255–263, 1990. View at: Publisher Site | Google Scholar.
41. Ionus O., "Water quality index—assessment method of the Motru River water quality (Oltenia, Romania)," *Annals of the University of Craiova, Series Geography*, vol. 13, pp. 74–83, 2010. View at: Google Scholar.
42. IPCC, 2013. Climate Change (2013). The Physical Science Basis. Working Group 1, contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge Univ. Press, Cambridge, UK.
43. Jahin Hossam S., Abuzaid Ahmed S., Abdellatif Abdellatif D., (2020). Using multivariate analysis to develop irrigation water quality index for surface water in Kafr El-Sheikh Governorate, Egypt. Environmental Technology & Innovation 17 (2020) 100532. https://doi.org/10.1016/j.eti.2019.100532.

44. Jain Y, Dhanija SK., (2000). Studies in a polluted centric water body of Jabalpur with special reference to physico-chemical and biological parameters. Journal of Environmental Biology. 2000,(7):83-88.
45. Johnson GL, Hanson CL (1995). Topographic and atmospheric influences on precipitation variability over a mountainous watershed. J Appl Meteorol 34(1):68–87.
46. Kumar A, Siddiqui EN., (1997). Quality of drinking water in and around Ranchi. International Journal of Environment Protection. 1997,18(5):339-345.
47. Kurunc, A., Aslan, G.E., Karaca, C., Tezcan, A., Turgut, K., Karhan, M., Kaplan, B. E, (2020). ects of salt source and irrigation water salinity on growth, yield and quality parameters of Stevia rebaudiana Bertoni. Sci. Hortic. 2020, 270, 109458.
48. Lacaze. JC, (1996). Eutrophisation des eaux marines et continentales : causes, manifestation, conséquences et moyens de lutte. Edition Ellipse. 191 p.
49. L'eau en Loire-Bretagne – juin(2003) / n° 68. **L'eau : véritable enjeu mondial** Afrique, Amérique du Nord, Amérique du Sud, Asie, Europe.
50. Léon-Vizcaíno, R., (1991). Indices de Calidad del Agua,. Formas de Estimarlos y Aplicación en la Cuenca Lerma-Chapala, México, Instituto Tecnológico del Agua: Morelos, Mexico, 1991, pp. 1–7.
51. Lin Y, Han P, Huang Y, Yuan GL, Guo X, Li J (2017). Source identification of potentially hazardous elements and their relationships with soil properties in agricultural soil of the Pinggu district of Beijing, China: Multivariate statistical analysis and redundancy analysis. J Geochem Explor 173:110–118.
52. Liou, S.M., Lo, S.L., Hu, C.Y., (2003). Application of two-stage fuzzy set theory to river quality evaluation in Taiwan. Water Res. 2003, 37, 1406–1416.
53. Machael, A.M., (1985). Irrigation Principles and Practice, Vikas publishing house ltd.: New Delhi, India, 1985, pp. 702–720.
54. Massoud MA (2012). Assessment of water quality along a recreational section of the Damour River in Lebanon using the water quality index. Environ Monit Assess 184:4151–4160.
55. Merhabi F., H. Amine, J. Halwani. (2019). Evaluation de la qualité des eaux de surface de la rivière Kadicha. *Journal Scientifique Libanais*. 20(1): 10-34.
56. Merili Samiha et Belouazani Hamida (2016). Origine et caractéristiques des eaux d'irrigation de la plaine de Djendel (Barrage Ghrib). Memoire de master de l'université de Khemis Miliana, Algérie, 128 pages.
57. Ministry of Water Resources (2019), interne document.
58. Miquel Gérard, (2003). La qualité de l'eau et l'assainissement en France. Rapport de l'OPECST n° 215 (2002-2003). https://www.senat.fr/rap/l02-215-1/l02-215-1.html
59. Misaghi F, Delgosha F, Razzaghmanesh M, Myers B (2017). Introducing a water quality index for assessing water for irrigation purposes: a case study of the Ghezel Ozan River. Sci Total Environ 589:107–116.
60. Mohamed AK, Dan L, Kai S, Mohamed MAA, Aldaw E, Elubid BA., (2019). Hydrochemical Analysis and Fuzzy Logic Method for Evaluation of Groundwater Quality in the North Chengdu Plain, China. *Int J Environ Res Public Health*. 2019,16(3):302. Published 2019 Jan 23. doi:10.3390/ijerph16030302).
61. Mokhtari El Hadj, (2017). Impact de l'érosion hydrique sur l'envasement du barrage Ghrib. Thèse de Doctorat E-Sciences, université Hassiba BEN BOUALI, Chlef, Algérie, 272p.
62. Nagel, J.W., Davies-Colley, R.J., Smith, D.G., (2001). A water quality index for contact recreation in New Zealand. Water Sci. Technol. 2001, 43, 285–292.
63. National Research Council, (2001). Basic Research Opportunities in Earth Science. National Academy Press Washington, D.C. https://doi.org/10.17226/9981
64. Nisbet. M et Verneau. J, (1970). Composant chimiques des eaux courantes, discussions et propositions des classes entant que base d'interprétation des analyses chimiques. Annale de limnologie : 1.6 fasc 2, 161-190p.
65. Noori R, Abdoli MA, Jalili Ghazizade M et al (2009). Comparison of neural network and principal component-regression analysis to predict the solid waste generation in Tehran, Iran. J Public Health 38:74–84 **(In Persian)**.
66. Noori R, Khakpour A, Omidvar B et al (2010). Comparison of ANN and principal component analysis-multivariate linear regression models for predicting the river flow based on developed discrepancy ratio statistic. Expert Syst Appl 37:5856–5862 **(In Persian).**
67. Noori, R., Berndtsson, R., Hosseinzadeh, M., Adamowski, J.F., Abyaneh, M.R., (2019). A critical review on the application of the National Sanitation Foundation Water Quality Index. Environ. Pollut. 2019, 244, 575–587.
68. Noshadi M, Ghafourian A., (2016). Groundwater quality analysis using multivariate statistical techniques (case study: Fars province, Iran). Environ Monit Assess. 2016 Jul,188(7):419. doi: 10.1007/s10661-016-5412-2. Epub 2016 Jun 18. PMID: 27317054.
69. Office National de l'Irrigation et du Drainage- Direction Générale (ONID-DG) (2012). L'ONID et sa contribution au développement de l'agriculture. Regroupement ABH-Chlef, fevrier-2012, 15p. http://www.onid.com.dz
70. Office National de l'Irrigation et du Drainage (ONID) (2006). Monographie de l'Aménagement Hydro-Agricole Du Périmètre du Haut Chéliff (W) de Ain-Defla, 66 pages. www.onid.com.dz
71. Osuolale, O., Okoh, A., (2017). Human enteric bacteria and viruses in five wastewater treatment plants in the Eastern Cape, South Africa. Journal of Infection and Public Health 10, 541–547. https://doi.org/10.1016/j.jiph.2016.11.012.
72. Perez, A.R.S., (2011). Characterizing Salinity Tolerance in Greenhouse Roses. Ph.D. Thesis, Texas A&M University, College Station, TX, USA, August 2011. Available online: https://oaktrust.library.tamu.edu/handle/1969.1/ ETD-TAMU-2009-05-725 (accessed on 15 November 2020).
73. Prasannakumari AA, Ganagadevi T, Sukeshkumar CP, (2003). Surface water quality of river Neyyar- Thiruvanathapuram, Kerala, India. Pollution Research. 2003,22(4):515-525.
74. Rasul M. Khalaf & Waqed H. Hassan, (2013). Evaluation of irrigation water quality index (IWQI) for al-Dammam confined aquifer in the west and southwest of Karbala city, IRAQ. International Journal of Civil Engineering (IJCE) ISSN 2278-9987 Vol. 2, Issue 3, July 2013, 21-34.

75. Razmkhah, H., Abrishamchi, A., Torkian, A., (2010). Evaluation of spatial and temporal variation in water quality by pattern recognition techniques: A case study on Jajrood River (Tehran, Iran). J. Environ. Manag. 2010, 91, 852–860.
76. Rodier J., (2009) : L'analyse de l'eau – eaux naturelles, eaux résiduaires, eau de mer, 9ème édition, Paris, Dunod, 1475 p.
77. Rodier Jean, Legube Bernard, merlet Nicole, Brunet Régis (2009). L'analyse de l'eau - 9ème édition - Eaux naturelles, eaux résiduaires, eau de mer: Eaux naturelles, eaux résiduaires, eau de mer(Français) Broché – 17 juin 2009. 1579 pages.
78. Rokbani MK, Gueddari N, Bouhlila R (2011). Use of geographical information system and water quality index to assess groundwater quality in El Khairat Deep Aquifer (Enfidha, Tunisian Sahel). Iran J Energy Environ 2(2):133–144
79. Roselli, L., Fabbrocini, A., Manzo, C., D'Adamo, R., (2009). Hydrological heterogeneity, nutrient dynamics and water quality of a non-tidal lentic ecosystem (Lesina Lagoon, Italy). Estuar. Coast. Shelf Sci. 2009, 84, 539–552.
80. Saluja Ridhi and Garg J. K., (2015). Surface water quality assessment of Bhindawas lake (Haryana, India) using multivariate statistical techniques. Journal of Global Ecology and Environment 2(1): 34-46, 2015. International Knowledge Press, www.ikpress.org.
81. Sarkar, B., Islam, A., (2019). Assessing the suitability of water for irrigation using major physical parameters and ion chemistry: A study of the Churni River, India. Arab. J. Geosci. 2019, 12, 637.
82. Schueneman, T.J., (2001). Characterization of sulfur sources in the EAA. Soil Crop Sci. Soc. Fla. Proc. 2001, 60, 49–52.
83. Shrestha S, Kazama F (2007). Assessment of surface water quality using multivariate statistical techniques: a case study of the Fuji river basin, Japan. J Environ Model Softw 22:464–475.
84. Simeonova V, Stratis JA, Samara C, Zachariadis G, Voutsa D, Anthemidis A, Sofoniou M, Kouimitzis T., (2003). Assessment of the surface water quality in Northern Greece. Water Research. 2003,37:4119-4124.
85. Simsek, C., and Gunduz, O. (2007): "IWQ index: A GIS integrated technique to assess irrigation water quality", Environmental Monitoring and Assessment, Vol. (128), pp. 277–300.
86. Singh KP, Malik A, Mohan D, Sinha S (2004). Multivariate statistical techniques for the evaluation of spatial and temporal variations in water quality of Gomti River (India)—a case study. Water Res 38(18):3980–3992. doi:10.1016/j.watres.2004.06.011
87. Sirajudeen, J., Mubashir, M., (2013). Statistical approach and assessment of physico-chemical status of ground water in near proximity of South Bank Canal, Tamil Nadu, India. *Arch. Appl. Sci. Res.* **2013**, *5*, 25–32.
88. Swamee, P.K., Tyagi, A., (2000). Describing water quality with aggregate index. J. Environ. Eng. 2000, 126, 451–455.
89. Touhari Fadhila, Mehaiguene Madjid, Messelmi Hayet, (2018). Évolution de la qualité des eaux des barrages dans le bassin du Haut Cheliff. SAGREN Vol 02, No 01, pp 41-57, Janvier 2018.
90. US Salinity Laboratory Sta_. Diagnosis and Improvement of Saline and Alkali Soils, Agriculture Handbook No. 60, Richards, L.A., Ed., United States Department of Agriculture: Washington, DC, USA, 1954.
91. Vollenweider RA., (1968). Scientific fundamentals of eutrophication of lakes and flowing waters with special reference to nitrogen and phosphorus as factors in Eutrophication. OECD, France.1968,27:182.
92. Vaithiyanathan P, Jha PK, Subramanian V., (1993). Phosphorus distribution in the sediments of the Hoogly (Ganges) Estuary, India. Estuar. Coast. Shelf. Sci. 1993,37(6):603-614.
93. Niswander SF, Mitsch WJ., (1995). Functional analysis of a two-year-old created in stream wetland: Hydrology, phosphorus retention and vegetation survival and growth. Wetlands. 1995,15(3):212-215.
94. Wetzel RG. Limnology (1983). Second edition. Saunders College of Publishing, New York, 1983.
95. Wu, J., Li, P., Qian, H., Duan, Z., Zhang, X., (201$). Using correlation and multivariate statistical analysis to identify hydrogeochemical processes affecting the major ion chemistry of waters: A case study in Laoheba phosphorite mine in Sichuan, China. Arab. J. Geosci. 2014, 7, 3973–3982.
96. Youmbi, J.G.T., Feumba, R., Njitat, V.T., De Marsily, G., Ekodeck, G.E., (2013). Pollution de l'eau souterraine et risques sanitaires à Yaoundé au Cameroun. Comptes Rendus - Biologies 336: 310–316. https://doi.org/10.1016/j.crvi.2013.04.013
97. Zamani-Ahmadmahmoodi R, Jafari A, Alibeygi-Beni H (2017). Potential ecological risk assessment, enrichment, geoaccumulation, and source identification of metals in the surface sediments of Choghakhor Wetland, Iran. Environ Earth Sci 76(11):398.

Figures

Figure 1

Cheliff-Ghrib sub-watershed situation. Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

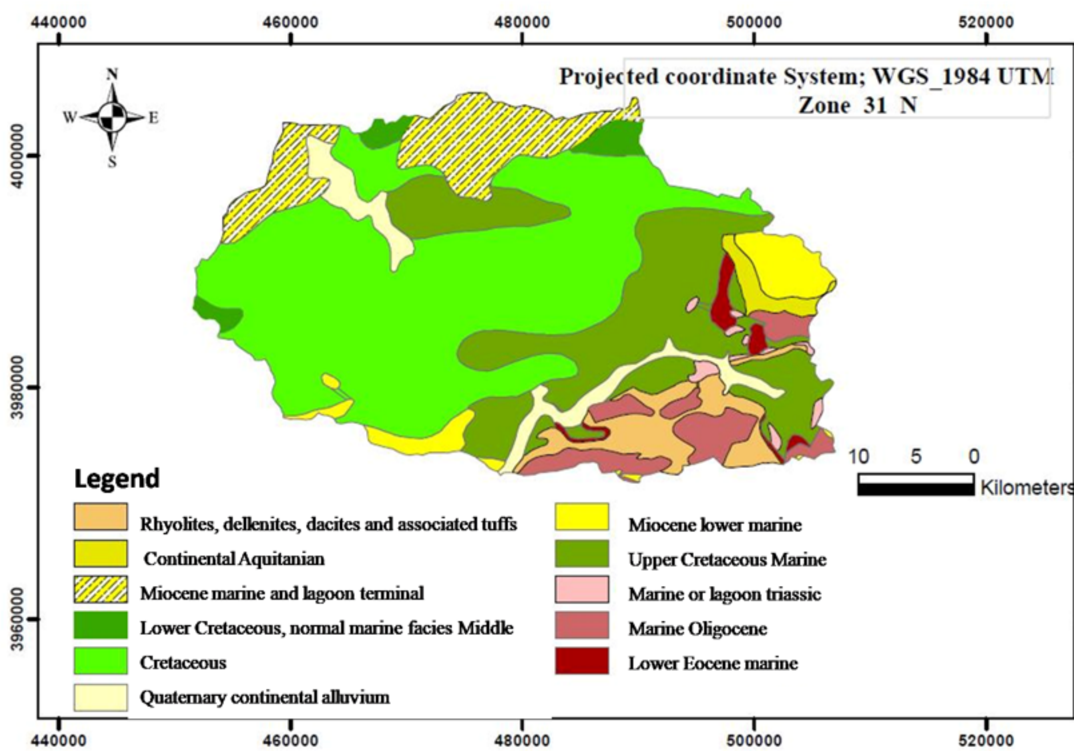

Figure 2

Geological map (Mokhtari, 2017). Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

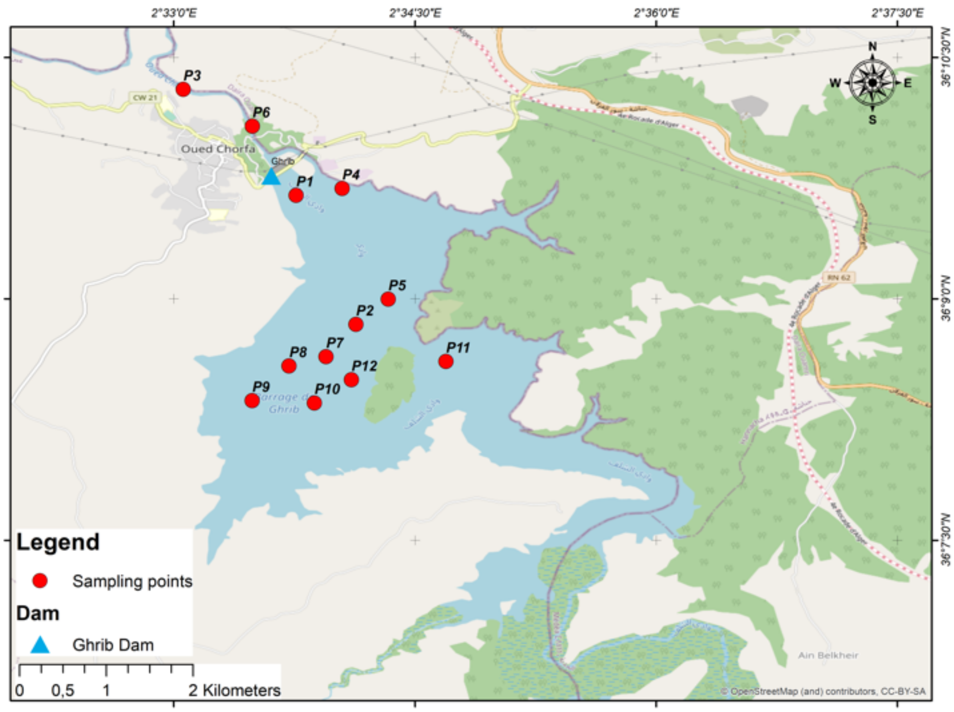

Figure 3

Sample points of water from the Ghrib dam Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

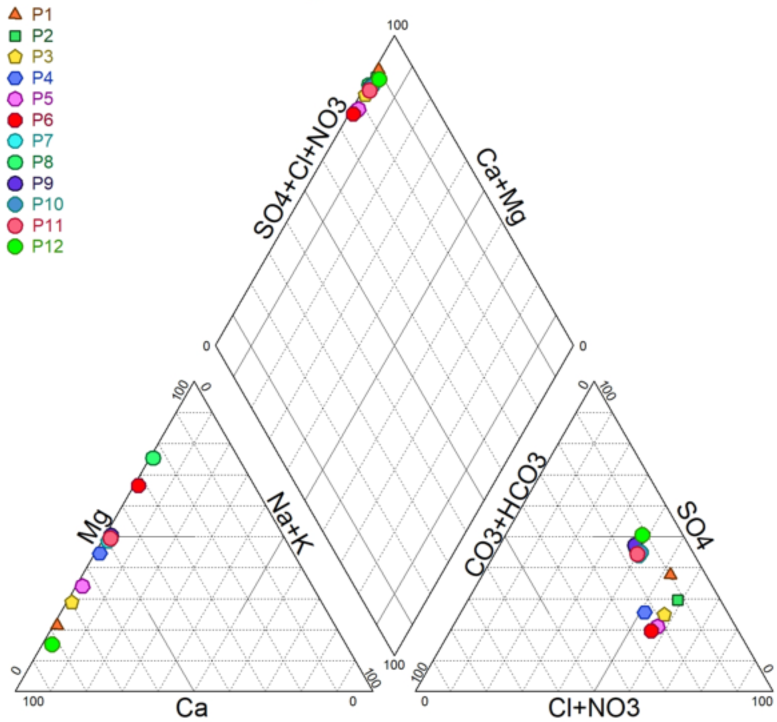

Figure 4

Piper diagram of Ghrib Dam waters for both sampling campaigns (January and May 2016, April and September 2017 and February, mars, April, and May 2018)

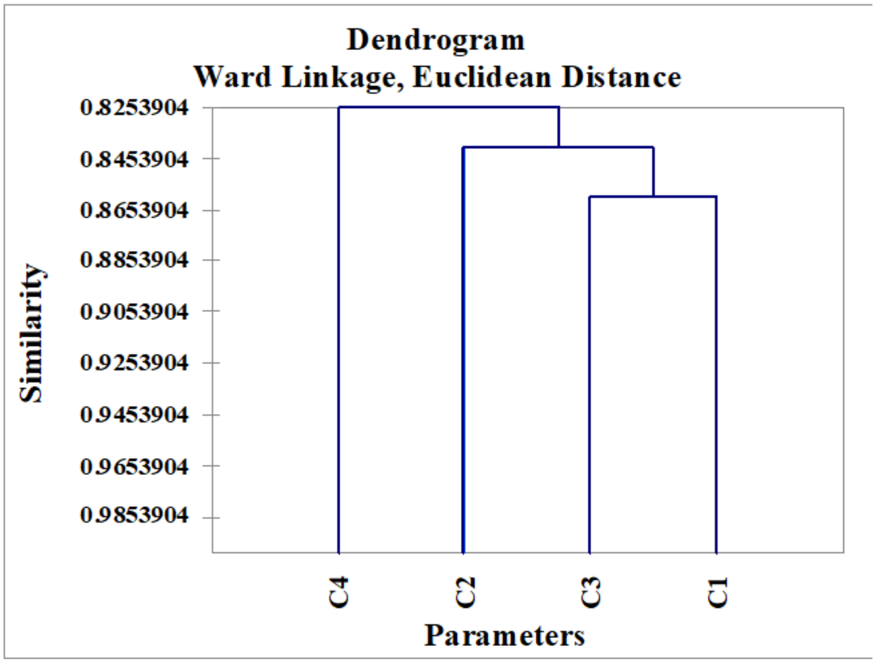

Figure 5

Dendrogram of HCA including all water samples of Ghrib dam water