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Impact of quarry sand exploitation on surface water flow quality—case of El Harrach stream channel, Algeria

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ABSTRACT

The surface waters near Megtaa Lazreg area, close to Hammam Melouane (a touristic area in Algeria), is well known for its good water quality. However, just downstream, the water flow of El Harrach channel takes a yellowish color appearance that is potentially related to the gravel and sand extracted from the quarry located in the vicinity. The main aim of this study was the assessment of aggregates extraction impact on the surface water quality in quarry site named SAMBA. Ten physical and chemical parameters were measured for each of the six sampling points, in addition to the turbidity. All the water analysis results were studied with multivariate statistics and Piper diagram in order to classify and determine water quality. The pH varied between 7.8 and 8.3, which indicate the alkalinity of the site water. The physicochemical analysis of all water samples collected upstream and downstream of the quarry showed that the concentration values of chemical components did not change, while physical parameter values increased considerably. The electrical conductivity values ranged between 510 and 2,570 μS/cm. The classification of chemical analysis results using Piper diagram revealed two water groups. Furthermore, the hierarchical cluster analysis indicated that three factors controlled the mineralization of the regional water. There are residence time, through fall soil by surface water and the influence of human activities on water pollution. Most of water physical and chemical components were not affected by extractions and wash water discharges, except the dry residue levels, the conductivity and the turbidity which increased downstream of the quarry.

Keywords: El Harrach channel; Aggregate; Quarry; Surface water

1. Introduction

The impact of aggregates exploitation along stream channel on surface water quality has become severe in recent years in northern Algeria. Algeria has actually 782 units of aggregates extraction for an effective production capacity of 32 million tons/year across 46 states [1,2]. The uncontrolled extraction of large quantities of sand from ephemeral stream channel, rivers, or the sea may causes serious damage to the environment and in particular to surface waters quality [3]. These stream channel changes would affect the water flow system, the deterioration of channel banks, reduction of light transmission in soil depth, and

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clogging the channel bed. Most physicochemical components of water are not affected by the extraction and the washing water discharge. Only the rates of dry residue and water turbidity increase downstream. Many authors through different studies have quantified the impact [4,5].

Moreover, if the pit quarry communicates with the groundwater reservoir, it may be polluted by extractions due to the suspension of fine particles, and mainly by accidental release of oil and petroleum products by machinery. A study of 22 gravel pits of the Eure Valley showed the presence of chloroform extractable in seven of them [6]. Control and monitoring of the quality of surface water and groundwater should be a particular interest to managers. They must have as main objectives the preservation of the health of the population and investigating for all types of pollution that may harm human health [7]. Therefore, it is essential to identify the sources of water pollution for better understanding their ecological impacts. Many authors have opted in recent years the analysis of the sediment partition for assessing pollution from non-degradable chemical contaminants in time [8–10]. Thus, the results of the application of this method permitted the assessment of the state of pollution by heavy metals and their origins.

This present study is an attempt to assess the impact of aggregate extraction on the physicochemical quality of surface water resources site at the quarry “SAMBA”.

SAMBA quarry is located on the upstream portion of El Harrach stream channel, and about 1-km downstream of the village, Hammam Melouane. This quarry exploits beige and gray limestone at a daily average rate of 1,500 tons. Ten physical and chemical parameters were measured for each of the six sampling points, in addition to the turbidity. All the water analysis results were studied with multivariate statistics and Piper diagram in order to classify and determine water quality.

2. Materials and methods

2.1. Presentation of the study area

The study site is 7 km long and belongs to Hammam Melouane region and it is encompassed between Magtaa Lazreg and the quarry “SAMBA” about 2-km downstream (Fig. 1). The region is located southeast of the town of Blida, in the prolongation of the mountains of Chréa. It is characterized by a mountainous territory (85% of the area). The region is well known for tourism and agricultural. Agricultural land is estimated about 2,000 hectares and forests cover an area of 12,000 hectares. Geologically, the region has Cretaceous formations in the South (marl and limestone), and land Miocene in the North (limestone, marl, sandstone, and conglomerate). The hydro-climate-region is subject to a Mediterranean climate, with an average annual rainfall of about 800 mm. Before the drought that affected the region during the eighties, the channel water flow was permanent with an average flow of 4.25 m^3/s. Presently, the water flow is ephemeral and does not exceed ten liters per

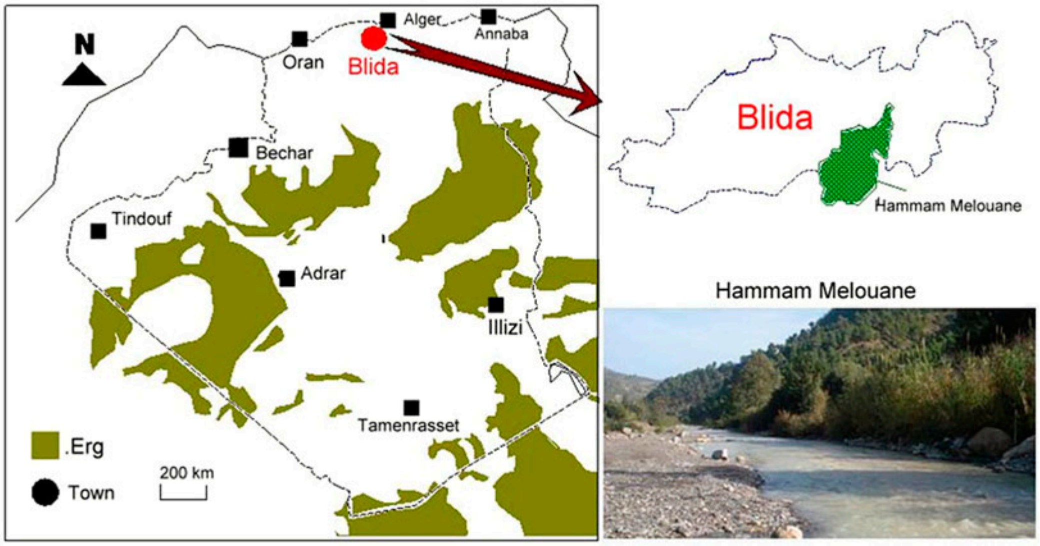


Fig. 1. Geographical location of the study area (Source: Remini et al. [22]; modified by the authors).

second during the dry season and about ten cubic meters per second on wet period.

2.2. Sampling and analysis

To assess the impact of aggregate extraction on the physicochemical quality of surface waters, five field campaigns were carried out between 2010 and 2012. Monitoring the evolution of water quality through a sampling network of six sampling points was selected to acquire representative data on the spatial and temporal variability of the surface waters quality (Fig. 2). The physicochemical analyses were carried on pH measurement, conductivity, turbidity, and concentration of the major elements.

Along the steam channel section, water samples are collected in sterile bottles, washed previously with distilled water and rinsed with withdrawn stream water. Water bottles were kept in a cooler at 4˚C, and transported to the laboratory for analysis.

Each collected sample was labeled with the exact coordinates identified on the topographic map 1:50,000, the water pH and conductivity values were also recorded. Chemical analysis for major elements and turbidity were performed at the ANRH (national agency of water resources) Laboratory. The collected data were processed using a combination of multivariate statistical and hydrochemical methods. A first approach by the principal component analysis (ACP) using the XLSTAT software on reduced centered variables was considered. Statistical analysis (ACP) was used to highlight the similarities and graphical position that would have two or more chemical variables during their evolution. This analysis is intended to follow the chemical evolution of the water. Indeed, the ACP is a descriptive multivariate statistical method used as a support to the interpretation of data matrix [11]. The second approach is based on the use of the analysis by the Hierarchical Ascendant Classification (CHA) for studying phenomena that may be at the origin of water mineralization. The CHA is a powerful tool for analyzing water chemistry data and the formulation of geochemical models [12].

3. Results and discussions

3.1. Physicochemical characterization

3.1.1. Temperature

Water temperatures in the sites vary from 9.8˚C in winter to 29˚C in summer with an average of 17.5˚C. This temperature is influenced by that of the air—it depends on seasonal variations.

3.1.2. Turbidity

Turbidity is defined by the standard EN ISO 7027 as the reduction in the transparency of a liquid due to undissolved materials [13]. This parameter indicates the amount of colloidal compounds. It is due to the presence of suspended solids of organic and inorganic origin, metal oxides and hydroxides, clays, silica, and planktonic micro-organisms [14,15]. Sediment transport is a natural phenomenon caused by water erosion, which can be accentuated by human action. The large

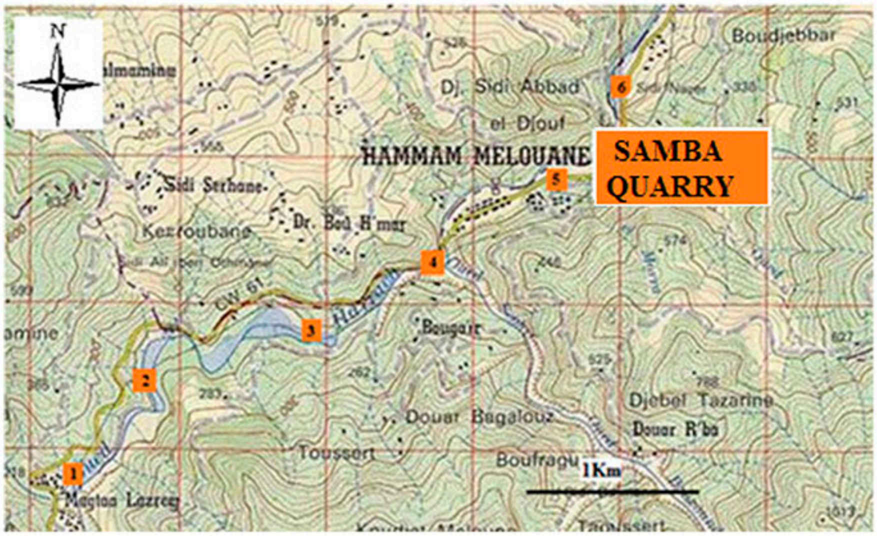
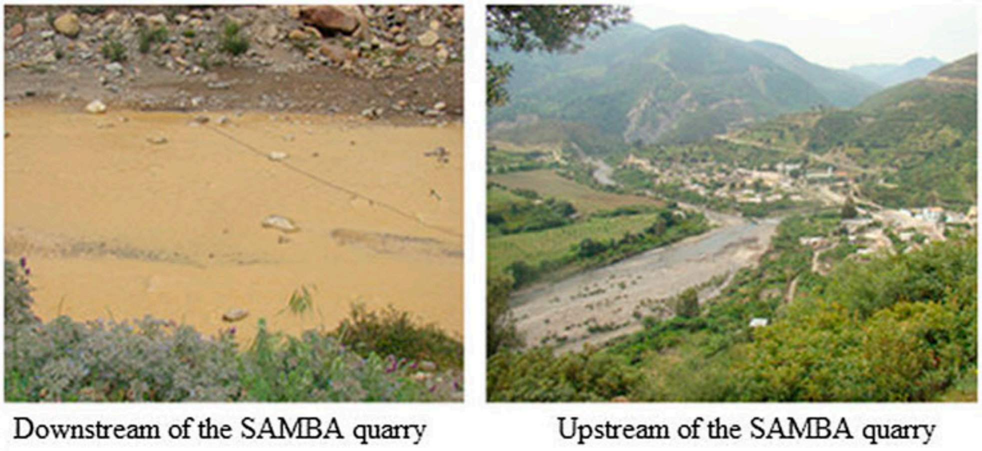


Fig. 2. 🟧 Location of sampling points from the SAMBA quarry (Source: National Institute of Cartography; modified by the authors).



Downstream of the SAMBA quarry

Upstream of the SAMBA quarry

Fig. 3. Variation between water color upstream and downstream of the SAMBA quarry.

volume of aggregates quantities extracted from adjacent rocks on the rivers banks generates high sediment content affecting the water turbidity. Fig. 3 shows clearly the color differences between the upstream and downstream water flow. The yellow color indicates high water turbidity downstream for about 01 km from the quarry (Fig. 4), the resulting suspension of fine clay particles in water can cause channel bottom clogging and limiting the water exchanges with aquifer. The intensification of clogging implies a rise in the height of water level in the river causing an overflow downstream. Besides that, the possibility of silt deposition and degradation of water quality may occur.

3.1.3. The pH

pH measurements show that all the points are in the potable water standard interval; this is due to direct contact of surface with air. Natural water pH is a function of the concentrations of dissolved carbon dioxide and hydrogen carbonates [16,17].

Between the periods of high and low water flow in the upstream of the exploitation system, Fig. 5 shows a maximum increase of almost 0.3 units near the sampling point P5 (located at about 2,000 m from point of origin). On the other hand, in the downstream area there was a rise of about 0.6 units. Near the extraction and washing pit quarry, fluctuations in the pH seem insignificant. This slight increase in pH indicates a low chemical change in the composition of surface waters that might be attributed to the temporary exposition of the exuviated quarry aggregates to the open air. During year 2010, the water pH was particularly alkaline. The slight pH variation throughout the study period illustrates the water buffering effect. This phenomenon can be explained by the combination of a significant photosynthetic activity (as evidenced by the growth of algae in the bed of the stream), the lithology of land crossed by water and by ionic reactions occurring in the contributions of discharges at the residential areas.

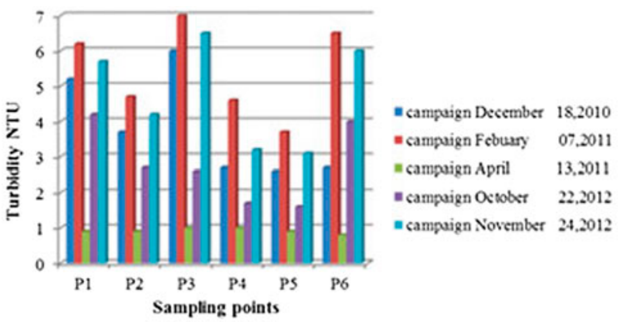


Fig. 4. Evolution of turbidity during the five campaigns.

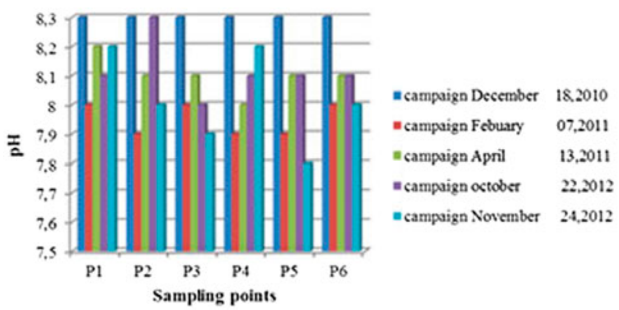


Fig. 5. Evolution of pH during the five campaigns.

3.1.4. Calcium

Calcium is present in all natural waters. Through the six sampling points, the calcium concentrations evolution shows an almost constant distribution near the quarry (Fig. 6), except during the last two campaigns in October 2012 and November 2012 where the sampling points P5 (100 and 117 mg/l) and P6 (100 and 109 mg/l) show concentrations above the threshold value of 80 mg/l. This significant increase in calcium levels indicates a runoff of fine particles associated with the dissolution of the surrounding limestone following rainfall events preceding sampling periods.

The calcium can also come from gypsiferous formations ($CaSO_4{\cdot}2H_2O$) that are easily soluble in water [18], the contents of Ca^{2+} are lower upstream because of the dilution of the ions by the contributions of steam channel flow or probably the water is beginning its mineralization.

3.1.5. Magnesium

During the 4th campaign, there was an increase in magnesium concentrations between P1 and P6 sampling points (Fig. 7). The last campaign shows a clear increase in the concentration value over the entire section. This variation is due to the influence of carbonate formations such as limestone and to clay and marl formations rich in Mg^{2+}.

3.1.6. Sodium

Note that the low concentrations are located upstream of the site, where the first 4 sampling points show a similar distribution of sodium during the five campaigns (Fig. 8). At P5 and P6 point (encompassing quarry), concentrations are increased by three for the five campaigns.

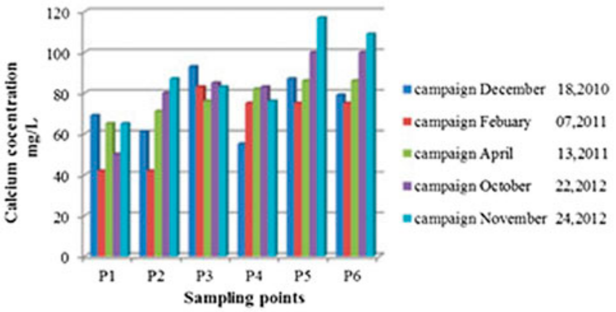


Fig. 6. Calcium evolution during the five campaigns.

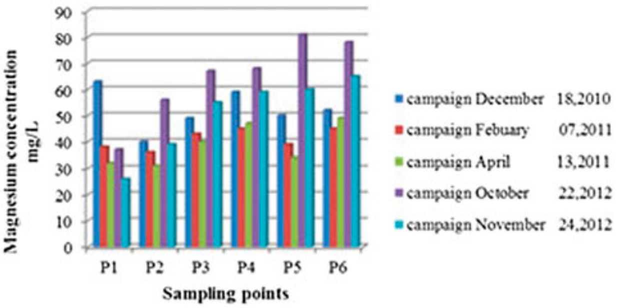


Fig. 7. Magnesium evolution during the five campaigns.

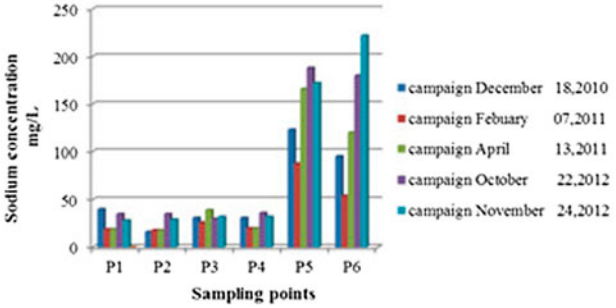


Fig. 8. Sodium evolution during the five campaigns.

Sodium ions in high concentrations are due to phenomena of leaching, and basic exchanges. Independently of leaching geological formations containing sodium chloride, the salt can also result from the decomposition of mineral salts such as sodium silicates and aluminum. The presence of sodium ions is mainly due to the dissolution of evaporitic formations rich in halite. The correlation between the sodium and chloride is due to natural weathering of the natural rock.

3.1.7. Chloride

The chloride contents are comparable to those of sodium. The minimum values are observed in the upstream portion of the river, and the maximum values are observed in the points P5 and P6, respectively, located downstream. Chlorides goes from 50 mg/l between P1 and P4 points for all campaigns to 400 mg/l in points P5 and P6 in October 2012. The homogeneity of concentrations for the first 4 points during the five campaigns and the sudden increase of these values (Fig. 9) near the quarry may indicate a direct influence of the quarry on the water quality. This trend indicates the contribution of anthropogenic input can be from urban and from the dissolution of

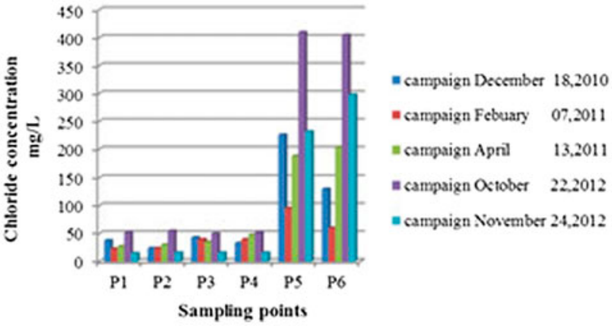


Fig. 9. Evolution of chlorides in the five campaigns.

evaporitic formations. Therefore, chloride ion considered as a natural tracer, highly mobile, and is relatively inert chemically. It does not participate in the precipitation reactions and is not adsorbed by the geological formations.

3.1.8. Potassium

Potassium presence in natural water usually does not exceed 10–15 mg/l. Net increase is potassium was observed between the points P1 and P6 in the last campaign except for the point P2 (Fig. 10). This increase is very noticeable from point P3.

In fact, although soluble potassium salts are mainly adsorbed in soils. Potassium comes from the weathering of silicate formations (Gneiss, Schiste), potassium clays and dissolution of chemical fertilizers [18]. The presence of this element may be also related to the discharge of domestic sewage in the area.

3.1.9. Sulfates

The distribution of sulfates (Fig. 11) shows an increase from April 2011 between P2 and P6 point and negligible concentration at point P6 in February 2011. The highest values are recorded during the period of low water flow, following the phenomenon of water evaporation, and may also be due to agricultural activities.

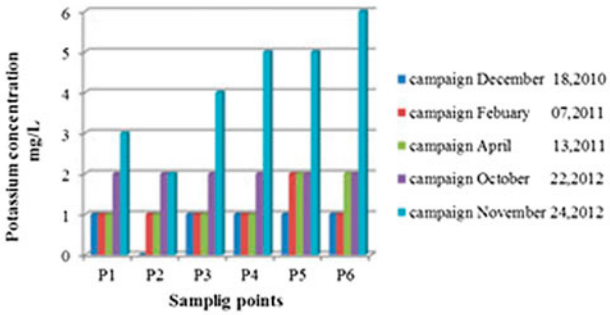


Fig. 10. Evolution of potassium in the five campaigns.

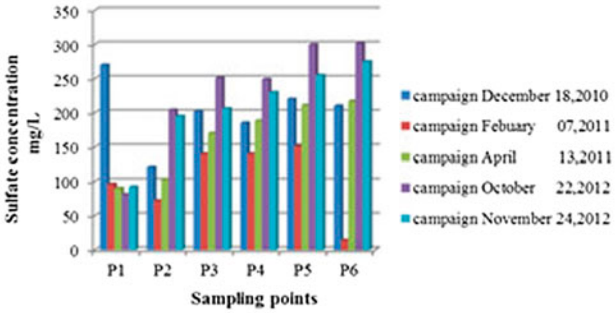


Fig. 11. Evolution of sulfates in the five campaigns.

The presence of sulfates in water is related to the dissolution of gypsum content in blackish slate marl from the Upper Cretaceous. Sulfates come from runoff or infiltration into the gypsum soils. They can also result from the activity of certain bacteria (chlorothiobactéries, rhodothiobactéries, etc.). This activity can oxidize hydrogen sulfide (H_2S) toxic sulfate [19].

3.1.10. Bicarbonates

The distribution of bicarbonates (Fig. 12) remains approximately uniform across the first 4 points and for the 5 campaigns. However, there was an increase in concentration values for this element (300 mg/l). For points P5 and P6, the presence of bicarbonate in the waters is due to the dissolution of carbonate formations (limestone) by water containing carbon dioxide. According to Faillat and Drogue [20], the presence of CO_2 in the water from soils facilitates the hydrolysis of silicate minerals and the formation of HCO^{3-} ions, and gives the water a much higher dissolution force by converting calcium carbonate into

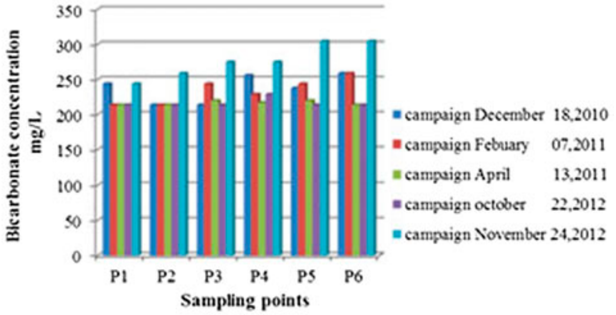


Fig. 12. Evolution of bicarbonates in the five campaigns.

calcium bicarbonate, that are more soluble in water according to the following reaction:

$$CaCO_3 + CO_2 \rightarrow Ca(HCO_3)_2 \rightarrow Ca^{2+} + 2HCO_3^-$$

3.1.11. Dry residues

The evolution of dry residues (Fig. 13) during the 5 campaigns reveals a relative steadiness, while the maximum was recorded at points P5 (1,696 mg/l) and P6 (1,650 mg/l), encompassing quarry. It clearly appears as a change in the concentrations of dry residues. Near the quarry, the concentrations of dry residues went from simple to double, reflecting the impact of the quarry on the water quality.

3.1.12. Conductivity

The trend of conductivity values (Fig. 14) is similar to that of dry residues through all sampling points. The conductivity is still above 500 µS/cm fluctuating between 1,542 and 2,570 µS/cm.

These measured conductivity values exceed the recommended standard for drinking water (AEP) which is 400 µS/cm. This is due to the significant effect of evaporitic in increasing the conductivity by its quick dissolution in water. The conductivity is related to the presence of ionic species in solution [21], it depends on the loads of endogenous and exogenous organic material, generating salts after decomposition and mineralization and with the evaporation phenomenon that concentrates these salts in water, and it also varies through the geological substrate.

3.2. Hydrochemical classification of surface water

The chemical facies of surface waters in the study area is given by the Piper diagram (Fig. 15). According to the Piper diagram, it appears that the surface waters in the study area are mainly calcium, magnesium, chloride and sulfate. This facies is the most dominant in the study area with 73.4% of the analyses. However, we observe a calcium and magnesium bicarbonate facies at sampling points 1, 2, and 6.

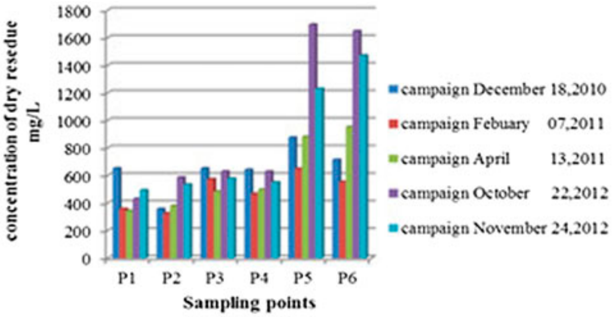


Fig. 13. Evolution of dry residues in the five campaigns.

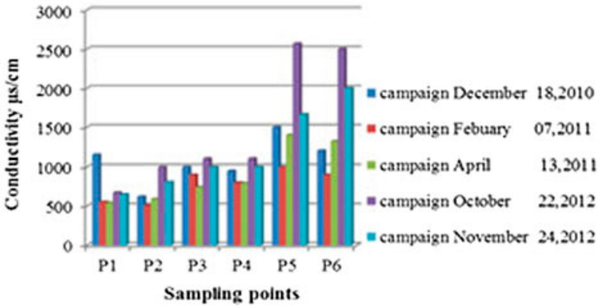


Fig. 14. Evolution of the conductivity in the five campaigns.

3.3. Multivariates statistical methods

3.3.1. Normed principal component analysis (ACPN)

The analyses were performed using XLSTAT software. The eigenvalues of the factors are shown in Table 1. The correlation matrix between the 11 parameters is shown in Table 2.

The first two factors (F1–F2) represent 72.03% of the variance expressed. Thereby, only the first two axes will complete analysis of the ACP results. The correlation coefficients between the physicochemical parameters are reported in Table 2.

Bold values are significantly different from zero at a confidence level of 95%. Data review on the correlation matrix between the variables reveal except for pH and turbidity, the existence of a strong significantly high correlation between the variables, which means that all these parameters fluctuate on average in the same direction. There are strong correlations between dry residues, conductivity, chloride, and sodium; all other elements are correlated at least moderately to weakly. Noting that potassium is correlated with bicarbonates, sodium, and calcium, and the turbidity is correlated only with bicarbonates. The low correlation between bicarbonate and cations show that the incongruent dissolution of silicate minerals is not the only process leading to the dissolution of these cations. Other sources and processes are involved in the mineralization of these waters as showed by the different observed correlations. The relationship between bicarbonate and electrical conductivity is not significant

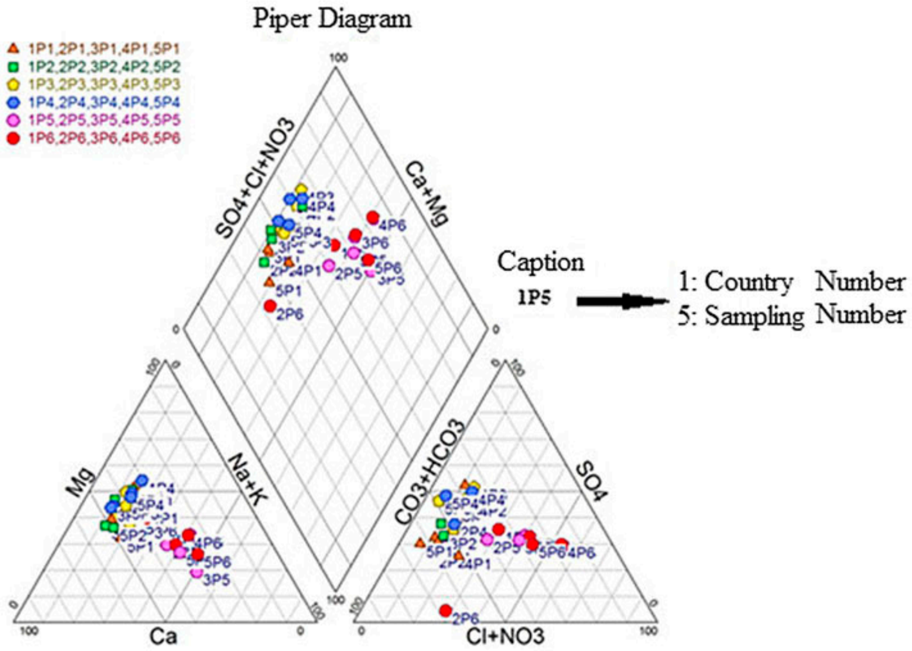


Fig. 15. Hydrochemical classification of surface waters in the study area.

Table 1
Eigenvalues and percentage of variance expressed

	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11
Valeur propre	5.983	1.941	0.964	0.797	0.604	0.330	0.222	0.116	0.025	0.010	0.008
% Variance	54.389	17.642	8.767	7.244	5.489	3.004	2.016	1.054	0.232	0.095	0.069
% Cumulé	54.389	72.031	80.798	88.042	93.531	96.535	98.550	99.604	99.836	99.931	100.000

indicating that the bicarbonates are not involved in salinity. Analysis of the variables in the factorial design ACPN F1–F2 is shown in Fig. 16.

3.3.1.1. Factor 1. The conductivity, dry residues, calcium, chloride, sodium, magnesium, and sulfates define factor 1 expressing 54.39% of the total variance. In the negative part of the factor 2, chloride, sodium, sulfate, magnesium, dry residues, and conductivity are clustered. This grouping can express mineralization related to domestic activities. The conductivity reflects the overall mineral content of water. F1 factor defines a mineralization gradient from left to right of the axis, indicating the pole evaporitic by the positive relationship between the elements SO_4^{2-}, Ca^{2+}, Mg^{2+}, Na^+, Cl^-, and electrical conductivity. Calcium and magnesium come from rock weathering and acid hydrolysis of the silicate minerals. This grouping then translates mineralization of waters due to contact water–rock (mineralization residence time). The F1 factor is therefore considered an axis original mineralization of both natural (contact water–rock) and anthropogenic origin.

3.3.1.2. Factor 2. Bicarbonates, potassium are close to the axis 2 factorial this means that these elements are brought into solution by the same phenomenon. Their closeness to this factor axis 2 the bicarbonate, potassium means that these elements are brought into solution by the same phenomenon. It is therefore considered as being the axis of mineralization expressing the phenomenon of soil runoff by the acid hydrolysis mechanism, indicating urban pollution. The contamination process is the cause of the union between bicarbonate and potassium. Indeed, the presence of bicarbonate would be related to the increase of CO_2 from the decomposition of organic matter. On the other hand, the inverse relationship between changes in bicarbonates and pH indicates the pole carbonates. The origin of these two elements in the waters is natural.

Table 2
Correlation matrix between variables

	Calcium	Magnesium	Sodium	Potassium	Chlorides	Sulfates	Bicarbonates	pH	Conductivity	Dry residues	Turbidity
Calcium	1										
Magnesium	**0.566**	1									
Sodium	**0.699**	**0.490**	1								
Potassium	**0.515**	0.338	**0.478**	1							
Chlorides	**0.657**	**0.592**	**0.939**	0.311	1						
Sulfates	**0.719**	**0.819**	**0.597**	**0.423**	**0.612**	1					
Bicarbonates	**0.411**	0.219	0.322	**0.722**	0.105	0.232	1				
pH	–0.177	0.051	–0.130	–0.336	–0.068	0.113	–0.260	1			
Conductivity	**0.746**	**0.778**	**0.892**	**0.402**	**0.948**	**0.777**	0.218	–0.025	1		
Dry residues	**0.754**	**0.719**	**0.923**	**0.453**	**0.959**	**0.731**	0.261	–0.084	**0.985**	1	
Turbidity	–0.115	–0.044	–0.144	0.161	–0.188	–0.241	**0.369**	–0.205	–0.103	–0.084	1

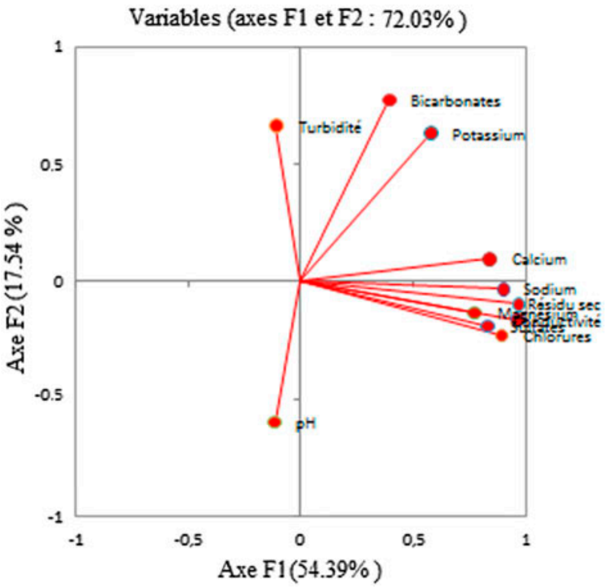


Fig. 16. ACP of the physicochemical parameters. Map factorial variables in terms F1–F2.

3.3.2. *Analysis ascending hierarchical classification (CHA)*

Fig. 17 shows the dendrogram resulting from the classification of the region's surface water based on their mineralization. This dendrogram highlights four groups (high dissimilarity) and sub-groups (low dissimilarity).

The analysis of individuals in the factorial F1–F2 has enabled us to distinguish four main groups (Fig. 18):

3.3.2.1. Group I. It includes points upstream of the study site, characterized by low conductivity in connection with a low mineralization. These waters have relatively low levels of sulfates.

3.3.2.2. Group II. This group is characterized by an intermediate mineralization influenced by anthropogenic activities. Relatively high sulfate contents are observed.

3.3.2.3. Group III and IV. The points P5 and P6 (Fig. 18) forms them, points encompassing quarry. These groups are characterized by high contents of major elements, which results in a significant conductivity, turbidity, and dry residues. They are therefore highly mineralized stations. Group IV is characterized by higher levels of bicarbonate and potassium; however, group III is characterized by the highest levels of dry residue. It was a demonstration of the impact of the quarry on the modification of the physicochemical quality of surface waters.

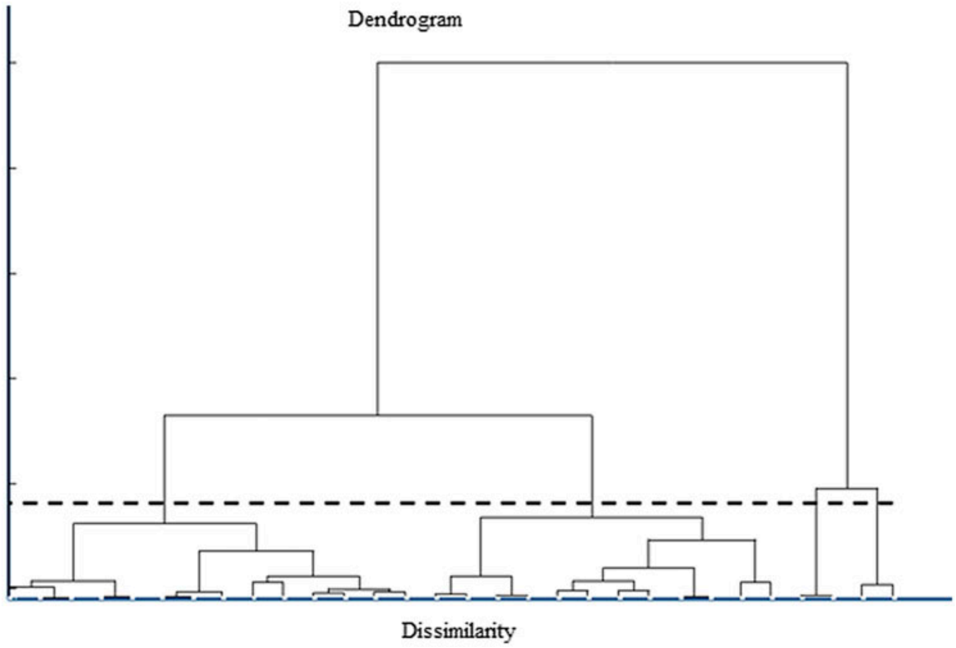


Fig. 17. Dendrogram of the classification of the area of surface water.

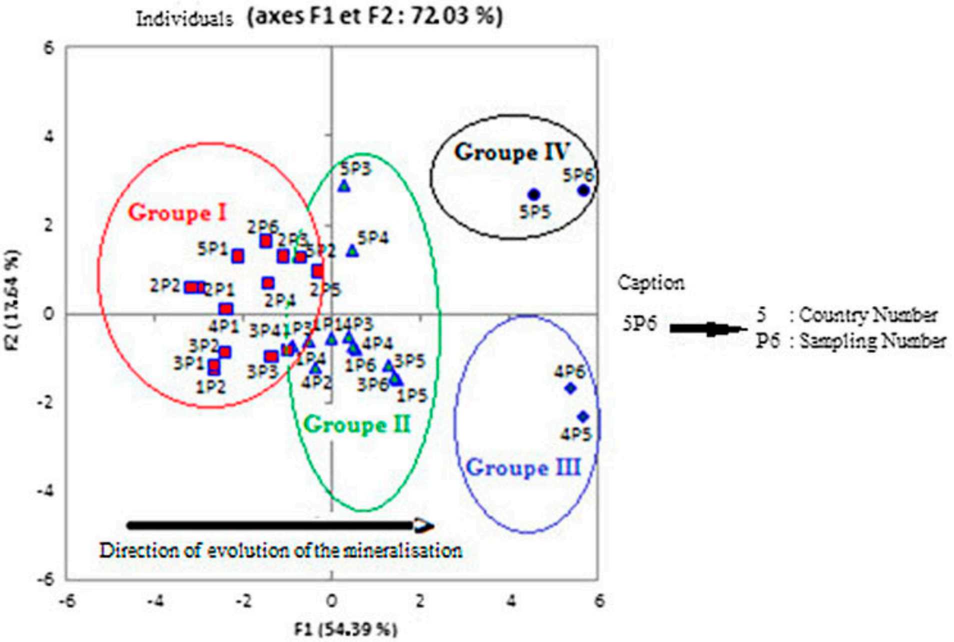


Fig. 18. ACP individuals. Factorial map of individuals.

4. Conclusion

This study allowed us to evaluate the degree of impact generated by the operation of the SAMBA quarry. The study of hydrogeochemical characteristics of water resources in the study site was made from the combination of hydrochemical methods, and multivariate statistical analysis. From the physical point of view, the temperature of the waters of the study area ranges from 9.8°C in winter to 29°C in summer with an average of 17.5°C. The water pH ranges between 7.8 and 8.3, indicating that the site waters are basic; this confirms the presence of limestone formations on the watershed. The electrical conductivity of the waters is high and varies between 510 and 2,570 µS/cm. The study notes that the site surface water is hard. The classification of chemical analysis results obtained from Piper triangular diagram identifies two water groups. Calcium and magnesium bicarbonate waters that are less important 26.67% of the studied waters, calcium chloride and sulfate waters are the most important Mg (73.33%). Over the entire study area, the water is characterized by a predominance of bicarbonate ions HCO^{3-} on Cl^- chloride ions and sulfate ions SO_4^{2-}. Calcium is the most important cation, followed by the sodium Na^+ and potassium K^+. The ACP and analysis ascending hierarchical classification (CHA) indicate that the mineralization of water in the region is controlled by three major phenomena. These are the mineralization residence time, soil runoff by surface water, and the influence of human activities in the pollution of surface waters. Most physicochemical components of the water are not affected by the extraction and the washing water discharge. Only the dry residue levels and turbidity of the water augmented downstream. The results of this study are interesting but certainly deserve to be enhanced by further investigations including a detailed analysis of heavy metals, nitrogen cycle, total phosphorus, and its relationship with suspended solids that justify pollution by organic matters or not.

References

[1] Bilans des activités minières du ministère de l'énergie et des mines (Balances of mining activities of the Ministry of Energy and Mines), 2010 ed., 2009.
[2] M. Khattaoui, O. Boudlal, A. Benamar, Journées Nationales de Géotechnique et de Géologie de l'ingénieur JNGG 2014 (National Days and Geotechnical Engineering geology JNGG 2014)—Beauvais, 8–10 July, 2014.
[3] Groupement d'intérêt scientifique "suivi des impacts de l'extraction de granulats marins (Monitoring the impacts of marine aggregate extraction)" GIS SIEGMA, July, 2012.
[4] Les Etudes des Agences de l'Eau (Studies of Water Agencies), No. 71, 2000.
[5] D. Mimoun, Spatialisation de l'information: Une aide à l'analyse hydraulique et paysagère développée lors de la réhabilitation des sites post industriels–cas des réaménagements des gravières en eau en milieu alluvionnaire (Spatial Information: Aid to hydraulics and

landscape analysis developed in the rehabilitation of industrial site post–cases water in alluvial gravel redevelopment areas)—Thèse de doctorat, Ecole nationale supérieure des mines de Saint Etienne et de l'université Jean Monnet Spécialité Science de la Terre et de l'environnement, 2004.

[6] Rapport à l'Agence de l'Eau Loire (Report to the Water Agency Loire)—Bretagne, IEA, Effets des extractions alluvionnaires (Effects alluvial extractions), 1995.

[7] K. Henni-Chebra, A. Bougara, A. Hallal, Estimation des particules de poussières causées par l'industrie cimentière les plaques métalliques, Revue "Nature &Technologie" (Dust particles Estimate cement industry caused by the metal plates. "Nature & Technology"). A-Sciences fondamentales et Engineering 12 (2015) 02–10.

[8] A. Abdallaoui, Contribution à l'étude du phosphore et des métaux lourds contenus dans les sédiments et de leur influence sur les phénomènes d'eutrophisation et de la pollution—Cas du bassin versant de l'oued Beht et de la retenue du barrage El Kansera (Contribution to the study of phosphorus and heavy metals in sediments and their influence on eutrophication and pollution – Case watershed of Wadi Beht and the dam El Kansera), Thèse de doctorat, Université Moulay Ismail Faculté des Sciences de Meknès, 1998.

[9] P.M. Chapman, Determining when contamination is pollution—Weight of evidence determinations for sediments and effluents, Environ. Int. 33(4) (2007) 492–501.

[10] Agence de l'eau Seine-Normandie, l'extraction de granulats dans le bassin Seine-Normandie (Aggregate extraction in the Seine-Normandy Basin) May, 2007.

[11] Y. Travi, J. Mudry, Méthode pour l'évaluation et la gestion du risque nitrate dans les aquifères du socle de la zone sahélienne d'Afrique de l'Ouest (Method for assessment and risk management nitrate in aquifers of the base of the Sahelian zone of West Africa), Revue d'Hydrogéologie 1 (1997) 13–21.

[12] S.M. Yiadana, D. Ophori, B. Banoeng-Yakubo, A multivariate statistical analysis of surface water chemistry data—The Ankobra Basin, Ghana, J. Environ. Manage. 86 (2008) 80–87.

[13] J. Lanteigne, Encyclopédie de l'agora (Encyclopedia of the Agora), 2003.

[14] Directive Cadre Stratégie pour le Milieu Marin DCSMM: Evaluation et suivi de l'impact des extractions de granulats marins sur les écosystèmes et la biodiversité (Strategy Framework Directive for the MSFD Marine Environment: Evaluation and Monitoring of the Impact of Marine Gravel Extraction on Ecosystems and Biodiversity), 2014.

[15] P.A. Duclos, Impact morpho-sédimentaires de l'extraction de granulats sur les fonds marins de la Manche orientale (Morphosedimentary impact of aggregate extraction on the seabed of the eastern English Channel). Thèse de doctorat, Université de Rouen, 2012, 266 p.

[16] M.L. Belghiti, A. Chahlaoui, D. Bengoumi, R. El Mostain, Etude de la qualité physico chimique et bactériologique des eaux souterraines de la nappe Plio-quaternaire dans la région de Meknès (Maroc) (Quality physico chemical and bacteriological study of groundwater in the quaternary Plio-web in the region of Meknes (Morocco)), Larhyss J. 14 (2013) 21–36.

[17] J. Rodier, L'analyse de l'eau: Eaux naturelles, Eaux résiduaires, Eau de mer. (Analysis of Water: Natural water, Wastewater, Seawater), ninth ed., Dunod, Paris, 2009.

[18] T.H. Debieche, 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 de la plaine Seybouse–Nord–Est Algérien), (Changes in water quality (salinity, nitrogen and heavy metals) due to salt pollution, agricultural and industrial (application to the bass Seybouse – North – Is Algerian plain)) Thèse de Doctorat, Université de Franche-Comté, France, 2002, p. 235.

[19] Haut-Commissariat Aux Eaux et Forêt et la Lutte Contre la Désertification (HCEFLCD), Etude sur la pisciculture au barrage Almassira, CR dar CHAFAAI, Cercle d'ELBROUGE (Office For Water and Forests and Desertification Control (HCEFLCD) Study on the fish at the dam Almassira, CR dar CHAFAAI, Circle ELBROUGE), Province de Settat, 2006, p. 201.

[20] J.P. Faillat, C. Drogue, Différenciation hydrochimique de nappes superposées d'altérites et de fissures en socle granitique (Hydrochemical differentiation of superimposed layers of regolith and cracks in granite base), Hydrol. Sci. J. 38(3) (1993) 215–229.

[21] J. Rodier, L'analyse de l'eau: Eaux naturelles, Eaux résiduaires, Eau de mer. (Analysis of Water: Natural water, Wastewater, Seawater), eigth ed., Dunod, Paris, 2005.

[22] B. Remini, D. Bensafia, M. Missoum, Silting of Foum el Gherza Reservoir, GeoSci. Eng. LXI(1) (2015) 1–9.