EEET ECOLOGICAL ENGINEERING & ENVIRONMENTAL TECHNOLOGY

Ecological Engineering & Environmental Technology 2023, 24(1), 1–11
https://doi.org/10.12912/27197050/154911
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Received: 2022.08.27
Accepted: 2022.10.08
Published: 2022.11.01

Physicochemical Characterization and Metallic Contamination of the Waters of Oued Nfifikh (Morocco)

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ABSTRACT

Oued Nfifikh is a coastal stream of the Bouregreg and Chaouia watershed (Morocco). It passes through many rural and urban areas and receives different types of liquid and solid discharges from anthropogenic activities adopted along the watercourse. This study aims to evaluate the physicochemical quality of the water from the most accessible sites upstream and downstream of Oued Nfifikh, along with highlighting the impact of human activities on these waters' quality. For this purpose, water samples were collected and analyzed within normalized methods. Statistical analysis of the collected data shows significant spatial variations ($p_{value} < 0.05$) for pH, electrical conductivity, nitrate and chloride, and for metallic trace elements (Zn, Fe, Ba, Mn, Cr and Al). Unlike (temperature, Pb, Ni, Cu and Cd), whose values do not present statistically significant variations ($p_{value} > 0.05$). The study of the physicochemical quality reveals that the waters at the upstream are classed as good quality, except for site (S2), located at the upstream part of the river, it is affected by human activities. Consequently, its physicochemical composition is quite similar to that of waters of poor quality at the downstream sites. The Principal Component Analysis of the results followed by the Ascending Hierarchical Classification on the same data matrix allowed to regroup the sampling sites with similar characteristics into three distinct groups. A group of highly mineralized waters, a second group dominated by elements indicating urban pollution, and a group of waters with low mineral content and low metallic contamination indicating agricultural pollution.

Keywords: surface water; physicochemical characterization; metallic trace elements; descriptive statistics; PCA; Oued Nfifikh.

INTRODUCTION

Continental aquatic systems such as lakes, wetlands, groundwater and streams, are under increasing stress from a broad array of anthropogenic impacts, which are direct results of socio-economic growth (OECD, 2016) and climate change (CESE, 2014; DREAL, 2019). The degradation of the overall ecological status of hydrosystems and the deterioration of their water quality are the main consequences, thereby compromising the various uses of water (UNICEF, 2008).

Until now, intermittent streams, also called temporary watercourses, had often been overlooked by both managers and scientists. These rivers receive sediment, nutrients, and toxic substances produced or used within their watershed, making them sensitive ecosystems that require special attention at a local and national level to provide the data needed for sustainable development and proper management of these precious water resources. Therefore, the required information lies in the key factors structuring the functioning of aquatic systems, namely physicochemical characterization and the evaluation of metallic trace elements (MTE) in the waters.

Several streams and river basins have attracted great interest from the scientific community. For example, in Morocco, many studies of different rivers have been the subject of specific studies on water quality. Various examples can be cited, such as Oued Moulouya, which was assessed by Makhoukh et al. (2011), and the Oum Er Rbia River as part of the study of Barakat et al. (2016). Some recent studies can also be stated, such as Afgane et al. (2021) on the Larbaa basin and that of Kabriti et al. (2021) on the Sebou watershed.

Moreover, at a regional level, many Oueds have been studied, such as Oued El Maleh by Oubraim (2002), Oued Merzeg by Mounjid et al. (2014), Oued Hassar by Nahli et al. (2015), Oued Daliya, a tributary of Oued Nfifikh, by Iounes et al. (2016) and Oued Boumoussa by El Amrani et al. (2018). Nevertheless, several coastal streams in the region remain neglected and less studied, such as Oued Nfifikh, which has no specific study regarding its water quality, besides a previous work by Merbouh et al. (2022) on the impact of an urban effluent on its downstream part. Additionally, a study by Tazi (2004) focused on the impact of climate on the estuarian of Oued Nfifikh.

Thereby, this work represents a continuity of the mentioned work above (i.e. Merbouh et al., 2022). Hence, the current study, which is also part of a thesis subject, is focused on the assessment of the water quality in the upstream and downstream parts of Oued Nfifikh, which are affected by different sources of pollution.

LOCATION AND SAMPLING SITES

Oued Nfifikh is an intermittent watercourse that covers an area of 607 km^2. The river originates in the region of Ziaida in Benslimane and pours into the Atlantic Ocean at the city of Mohammedia. The watercourse is not controlled by any dam upstream and the flow characteristics of this basin are evaluated at the Feddane Taba hydrometric station at 180 m^3/s for a 10-year return period (ABHBC, 2011).

From a climatic point of view, the study area is part of the semi-arid bioclimatic belt (Communal monography, 2010; General monography, 2015). The area records an average annual rainfall of 400 mm and a temperature varying between 7 °C and 27 °C. Peaks can reach up to 40 °C during the year, but their frequency remains exceptional (Akil, 1990; General monography, 2015). Geologically, the rocky outcrops in the study area are usually made up of schists and red pelites with basaltic doleritic intercalations (Farki et al., 2012; Farki et al., 2014; Farki et al., 2016).

Concerning this study, which covers a period of twelve months from August 2018 to July 2019, six sites along the river were targeted to assess the physico-chemical quality of their water, as well as their contamination by metallic trace elements. Table 1 and Figure 1 contain the descriptions and sampling locations for all the sites (S1, S2, SW, DP, S3 and S4), with (SW) as an acronym for spring water and (DP) for the discharge point.

Table 1. Description of sampling sites

Sampling site	Geographical coordinates	Description
Upstream sites		
S1	33°29'16.51"N; 7° 6'20.59"O	The site is often dry and within an agricultural watershed. The water is used for irrigation and to sustain livestock.
S2	33°33'43.36"N; 7°11'12.04"O	Located in a rural area within an agricultural watershed, where the population uses its water for daily activities, irrigation and livestock watering.
SW	33°39'41.41"N; 7°16'21.25"O	Natural discharge point of water at the surface ground that pours directly into the bed of the stream. It's a livestock watering point and a water source for the daily use of the local population.
Downstream sites		
DP	33°42'15.30"N; 7°19'54.27"O	An outfall through which domestic wastewater runs and pours directly into the stream's bed.
S3	33°42'20.47"N; 7°19'55.89"O	Situated directly downstream of the discharge point (DP). Its water can be used by shepherds to water their flocks.
S4	33°42'45.15"N; 7°20'14.61"O	The site is at the limit of the confluence zone between surface waters and those of the ocean.

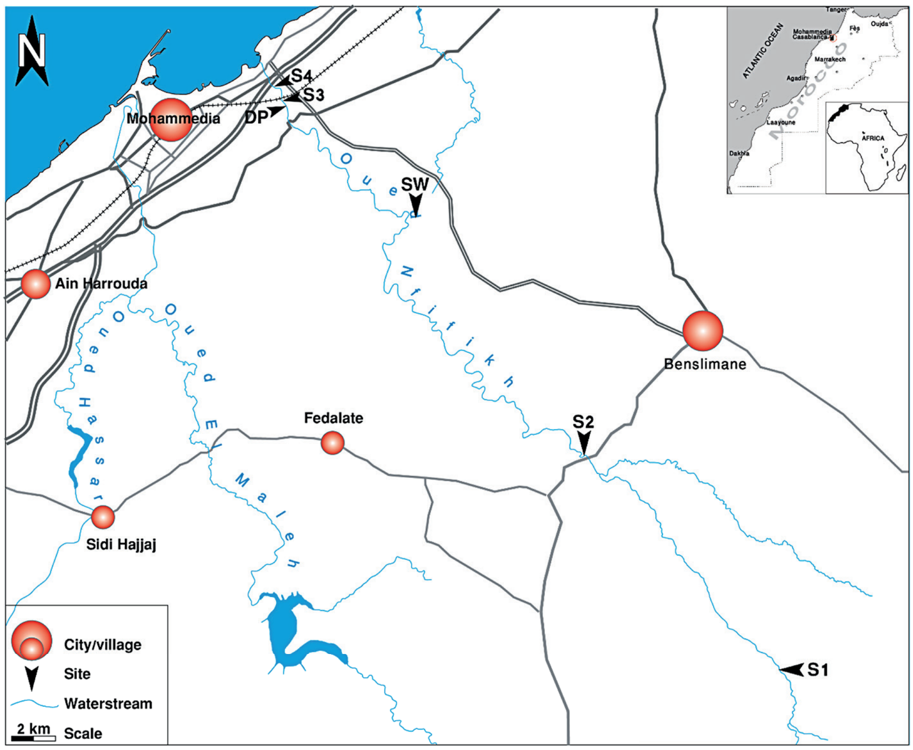

Figure 1. Location map of sampling sites in Oued Nfifikh

MATERIALS AND METHODS

The surface water sampling was carried out according to the methodology dictated by NF EN ISO 5667-1 standard using polyethylene bottles. Samples were collected between 9 a.m. and 2 p.m. The test equipment used for in situ measurements have been previously calibrated according to the manufacturer's instructions. Temperature, pH and the electrical conductivity were measured using a portable multi-parameter (*pHenomenal MU 6100 H*). The samples were then stored at 4 °C in the dark during transport to the laboratory and analyzed within the same standard cited above.

The analyses of nitrate and chloride were carried out according to the methods recommended by the AFNOR standards. Metallic trace elements in the waters (Cd, Zn, Fe, Ba, Cu, Ni, Pb, Mn, Cr and Al) were determined by microwave plasma-atomic emission spectrometry using the Agilent 4100 (MP-AES) according to an internal method used at the National Laboratory for Studies and Pollution Monitoring (Table 2).

For a better interpretation of the data, the results from physico-chemical analyzes and metallic trace elements assessment were subject to a descriptive statistical study using XLSTAT 2016 software. The methods used for descriptive analysis are non-parametric tests following the Kruskal-Wallis test procedure simultaneously with Dunn's test by applying Bonferroni's correction. Finally, a principal component analysis (PCA) followed by ascending hierarchical classification (AHC) were performed. To minimize the influence of different variables (evaluated parameters) and their respective units of measurements, the data underwent a log10 transformation on a matrix of 66 observations (samples) and 15 variables before PCA.

The physicochemical analyses were carried out at the Ecology and Environment Laboratory of the Faculty of Sciences Ben M'sick. While the concentrations of (MTE) in the waters were measured at the National Laboratory for Pollution Research and Monitoring.

Table 2. Parameters and analysis methods

Parameter	Methods	Reference
Metallic trace elements	Microwave plasma-atomic emission spectrometry 4100 (MP-AES)	Internal method
Nitrate ions	Sodium salicylate method	NF T 90-012
Chloride ions	Mohr's method	NF T 90-014

RESULTS AND DISCUSSION

Physicochemical parameters and metallic trace elements assessment

Table 3 presents the average values and the standards deviations of all the evaluated parameters, as well as the p-values obtained by the Kruskal-Wallis test.

Temperature is an important parameter in determining water quality. This parameter is related to the physical, chemical and biological properties of water (Blakey, 1966; Leynaud et al., 1974; IBGE 2005). The recorded values for the current study (Table 3) ranged between 7.5 and 31.2 °C with an average of 17.96 ± 4.6 °C at upstream sites S1, S2 and SW, 19.33 ± 2.790 °C at DP and 20.42 ± 5.846 °C at downstream sites S3 and S4.

It is to highlight that the variations in water temperature are strongly related to the exchanges with air temperature, as well as the water depth in the sampling sites. Temperature exchange between the two matrices has been demonstrated in the work of Dallas (2008) and Harvey et al. (2011) and previous data collected for Oued Nfifikh by Merbouh et al. (2022). However, the slight spatial variations in the values obtained for the temperature are statistically insignificant ($p_{value} > 0.05$) (Table 3) and the pairwise comparison according to Dunn's test shows that statistically there is no difference between the sites.

The values obtained do not exceed the irrigation standard (AC, 2002 a) at sites S1 and S2 and the direct discharge standard value (MDCEau, 2014) at the site DP. Moreover, comparing the results to the Moroccan water quality grid (AC, 2002 b) make it possible to classify the surface water of Oued Nfifikh as excellent quality for the upstream sites S1, S2 and SW and of good quality for the downstream sites S3 and S4 in terms of temperature.

Potential Hydrogen (pH) is a critical factor determining the health of a water stream as it affects most chemical and biological processes in water (WRC, 2020; US-EPA, 2022). The obtained values range between 6.97 and 8.68 with an average of 7.98 ± 0.2 at upstream sites S1, S2 and SW, 7.88 ± 0.07 at DP and 7.84 ± 0.2 at downstream sites S3 and S4 (Table 3). This basic tendency could be linked to the nature of the substrate crossed by the waters as stated in the works of the following authors for different watercourses Tfeil et al. (2018); Afgane et al. (2021); Kabriti et al. (2021) and Hbaiz et al. (2022).

Kruskal-Wallis and Dunn's tests show a significant spatial variation in the values of pH ($p_{value} < 0.05$), as well as a difference between sampling sites. This parameter variations can be linked to the organic matter decomposition of animal origin or human activities at the sites S1, S2, S3 and S4. However, the obtained values do not exceed

Table 3. Results of physico-chemical analyzes and evaluation of metallic trace elements

Parameters	S1		S2		SW		DP		S3		S4		P_{value}*
	Average	Standard deviation	Average	Standard deviation	Average	Standard deviation	Average	Standard deviation	Average	Standard deviation	Average	Standard deviation	
Temperature (°C)	16.071	5.061	19.458	5.743	18.358	3.203	19.936	2.790	20.033	5.927	20.825	5.765	0.224
pH	8.267	0.229	7.787	0.064	7.883	0.308	7.881	0.069	7.848	0.188	7.841	0.192	0.000
E.C (mS/cm)	0.810	0.345	4.061	0.891	1.448	0.043	2.640	1.084	3.017	0.593	3.023	0.588	< 0.0001
NO_3^- (mg/L)	1.852	1.034	3.342	1.394	13.445	6.179	12.503	22.918	7.555	8.515	3.896	6.021	0.006
Cl^- (mg/L)	93.996	30.524	632.715	202.809	208.096	68.298	321.778	175.746	480.975	175.237	421.287	218.184	< 0.0001
Cd (ppm)	0.008	0.009	0.011	0.009	0.007	0.005	0.012	0.010	0.010	0.009	0.013	0.009	0.707
Zn (ppm)	0.025	0.036	0.298	0.138	0.089	0.030	0.121	0.081	0.145	0.105	0.174	0.203	0.000
Fe (ppm)	1.467	1.246	1.274	0.499	0.111	0.053	0.505	0.354	3.775	2.154	2.851	2.981	< 0.0001
Ba (ppm)	0.077	0.057	0.103	0.028	0.161	0.052	0.037	0.017	0.122	0.043	0.210	0.298	0.021
Cu (ppm)	0.001	0.002	0.008	0.006	0.006	0.006	0.007	0.006	0.008	0.006	0.007	0.009	0.081
Ni (ppm)	0.006	0.007	0.005	0.005	0.004	0.002	0.007	0.008	0.008	0.006	0.016	0.026	0.607
Pb (ppm)	0.001	0.000	0.002	0.001	0.001	0.000	0.004	0.006	0.001	0.001	0.001	0.000	0.341
Mn (ppm)	0.225	0.472	0.274	0.100	0.010	0.009	0.140	0.116	0.528	0.513	0.571	0.462	< 0.0001
Cr (ppm)	0.011	0.002	0.012	0.002	0.008	0.001	0.010	0.001	0.016	0.004	0.036	0.077	0.004
Al (ppm)	2.416	2.068	2.169	1.687	0.103	0.172	0.281	0.369	5.318	3.400	4.614	6.637	< 0.0001

Note: * Kruskal-Wallis p-value less than 0.05 is statistically significant.

the irrigation standard (AC, 2002a) at sites S1 and S2 and the direct discharge standard value (MDCEau, 2014) at the site DP. By comparing the pH results of all sites to the Moroccan surface water quality grid (AC, 2002b), the assessed waters are classed as medium to excellent quality.

Values of the electrical conductivity (Table 3) varied between 0.43 and 4.84 mS/cm with an average of 2.106 ± 0.426 mS/cm at upstream sites S1, S2 and SW, 2.640 ± 1.084 mS/cm at DP site and 3.02 ± 0.59 mS/cm at downstream sites S3 and S4. According to the Kruskal-Wallis test, there is a significant spatial variation in E.C values ($p_{value} < 0.05$) (Table 3) and the pairwise comparison according to Dunn's test shows that statistically there is also a difference between the sites. Similarly, to pH variations, the electrical conductivity can be linked to the decomposition of organic matter from agricultural and domestic human activities, Barakat et al. (2016) and Benhassane et al. (2019) came to the same conclusions. The high values obtained in the waters at the upstream site S2 (4.06 mS/cm) and downstream sites S3 and S4 reflect the influence of these external inputs. Indeed, the site S2 is located in a rural area within an agricultural watershed, where the population uses its water for daily activities, irrigation and livestock watering. Sites S3 and S4 are located immediately downstream of the discharge point DP, which explains their contamination.

The measured conductivity does not exceed the irrigation standard (AC, 2002 a) at sites S1 and S2 and the direct discharge standard value (MDCEau, 2014) at the site DP. Nevertheless, comparing the obtained results to the Moroccan surface water quality grid (AC, 2002 b) reveals that the assessed waters from the downstream part of Oued Nfifikh (S3 and S4) are classed as of poor quality as for site S2 from the upstream part. Furthermore, the waters from the sites S1 and SW are classed as good and medium quality respectively.

The nitrate values obtained for all the sampling sites during the study period (table 3) showed a wide-ranging between 0 and 65.81 mg/L with an average of 6.213 ± 2.869 mg/L at upstream sites S1, S2 and SW, 12.503 ± 22.918 mg/L at DP and 5.725 ± 7.268 mg/L at downstream sites S3 and S4. These spatial variations in nitrates values are statistically significant (p-value < 0.05), and the pairwise comparison procedure shows a difference between sampling sites. According to Rodier et al. (2009), the nitrate content of water depends essentially on the intensification of agriculture in the watersheds and discharges of urban effluents, as it is stated in SW, DP, S3 and S4, where the maximum values reached respectively 28.41 mg/L, 65.81 mg/L, 30.74 mg/L and 18.51 mg/L.

The measured nitrate ions in water samples do not exceed the irrigation standard (AC, 2002 a) at the sites (S1 and S2). According to the Moroccan water quality grid (AC, 2002 b), the waters from all the sampling sites are classed as of good to excellent quality.

The chloride concentrations ranged between 62.39 and 879.23 mg/L with an average of 311.602 ± 100.543 mg/L at upstream sites S1, S2 and SW, 321.778 ± 175.746 mg/L at DP and 451.131 ± 196.710 mg/L at downstream sites S3 and S4 (Table 3). However, the spatial variations in chloride contents appear statistically significant (p-value < 0.05) and according to Dunn's test, there is a difference between the sampling sites. Variations in chloride values might be related to human activities in the Oued Nfifikh watershed and/or the outcrops crossed by the waters. Gartet et al. (2001) and Nahli et al. (2015) came to the same conclusion for Oued Lebéne and Oued Hassar, respectively, which high value of chlorides are also related to the Triassic outcrops crossed by the water.

Chloride ion concentration does not exceed the irrigation standard (AC, 2002 a) at the site S1 but greatly exceeds the standard at the site S2 (Table 3). Comparing the obtained results with the surface water quality grid (AC, 2002 b) reveals that the assessed waters from the downstream part S3 and S4 are classed as of medium quality as for the site S2 from the upstream part. However, the waters from the sites S1 and SW are classed as excellent and good quality respectively.

The measurements of Cd, Zn, Fe, Ba, Cu, Ni, Pb, Mn, Cr and Al show that the waters of Oued Nfifikh contain metallic trace elements at very low or even negligible levels (Table 3). Although, the presence of metals, even at low concentrations, in surface waters can have very harmful environmental and health impacts (Masindi and Muedi 2018; Mir et al. 2021). Due to their toxicity and ability to concentrate in the environment and accumulate in living organisms via bioaccumulation (De Villers et al., 2005; Briffa et al. 2020; Mitra et al. 2022).

Spatially, the values obtained for Pb, Ni, Cu and Cd reveal insignificant variations (p-value > 0.05) (Table 3), and the difference between the sites is absent, as shown by Dunn's test. However, these spatial variations in the concentrations of Zn, Fe, Ba, Mn, Cr and Al are statistically significant (p-value < 0.05). According to Dunn's test, there is a difference between the sampling sites. In surface waters, the levels of metallic elements often indicate contamination of anthropogenic origin, as stated by Rodier et al. (2009). Therefore, concentration levels obtained in this study depend on the wastewater discharges (DP, S3 and S4), as well as the landscape of the watersheds (S1, S2 and SW).

By comparing the values of each element (Table 3) with Moroccan standards (AC, 2002 a et b; MDCeau, 2014) depending on the type and use of water (Table 1), it appears that the concentrations of manganese in the waters of sites S1 and S2 (0.25±0.286 mg/L) and cadmium's concentrations in the waters of site S2 (0.011±0.01 mg/L) are slightly above the irrigation standard. As for the other metallic trace elements, they do not exceed the standard value of irrigation. Concerning the direct discharge limit value, none of the concentrations of the evaluated elements exceeds it. However, the overall quality of the surface waters assessed changes according to their concentration of metallic trace elements. Thus, cadmium concentrations (0.010±0.008 mg/L) in the water samples from all the sites and iron concentrations (3.313±2.567 mg/L) in the downstream sites' waters make it possible to qualify these waters as poor quality. As for the manganese concentrations (0.55±0.487 mg/L) in the waters from the downstream part of Oued Nfifikh, iron concentrations (1±0.6 mg/L) in the upstream sites' waters, the content of lead (0.002±0.001 mg/L) and chromium (0.016±0.015 mg/L) in all water samples qualify these surface waters as medium quality. Finally, zinc, barium, copper and nickel concentrations in all the water samples and the concentration of manganese in the upstream sites' waters classify them from good to excellent.

Principal component analysis and Ascending hierarchical classification

The Principal Component Analysis (PCA) with Varimax rotation allowed to highlight the potential relationships between the different variables and to assess the effect of human activities on water quality. Figure 2 shows the projection of the physico-chemical parameters in plan D1xD2 after Varimax rotation. Meanwhile, table 4 represents the contribution of the variables in the structuring of each of the two axes.

The PCA results indicate that the axis D1 explains 22.25% of the total variance in physico-chemical data. The D2 axis indicates 19.78% of the total variability in the data. Thus, 42.03% of the data variability is extracted by factorial D1xD2 after Varimax rotation (Figure 2 and Table 4).

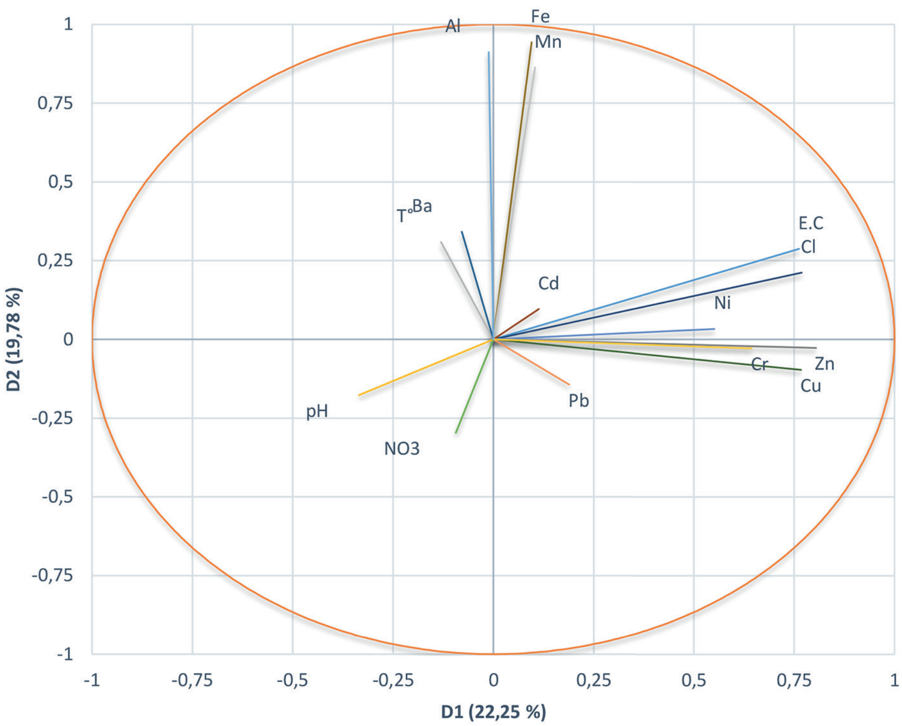

Figure 2. Correlation circle of the variables on the plan factorial D1 × D2

Table 4. Contribution of variables (%) after Varimax rotation

Variables/Axes	D1	D2
T°	0.509	3.208
pH	3.358	1.056
E.C	17.391	2.784
NO_3	0.262	2.966
Cl	17.702	1.515
Cd	0.383	0.312
Zn	19.384	0.024
Fe	0.272	29.975
Ba	0.186	3.930
Cu	17.629	0.314
Ni	9.097	0.037
Pb	1.069	0.695
Mn	0.323	25.123
Cr	12.430	0.027
Al	0.004	28.034

Note: The variables that form the D1 axis (pH, E.C, Cl^-, Cd, Zn, Cu, Ni, Pb and Cr) and the D2 axis (T°, NO_3^-, Fe, Ba, Mn and Al) present different forms of correlation. These correlations can be highly significant and others less (Figure 2 and Table 5).

The variables that contribute the most to the structuring of the axis D1 are Zn, Cl-, Cu, E.C and Cr. Thus, the D1 axis translate a gradient of pollution, mineralization and metallic contamination by Zn, Cu and Cr. Whereas, the Fe, Al and Mn variables contribute the most to the formation of D2 axis and reflect contamination of the waters by these MTEs.

Based on the results obtained in Table 5, the correlations between the variables forming the D1 axis are as follows: E.C and Cl^- (0.840), E.C and Zn (0.656), E.C and Cu (0.438), Cl^- and Zn (0.642), Cl^- and Cu (0.515), Zn and Cu (0.531), Zn and Cr (0.414), Cu and Ni (0.320), Cu and Cr (0.466), Ni and Cr (0.866), pH and E.C (-0.362), pH and Cl^- (-0.371). The meaningful positive associations of the D1 axis variables are that of chlorides and electrical conductivity and that of Nickel and Chromium. Thus, reflecting a mineral pollution that might be due to human activities in the watershed and the outcrops crossed by the waters. Regarding the D2 axis, the correlations between the different variables are as follows: T° and NO_3^- (0.028), T° and Mn (0.122), Fe and Mn (0.777), Fe and Al (0.949), Ba and Mn (0.272), Mn and Al (0.689), NO_3^- and Fe (-0.277), NO_3^- and Mn (-0.259). With one significant positive association of the variables, which is that of Iron and Aluminum. That, indicating possible metallic contamination from wastewater discharges and the influence of soil leaching from the watershed.

The projection of sampling sites on the D1xD2 factorial plan reveals the existence of three distinct groups (Figure 3). The group of highly mineralized waters (GI) with relatively high contamination by Zn, Cu and Cr, mainly from site S2; The group dominated by elements indicating urban pollution (GII), particularly, Al, Fe and Mn (downstream sites S3 and S4), and the group of alkaline waters with low mineral and metallic contents and relatively high concentration of nitrate (GIII), indicating agricultural pollution (sites S1 and SW).

Table 5. Correlation matrix between variables (Pearson (n))

Variables	T°	pH	E.C	NO3	Cl	Cd	Zn	Fe	Ba	Cu	Ni	Pb	Mn	Cr	Al
T°	1														
pH	-0.371	1													
E.C	0.082	-0.362	1												
NO3	0.028	-0.239	-0.079	1											
Cl	0.077	-0.371	0.840	0.016	1										
Cd	0.043	-0.140	0.157	-0.072	0.043	1									
Zn	-0.036	-0.217	0.656	-0.077	0.642	-0.091	1								
Fe	0.163	-0.083	0.280	-0.277	0.198	0.142	0.005	1							
Ba	0.079	-0.011	-0.007	0.037	-0.024	-0.244	0.044	0.221	1						
Cu	-0.062	-0.147	0.438	-0.030	0.515	0.041	0.531	0.022	-0.070	1					
Ni	-0.307	-0.069	0.131	-0.236	0.112	0.165	0.222	0.172	-0.002	0.320	1				
Pb	-0.001	-0.008	0.200	0.137	0.046	0.223	0.026	-0.032	-0.157	0.220	0.011	1			
Mn	0.122	-0.149	0.290	-0.259	0.224	0.029	0.020	0.777	0.272	0.021	0.145	-0.127	1		
Cr	-0.289	-0.016	0.159	-0.204	0.177	-0.030	0.414	0.123	0.056	0.466	0.866	-0.031	0.080	1	
Al	0.169	-0.077	0.204	-0.178	0.156	0.087	-0.031	0.949	0.199	-0.065	0.033	-0.034	0.689	0.003	1

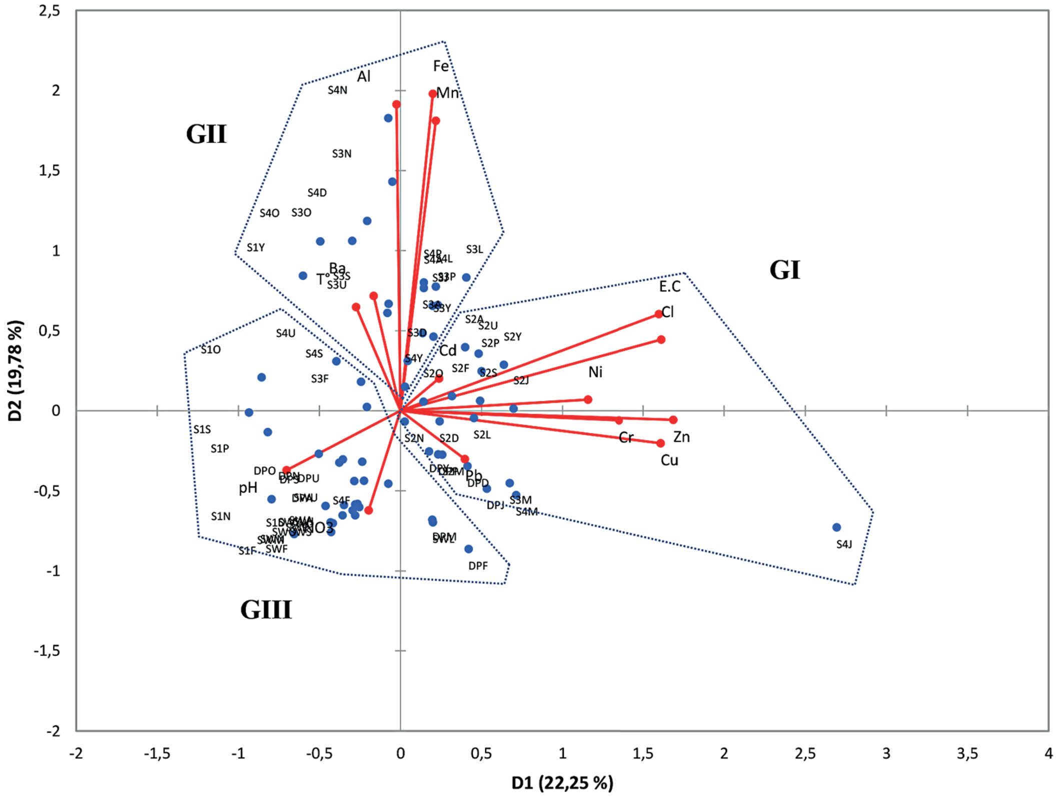

Figure 3. Distribution of physicochemical parameters and sampling sites according to axes D1 × D2

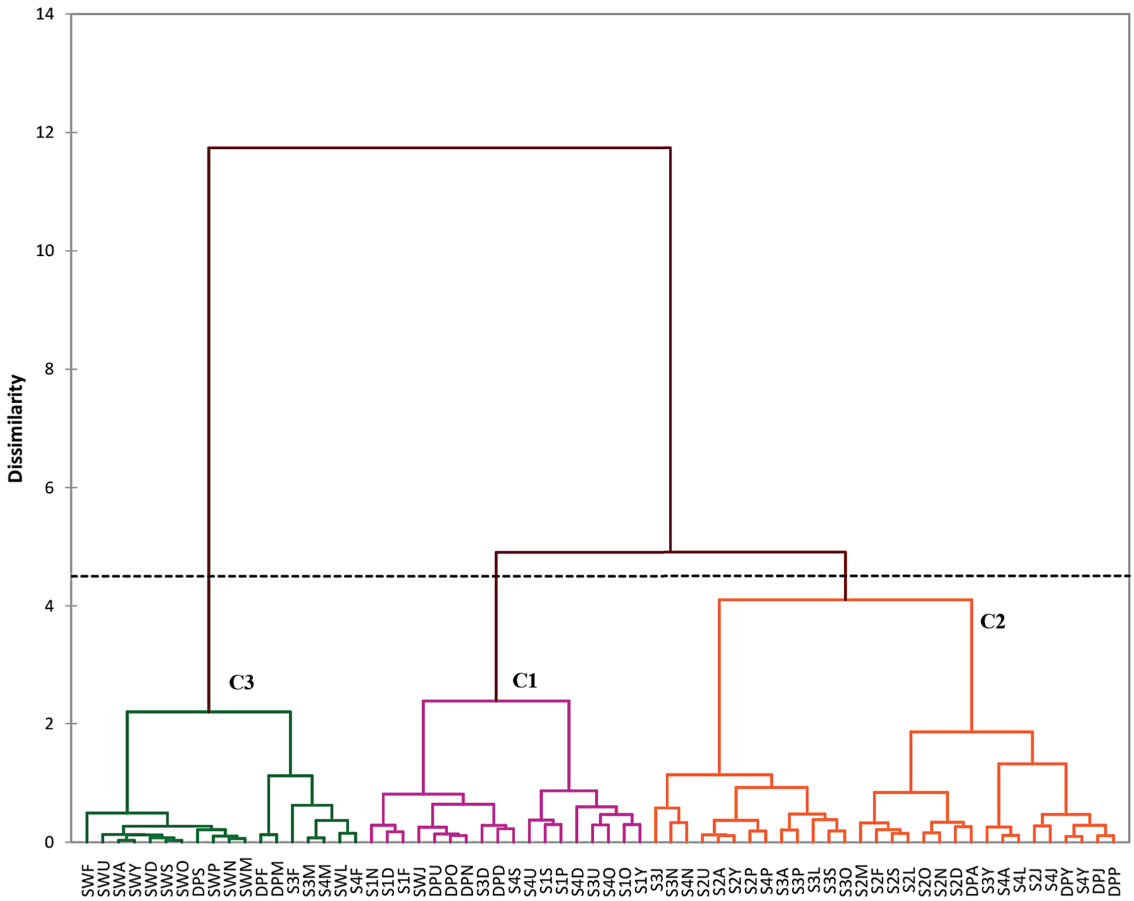

Figure 4. Dendrogram obtained from the Ascending Hierarchical Classification (AHC) based on the spatiotemporal matrix of water samples

In fact, as for the Principal Component Analysis (PCA), the application of (AHC) to the same matrix made it possible to regroup the sampling sites with similar characteristics into three distinct classes (Figure 4).

Compared to the other classes, class (C2) regroups the most impacted sampling sites. It includes the water from site S2 sampled during the 12 months of the study. It also includes the water from site S3, sampled during most of the study period, as well as the water from site S4. This class is represented, essentially, by the waters of the upstream site S2, which is severely impacted by different sources of contamination including natural processes such as the diffusion of external inputs through the leaching of the watershed's soil. As for the anthropogenic sources, this results in the presence of various solid wastes on the site and probably the impact of the infiltration of wastewater from septic tanks located in the area.

However, class (C3) of the dendrogram (Figure 4) regroups essentially the waters sampled at the spring water site (SW), which is the least contaminated site by the metallic pollution. The class also includes a few water samples from the discharge point (DP) and water samples from the downstream sites (S3 and S4). The waters of these sites are mainly impacted by the untreated urban discharge and by the presence of solid wastes in the banks and bed of Oued Nfifikh.

Class (C1) is represented essentially by the waters of the upstream site S1 (Figure 4) and few water samples from (DP, S3 and S4). This class gathers the sites that are impacted by the discharges of untreated effluent and solid wastes (S1, S3 and S4) and also the impact of unsustainable agricultural practices, as stated at the site S1, a site that often dries up following excessive and unreasonable withdrawals of these waters.

The cluster analysis shows that the two classes C1 and C2 have a relatively similar physicochemical and metallic quality of water compared to class C3. In addition, this analysis reveals that class C1 has a quality closer to class C3 than class C2. Thus, the distribution of water samples into the different classes is governed by two major phenomena: human activities and watershed leaching.

CONCLUSIONS

Efficient water resources management requires information on water quality and its variability. That is why this work was undertaken on Oued Nfifikh, an intermittent watercourse, which has never been the subject of a deep specific study of its water quality. According to the obtained results, the surface water quality of Oued Nfifikh changes depending on the parameter and elements evaluated. Generally, the sites located upstream are of good quality, unlike the sites which are often subject to the impacts of human activities, such as S2 and the sites located downstream. It is necessary to reduce the accumulation of pollutants in the waters and minimize the degradation of Oued Nfifikh's environment. This should be obtained by installing a suitable device for the treatment of urban wastewater before discharge into the environment, as well as the improvement of agricultural practices. Thus, the obtained results should make it possible to identify the contamination affecting the water quality in Oued Nfifikh and its potential sources. Consequently, helping managers make better decisions regarding Oued Nfifikh water management and action plans.

As limits encountered in the interpretation of this work, the presence of metals at low concentrations in the surface water since it flows, which makes its composition unstable and therefore leads to inaccurate metal analysis. In addition, the absence of Moroccan standards and limit values for some physicochemical parameters and metallic trace elements, whether for surface water, wastewater discharges or irrigation standards. However, sediments may contain the non-soluble fraction of metals and therefore allow for more reliable results regarding metal contamination in rivers. For these reasons, it is strongly recommended to assess the concentration of metallic trace elements in this stream sediment.

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