Spatial and temporal evaluation of the physico-chemical and microbiological quality of the water of the wadi Mechraa in a sustainable development perspective

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Abstract

Mechraa is one of the surface watercourses of the rural commune of Rommani. It is the main natural source of water for humans and livestock. However, it is currently threatened by the extent of urban, industrial and agricultural discharges. In order to identify the state of pollution of this watercourse, our study focused on the physico-chemical, spatio-temporal and microbiological variation (fecal and total coliforms and E. *Coli*). To do this, during the year 2021 seasonally, water samples were taken at five stations spatially distributed on the wadi. The results obtained describe a situation of the state of these streams is stagnant (S1, S2, S3) and the total evaporation of water downstream (S4 and S5) in dry periods. At the level of the stations where the wastewater of the municipality of Rommani is discharged, there is an increase in BOD5, chlorides, turbidity, temperature, sodium, Cl, potassium, nitrate and turbidity and a decrease in dissolved oxygen content, particularly in dry periods. The disappearance of fecal coliforms and E. *Coli* in the upstream (station 1) and is accompanied by an intensive increase in electrical conductivity downstream of the wadi in dry periods. Moreover, the degree of pollution differs from one station to another depending on the distance from the source of pollution.

Key words: Water, Physicochemistry, Microbiology, Pollution, Oued Machra, Morocco.

Introduction

Water is a natural resource essential for life in all ecosystems [1], and plays a very important role in socio-economic development. Indeed, water resources are a major concern in countries with arid or semi-arid climates. They are absolutely essential for the development of human, economic and social activities. It should be noted that the quality of water in the world has deteriorated in recent years due to the intensive use of chemical fertilizers in agriculture and uncontrolled industrial discharges. These cause a chemical change in the water [2], [3]. Thus, maintaining its quality is a major concern for a society that has to provide for increasing water needs.

In addition, many works have also focused on the study of the various effects of industrial and urban discharges on the evolution of surface water quality and the pollution of continental aquatic ecosystems [4]–[7]. Rivers play an essential role in the economic development of a country. The benefits of rivers are not limited to drinking water supply but also serve other activities such as irrigation, fishing, navigation, industry, hydroelectric power generation and waste disposal [8]. Thus, the increase in human activities along the river has an impact on the water quality of the rivers. Domestic, industrial and agricultural wastes are the main sources of river water pollution [9], [10].

For Morocco, the situation is more serious because it has had a water deficit for several years. In addition, the hydrosystems are increasingly threatened by various sources of pollution. The economic potential of Morocco is likely to be subject to adverse repercussions, particularly for human health [3]. Thus, in Morocco, the environmental approach has become an ecological as well as an economic issue, especially with its limited natural resources. Let us remember that water quality is defined by its chemical, physical and biological components, which depend on numerous endogenous and exogenous factors of the aquatic environment [11]. The quality of surface water is more or less regular, depending on the discharges that flow into it or on the runoff from rainfall, or according to the runoff of the rains, Socio-economic activities are the most important potential sources of pollution, and are those of agriculture, industry, artisanal fishing and tourism [12].

Regarding the Wadi Machraa, its waters have experienced, for several years, a significant deterioration in their quality. Indeed, the wastewater of the whole city of Rommani and agricultural residues are evacuated there. These discharges contain industrial domestic pollutants. The main objective of this work is to determine the state of water quality along Wadi Mechraa, based primarily on the study of physico-chemical and bacteriological parameters of water in the study area.

Material and Methods

- **Presentation of the study area**

All the watercourses in the Rommani basin are non-perennial. The main watercourse is Oued Mechraa. It has its source in Rommani, downstream at the level of the village "Nkhila" and it meets with Oued Krifla (Figure 1). Oued Mechraa is among the tributaries of the Bouragrag basin. Note that Oued Mechraa is located between latitudes 32° 18' and 35° 8' North and longitudes 1° 11' and 5° 37.

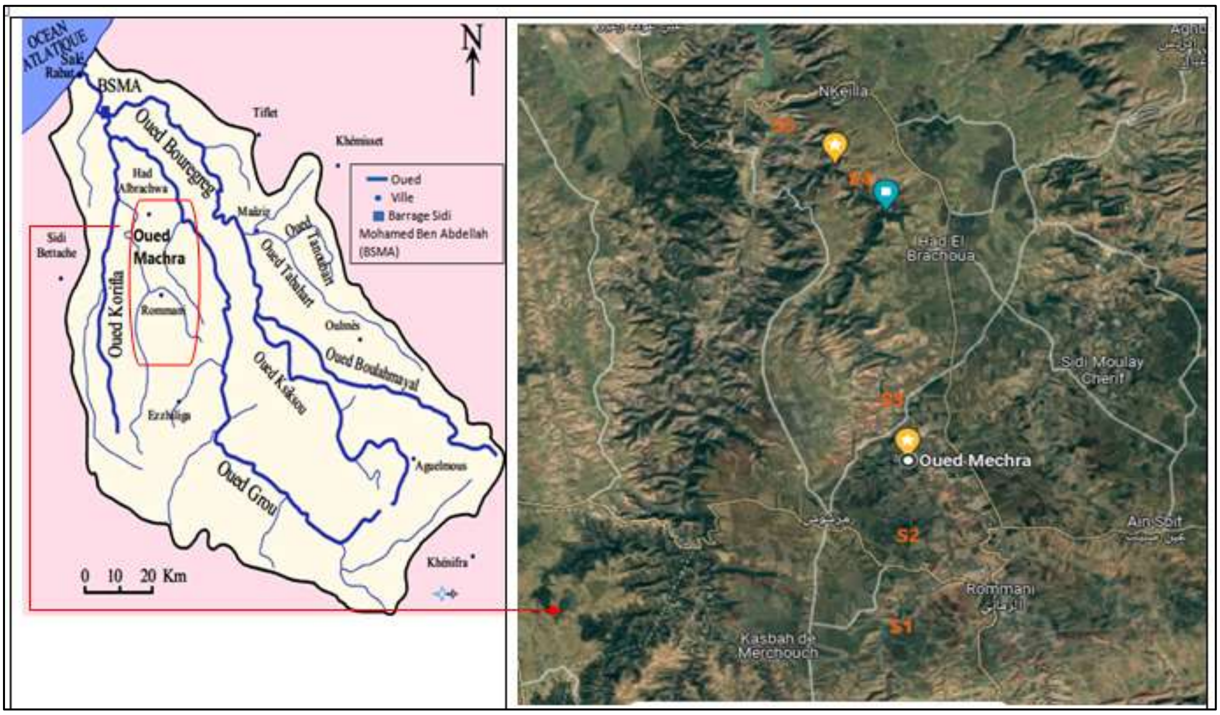

Figure 1 - Geographical location of Wadi Machra and sampling stations

- **Sampling process**

In order to establish a diagnosis of the state of surface water pollution along Wadi Mechraa, water samples were taken at five stations in wet and dry periods during the year 2021 (Figure 1 and Table 1). The water samples from each station were collected in bottles (polyethylene 1L) well cleaned and previously rinsed 3 times with water from the station. The bottles were filled to the brim and then the cap was screwed on to avoid any gas exchange with the atmosphere. Samples for microbiological analysis were taken using autoclaved bottles. The samples were kept in a refrigerated cooler during transport to the laboratory where the analyses were immediately performed. Physical parameters were measured in situ: temperature, electrical conductivity, dissolved oxygen and pH. For each sample, 17 parameters were measured including 14 physicochemical and 3 microbiological parameters.

Table 1: Geographical location and characteristics of the stations studied

Stations	Geographic coordinates		Background Substrates mm	Human activities
	Altitude N	Longitude w		
S1	33°36′31.7″	6°39′24.0″	Clay, sand	Entropic/agricultural
S2	33°32 ′17.0″	6°37′35.2″	Gravel Sand	Agriculture/forestry/ entropic

S3	33°605422	6.657288 ″	Coarse Aggregates	Forestry/agricultural
S4	33°45′16.6″	6°43′00.3″	Clay, Sand	Forester
S5	33˚76″11.45	6°72′8874	Sand, clay, gravel	Forestry/agricultural/

- **Chemical and bacteriological analyses**

The parameters of Temperature (T), pH, Electrical Conductivity (EC) and Dissolved Oxygen (DO) were measured directly on site: an Infrared thermometer (HANNA) measured Temperature; pH by a Model pH meter (HANNA); Conductivity was measured by a Conductivity meter (Model HACH) from the multi-parameter case and Dissolved Oxygen (O_2) was measured by an Oximeter (Model HACK). The other physico-chemical parameters indicating pollution were measured in the laboratory. Similarly, the degree of pollution by fecal bacteria was carried out in the laboratory. These analyses were carried out according to the methods of Rodier and Afnor [13], [14] in the laboratory of CNRST in RABAT.

Results and discussion

- **Physicochemical characteristics of the water of Wadi Mechraa**

Table 2 shows the variation interval, arithmetic mean, and calculated the standard deviation of the observed measurements for each of the 14 water quality parameters tested at each sampling station. The surface temperature was higher in summer (25.90-34°C) and lower in winter (14.90±0.5 -17.7 °C). A significant difference between the seasonal values of the stations is noted (p value = 0.000). These thermal variations depend on the seasonal variability of air temperature. The spatial and temporal evolution of pH at the different stations studied shows that the pH values measured are generally slightly alkaline and oscillate between 7.6 and 8.78. The increase in pH during the wet period may be due to the abundance of carbonate formations in the basin of Wadi Mechraa and are washed by rainwater and flooding of wadis [15]–[17].

The average oxygen content of Wadi Inaouen increases from upstream to downstream and passes from 3.8 mg/l (S1) to 4.5 mg/l (S5) during the dry period with a drop in value from DO to S2 which records a value of 0.98 mg/L. This important deficit in dissolved oxygen upstream of Mechraa is probably related to the high organic loads generated by the liquid effluents of the urban agglomerations of the region and which are loaded with high concentrations of polluting substances [18]. The drop observed at S2 is explained by the discharges of the city of Rommani.

The results obtained show an increase of the BOD5 of the water of the wadi Mechraa in dry period. Indeed, a maximum value of 650.33 mg/l was recorded in S2. For the other stations, the BOD5 values are relatively low. The high degree of pollution observed in S2 station can be explained by the discharge of raw wastewater rich in organic matter and nutrients from the urban agglomerations of (Rommani, Marchouch, Nkhila) [16]. These results conform to the work of Foutlane et al., and Brahimi et al., [19], [20].

Nitrate levels are low at stations S1, S5 and S4, S2. The value increases especially in the dry period and records 9.4mg/L. This increase may be related to the discharge of domestic wastewater from Rommani city [4], [15], [21] and the excessive use of fertilizers in agriculture [22], [23]. Nitrite levels vary from 0.08mg/l (S5) in wet periods to 1.66 mg/l (S2) in dry periods. The normal level of nitrite is set at 0.1mg/l according to the WHO. The high levels correspond to the reduction of nitrates to nitrites by sulfite-reducing anaerobes [24]. The concentrations of chloride, phosphate, potassium, sodium, magnesium and calcium ions found in the waters of Wadi Mechraa (Table 2) are very high in all stations during the dry period. This evolution indicates the contribution of an anthropic contribution which can be industrial. Also of urban origin and the decrease of these elements in wet period can be explained by dilution.

The average electrical conductivity values recorded show significant spatio-temporal variations. They fluctuate between 923µs/cm at S1 and 1386 µs/cm at S3 in wet periods and between 2143µs/cm at S3 and 8300µs/cm at S1 in dry periods. The latter values exceed the Moroccan standard for surface water which reaches a value of (2700 µs/cm). This indicates an excessive mineralization attributed to the wastewater of the urban commune Rommani and the presence of a saline water source called Elmilha next to the station (S1). The explanation of this decrease in wet period lies in the dilution of water by the contribution of rainwater [16].

Turbidity measurements show the presence of very high values at the stations (S1and S2) (Table 2) in wet periods than in dry periods. The maximum turbidity value is marked in station S1 upstream (202 mg/l, S1). These concentrations decrease significantly downstream to a minimum value of 3.85 mg/l recorded at S5 during the wet period. This variation in turbidity values can be explained by the concentration of suspended particles in the water (organic debris, clays, microscopic organisms from domestic discharges from nearby settlements at stations S1 and S2). In addition, the decrease observed during the dry period is explained by the decrease in precipitation during this period and the development of microscopic algae [25].

- **Bacteriological characteristics of the water of Wadi Mechraa**

The bacteriological results obtained are shown in Table 2.

Table 2: Spatial and temporal variations of the different germs in the water of Wadi Mechraa

Stations	Season	Escherichia coli UFC/100ml	Total coliforms	Fecal coliforms
S1	wet period	2300	2300	2700
	Dry period	0	0	81
S2	wet period	1600	1600	3600
	Dry period	970	970	1000
S3	wet period	1600	1600	2700
	Dry period	100	100	4500
S4	wet period	2000	2000	3700
	Dry period	110	110	4500
S5	wet period	1800	1800	3100
	Dry period	100	100	4700

The results obtained show that the concentrations of total coliforms and *Escherichia coli* recorded at the level of Wadi Mechraa are very high. The enumeration of total coliforms shows that their number varies from one station to another. The maximum value of 2300 CFU/100ml is recorded at station S1 in wet period and the minimum value of (0 CFU/100ml) at station S2. The high presence of total coliforms in surface water shows that the contamination of water is caused by domestic wastewater [26]. Total coliforms are absent at station 1 during dry periods (Table 3). A decrease in total coliforms and E. *Coli* in dry periods along Wadi Mechraa. This can be explained by the high content of electrical conductivity which affects negatively the charge of bacteria [27] and by the increase of sodium from the nature of the land which has brownish clay salt and blackish salt lite with potassium inclusions [28].

Fecal coliforms, indicative of fecal contamination, increase significantly from upstream to downstream in dry periods. The highest value is recorded at S5 (4700 CFU/100ml) and the lowest at S1 (81 CFU/100ml). This increase is due to the presence of animal rearing units and the use of animal manure in agriculture [27].

Table 3: Spatio-temporal variation of physicochemical parameters of the water of Wadi Mechraa

	Stations	T°C	PH	EC µs/cm	Tu mg/l	DO mg/l	BOD5 mg/l	CL mg/l	NO3 mg/l	nitrite mg/l	PO4 mg/l	K+ mg/l	Sodium mg/l	Mg mg/l	Calcium mg/l
S1	wet season	20,98 1±	8.72 ±0.5	923 ±15	202 ±7	3.13 ±0. 1	11.71 ±1	191.5 ±15	1.28 ±0. 1	0.22 ±0.01	0.65 ±0. 1	11.17 ±0.5	94.06 ±5	37.31 ±1.5	77.33 ±5
	dry period	33.99 ±1	8.55 ±0.5	8300 ±40	4.51 ±0.1	3.8 ±0. 1	16.13 ±0.24	2272 ±20	4.34 ±0. 1	0.77 ±0.1	0.85 ±0.1	7.81 ±0. 2	1678.6 ±10	121.45 ±5	120 ±10
S2	wet season	18.98 ±1	8.22 ±0.5	1356 ±20	125 ±5	3.05 ±0. 1	48.95 ± 1	225.2 5 ± 15	0.69 ±0. 1	0.12 ±0.1	7.03 ±0.5	18.02 ±0.5	127.21 ±5	52.32 ±1.5	82.86 ±5
	dry period	25.98 ±1	7.6 ±0.5	2143 ±25	167 ±10	0.98 ±0. 1	650.3 3 ±0.57	298.9 1 ±15	9.3 ±0.1	1.66 ±0.1	9.06 ±0.5	23.46 ±1	298.91 ±5	48.6±1	84±5
S3	wet season	14.97 ±0.5	8.29 ±0.1	1386 ±20	62 ±5	3.06 ±0.1	9.83 ±1	262.5 3±10	3.98 ±0. 5	0.24 ±0.01	0.72 ±0.1	11.11 ±0. 5	137.12 ±5	64.43±1 .5	109.42 ±5
	dry period	27.98 ±1	7.99 ±0.5	3543 ±30	7.72 ±1	4.01 ±0. 5	22±1	575. 1±15	7.44 ±0. 5	1.33 ±0.1	0.89 ±0. 1	4.68 ±0. 5	575.17 ±7	97.02 ±5	240±2
S4	wet season	16.98 ±0.5	8.78 ±0. 2	1346 ±25	91 ±5	3.06 ±0. 1	10.33 ±0.5	283.6 1±10	0.94 ±0. 5	0.10 ±0. 01	0.24 ±0.01	10.83 ± 1	141.91 ±5	57.71 ±5	106.18 ±5
	dry period	34±5	7.59 ±0.1	2750 ±30	6.5± 0.1	4.5±0. 1	20.55 ±1	570.5 ±10	7.42± 0.1	1.30± 0.1	0.9±0. .01	10.08 ±0.1	145.10± 10	90.5±1. 5	210.21± 5
S5	wet season	18.98 ±1.5	8.69 ±0. 1	1283 ±25	83 ±5	3.85 ±0. 1	9.16 ±0.7	340.3 4±10	1.75 ±0. 1	0. 8 ±0.1	0.25 ±0. 01	10.81 ±1	120.62 ±5	53.99 ±1.5	109.16 ±5
	dry period	34.5 ±5	7.65 ±0.5	2152± 30	6.21 ±0.5	4.02± 0.1	22.5 ±1	586.7 ±15	7.85± 0.5	1.35± 0.1	0.99± 0.01	10.91 ±0.5	151.52 ±7	85.97 ±5	215.01 ±5

Statistical analysis

Univariate (correlation tests), multivariate (similarity tests) and Principal Component Analysis (PCA) statistical analyses were performed to determine the different correlations existing between these parameters.

- **Principal Component Analysis (PCA)**

The percentage of variance expressed for each factor is given in Table 4. These values represent the contribution of each factor to the scatter plot. The first two factors express 94.03% of the variance of which 47.17% for component 1, 30.24% for component 2 and 16.62% for component 3. Component 1 is very important compared to the other factors and the factorial plane (Component 1 - Component 2) expresses 77.41% of the total variance of the scatter plot. The representation of the data in the (1-2) plane gives a fairly satisfactory account of the proximity of the elements.

- **Space of the variables**

The results of the statistical analyses, show that the first component 1 that contributes with 47.17% inertia is defined by the parameters Na (0.97), EC (0.96) and salinity (0.88) in its positive part and the parameters temperature (-0.96), Turbidity (-0.89) and dissolved oxygen (-0.8) in its negative part (Figure 1). Component 1 defines the mineralization gradient.

With an inertia of 30.24%, the second component is defined by the parameters phosphate (0.967), potassium (0.957) and BOD5 (0.948) in its positive part and by the PH (- 0.844) in its negative part (Figure 5) The fact that the high values of these parameters have a superficial origin of these elements, the component 2 defines the original anthropic factor of the nutrients by superficial contributions.

Finally, nitrites and nitrates, both of which are products of nitrogen oxidation (Figure 5), define component 3, which contributes with 16.62% inertia. Nitrates (NO_3^-) and nitrites (NO_2) are ions that occur naturally in the environment at a low level. They are the result of nitrification of the ammonium ion (NH_4^+) present in water and soil, which is oxidized to nitrite by bacteria of the genus Nitrosomonas, and then to nitrate by bacteria of the genus Nitrobacter. The component 3 expresses the phenomenon of nitrification

- **Spaces of statistical units**

In the factorial design (Component 1 X Component 2), three groups of statistical units can be distinguished (Figure 6). The first group is represented by stations S1 and S5. These stations are characterized by high concentrations of total coliforms, E. coli and dissolved oxygen. The second group is represented by station S2. This station is characterized by a high content of potassium, orthophosphate and BOD5 and little mineralized. The third group is represented by stations S3 and S4. These stations are characterized by a richness in Mg, Na and Ca.

Table 4: Percentage of factors.

Variance totale expliquée			
Component	Extraction Sum of squares of the selected factors		
	Total	% of variance	% accumulated
Component 1	8,020	47,174	47,174
Component 2	5,141	30,240	77,414
Component 3	2,825	16,619	94,033

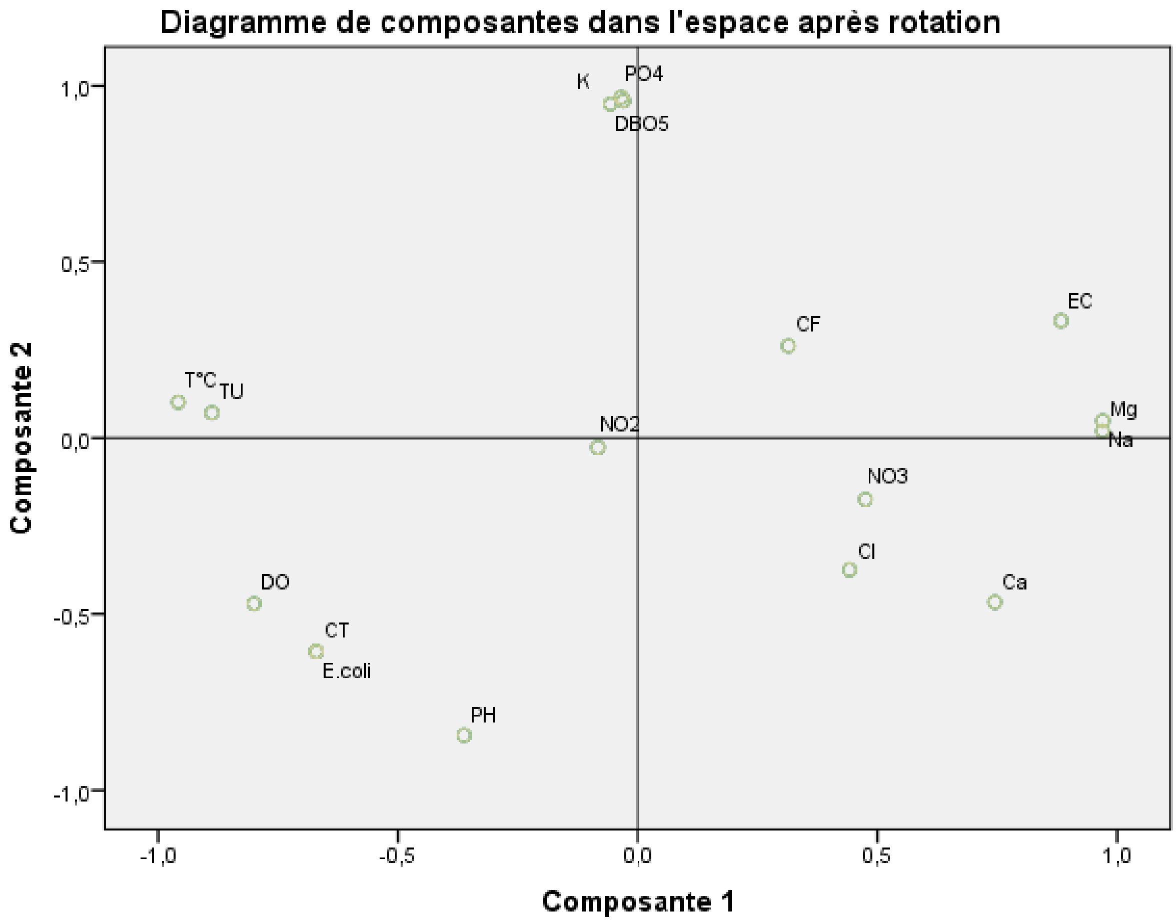

Figure 5: Principal Component Analysis in the Component 1-Component 2 factorial design (space of variables and statistical units).

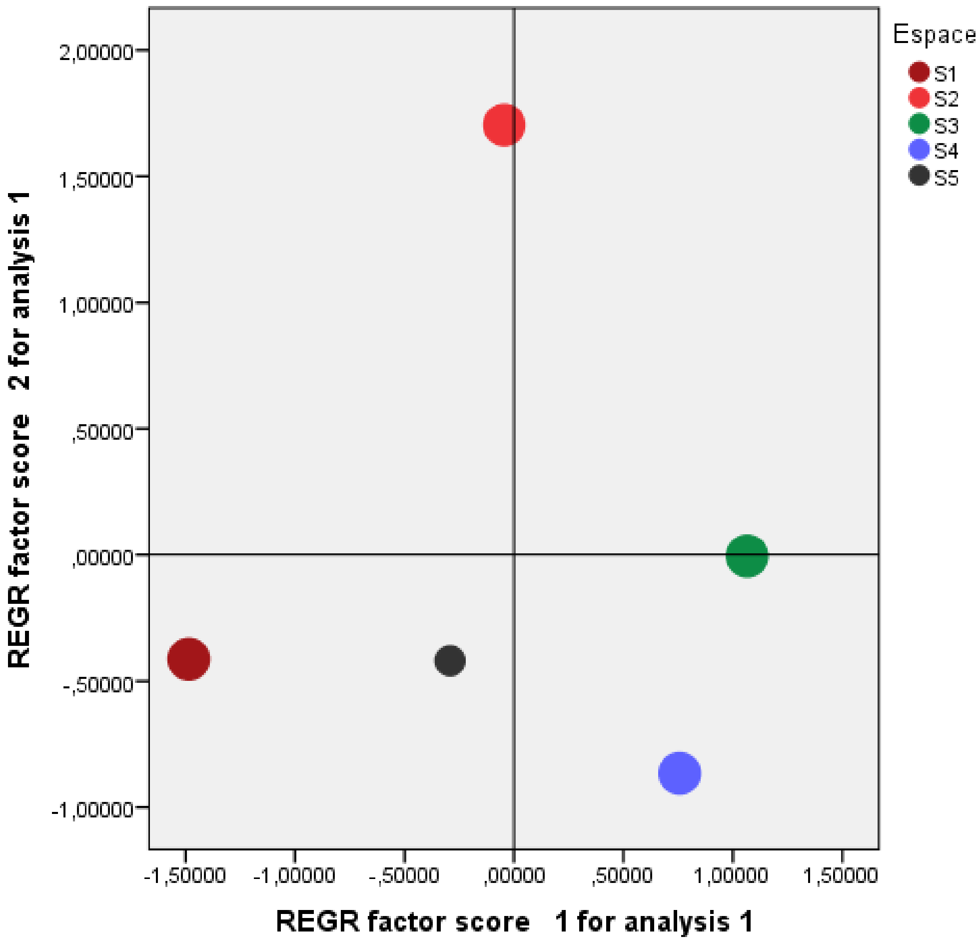

Figure 6: Distribution of study stations according to the Component 1-Component 2 factorial design)

Conclusion

The study of the quality of the waters of Wadi Mechraa has highlighted the direct impact of the global pollution, generated by the discharge of domestic and agricultural wastewater of the rural commune of Rommani. The statistical study showed that the high turbidity is in favor of a significant load of bacteria indicative of contamination of fecal origin, while the increase in electrical conductivity affects negatively the load in these bacteria. This study to comparatively assess water quality over time and space

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