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SPATIO-TEMPORAL VARIABILITY OF WATER POLLUTION IN THE WATERSHED OF WADI ECHAREF, SEDRATA, ALGERIA

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ABSTRACT

In order to monitor the spatio-temporal variability of water pollution in Wadi Echaref water shed, seven physico-chemical parameters are measured repeatedly over time (05 campaigns) in six selected sampling stations along this hydro system. The latter is subject to a pollution generated by discharges of domestic and industrial wastewater from two cities of Sédrata and M'daourouch. It receives daily more than 5313 m^3/day of waste water, 5000 of which are treated by the STEP (waste water treatment plant) of Sédrata and more than 313 m^3 are discharged directly without any prior treatment. In order to study the temporal stability of the spatial structure and measure the date station interaction in the 5 mesological tables obtained, we used partial triadic analysis. The study of the obtained results' temporal structure reveals the existence of a common structure among the different dates that reflect a downstream upstream type of spatial expression described by the variables that characterize the pollution. The stations (S1, S2, S3 and S4) located downstream the domestic and industrial discharges of the cities of Sédrata and M'Daourouch, are still opposed to other stations, highlighting that these stations remain polluted during the study period, as evidenced by the concentration of Nickel, Silver and Cobalt.

KEY WORDS : Wadi Echaref, Pollution, Partial triadic analysis, Discharges, Spatio-temporal variation.

INTRODUCTION

The wadis are sensitive and fragile ecosystems that are disrupted and sometimes destroyed by humans. The impacts of such activities are often very strong and persist for a long time. This is the case with discharges stemmed from domestic and industrial activities that, in most cases, lead to watercourses (Figuet *et al.,* 2000).

The town of Sédrata, like other regions in Algeria, witnesses every day multiple aggressions in its hydrographic network generated by discharges of domestic and industrial waters loaded with heavy metals coming particularly from M'daourouch and certain agglomerations that are not connected to the sanitation network and discharge directly into the aquatic environment without any prior treatment.

Several studies about the influence of wastewater on the water quality of wadis were conducted, we mention : Elements taking into account the impact of Urban discharges on natural discharges in the management of sanitation systems, Lyon (Wolff, 1994); discharges from small wastewater treatment plants and the quality of watercourses (Langhade, 1997); pollution of the Aquatic environment: Diagnosis and Proposal. Region of Annaba (Zenati, 2010); urban and industrial pollution of the surface waters of the Koudiat Medouar East Algerian dam (Tiri, 2010); Preliminary diagnosis of the physicochemical quality of the waters of the wadi Hassar after the installation of the Mediouna wastewater treatment plant (Casablanca, Marocco) (Nahli *et al.,* 2015); Spatio-temporal variability of the quality of running waters of Za Wadi (Eastern Marocco) (Mabrouki *et al.,* 2016); Impact of urban

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and industrial discharges of the water quality of the plain of Meboudja (Algeria) (Bougherira *et al.,* 2017); Assessing the suitability of stream water for five different uses and its aquatic environment (Fulazzaky, 2013); Water quality evaluation system to assess the status and the suitability of the Citarum river water to different uses (Fulazzaky, 2010) and Water Quality Evaluation System to Assess the Brantas River Water (Fulazzaky, 2009).

The main objective of the present study was to determine the impact of human activities on surface water pollution in the town of Sédrata.

To do so, the partial triadic analysis (PTA) was introduced in the field of ecology and the field of hydrology by Thioulouse and Chessel (Thioulouse *et al.,* 1987 and Centofant *et al.,* 1989), is repeated in this article to describe the spatial structure of pollution and specify its stability through a temporal superposition of several tables.

MATERIALS AND METHODS

Presentation of the region

Sédrata is one of the largest municipalities of Souk -Ahras (Figure 1), it has more than 58521 inhabitants. It offers great agricultural potential. The geomorphological configuration of the region is essentially flat, highly dominated by extensive agriculture (cereals, fodder, etc.) and sheep farming. The industry constitutes relatively the secondary sector in the economic scale, yet some industrial units are distributed in the municipality.

The geology of the region is characterized by sedimentary formations whose oldest age is the trias until the quaternary period. It is generally composed of limestones, clays, marls, sandstones, gravel and alluvium (David, 1956).

It is among the regions that suffer the most from drought and water stress. It is subject to a semi-arid climate characterized by irregular rainfall with periods of intense and persistent drought. The annual rainfall is of the order of 166 to 535 mm and the high temperatures which are more and more felt in recent years.

The watershed of Wadi Echaref is drained by several wadis. In the east, Wadi Tiffech which follows the axis of the synclinal plain of the same name. The syncline which forms the plain of Khamissa is crossed by wadi Crab magnified of the wadi Behezz, Wadi Ain Sfa and Wadi Es Souk towards which flows the waters coming from the southern slope of the Atlas chain. Wadi Crab that flows into Wadi Tiffech becomes Wadi Hamimine downstream. The latter and Wadi Crab merge in the South-West of Sédrata and give Wadi Echaref which passes at the foot of Jebel Zouabi , then comes wadi Ain Snob which has its source in the chott El Magéne and Jebel Terreguelet at the farthest points of the great basin of Seybouse. Wadi Settara formed from Wadi Ain Babouche and Wadi El Mebdoua; these tributaries are fed by the small streams descending from Jebel Sidi Reghis north of Oum El Bouaghi and the eastern flank of the Chebkat Sellaoua range (Fig. 2) (Halimi, 2008).

Sampling and analysis

We assessed the level of water pollution in the watershed system of Wadi Echaref watershed,

Fig.1. Location map of the study area

which is the recipient of several discharges based on a spatio-temporal sampling protocol covering 05 months and six sampling sites namely (Fig. 2):

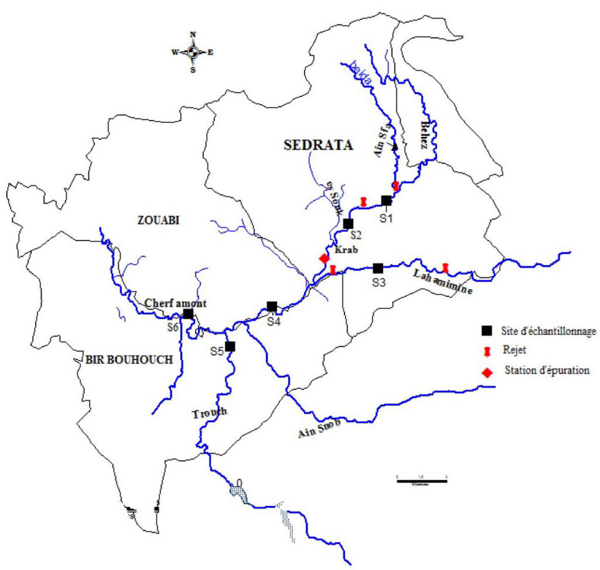

Fig. 2. Hydrographic network of Cherf Wadi watershed and the sites of the discharges and samplings.

- Crab Wadi (S1 and S2);
- Hamimine Wadi (S3);
- Trouch Wadi (S5),
- ECharef Wadi upstream (S4) and downstream (S6).

During the sampling campaigns of water withdrawal, from February to June 2016, we respected the sampling standards "filtration (0.45 ìm filter), acidification (5 mL of HCl or HNO_3) and conservation (4 °C) "(AFNOR / T91E).

The physicochemical parameters (pH, temperature) are measured in situ using a multi-parameter WTW device (Multi 340i/SET). The trace metals (Fe, Ni, Ag, Co and Cu) were determined by atomic absorption with flame (AA-620).

Methodology

The use of partial triadic analysis (PTA) is intended for the analysis of a block. The layout of the table meets the purpose of the study. Simultaneous analysis of 05 table-dates [stations x variables] using PTA makes it possible to identify an array [stations x variables], called compromise, constituted by the best combination of the 05 table-dates and which gives the best ACP. The implementation of the latter provides a model (Compromise) of the permanent spatial structure described by physicochemical parameters. The analysis of the deviation from this model (inter-structure) makes it possible to study the temporal evolution of this structure (Thioulouse *et al.*, 1987 in Blanc *et al.*, 1998). This strategy analysis offers a good alternative because it makes it possible to objectively identify a stable spatial structure common to all dates, which is not the case with the implementation of separate analyzes.

RESULTS AND DISCUSSION

Physico-chemical characteristics

Trace elements contribute to the functioning of aquatic ecosystems, being essential for the hydrological process; however, beyond a certain concentration or when they are in certain chemical forms, they become harmful for living species (Kremling, 1983).

Their concentrations depend on the pH. For example, copper trapped by the particulate phase is desorbed at acidic pH (Bordin, 1991); it becomes labile thereafter and bio available for aquatic life. The opposite effect occurs at high pH, where dissolved copper associates with the particulate phase (Bordin, 1991).

The results of the physicochemical parameters analysis of the waters of wadi Echaref and its tributaries are presented in Figure 3.

It appears that the pH of the water of our sampling stations varies between a minimum of 7.44 measured in S4 and a maximum of 8.28 recorded in S6 but, in general, the average pH of the water of the various stations remains neutral to slightly basic and are globally around 7.84.

The variation of the temperature of the surface waters follows those of the variations of the atmospheric temperatures. We observed strong monthly fluctuations with an average of 11 ° C in February and 20.8 °C in May. During our study period, Silver content ranged between 18.9 and 478.1 µg/L recorded respectively in S6 and S3, giving an overall average of 261.3 µg/L. However, this average silver concentration follows a decreasing trend from upstream to downstream. Concentrations of cobalt in middle waters fluctuate between a minimum of 1.5 µg/L recorded in S6 and a maximum of 162.7 ug/L reported in S3, for an overall average of 91.2 µg/L. These average concentrations of cobalt follow a decreasing gradient from upstream to downstream with a slight decrease in S2.

For copper, the concentrations range from 7 µg/

L in S2 to 53.8 µg/L in S3 with an overall average of 24.8 µg/L. The highest content recorded in S3 would be related to the high Copper load in the effluent waters of the city of M'Daourouch. The evolution of iron content follows a decreasing gradient from upstream to downstream. The high value recorded at the S3 station (47.6 µg/L) is linked to effluent discharges. In contrast, the lowest value is recorded in S4 (9.8 µg/L) in March.

Nickel concentration ranges from a low of 4.4

Fig. 3. Spatial variations in Physico-chemical characteristics

μg/L reported at the S5 station to a high of 153.2 μg/L recorded at S3 with an overall average of 55.7 μg/L. It should be noted that, with the exception of copper where minimum concentrations were recorded in February, the lowest metal concentrations are observed in March.

To assess the quality of the waters with respect to the elements Fe, Ni, Ag, Co and Cu known for their toxic character, we have established a classification of six stations in terms of contents of metallic elements.

To do this, we calculated a contamination factor (CF), which is defined as the ratio between the measured concentration of a metal and that of the same metal for the natural background noise (ref) (equation 00). The latter is always the same at a given station and is very generally for a homogeneous basin (Forstner *et al.*, 1981 in Rubio *et al.*, 2000).

We have :

$$CF = \frac{[Me]mes}{[Me]TH} \quad .. (1)$$

With :

CF : Contamination Factor,

[Me]mes :. measured concentration of the element,

[Me]TH : the reference concentration of the element (usually the natural background content found in the literature).

Hence the definition of the following classes of contamination (Table 1).

The results of the calculation for the six sites (Table 2) make it possible to draw the following conclusions :

* With the exception of the month of February, when there was no contamination factor to moderate at the level of the first five sites towards copper, the waters of wadi Echaref and its tributaries present a very high contamination gradient during the study period.

* Silver, Cobalt and Nickel present a very high contamination factor in wadis during all campaigns.

* With the exception of February, where iron has a considerable contamination factor; Wadi waters are characterized by a moderate contamination gradient.

Table 1. The classes of contamination factor (CF)

CF	Contamination gradient
CF < 1	Low
1 ≤ CF < 3	Moderate
3 ≤ CF < 6	Considerable
6 ≤ CF	Very high

Partial Triadic Analysis

The first step in the interpretation of the partial triadic analysis is the inter-structure analysis from the results of the vector correlation matrix between date-tables (Table 3). The matrix reveals quite good correlation between months (February, April, May, June) except for the month of March. The diagonalization of the matrix of covvs (inter-array vectorial covariances) provides components, the first two of which explain 85% of the variation of the inter-structure PCA. The projections of the date-tables on these axes give an overview of the resemblance between the tables measured by the RVs. The F1 axis dominates with a rate of inertia of 65.87%. It shows a size effect that reveals the existence of a compromise. Axis F2 contrasts the structures of the date tables. There is a structural gap between the March table and the other months. The diagonalization also provides for each table a weight Wtab (the normalized components of the first eigenvector). The sum of the initial tables in proportion to their weight gives a common structure called compromise.

The Analysis of the Compromised Table (ACP Analysis) provides principal axes and principal

Table 2. Factors of contamination of surface waters of some heavy metals

Heavy Metal	Natural background value of my heavy metals. (Martin *et al.*, 1979 in Martin *et al.*, 1983)	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6
Ag	0.0003	189 - 1153	315 - 1069	461 - 1594	430 - 1436	210 - 839	63 - 765
Co	0.0002	173 - 814	117 - 633	271 - 814	347 - 751	128 - 607	8 - 460
Cu	0.0015	1 - 24	0 - 24	1 – 36	0 - 17	1 -26	13 - 33
Fe	0.01	1 - 3	1 - 3	1 - 5	1 - 4	1 - 2	1 - 2
Ni	0.0005	33 - 250	23 - 213	47 - 306	31 - 287	9- 207	39 - 162

Table 3. Numerical parameters associated with partial triadic analysis processed on the faunistic data. RV = corrlation matrix beetween tables; w tab = weights of tables in the definition of the compromise; Cos^2 = squarecosine between a table and the approximated compromise using two axes

	RV					W.tab	αi=cos2
April	1					0.49	0.89
February	0.64	1				0.46	0.83
June	0.73	0.64	1			0.48	0.88
May	0.84	0.69	0.82	1		0.52	0.94
March	0.26	0.30	0.14	0.27	1	0.21	0.37

components respectively in the row space and in the space of the columns on which the columns and rows of the compromised table are projected (Figure 4). This analysis makes it possible to establish a typology common to all the tables. The F1xF2 plan of the analysis explains 84.38% of the total variability. Figure 4 shows the variable compromise plane F1xF2 whose axis F1 defines a pollution gradient described by the set of elements Fe, Ni Ag, Co. The axis F2 defines a second copper pollution gradient. The plan F1xF2 compromises stations defined on axis F1 a common structure characterized by the opposition of the most polluted stations (S1, S2, S3, S4), with the other stations distant from the discharges (S5,S6).

In fact, the S1, S2, S3 and S4 stations are located downstream and undergo wastewater discharges from certain agglomerations that are not connected to the treatment plant, plus the rejection of the treatment plant for S4 and the rejection of the

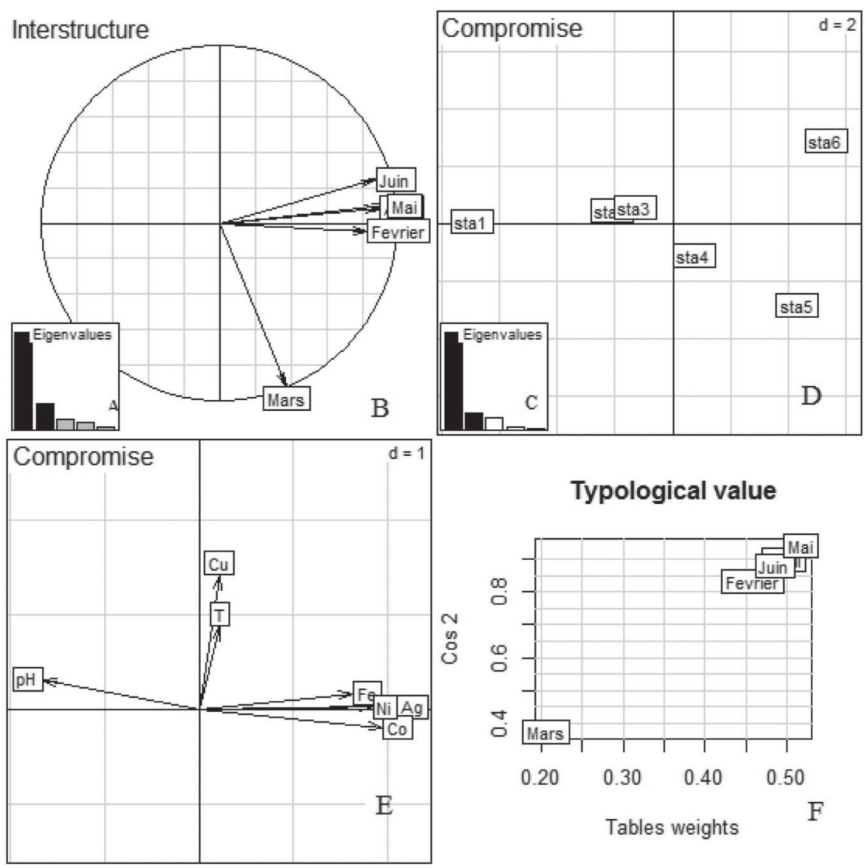

Fig. 4. Results of interstructure and compromise of partial triadic analysis of physicochemical data. (A) Histogram of the eigenvalues of the interstructure. (B) Projections of the five tables (campaigns) on axes 1 and 2 of the interstructure. (C) Histogram of the eigenvalues of the compromise emphasizing the existence of a two-dimensional average structure. (D) Coordinates of the Stations on plan 1-2 of the compromise. (E) Coordinates of variables on plan 1-2 of the compromise. (F) typology of the weights of the five tables (campaigns)

wastewater treatment plant from the town of M'Daourouche for S3. It should be noted in passing that wastewater from the town of M'Daourouche is rejected without treatment in the receiving environment.

The reproducibility of the structure compromised over time can be represented for the variables (Figure 5A) and the stations (Figure 5C) and will make it possible to discuss the temporal evolution of the variable-station relationships (typology internal to each table). For this, we project on the plane 1-2 of the compromise analyzed above the lines (Figure 5C), the columns (Figure 5A), the axes (Figure 5D) and the principal components (Figure 5B) resulting from the separate analyzes of each of the tables.

It is noted that during the entire study period, except for the month of March, when there was heavy precipitation, the stations show an almost constant difference in the physicochemical characteristics of the waters. The discharges of the various effluents disturb this quality, and pollute the water at the four stations situated upstream.

Also recording a somewhat high concentration of these chemical elements in traces, this would be explained by the drought endured by this region and which has led to a considerable decrease in river flows.

Downstream, the self-cleaning power of water returns to its shape at the S5 and S6 stations. This is due to the confluence of wadi Cherf with several of these tributaries

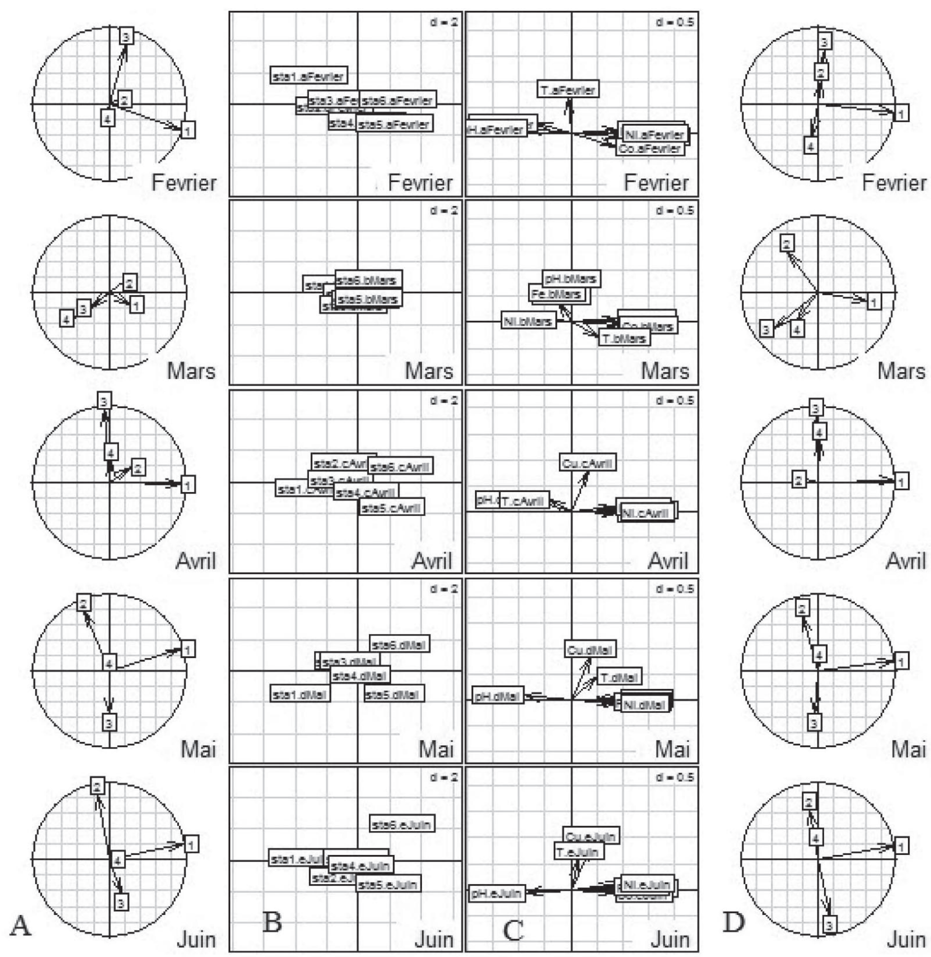

Fig. 5. Analysis of the reproductibility of the compromise structure. (A) Multi windowed projection of the first four principal axes of the separate analyses on the first compromise plane. (B) Multi windowe projection of rows on the first compromise plane. (C) Multi windowed projection of columns on the first compromise plane. (D) Multi windowed projection of the first four principal components of the the separate analyses on the first compromise plane. The first character identifies the table number and the secondre presents the axis number of the corresponding separate analysis.

CONCLUSION

The undertaken study allowed us to show the influence of domestic and industrial discharges on the water quality of wadi Echaref and its tributaries. We focused on five chemical elements Copper, Iron, Nickel, Cobalt and Silver. Calculations have shown that sites five and six, located downstream, have the lowest concentrations. Station three is marked by high values of Ag, Cu, Fe and Ni. This station is subject to the impact of M'Daourouch municipality effluent. Sites one and two located upstream still have strong values of certain elements. These two sites are under the impact of two discharges from two agglomerations in the town of Sédrata that are not connected to the sewerage network that feeds the wastewater treatment plant. The high values of Ag, Fe and Ni at site four are the result of the two effluents' discharges that of the treatment plant and an agglomeration not connected to the treatment plant.

The statistical analysis by the PTA of the metallic data made it possible to differentiate a zonality of the quality of the superficial water in the studied region, whose most polluted areas are those represented by the stations S1, S2, S3 and S4 which are located upstream the watershed.

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