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Assessment of wastewater discharges from Taourirt City on the water quality of the Oued Za (Eastern Morocco)

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- ✓ Oued Za;
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- ✓ inter and intra-class PCA.

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Abstract

In order to monitor the spatial and temporal variability of the water quality of Oued Za on its passage from the town of Taourirt, eleven physicochemical descriptors were repeatedly measured over time (the four Seasons of the year 2015) in four stations located upstream and downstream of the agglomeration. To study the temporal stability of the spatial structure, and to measure the interaction between dates and stations, in the four mesological tables obtained, we used inter and intra-class PCA. The study of the spatial structure of the obtained results showed that, whatever the sampling season, S2 and S3 stations located downstream of the domestic and industrial wastewater discharges of Taourirt City are still opposed to the two other stations, showing that these stations remain polluted throughout the year. The peak of pollution is reported in autumn, during massive trituration of olives. This pollution is attenuated at the level of the S4station, thanks to the self-purifying power of the water before throwing in the Moulouya River.

I. Introduction

Morocco is one of the African countries the most threatened by the scourge of pollution of its waters [1-3]. Water resources are limited due to the semi-arid climate that characterizes most of the territory. This is compounded by episodic droughts. This issue is not limited to the quantity of water resources, but also to the quality of these resources that should be better managed now more than ever.

The situation of surface watercourses in Oriental Morocco is becoming more and more worrying because of the large quantities of the untreated pollution released directly into aquatic ecosystems [4-8]. This anthropogenic activity has a major impact on aquatic biodiversity [9-14].

Oued Za, the main tributary of the right bank of the Moulouya River, is hardly immune to pollution. Indeed, the river that has been the subject of several researches concerning the quality of surface water and sediment crosses on its downstream the city of Taourirt and make an example of intense pollution from domestic and industrial waste highly charged with organic matters [6].

This work, which is part of the control quality of the surface water of this watercourse, aims to monitor the spatio-temporal evolution of the main physicochemical parameters of water. To do this, eleven physicochemical descriptors were repeatedly measured over time (the four seasons of the year 2015) in four stations located upstream and downstream of Taourirt City.

The results of the physicochemical analyzes show that the stations located downstream of the pollutant discharges have water of very poor quality throughout the year, presenting high values of the pollution indicators during the four seasons, which increase in autumn and record a peak of pollution during the season of olive trituration. On the other hand, the river experiences an improvement in the physicochemical quality of the water at its confluence with the Moulouya River, thanks to the phenomena of dilution and self-purification.

1.1. *The study area*

Oued Za is a permanent tributary of the right bank of the Moulouya (Figure 1). Its watershed covers an area of 18 000 km^2. It takes its source in the Eastern High Plateau and joins the river at Melg El Ouidane, downstream of Taourirt City, the latter causes enormous pressure on water resources in its territory. Anthropogenic activities in the region such as agriculture and wastewater discharge contribute to the degradation of water quality.

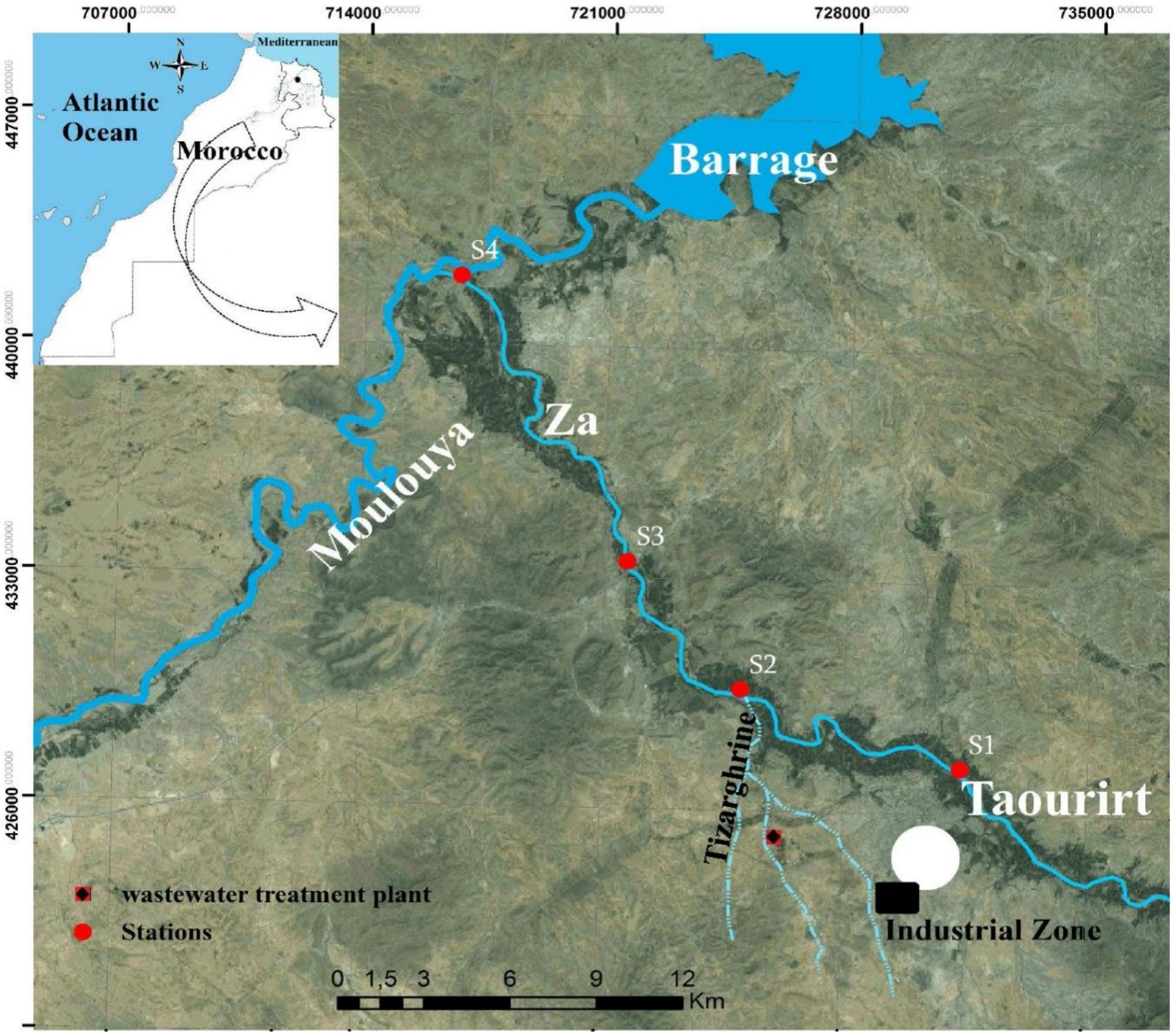

Figure 1: Location of study area and stations

The existing wastewater treatment plant, commissioned in August 2006, is designed to receive a nominal flow of 5400 m^3/d and a BOD_5 load of 3900 kg/d. The pollutant loads estimated by the "Eau Globe" study and the loads calculated during the January 2012 campaign of the "ONEE" are presented in the following table [15]:

Table 1: The pollutant loads estimation of wastewater treatment plant

Pollution parameters	The pollutant loads estimated by the "Eau Globe" study (Kg/d)	The pollutant loads calculated during the January 2012 campaign of the ONEE (kg/d)
BOD_5	4750	5340
COD	17100	12009
TSS	2000	2226

The wastewater discharged into Za river has an average flow of 1500 m^3/d and a concentration in terms of:

- BOD_5: 3700 mg/l;
- COD: 7470 mg/l (Assuming a 10% reduction by individual pre-treatment in the industrial sector to go from 8300 mg/l to 7470 mg/l);
- TSS: 1540 mg/l;
- Conductivity: 13800 µs/cm.

The stations choice was made taking into account the general objective of our studies and the upstream and downstream situation in relation with the agglomerations and the factories, in order to detect the impact of the mainly industrial discharges on the quality of Oued Za. Thus, we chose 4 stations:
Station 1 upstream: a reference station located upstream of all discharges;
Station 2: located at Tizaghrine tributary and its confluence with Oued Za;
Station 3: located downstream of the town of Taourirt at Douar Ouled Fkir;
Station 4: located at the end of the Oued Za.

2. Material & methods

2.1. *Sampling and analysis of the Physico-chemical parameters*

The sampling campaigns were carried out at the four stations four times, successively representing the four seasons of the year 2015. The samples were taken in the first week of March, June, September and December 2015 respectively.

Two replicates of water samples from each station were taken in 500 ml polyethylene bottles. The water samples were preserved with 2 ml of concentrated hydrochloric acid (pH = 2). According to the standards ISO 5667-6 (1990); ISO 5667-2 (1991) and ISO 5667-3 (1994), the water samples were conveyed to a cooler at a low temperature (± 4 ° C) to stop the metabolic activities of organisms in water. The following physicochemical parameters (Table 2): Suspended Matter (MES), Biological Oxygen Demand after 5 days (BOD_5), Chemical Oxygen Demand (COD), Kjeldahl Nitrogen (NTK), Total Phosphate (PT), Chlorine (Cl-) and Nitrates (NO^3) are measured in the laboratory according to AFNOR standards. Conductivity, pH, dissolved oxygen and temperature are measured (in situ) in the field.

Table 2: The spatiotemporal variability of the studied physico-chemical parameters (from March to December 2015)

Station	GPS	Date	T °C	pH	Condu $\mu s.cm^{-1}$	MES $mg.l^{-1}$	O2 $mg.l^{-1}$	DBO_5 $mg.l^{-1}$	DCO $mg.l^{-1}$	NTK $mg.l^{-1}$	PT $mg.l^{-1}$	Cl $mg.l^{-1}$	NO^3- $mg.l^{-1}$
S1	X = 731351.23 Y = 427372.51	05-mars	17	8.16	1000	14	9.75	2	9	0.136	0.2	262.918	2.194
		04-juin	22	8.06	1200	17	8.5	2	17	0.2	0.085	254.921	2.068
		03-sept	25	8.2	1250	12	7.02	3	21	0.18	0.01	255.81	2.08
		03-déc	18	8.04	1100	18	8.5	2	23	0.15	0.18	261.3	2.18
S2	X = 724996.84 Y = 429672.23	05-mars	16.7	7	1690	1250	2.8	111	201	28.1	2.6	3.7	4.78
		04-juin	24	6.8	2600	1000	1.7	200	336	51	3.53	390	4.8
		03-sept	25	6.6	3100	1200	0.9	350	534	54.6	4.52	400	5.72
		03-déc	17	6.5	3246	1100	0.3	489	1048	57.4	4.609	469	11.81
S3	X = 721672.28 Y = 433504.92	05-mars	18	8.40	1300	913	3.8	61	153	2.4	2.28	3.5	3.38
		04-juin	19	7.8	2000	769	3	96	179	3	3.2	240	4
		03-sept	21.5	7.82	2900	684	2.8	153	321	3.1	3.31	300	4.13
		03-déc	18.6	7.85	3185	315.3	0.8	193	354	3.4	4.26	345	9.81
S4	X = 716720.63 Y = 442100.22	05-mars	16	8.40	1000	55.1	8.6	2.9	12	2.1	0.23	2.17	2.38
		04-juin	22	7.5	1100	50.4	8.3	3	23	2.2	0.12	30	2.8
		03-sept	24	7.82	1180	51.1	7.40	3.1	25	2.14	1.13	123	3.13
		03-déc	17	8	1724	51.6	7.68	3.9	37.8	2.13	1.3	197	3.76

2.2. *Statistical analysis*

To focus on the spatial or temporal effect, we can use the inter- and intra-class analyzes proposed by Dolédec and Chessel [16-20]. Inter-class analysis focuses on a chosen effect (spatial or temporal), while intra-class analysis seeks to remove this effect. For example, if the sampling dates correspond to campaigns, an inter-date analysis will seek to highlight the temporal structure and an intra-date analysis will seek instead to eliminate this temporal structure. The sum of the inter-class inertia and the intra-class inertia thus restores the total inertia contained in the data table. These analyzes allow us to take into account a priori the three indices studied: the variable, the space and the time. The multivariate analyzes were carried out using the R software under the ADE4 program library (Analysis of Ecological Data: Exploratory and Euclidean Methods in Environmental Sciences).

3. Results and Discussions

The decomposition of the total variability of PCA (principal component analysis) with inter- and intra-class analyzes (Figure 2) shows that the spatial structure is largely dominant as the temporal structure. Indeed, the intra-season analysis, which eliminates the effect of time, represents 79.07% of the total inertia (IT = 11), whereas the inter-season analysis emphasizing the temporal effect represents only 20.93% of total inertia.

3.1. *Inter and intra-season analysis*

In terms of inertia, the overall PCA of the environmental data is equal to 11 (total number of variables in a standardized PCA). The inertia intra season represents 79.07% of the total inertia; moreover, the first two axes F1-F2 of the intra-season PCA totalizes 70.16% of the overall PCA inertia, (that to say 88.73% of the intra-season PCA inertia). The inter-season inertia, which accounts 20.93% of the total inertia, totals on the F1-F2 plane of the analysis 20.64% of the total PCA inertia (98.67% of the PCA inertia Inter-season).

In order to study the spatial typology of variables by eliminating the temporal effect, an intra-season PCA is performed (Figure 3A and B). The correlation circle (Figure 3B) shows that the F1 axis, which accounts for 81.23% of the total information of intra-season analysis, expresses a dominant pollution gradient by separating on the left the pollution indicators (BOD_5, COD…etc.) and on the right the oxygen dissolved in water and pH. Thus, the most polluted stations are in descending order S2 and S3, these two stations have an acid pH. The most oxygenated stations with a neutral pH are respectively S1 and S4.

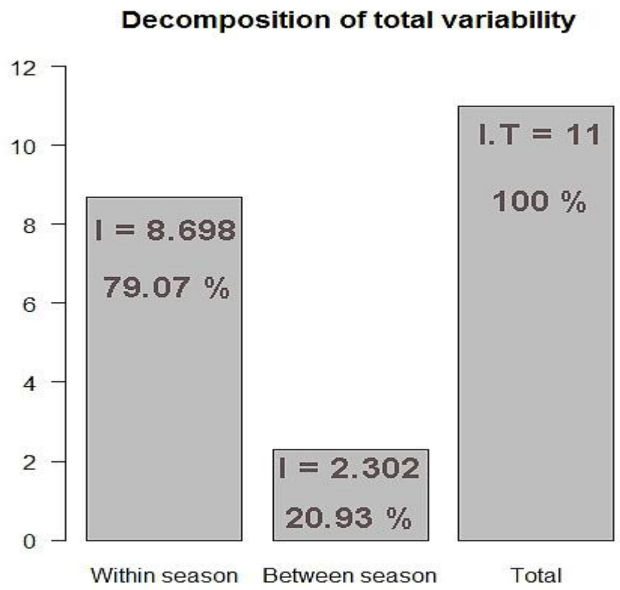

Figure 2: Decomposition of total variability

Station S2 located just downstream of the confluence of Tizarghrine with Oued Za continually receives discharges of domestic treated sewage at the secondary level and untreated industrial waste coming from the industrial zone of Taourirt. This situation explains the high pollution recorded in this station.

The S3 station, although less polluted than S4, records pollution values that place its water in the grid of very poor quality (BOD_5 in the four seasons> 60 $mg.l^{-1}$). The S1 station taken as reference and S4 present waters of good physicochemical quality, this return to the normal reported at the level of the S4 station is due to the self-purification of the water.

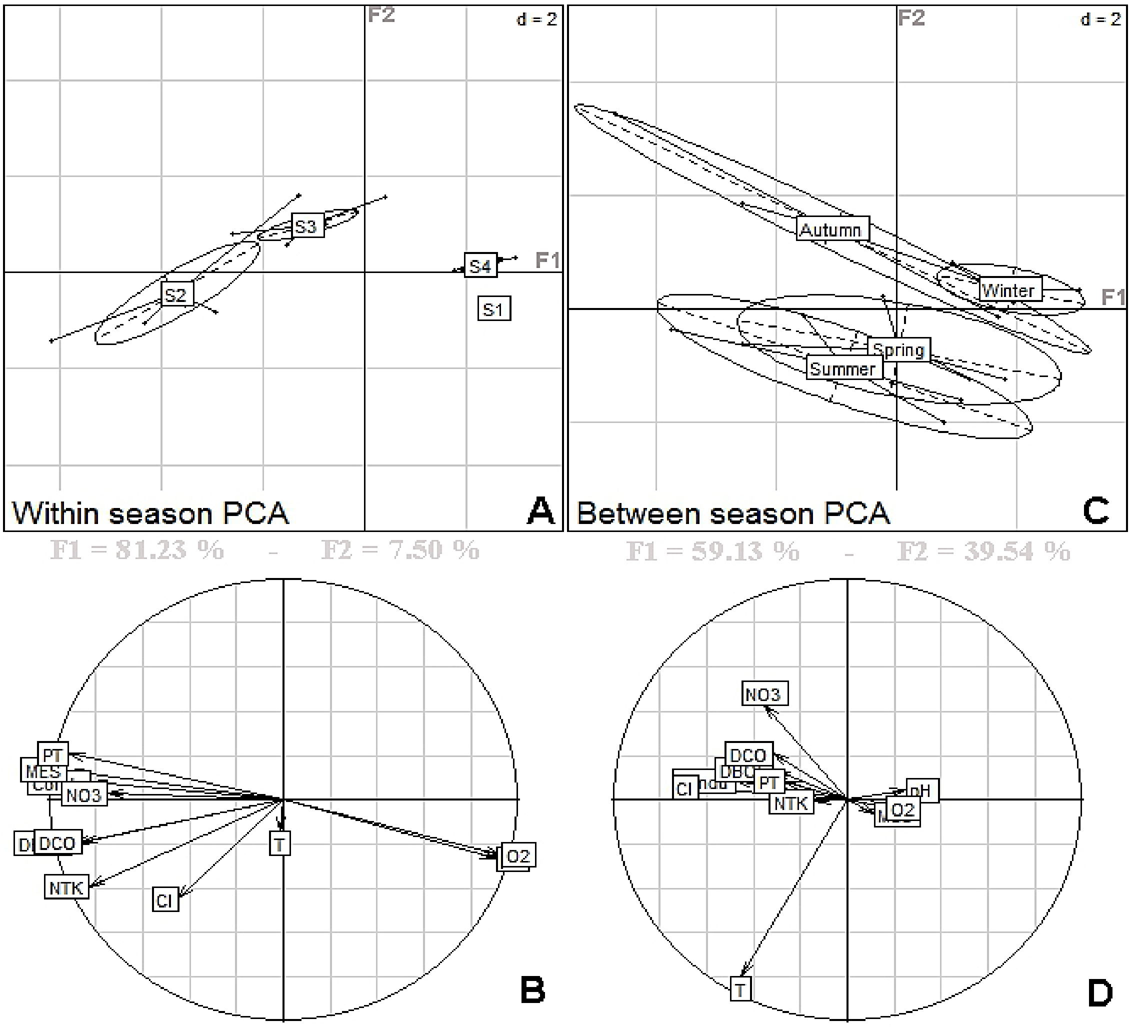

Figure 3: A: Intra-season PCA of 11 environmental variables; B: Intra-season PCA correlation circle; C: inter-season PCA; D: Inter-season PCA correlation circle

The correlation circle of the inter-season PCA (temporal typology, Figure 3C and D) expresses on its axis F1 a small gradient of pollution. The season with the greatest deviations in the values of water pollution indicators is the fall season (circle diameter) followed by summer, spring and winter, respectively. The dilution of the pollutant load by precipitation during the winter season explains the small differences in the values of the pollution indicators recorded during this season.

The F2 axis expresses an increasing gradient of temperature and places the winter, autumn, spring and summer respectively from top to bottom.

Realizing an intra-season PCA is almost the same as simultaneously carrying out the PCAs of the four "station-variable" tables defined by the 4 seasons. It would therefore be possible to look for a graphical representation linking four different factor maps to the intra-group PCA, the so-called separate analyzes (Figure 4). Figure 4 shows the temporal evolution (by eliminating the time factor) of the spatial structure of the environmental variables during the four seasons.

The general spatial structure of the stations remains identical throughout the year (figure 4) by separating on the left the polluted stations S2 and S3 and on the right, the well-oxygenated stations S1 and S4.

The peak of pollution is recorded in autumn, in effect, S2 and S3 are more left on the F1 factor in autumn than in other seasons, and this peak of pollution coincides with the olive season that the Taourirt region experiences each year. The trituration of olives during the autumn remains the main cause of this peak of pollution that knows the S2 station located just downstream of the confluence of Tizarghrine with Oued Za.

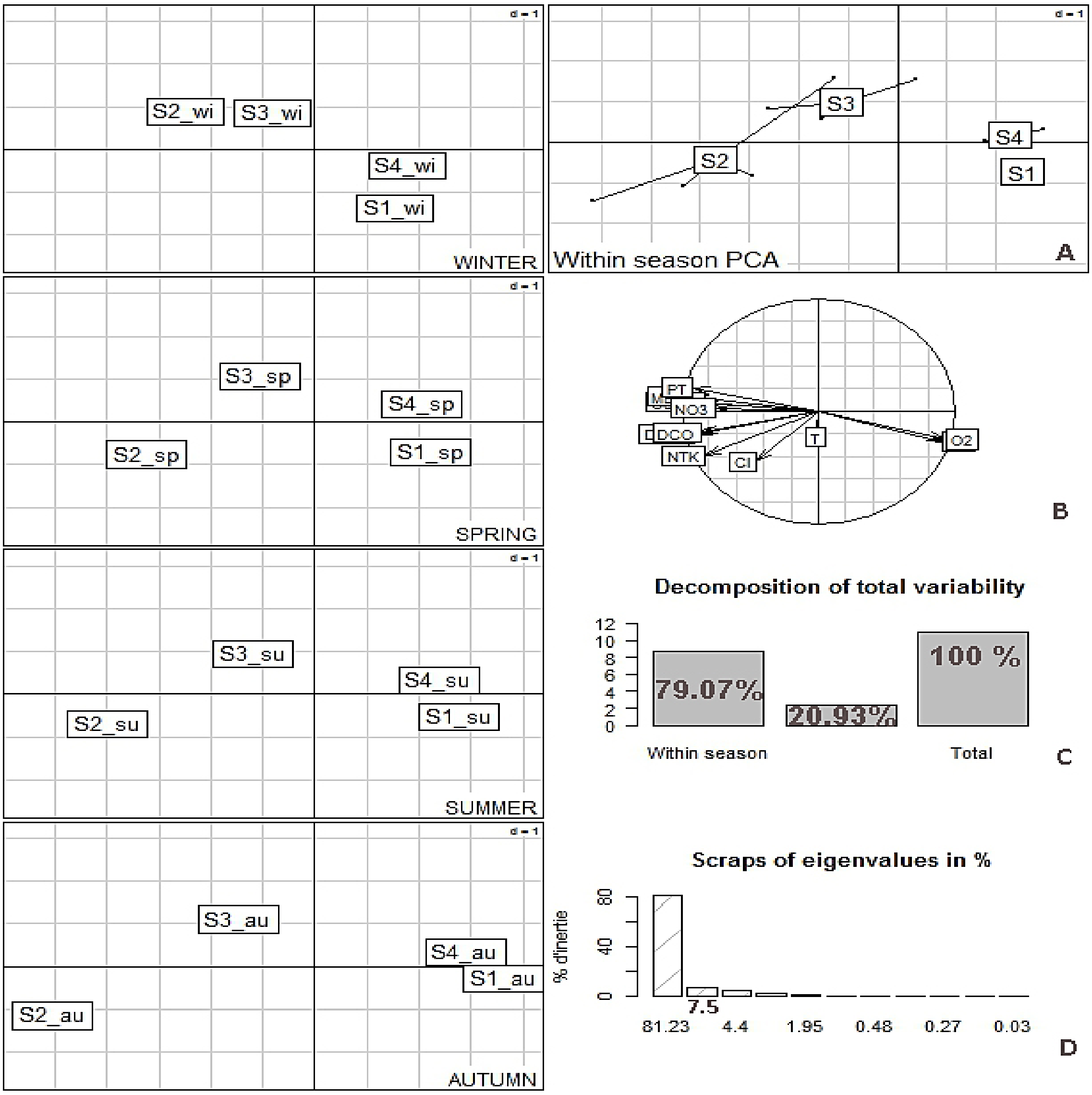

Figure 4 : Left top to bottom: graphical representation linking the four factor maps of the intra-season analysis. A: Intra-season PCA; B: Circle of correlations between variables; C: Decomposition of total inertia; D: Eigenvalues histogram of intra-season PCA

3.2. *Intra-season analysis*

After autumn, the highest pollution is recorded in summer. Pollution during the summer is explained by the low flow of Oued Za during this period and by the activity of the industrial zone that rejects its liquid waste without previous treatments in Oued Tizarghrine, accentuated with domestic wastewater discharges, treated only to the secondary level and still containing a large polluting load. The least polluted season remains during the winter, thanks to the rainfall that dilutes the polluting load that Oued Za receives in his confluence with Oued Tizarghrine.

The smaller precipitation experienced in the region during the spring explains in part the third place of this season in the decreasing order of pollution. The return to the normal that knows the S4 station throughout the study period is certainly due to the self-purifying power of the water, as mentioned by several studies [6, 21].

Conclusion

The results of the physicochemical analyzes show that the overall quality of the water at the S2 and S3 station remains very poor. These two stations located downstream of the pollutant discharges have water of very poor quality throughout the year.

The values of pollution indicators recorded at stations S2 and S3 remain high during the four seasons, but increase in autumn and record a peak of pollution during the olive trituration season.

The downstream of S4 station, shows an improvement in the physicochemical quality of the water thanks to the phenomena of dilution and self-purification.

The Taourirt wastewater treatment plant, which treats wastewater at the secondary level, is experiencing dysfunction due to industrial discharges from informal craft units located in the center of the agglomerations and connected to the domestic sewerage network. It should be noted, that secondary treatment of wastewater is not at all appropriate for sensitive receptor such as Oued Za. In addition to this malfunctioning of the treatment plant, Oued Za receives liquid waste from the industrial zone without prior treatment via Oued Tizarghrine.

To maximize the benefits of using our limited water resources, improving water management, both quantitatively and qualitatively, must be the primary goal of any provincial, regional or national policy. To do this it is recommended to push the treatment of wastewater from the existing treatment plant of Taourirt to the tertiary level; and to demand the adhesion of the industrialists to the voluntary mechanism of the depollution of water to implant a new station of purification separated and specialized for the liquid industrial waste.

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