African Journal of Environmental Science and Technology Vol. 5(5), pp. 348-354, May 2011
Available online at http://www.academicjournals.org/AJEST
ISSN 1996-0786 ©2011 Academic Journals

Full Length Research Paper

Physicochemical typology of water of a middle atlas river (Morocco) where the common trout (*Salmo trutta macrstigma*, Duméril, 1858) live: Oued Sidi Rachid

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Accepted 27 April 2011

For every live being, ecological conditions greatly influence biology. In the case of a fish, these conditions may be responsible for its presence or absence in the medium, its development and its population size. This work studies the characteristics and physicochemical typology of Sidi Rachid River, known by its wealth of the Salmonidae fish: *Salmo trutta macrostigma* (Duméril, 1858). The results show that apart from the appearance of nitrates, whose high levels indicate an organic pollution, during some times of the year, coming seemingly from the Ras Elma fish farm waste water, the water quality is good. The results also show that the physico-chemical typology of the watercourse is mainly influenced by the "season" factor and that among the studied variables, only the pH does not influence the spatial and temporal variation of the medium studied characteristics.

Key words: Sidi Rachid River, physicochemical typology, *Salmo fario*, Morocco.

INTRODUCTION

The habitat has a number of constraints on any population of fish through several abiotic filters also called local habitat filters such as temperature, oxygen, pH (Ivol-Rigau, 1998). Thus, for any species, the physico-chemical study of some is very useful for determining habitat preferences of local environment and acquisition of a maximum of information for better environment management.

As a result, to identify key factors that determine the water physico-chemical of Sidi Rachid River (Figure 1) which is a living environment of a Salmonidal fish: Brown trout (*Salmo fario*). We evaluated eleven physico-chemical environment characteristics. These characteristics can identify certain conditions for the ecology of this species.

Furthermore, in order to highlight the various existing correlations between different parameters evaluated at two study sites surveyed and to identify the main factors responsible for the water physicochemical quality of of Sidi Rachid River (Figure 1), home to brown trout, data collections were analysed using the multivariate statistical method: Principal component analysis (PCA) whose main objective is to condense the essential information content in baseline variables, often correlated with a smaller number of new variables called principal components (Bouroche and Saporta, 1980; Benzeccri et al., 1979; Eby et al., 2008). This method had been applied to physicochemical characteristics of inland waters by several authors (Boet, 1987; Vespini et al., 1987; Bengen et al., 1991). The statistical software used for this analysis was "Statistica" developed by Statsoft France.

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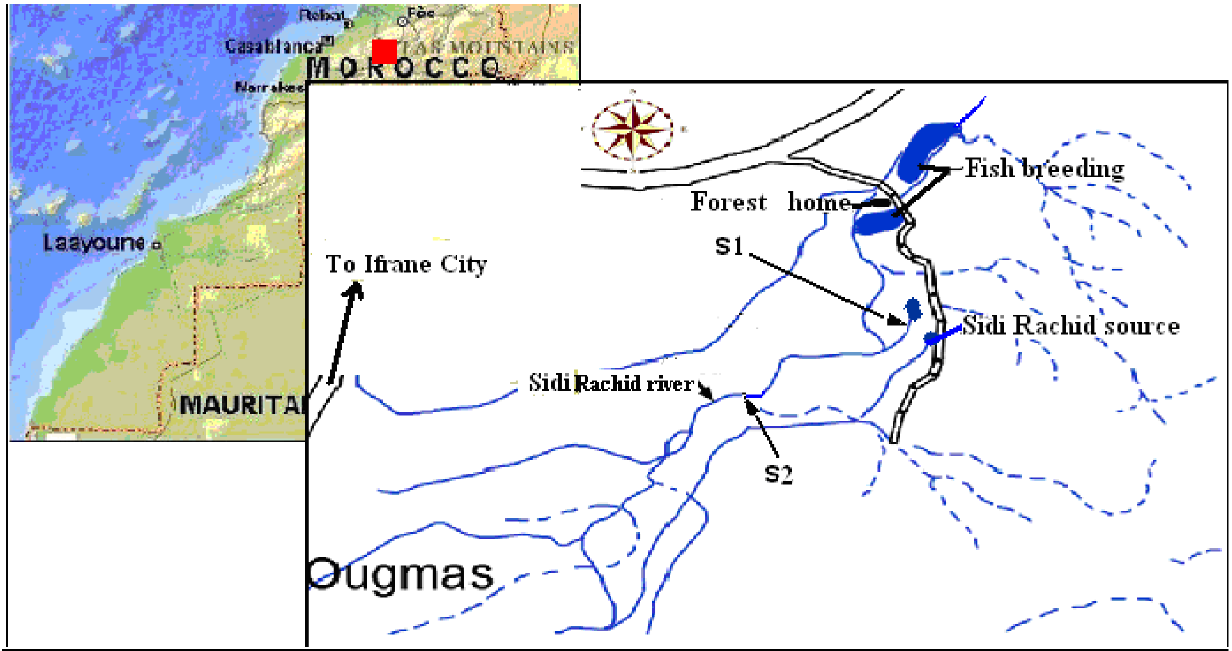

Figure 1. Location of study sites (From the topographic map of Azrou. E:1/50.000.1974).

MATERIALS AND METHODS

Study stations

We chose to survey two sites (Figure 1): The first station S1 located on the upstream of Sidi Rachid River and the second station S2 located in the downstream portion of the river at the graft point of water coming from the aquaculture station of Ras El Ma (Azrou).

Sampling and analytical methods of water

Monthly sampling was conducted between May 2007 and April 2008. The water to be analyzed was taken in polyethylene bottles in areas where water is not stagnant, at 10:00 and noon, during the last week of each month. This sampling procedure has been recommended by some authors including Boschet (2002).

We performed *in situ* measurement of water temperature (Tp), electrical conductivity (Cd), dissolved oxygen (DO) and pH with lots of devices (Orion, model 260, Orion, model 330 Orion, model 130). Other variables were analysed in the laboratory of Water Quality National Center of Hydrobiology and Fish (CNHP) in the Azrou City (Morocco) with dataloging spectrophotometer (HACH. DR/ 2010). The assays were either volumetric or by spectroscopic methods of analysis proposed by Rodier (1996).These variables are nitrite (Nit), orthophosphates (DPOs), complete alkalimetry titre (TAC), calcium content (Ca), magnesium content (Mg), hydrometric titre (TH) and chloride content (Cl).

Treatment of physicochemical collected data

A data processing was performed by multivariate statistical method called P developed by Statsoft France CA (Pricipal Compoment Analysis). The statistical software used for this analysis is the "STATISTICA" developed by Statsoft France. Moreover, the interpretation of results is facilitated by numbering the samples taken (Table 1).

Description of data matrix

For the eleven physicochemical parameters evaluated, all the results are illustrated in Table 1. The same table also contains the matrix data statistically processed by the PCA. It is a matrix of data consisting of a double entry table"1 variables times 24 samples." The codes of eleven (11) physicochemical parameters and the numbers of samples taken during the year used in PCA are reported in Table 2.

RESULTS AND DISCUSSION

The analysis of results shows that the majority of information is explained by the first three factorial axes (Tables 3 and 4 and Figures 2 and 3). The contributions of different parameters in the expression of the first three factorial axes C1, C2 and C3 are respectively 27.79, 18.80 and 15.91% or a total of 62.5% of the information explained. The maximum of the total inertia is accumulated by the planes formed by the factorial axes C1 × C2 and C1 × C3. Thus, the significance of physicochemical factor axes C1, C2 and C3 is necessary.

Table 3 shows the degree of contribution of the 11 physico-chemical variables in the inertia factor axes C1, C2 and C3, and plans in Figures 2 and 3 shows the projection of these variables on the plans C1 × C2 and C1 × C3. Since two variables close on the chart are not necessarily related in behaviour, the projection can sometimes be unreliable. It is therefore advisable to assess the importance of the cosine of the angle between the vector of this point and the plane projection of the variable to assess the quality of the projection of this variable on a given factorial axis or determine the

Table 1. Dates and numbers of samples taken.

Sampling date	Station and sample code	
	S1	S2
May 2007	01	02
June 2007	03	04
July 2007	05	06
August 2007	07	08
September 2007	09	10
October 2007	11	12
November 2007	13	14
December 2007	15	16
January 2008	17	18
February 2008	19	20
March 2008	21	22
April 2008	23	24

Table 2. Matrix data grouping estimated 11 physicochemical variables studied in 24 sampling.

Record number	Tp	pH	Cd	OD	Nit	OPh	TAC	Mg	Ca	TH	Cl
1	12	7.25	521	8.94	0.012	0.09	17.1	39.39	30.46	95.2	35.5
2	13.5	7.3	515	9.38	0.009	0.23	27.5	29.23	33.66	80	53.25
3	13.8	7.44	552	8.2	0	0.48	22.1	30.6	31.3	80.5	35.5
4	14.9	7.7	547	9.4	0.01	0.1	20.2	25.4	35.4	74.3	35.5
5	12.2	7.86	413	8.05	0.01	0.16	23.8	21.88	32.06	64	35.5
6	15.6	7.8	436	10.35	0.01	0.64	21.4	21.4	44.88	58.4	35.5
7	12.1	7.34	411	8.4	0.01	1.2	31.7	10.7	24.04	64	53.25
8	14.3	7.44	422	9.8	0.01	3.16	30.4	26.75	40.2	60.4	53.25
9	12	7.38	556	9.46	0.01	1.42	13.4	15.08	24.05	48.8	35.5
10	15.7	7.68	538	13.32	0.01	0.5	18.9	28.21	20.84	67.2	35.5
11	11.8	7.13	118.1	10.46	0.01	0.13	17.7	30.15	28.85	78.4	44.38
12	12.8	8.06	114.1	12.59	0.01	0.11	23.2	27.23	33.66	78.4	44.38
13	11.8	7.06	118.7	7.78	0.01	1.04	34.2	29.18	32.06	80	35.5
14	12.2	7.6	115	7.9	0.01	0.2	29.9	13.62	40.08	62.4	35.5
15	11.8	7.02	118.6	7.2	0.01	0.25	28.7	24.3	48.1	96	44.38
16	11.9	7.64	114.5	7.95	0.01	0.16	27.5	10.21	75.35	92	35.5
17	11.9	8.5	118.4	8.5	0.01	0.48	27.4	23.3	52.12	90	35.5
18	11.8	7.38	114.9	7.38	0.01	1.81	35.4	26.75	60.12	104	35.5
19	11.7	7.1	117.9	7.6	0.01	0.08	29.9	23.37	32.06	70.4	53.25
20	14	7.68	114.5	9.8	0.01	0.08	18.9	12.16	28.06	48	17.75
21	11.9	6.3	118.4	6.4	0.01	0.34	24.3	28.6	36.6	80.4	45.3
22	13.6	7.11	114.6	10.75	0.01	0.18	22.3	21.3	38.2	66.4	18.4
23	12	7.06	118.2	9.62	0.01	0.34	23.8	32.52	40.08	93.6	35.5
24	15.2	7.48	114.3	12.4	0.01	0.18	25	22.37	44.88	81.6	17.75

correlation between the axis and the variable factor (Table 4).

Indeed, the greater the degree of correlation is close to unity (1) the more the variable is related to the factorial axis. Conversely, the greater the degree of correlation is close to 0 (zero) the less the variable is bound to this axis.

The analysis of correlations between variables and the factorial axes reveals the nature of these axes. Figure 2 shows that the variables studied are not all well represented on the circle of correlations. Indeed, the pH did not present a sufficiently significant degree of correlation with a particular principal axis. It should not therefore used in the explanation of these axes. Instead, other

Table 3. Eigen values, contributions and percentages of inertia explained by the first three axes.

	C1	C2	C3
Eigen values	3.056	2.068	1.75
Variance (%)	27.79	18.8	15.9
Cumulative (%)	27.79	46.58	62.49

Table 4. Degree of correlation between variables and different axes.

	Axe		
Variable	**C1**	**C2**	**C3**
Tp	0.75657	-0.185937	0.017894
pH	0.365359	-0.439753	0.188789
Cd	0.579444	0.384305	-0.439450
Od	0.752759	-0.081151	0.230426
Nit	0.054850	0.733370	0.266579
OPh	-0.112333	-0.108105	- 0.693488
TAC	-0.738831	-0.304028	-0.269447
Mg	-0.039222	0.814459	0.137168
Ca	-0.584895	-0.400674	0.383111
TH	-0.650878	0.360299	0.464691
Cl	-0.351820	0.300402	- 0.679435

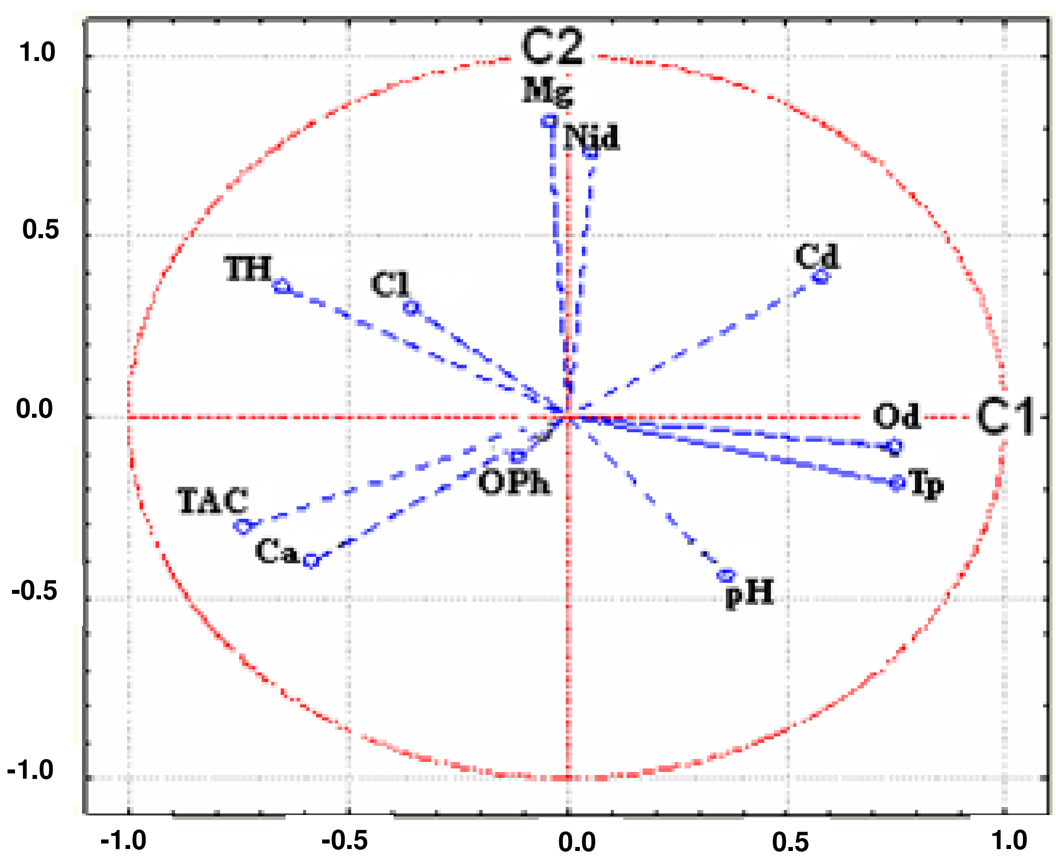

Figure 2. Projection of the variables in the factorial plan C1 × C2.

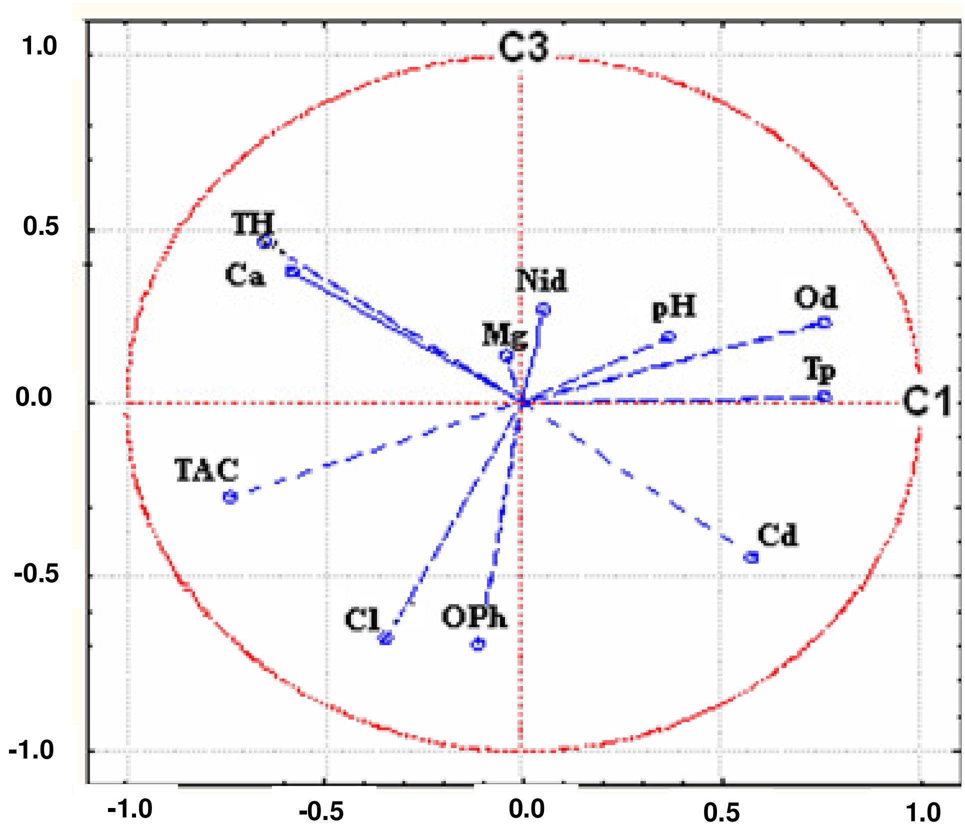

Figure 3. Projection of the variables in the factorial plan C1 × C3.

other variables contribute significantly in C1, C2 or C3 axis. Thus:

1. C1 axis is mainly correlated with temperature (Tp), conductivity (Cd) content of dissolved oxygen (Od), the concentration of calcium (Ca), full titre alkalimetric (TAC) and the titre humidity (TH). In addition, from the negative side to the positive one of this axis, there is an increasing concentration gradient for the first three variables and decreasing for the other variables
2. Significantly, the axis C2 is negatively correlated with levels of nitrate (Nit) and positively with levels of magnesium (Mg);
3. Similarly, the C3 axis is negatively correlated with levels of chloride (Cl), and positively with levels of orthophosphate (DPOs).

Analysis of factorial designs C1 × C2 and C1 × C3

The analysis of the map factor C1 × C2 (Figure 4) allows distinguishing the two groups reported. A first group of samples, denoted (A), carried out during winter or spring and mostly from the station S1, and only 3 samples (10, 16 and 18) were from S2. Parameters of group (A) are characterized by low temperature, conductivity and dissolved oxygen levels and high levels of total alkalimetric, total hardness (TH) and magnesium. A second group (B) of samples taken during the summer or fall with similar physico-chemicals are opposite to those reported for the sample group (A). The effect of the factor "season" is especially significant in the S1 station, because for S2, only statements made during the months of December, November and January differ significantly in relation to physicochemical variables correlated to the axis C1.

In addition, the plan C1 × C2 shows that taking into account the levels of magnesium and nitrates alone raised an issue that has been made in the month of the station, S1 differ so markedly from other surveys. This statement contains a high content of magnesium and low in nitrates compared to other surveys. The important concentration of magnesium could be due to dissolution of the rock belonging to the area.

With the variables correlated to axis C3 (DPOs and Cl) (Figure 5), we distinguish two groups of statements (A) and (B) separated roughly by the axis C1. The statements of the group (A) is characterized by weak and under higher hydrometric chloride concentrations, which is not the case of the statements formed in the group (B). Note that except for statements 1 and 4, all statements forming group (A) are carried out in winter or spring. Thus, even for levels of orthophosphate and

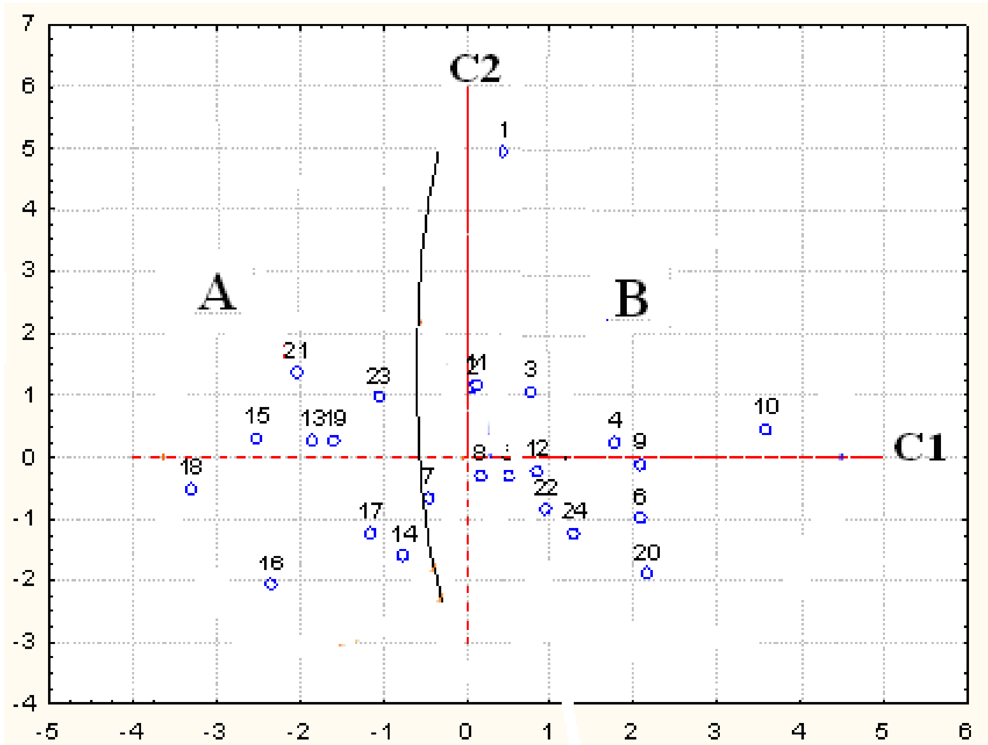

Figure 4. Projection of records in the factorial C1 × C2.

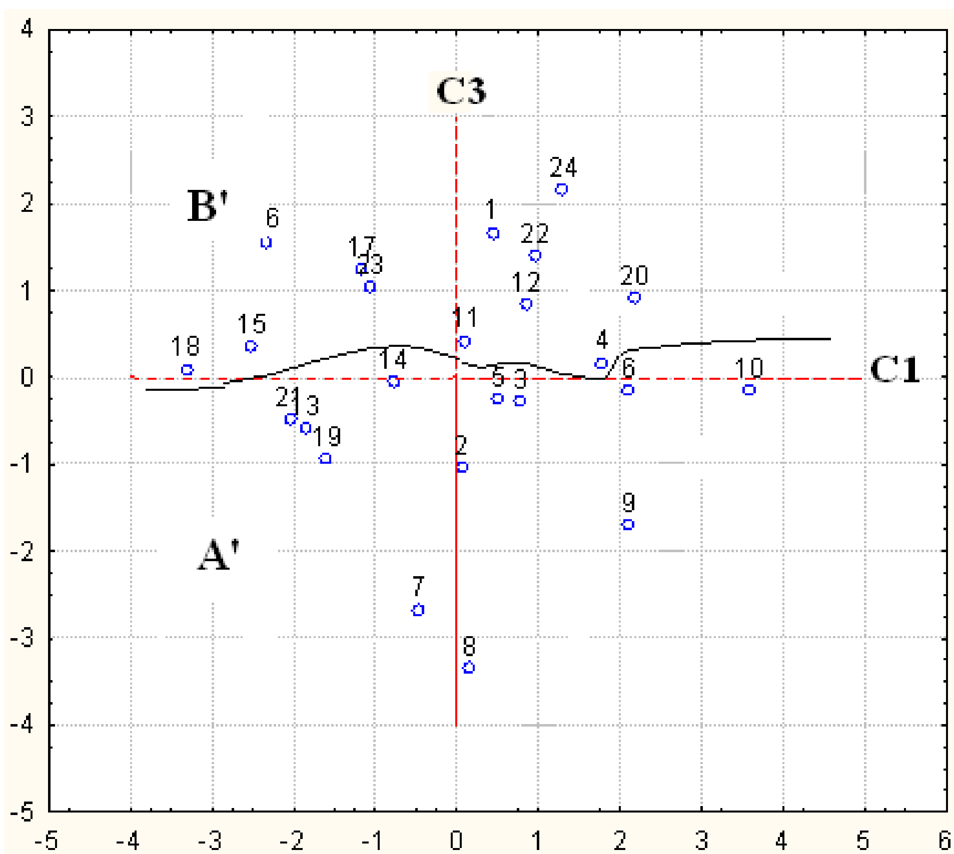

Figure 5. Projection of records in the factorial plan C1 × C3.

chloride, the factor "season" seems to play a decisive role in the evolution of the physico-chemical quality of waters of the Sidi Rashid River.

Conclusion

Except pH, all the physicochemical parameters estimated participate in the typology of Sidi Rashid River. But, temperature, conductivity, concentrations of dissolved oxygen content, calcium content titre and full titre alkalimetric humidity are the physico-chemical elements that influence over the type, followed by concentrations of nitrate and magnesium. The concentrations of orthophosphate are in the third place.

According to these physicochemical parameters reported, different groups identified were differentiated according to the first season when the measurements were made and according to the sampling stations. Thus, the factor "season" seems to be a determinant in the type of stream studied. Note also that except for momentary appearance of some relatively high concentrations of nitrates, the quality of Sidi Rashid River seems to be a very good environment for *Salmo trutta macrostigma*

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