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WATER QUALITY AND PROTECTION: ENVIRONMENTAL ASPECTS

Study of the Influence of the Physicochemical Parameters on Microbial Abundance in Various Ambient Conditions[1]

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Abstract—Nowadays, the problems of rejections constitute an increasingly important danger in the receiving mediums. Indeed, water is increasingly affected by minerals and organic matters and even by the microorganisms of which some are pathogenic and thus dangerous for the ecosystem. In this context, the present study was conducted to investigate the microbiological pollution of water of the lake Mellah, located in the national park of El Kala, North-eastern Algerian. This lake is a depression which communicates with the sea and flowing the domestic effluents of the neighbouring localities. The physicochemical parameters (Temperature, pH; Eh; Electric conductivity; Salinity, Turbidity, and O_2) and bacteriological (coliformes total, coliformes thermo tolerant, streptococci) were followed during the year 2011 with a seasonal frequency (February, May, August, November). Seventeen (17) sites of three different habitats were investigated; the wastewater treatment plant (WWTP), Wadis and their upstream to the estuary and the lake. The follow-up of analysis of the physicochemical and biological parameters in the various points of observation was the object of a graphs data processing and statistics (ACP) to determine the bacteriological degree of pollution. Results showed a contamination by the fecal matter with a gradient decreasing from the upstream of the discharge system towards the downstream. Compared to rain waters, microbiological pollution in the lake was selective in time. The CT and the CTT decreased in dry season where the ambient conditions (salinity, pH and temperature) become unfavorable, putting the factor salinity concerned to degrade the water pollution.

Keywords: microbiological pollution, physicochemical, bacteriological, lake of Mellah, the Algerian North-East

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INTRODUCTION

The water surface was always confederated like the universal receptacle of all the form of pollution. The water pollution is a deterioration which makes its use dangerous and (or) disturb the watery ecosystem it can relate to surface waters (river, lake, lake) and (or) the ground waters [6]. Protected zones and in particular wetlands of international importance "Ramsar zone" are ecosystems very complex, vulnerable, and whose operation however neither well-known nor is well understood. In Algeria, the increasing influence of the man on these wetlands and their basins slopes, introduced risks which cause fears at the level of only a few years for this afro-Mediterranean country [16]. The Ramsar site of the lake Mellah is an example to undergo an intense degradation in the long run caused by the human action especially but also by natural factors. With the development of the urbanisation, the problems of hygiene and public health are related to the bacterial contamination by waste waters. The estimate of the contamination is done by the means of the indicating bacteria of fecal pollution and pathogenic germs. These bacterial indicators are the coliformes fecal totals (CT) and coliforme thermo-tolerant (CTT) and streptococci (STREP).

In the present study, one proposes to evaluate the risk of contamination fecal and to characterize the fecal load contained in water of the effluents to their discharge system (Lake Mallah), and estimate the influence of environmental parameters (Temperature, pH, Eh, electric conductivity, salinity, dissolved oxygen and turbidity) on microbial abundance in two periods of the season (winter and summer).

MATERIALS AND METHODS

Study Area

Wetlands and their ecosystem services are extremely valuable for all peoples of the world: It is one of the major conclusions of the evaluation of the Millennium Ecosystem [9]. Algeria includes several orni-

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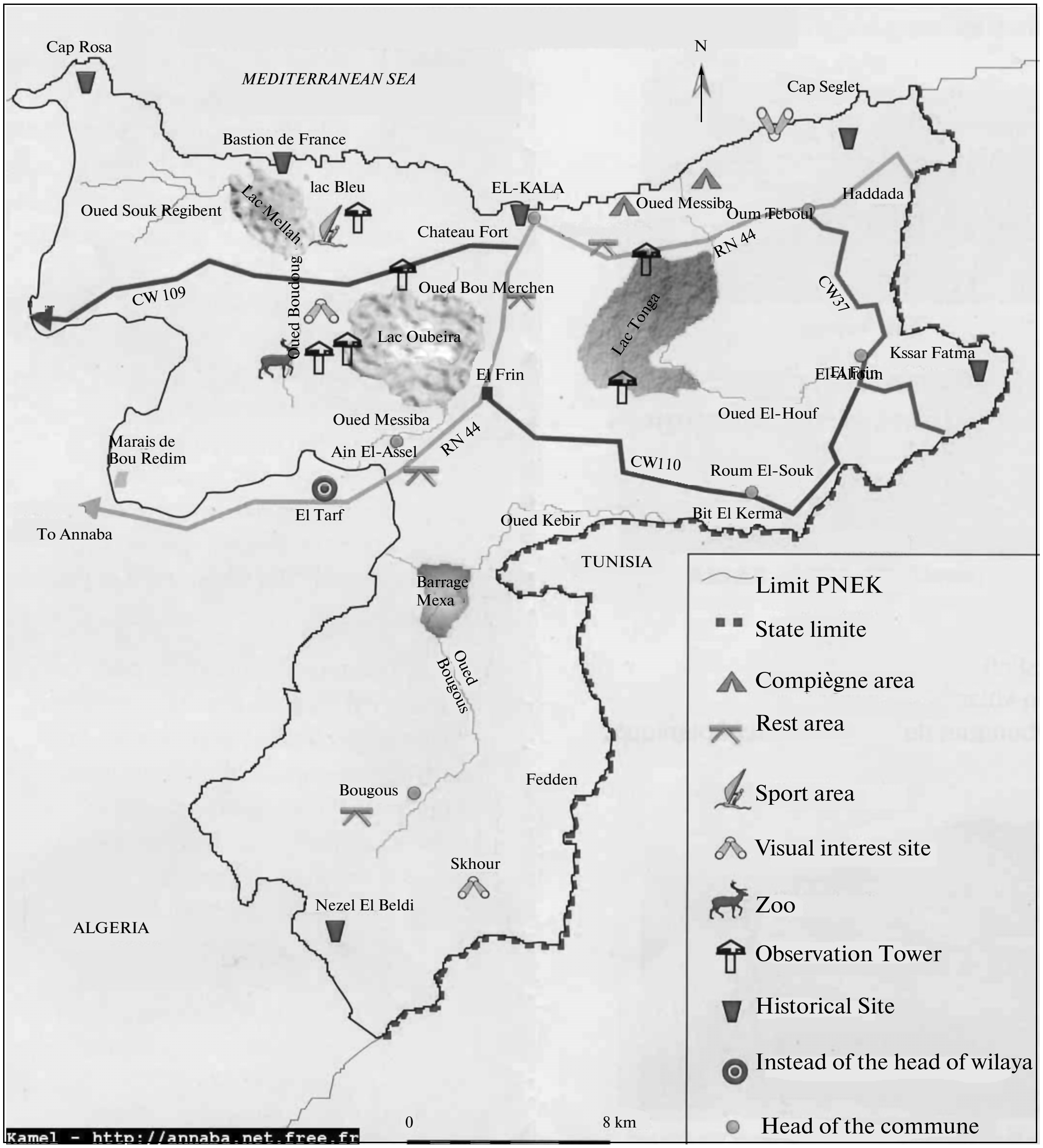

Fig. 1. Location and geographical boundaries of the study area.

thological sites of very high quality where a major life exists between fauna and the flora. The national park of El-Kala represents one of the most important sites, located at the North-East of the country (Fig. 1), which has exceptional natural wealth, represented by a multiplicity of plant species and animal. It is characterized by a diversity of hydrological situations which confers a great halieutic and limnologic wealth to him [5]. The Lake Mellah is a depression which communicates with the sea; it is an old river valley invaded by the sea and was transformed into lagoon. The lake is fed primarily in the South by the Wadi El-Aroug, Wadi Mellah and also by the rejections of the sewage treatment plant of the town of El Hamra, willaya of gantra. In North, the Reguibet Wadi and the Boumalek wadi contribute in a relatively weak way to the food of the lake Mellah. The lake Mellah is always exploited for the fish breeding, the fishing season and sometimes even for the bathe. These last years, a socio-economic development becomes important (tourism and leisures), obliging a narrow glance on the quality of water of the lake. Around the Lake Mellah settles urban areas in constant progression. The latter reaches currently more than 5000 inhabitants [17]. It has a strong

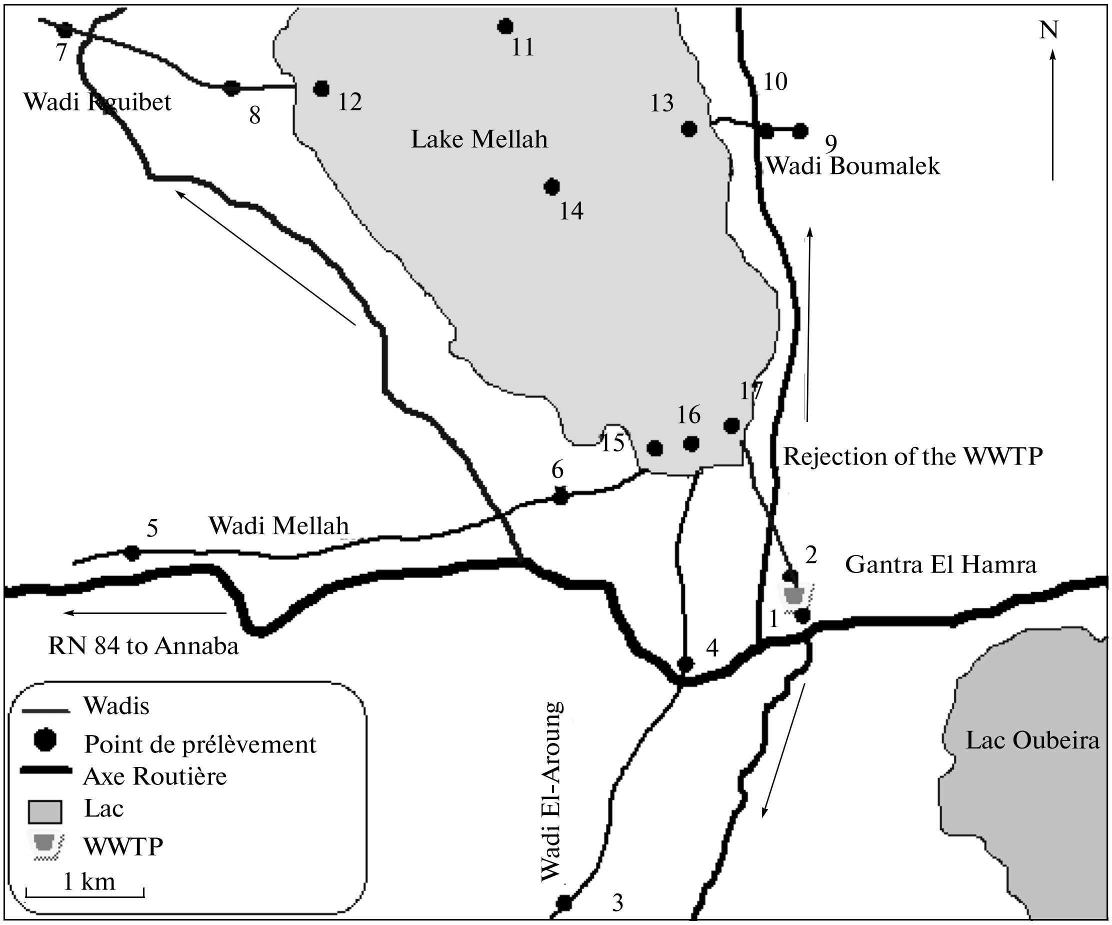

Fig. 2. Hydrographic map of lake system Mellah and sampling sites.

tendency to extend its establishment and its activities. This is not without effectson the environment of the lake Mellah.

Chemical Analysis

In this study, physicochemical parameters (Temperature (*T*), potential of hydrogen (pH), Redox potential (Eh), Conductivity, Salinity, Oxygen (O_2), Turbidity) bacteriological (coliformes total (CT), coliformes thermo tolerant (CTT), streptococci (STREP) were followed during the year (2011–2012) with a seasonal frequency (May, August, November, February). Seventeen (17) sites of three different habitats were investigated: the Waste Water Treatment Plant (WWTP) input and output, Wadis and their upstream tothe estuary and the lake (Fig. 2). The takings away were usually made in not very deep water of the zone of the littoral. One advances in water worthy of ankles and one extends the arm to take the sample with approximately 2 inches under water surface. These taking away were close to surface to recover the maximum of bacteria. Bottles out of glass of 500 mL were used for the test sample selections for the bacteriological analysis, carefully washed, rinsed three times at bidistilléeandsteamed and sterilized water (120°C, 90 min). The bottles (in situ) were put in a refrigerator at 4°C, and were turned over to the laboratory within 04 hour less, for analysis. The contact the various intake points were taken by Total a positioning system (GPS) (Table 1). In front of the significant number of measurements, we used average statistics of data processing which is the Analysis in Principal Component (ACP). The estimate of the contamination of water and the evaluation of the environmental parameters were done by the means of indicating bacteria of fecal pollution and the physicochemical parameters of water [11]. The variables in time are the coliformes (CT; CTT and STERP) and the physicochemical parameters (Temperature, pH, Eh, Conductivity, Salinity, Oxygen (O_2), Turbidity); the individuals are the sites of taking away carried out on the level of the sewage treatment plant; wadis and in the lake by two periods of the seasons (heat and cold). Thus the ACP STATE is a tool for analysis of data which makes it possible to explain the structure of the correlations or covariances by using linear combinations of the original data. Its use makes it possible to reduce and interpret the data on a reduced space. The ACP STATE aimed to present, in a written

Table 1. Inventory of the different sampling stations with name and address

Name of the sampling station			Coordinats "North"	Coordinats "East"
WWTP	Raw water	1	N 36.52.00.0	E 008.20.25.6
	Clean water	2	N 36.51.51.5	E 008.20.38.4
WADIS	Wadi El Aroug upstream	3	N 36.50.51.6	E 008.19.30.9
	Wadi El Aroug downstream	4	N 36.51.45.2	E 008.20.06.6
	Wadi Mellah upstream	5	N 36.52.07.0	E 008.17.35.1
	Wadi Mellah downstream	6	N 36.51.21.4	E 008.19.38.3
	Wadi Souk Rguibet upstream	7	N 36.54.08.3	E 008.15.56.8
	Wadi Souk Rguibet downstream	8	N 36.54.01.4	E 008.17.42.6
	Wadi Boumalek upstream	9	N 36.53.40.8	E 008.20.41.4
	Wadi downstream Boumalek	10	N 36.53.40.6	E 008.20.35.0
LAKE	Channel of Lake	11	N 36.54.39.1	E 008.18.22.4
	Exit of Wadi Souk Rguibet	12	N 36.54.08.4	E 008.18.22.4
	Exit of Wadi Boumalek	13	N 36.53.49.7	E 008.20.16.2
	Center of the lake	14	N 36.53.27.6	E 008.19.45.0
	Exit of wadi Mellah	15	N 36.52.36.0	E 008.19.39.8
	Exit of wadi El Aroug	16	N 36.52.29.03	E 008.20.16.1
	Exit of the WWTP	17	N 36.52.35.1	E 008.20.25.4

form the maximum of contained information in data table, based on the principle of double projection on the factorial axes [2].

RESULTS AND DISCUSSION

Treatment of the physicochemical and bacteriological parameters of water in three different ambient conditions (Hot and cold Season) allowed us to see the influence of the environmental parameters on spatiotemporal evolution of the behavior of the micro-organisms. According to Table 2; the concentration of the of total coliforms has a maximum concentration in summer and winter, witness of a direct or indirect contamination by the fecal matter, decreasing downstream-to- upstream gradient. Overall, coliforms decreased gradually as of the distance of the upstream towards the point of the rejection of lagoon water.

Influence of the Environmental Parameters on Microbial Abundance

The proliferation of the micro-organisms requires ambient conditions whose physicochemical parameters of water, play a paramount role. The results got starting from the analysis in component principal (ACP) watch with the threshold of significance alpha = 0.05' a strong correlation between the variables (samples analyzed and/or parameters measured).

Influence of the Environmental Parameters in Summer Conditions

Table 3 presents the coefficients of correlation for the summer period between the variables and the first two axes *F*1 and *F*2. Figure 3 reveal that the projection of the variables within the space of axes *F*1 et *F*2. These considerations enabled us to obtain the matrix of correlation of the data, and the chart the regrouping of the

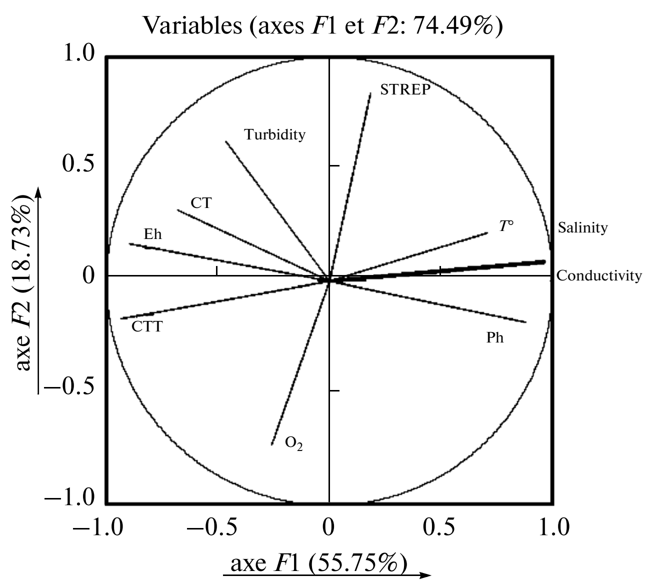

Fig. 3. The projection of variables in the summer on the factorial plan (1 × 2).

Table 2. Seasonal variation of physico-chemical and bacteriological parameters of water sites studied

Middle/season			CT, germ/100 mL	CTT, germ/100 mL	STREP, germ/100 mL	pH	Eh	T	Conductivity, μS/cm	Salinity, ppm	O_2, mg/L	Turbidity, NTU
WWTP	Hot season	Entry	1400	1100	25	6.2	75	28.5	864	455	0.88	79.8
		Exit	1400	450	0	5.9	62	26.1	551	292	0.35	1.34
	Cold season	Entry	1400	11	0	7.1	11	15.6	1158	620	2.9	75
		Exit	1400	3	0	7.1	9	12.2	592	314	2.2	12
WADIS	Hot season	Upstream (Avg)	1400	1400	6.25	6.20	62.5	26.48	229.75	120.75	3.525	13.5
		Aval (Avg)	1400	1400	0	6.2575	57.5	26.58	216.75	113.5	3.47	13.35
	Cold season	Upstream (Avg)	1325	34	11	7.085	12.5	11.3	252	133	10.03	23.38
		Aval (Avg)	1073.75	409.75	14.5	6.905	22.75	11.2	224.5	118	9.255	15.87
LAKE	Hot season	Max	1400	40	65	7.33	16	31.5	59418	29734	3.25	13.2
		Min	3	0	0	7.01	0	27.4	54412	27231	0.8	1.27
		Moye	606.9	14.3	14.1	7.2	8.1	29.2	57665.14	28857.57	2.2	3.81
	Cold season	Max	1400	65	9	7.8	9	11.1	47404	23727	14.1	17.9
		Min	75	0	0	7.15	-23	9	44200	22125	8.78	1.25
		Moy	910.7	19.6	1.9	7.6	-12.6	9.7	45292.29	22671.14	10.3	5.22

Table 3. Correlation matrix of the physico-chemical parameters and biological samples (hot season)

	CT	CTT	STREP	Ph	Eh	Turbidity	*T*	Conductivity	Salinity	O_2
CT	**1**									
CTT	**0.629**	**1**								
STREP	0.281	–0.252	**1**							
Ph	**–0.509**	**–0.708**	0.020	**1**						
Eh	**0.540**	**0.734**	–0.037	**–0.996**	**1**					
Turbidity	0.286	0.338	0.285	**–0.488**	0.478	**1**				
T	**–0.321**	**–0.655**	0.365	**0.549**	**–0.552**	–0.279	**1**			
Conductivity	**–0.664**	**–0.942**	0.259	**0.762**	**–0.793**	–0.367	**0.611**	**1**		
Salinity	**–0.664**	**–0.942**	0.259	**0.762**	**–0.793**	–0.367	**0.611**	**1.000**	**1**	
O_2	0.043	0.394	–0.421	–0.122	0.125	–0.308	–0.189	–0.263	–0.263	**1**

sites of sampling. These axes show a good distribution and representation of the variables studied. The axis *F*1 (55.75%) is expressed by its positive pole by the pH, the temperature, conductivity, salinity in the positive direction and the CT and the CTT, Eh, in the negative direction. This axis then defines a gradient of mineralization and of microbiological pollution; it describes also the ambient conditions pertaining to the lake. In the positive direction, the axis *F*2 (18.73%) is consisted Turbidity, STREP; on the other hand dissolved oxygen is opposed to these parameters with a negative coefficient of correlation. The provision of the physicochemical variables and the microbial ones, make it possible to highlight a relation between the various variables, in particular the existence of a close connection between the bacteriological data (CT, CTT, STREP) and the physicochemical variables (temperature, salinity, conductivity and pH, Eh, Turbidity, O_2). This bringing together is underlined, on the Table 4, by microbial germs which are in strong positive correlation with Hey. And they are also in strong negative correlation with the temperature Conductivity, Salinity and the pH [11].

Figure 4 shows the chart the regrouping of the sites of sampling (individuals) in the factorial design (*F*1–*F*2). According to this statistical analysis and graph, one can conclude that the distribution of the values of the studied parameters corresponds to a space distribution of the points of sampling with three classes: first class takes into account water outgoing of the WWTP and water of the wadis (lover and downstream), who represent with which water qual-

Table 4. Distribution of inertia between the two axes (*F*1 × *F*2) during the summer

	*F*1 (55.75%)	*F*2 (18.73%)
CT	–0.681	0.316
CTT	–0.937	–0.166
STREP	0.181	0.837
Ph	0.878	–0.181
Eh	–0.897	0.169
Turbidity	–0.468	0.622
T	0.705	0.218
Conductivity	0.960	0.086
Salinity	0.960	0.087
O_2	–0.260	–0.732

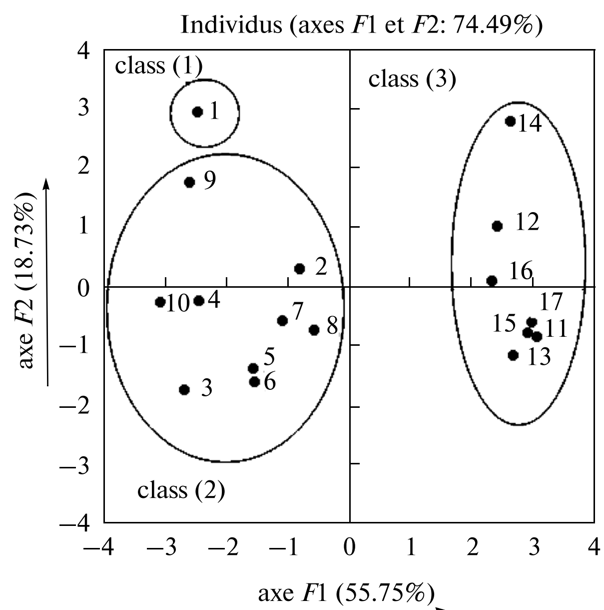

Fig. 4. The projection of individuals (sampling stations) on the factorial design (1 × 2).

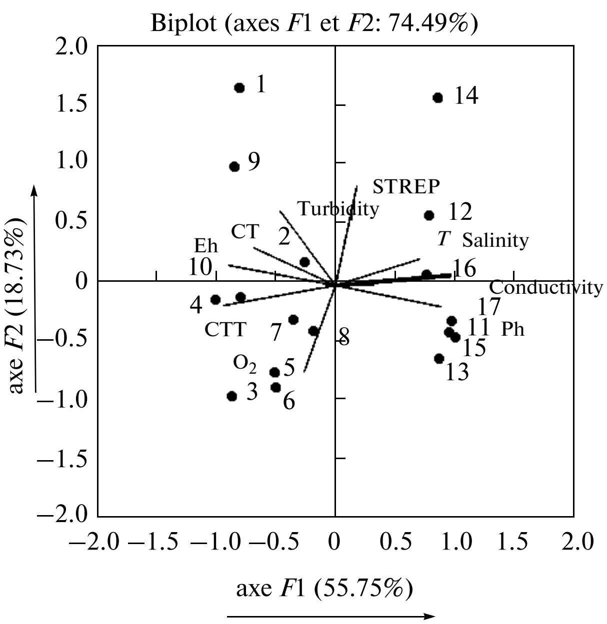

Fig. 5. Spatial analysis of individual statistical factorial ($F1$–$F2$) in the summer time.

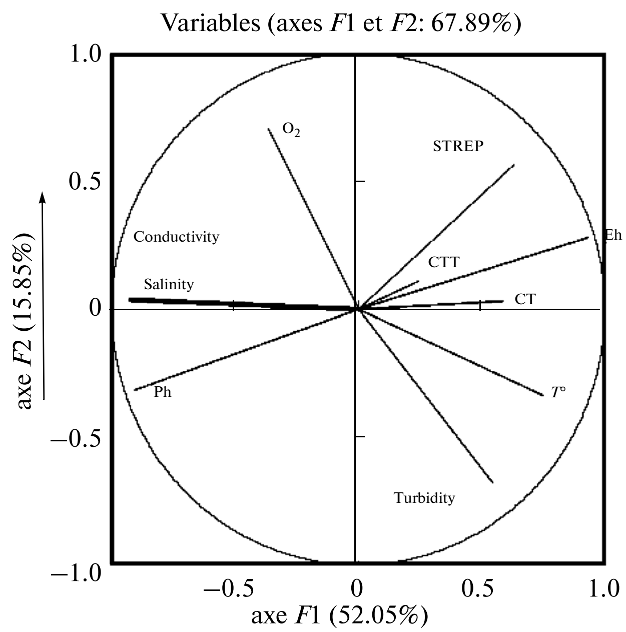

Fig. 6. The projection of variables in the winter on the factorial plan (1 × 2).

ity is charged in CT and CTT and turbidity; the second class contains water entering the WWTP which has strong turbidity; the third class contains only water of the lake Mellah who have the points whose water quality is expressed by the STREP, salinity, conductivity, the pH during the summer period (Fig. 5).

Influence of the Environmental Parameters in Conditions Winter

Table 5 presents the coefficients of correlation between the variables and the first two axes $F1$ and $F2$. Figure 6 reveal that the projection of the variables within the space of axes $F1$ et $F2$.

The circle of correlation formed by the axes $F1$ and $F2$ giving 67.89% of total information shows, according to the axis $F1$ (52.05%), where variables are correlated positively significant between it, such that the Streptococci present a strongly significant correlation, on the one hand positive with the temperature and Eh and on the other hand negative one with conductivity, salinity and the pH. The axis $F1$ then defines an important microbial pollution and a natural mineralization (water is slightly charged with dissolved salts). The axis $F2$ expresses weak information (15.85%), however one notes a correlation opposed between dissolved oxygen and turbidity (Table 6).

Figure 7 shows water gather into three classifies: water entering the WWTP, water outgoing of the WWTP and the wadis (upstream, downstream); water of the lake mellah during wintry time one observes that the taking into account of the variables physicochem-

Table 5. Correlation matrix of the physic-chemical parameters and biological samples (cold season)

	CT	CTT	STREP	PH	EH	T	Conductivity	Salinity	O_2	Turbidity
CT	**1**									
CTT	0.130	**1**								
STREP	0.205	0.060	**1**							
PH	**–0.462**	–0.163	**–0.784**	**1**						
EH	**0.449**	0.201	**0.769**	**–0.969**	**1**					
T	**0.390**	0.154	0.444	**–0.585**	**0.562**	**1**				
Conductivity	**–0.553**	–0.243	–0.421	**0.786**	**–0.846**	**–0.565**	**1**			
Salinity	**–0.553**	–0.243	–0.421	**0.786**	**–0.846**	**–0.565**	**1.000**	**1**		
O_2	–0.052	0.034	0.006	0.133	–0.229	**–0.537**	0.284	0.284	**1**	
Turbidity	0.256	0.050	–0.050	–0.311	0.297	**0.587**	**–0.531**	**–0.530**	–0.458	**1**

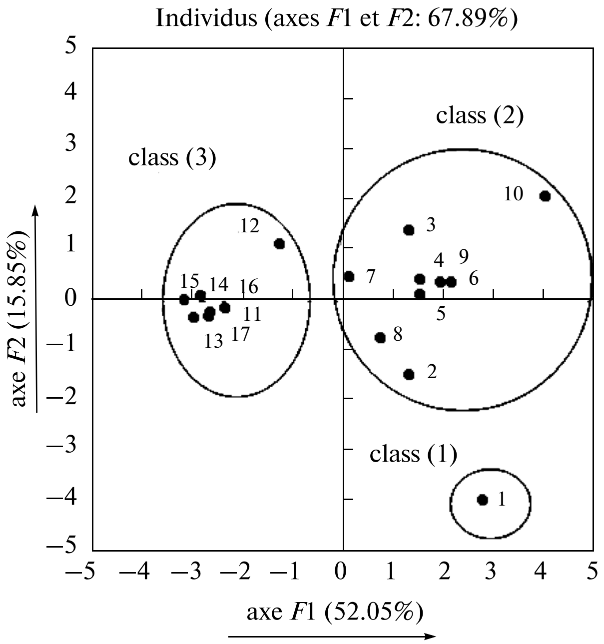

Fig. 7. The projection of individuals (sampling stations) on the factorial design (1 × 2).

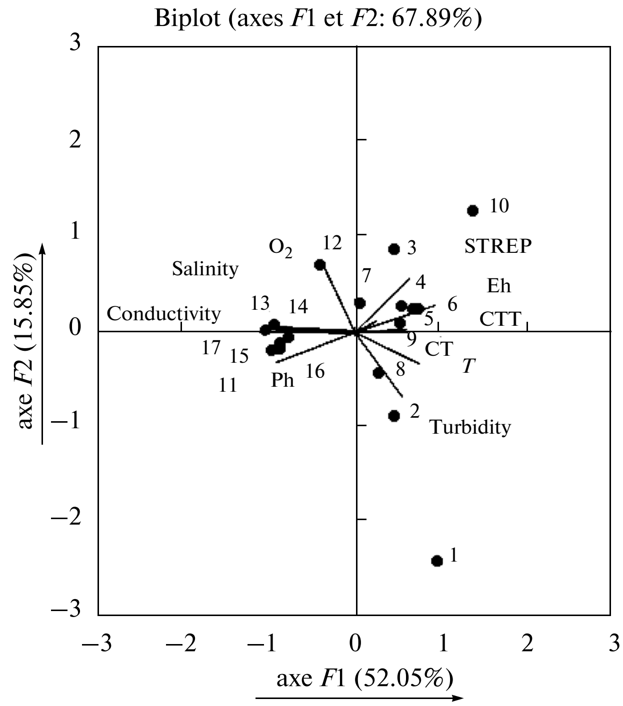

Fig. 8. Spatial analysis of individual statistical factorial (*F*1–*F*2) in the winter.

ical and microbiological results primarily in observations such that the intake points on the level as of Wadis and in the sewage treatment plant represent the points with which water quality is charged with the CT and CTT and STREP and turbidity is important. On the other hand the intake points on the level of the lake Mellah represent the points whose pH, O_2, salinity and conductivity of water are very important (Fig. 8). The strong variations of salinity from one medium to another tend to prevent the habituation of the immigrant bacteria in their new medium (Lake), what leads to the decrease of their number malgré dilution of water on the level of the lake Mellah.

The results of the statistical analysis and graph indicated that water passes from a strong microbial abundance to a poor abundance. This is observed on the level of the lake. On the other hand the points which present water of poor qualities are on the levels of effluents (wads and WWTP) (strong microbial abundance). In little to note that microbial abundance in water of the lake Mellah is directly related to mineralization, the temperature, the pH, and Eh. These last parameters influence the living conditions of bacterial (CT, CTT, and STREP).

Behavior of the Microorganisms in Relation to the Environmental Parameters

By comparing average microbial abundance of the CT, CT and STREP according to salinity and or conductivity, pH and Eh in different ambient, one can estimate the effect of these last on the survival of the bacteria.

Behavior of the Microorganisms in Relation to Salinity and (or) Conductivity

Results of measurements on the levels of the wadis in the two study periods allowed observing conductivity and a low salinity reaching to the maximum of 270 µs/cm and these values are very close to those of rainwater. On the level of WWTP conductivity and salinity reaches there maximum (1200 µs/cm). On

Table 6. Distribution of inertia between the two axes (*F*1 × *F*2) during winter

	*F*1 (52.05%)	*F*2 (15.85%)
CT	0.589	0.031
CTT	0.245	0.111
STREP	0.630	0.567
PH	–0.909	–0.316
EH	0.931	0.278
T	0.752	–0.338
Conductivity	–0.926	0.038
Salinity	–0.926	0.037
O_2	–0.364	0.706
Turbidity	0.543	–0.677

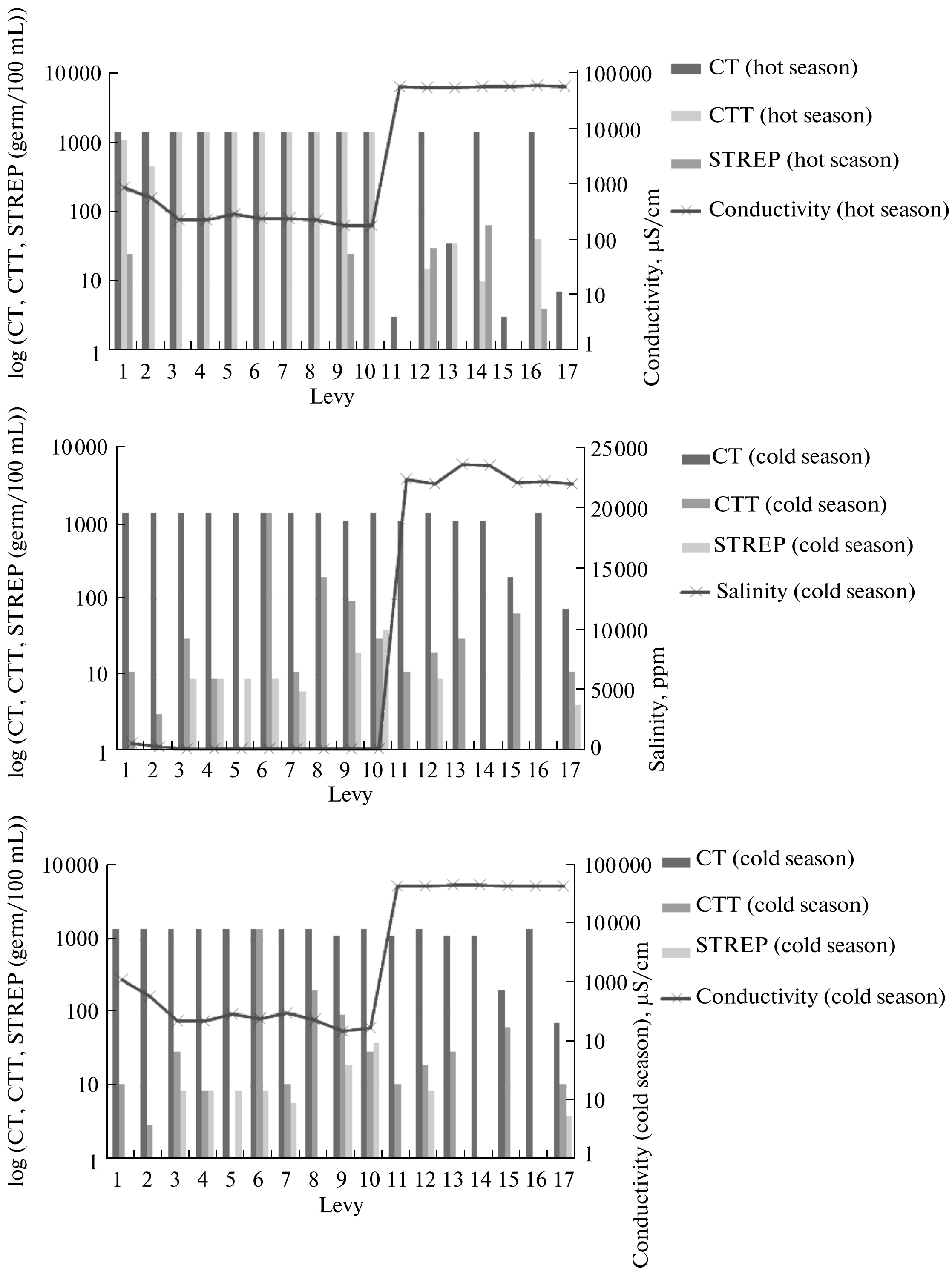

Fig. 9. Behavior of the microorganisms in relation to salinity and (or) conductivity in two periods (hot and cold).

the level of the lake, mineralization is excessive because water of the lake is slightly in charge out of dissolved salts for the two periods of season (Fig. 9). This increase is due to important mixing on the level of the channel (lake-sea contact). The low concentrations value of water salinity and conductivity represent the maximum of the bacterial germs on the level of WWTP and wadis in the two seasons, witness of a direct or indirect contamination by the fecal matter, decreasing downstream-to-upstream gradi-

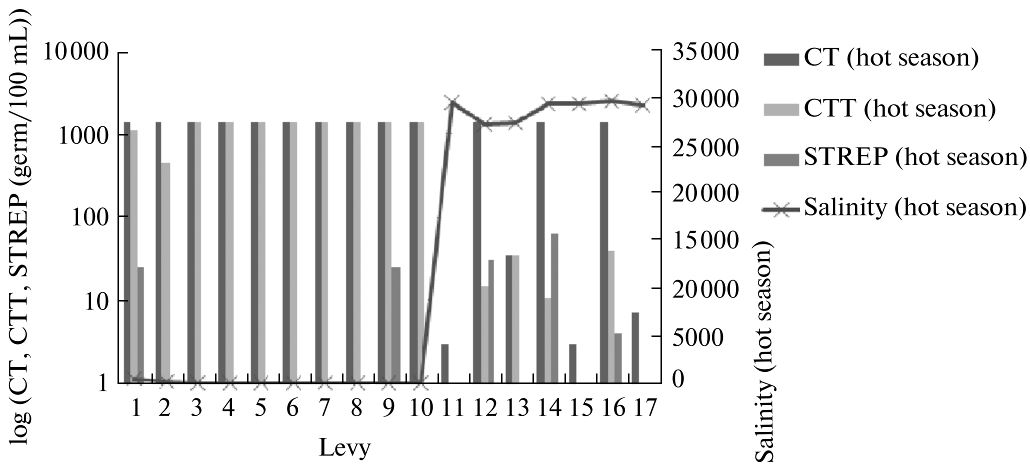

Fig. 9. (Contd.)

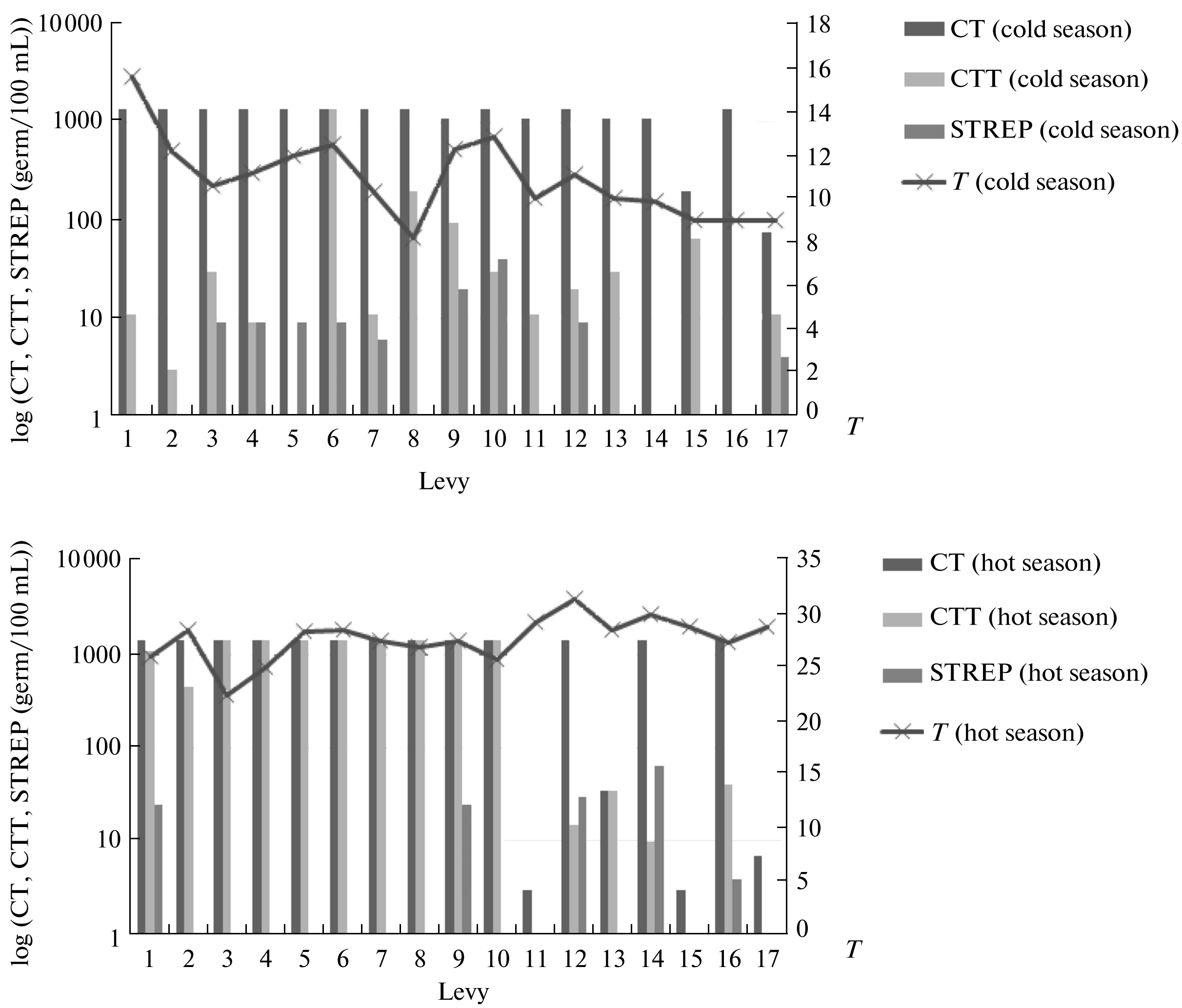

Fig. 10. Behavior of the microorganisms in relation to the temperature in two periods (hot and cold).

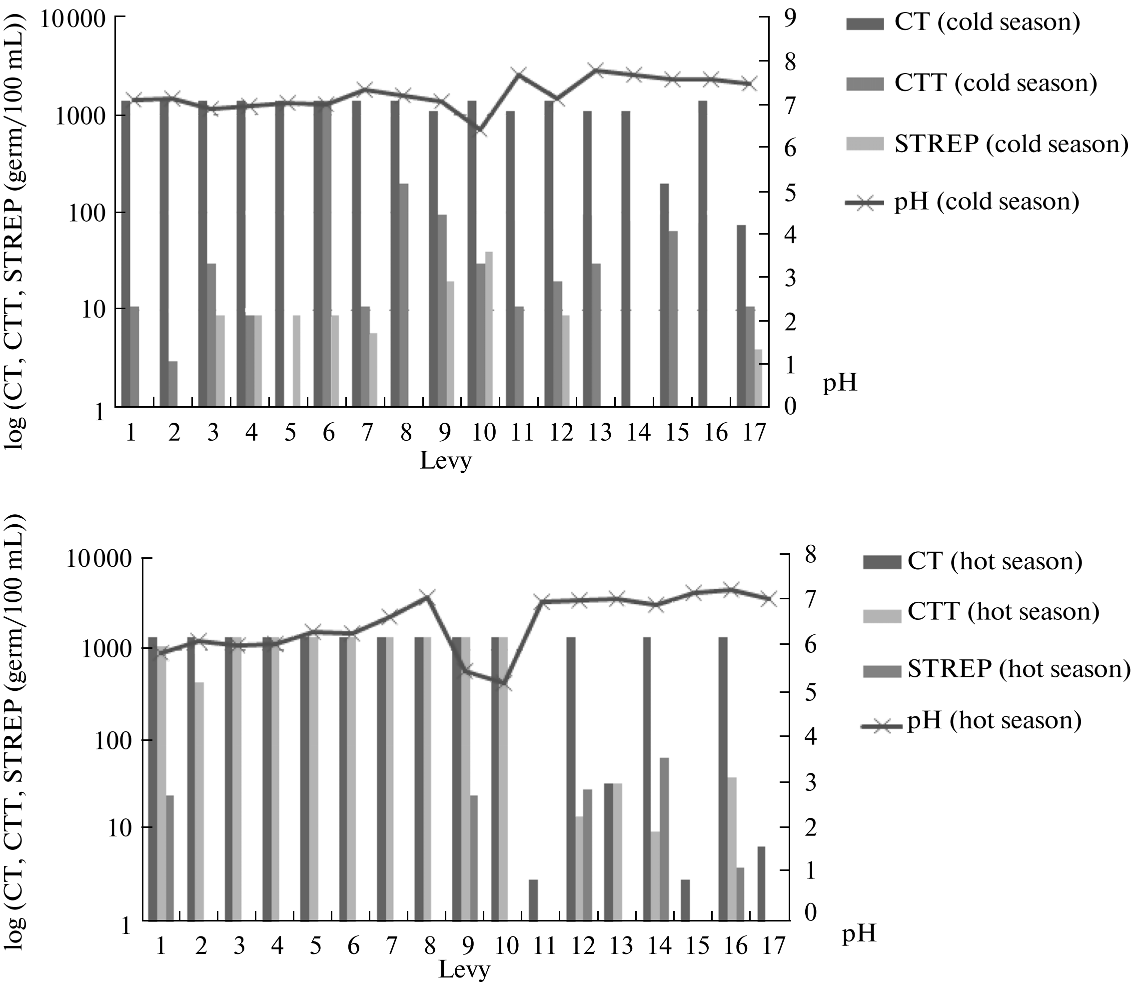

Fig. 11. Behavior of the microorganisms according to Hydrogen Potential (pH) in two periods (hot and cold).

ent. The concentration of salinity ranged between from 113.5 and 28857.57 ppm medium salinity. The concentration of CT ranged between 1400 germ/100 mL at the wadi to 606 germ/100 mL at the lake. These magnitudes of concentration show a reduction in microbial abundance in the two study periods. This study shows the existence of a beneficial effect of salinity on the survival of the bacteria in the lake consequently confirm the tolerance of the fecal bacteria for the salinity evoked by certain authors like [7].

Behavior of the Microorganisms in Relation to the Temperature

The results showed the presence of a significant difference between the three ambient conditions (sites of taking away) and between the periods of believed and the periods of dry time (Fig. 10). The high temperatures do not seem to support the bacteriological contamination of water in particular the CT and the CTT on the level of the STREP and the levels of the wadis during the hot season, these bacterial groups is capable of oversteer at elevated temperature [13]. Beyond these temperatures, the medium is favorable for their growth. Other authors underlined the existence of important seasonal fluctuations of the total coliforms on the level as of waterway [1]. Concerning water of the lake Mellah, for the same parameters, the results show average fecal contaminations and constants during the two seasons. This is explained by the altitude of the lake being to the sea level, the channel evacuates on its average level water the too full one consisted the winter fresh water contributions. The water supply of rainwater and the streaming can play the part of degrading pollution by the fact of dilution and for the summer period flow is reversed in the channel. The deficit caused by evaporation and the scarcity of precipitations causes a fall of the mean level and the intrusion of marine water which is due to the increase in the temperature of water which reach the 31.5°C, this explained by the fact that polluted water cannot move towards the sea.

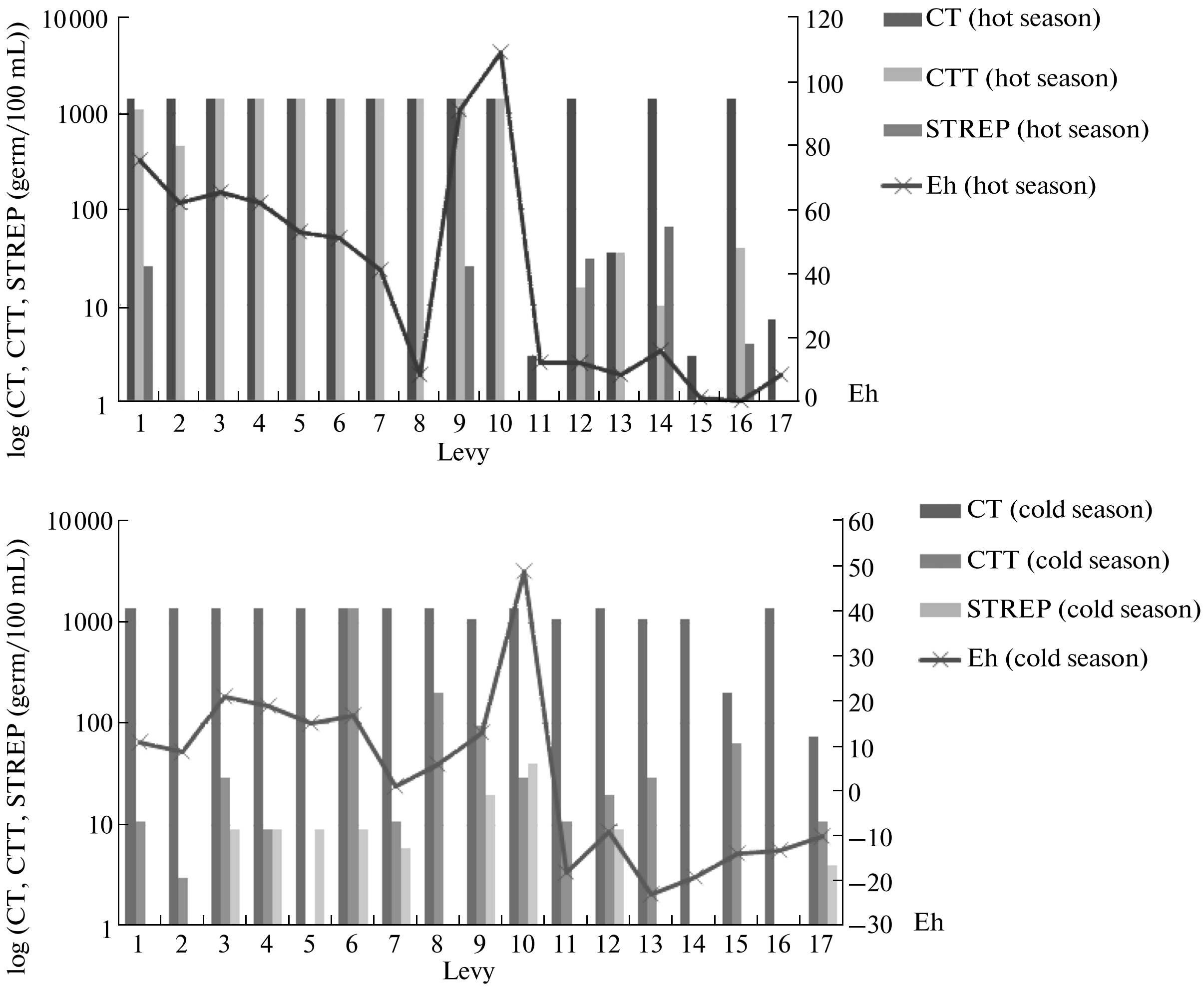

Fig. 12. Behavior of the microorganisms according to Redox Potential (Eh) in two periods (hot and cold).

Behavior of the Microorganisms in Relation to Hydrogen Potential (pH)

The pH is a measurement of the acidity of water that is to say of the hydrogen ion concentration (H+). The actual values reveal that the pH is slightly acid with neutral in all the stations of the effluents of the wadis and the WWTP, as well in period of dry as in period of rain (Fig. 11). The pH is very variable from one state to another and from one season to another all recording indicated an increase in period of rain for the three mediums. This can be also explained the dilution of water by the contribution of rain waters. Indeed, this watch analysis which variation of abundance of the CT, CTT and streptococci fecal was significantly correlated negatively with the pH during the two periods. These results confirm work of [15]. Who showed that the increase in the pH affects the abundance of the coliforms that is to say the pH basic involve a clear reduction in the survival of the bacteria.

Behavior of the Microorganisms According to Redox Potential (Eh)

The redox potential (Eh) measures the ease with which an environment loses or gains electrons. *a medium* is oxidized when it collects electrons (its Eh is positive); and it is reducing when it loses electrons (its Eh is negative). The results showed that water of the lake Mellah is a medium oxidizing during the summer period but for wintry time is a reducing medium (Fig. 12). This is due to the presence, in water of the strongly hydrogenated substances. But the other mediums such as the WWTP and the affluent of the wadis are mediums also oxidizing, for the two periods. The effect oxidizing of a medium is due primarily to the atmospheric presence of oxygen. The values of Eh positive represent concentrations of the CT, CTT and STREP on the level as of water of the zone of study.

CONCLUSIONS

The present study examined the influence of the physicochemical parameters on microbial abundance. The obtained results made it possible to distinguish three different ambient conditions. It is noted that the behavior of the micro-organisms in the wadi and the sewage treatment plant is relatively different compared to water from the lake for the two periods of seasons. In conclusion, the variation of seasonal bacteriological contamination is not very clear for the various sampling stations on the level of affluent (Wadis and WWTP); the counted germs are in concentrations very important and regular during all the study period. However, the other stations, mainly to the level of the lake Mellah present quantities not very important and more apparent during the summer that the winter, or one attends with a reduction in the water flow and a contribution increased of waste waters and effluents of breeding. In little to note that microbial abundance in water of the lake Mellah is directly related to mineralization, the temperature, the pH, and Eh. These last parameters influence the living conditions of bacterial (CT, CTT, and STREP).

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