JEE Journal of Ecological Engineering

Journal of Ecological Engineering 2023, 24(1), 205–217
https://doi.org/10.12911/22998993/156005
ISSN 2299–8993, License CC-BY 4.0

Received: 2022.09.26
Accepted: 2022.11.18
Published: 2022.12.01

Study of the Bacteriological Quality of a Continental Wetland – Case of the Dayet Er Roumi Lake (Khemisset, Morocco)

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ABSTRACT

The Dayet Er Roumi lake located in the biogeographic zone of the central meseta belonging to the province of Khemisset, constitutes the only permanent natural lake of low altitude in Morocco. The lake's water body is the essence of the existence of this natural and environmental space. The objective of the present study was on the one hand to evaluate the current state of the bacteriological quality of the waters lake Dayet Er Roumi, and on the other hand to define the risks of the pollution waters lake, and its origin. In order to carry out this work well, the evolution of the bacteriological parameters of the waters lake during the period from October 2020 until September 2021 was studied at the level of four stations of sampling. The obtained results showed that the waters of Dayet Er Roumi are confronted with a strong pressure generated by the discharges of domestic waters of the neighbouring agglomerations and also by activities of natural, agricultural and tourist origin. Indeed, the bacterial load is expressed by a high load of bacteria indicative of fecal contamination which varies between 50 and $346 \cdot 10^3$ CFU/1 ml for total aerobic mesophilic flora (TAMF) at 22 °C, 6 and $72 \cdot 10^3$ CFU/1 ml for TAMF at 37 °C, 15 and $62 \cdot 10^3$ CFU/100 ml for total coliforms (TC), 0 and 4350 CFU/100 ml for faecal coliforms, 0 and 16 350 CFU/100 ml for faecal streptococci, 1 and $13 \cdot 10^3$ CFU/20 ml for sulphite-reducing anaerobes, 38 and 22 680 CFU/100 ml for *Staphylococcus aureus* and between 160 and 33 600 CFU/100 ml for *Pseudomonas aeruginosa*. These results largely exceed the Moroccan standards for the water intended for irrigation. They could be the cause of possible contamination of irrigated crops as well as groundwater in the region, and consequently have repercussions on human health.

Keywords: Dayet Er Roumi, wetland, fecal contamination index, bacteriology, Khemisset, Morocco.

INTRODUCTION

The water of the lake Dayet Er Roumi constitutes a natural biotope for the survival of various organisms which plays an essential role in the trophic chain of the site. However, the quality of these waters could be degraded under the effect of several pollutants of domestic, industrial and agricultural origin which can cause an imbalance of the natural ecosystem and consequently impact the human and animal health [Afri-Mehennaoui et al., 2009].

Dayet Er Roumi is an area of biological and ecological interest [AEFCS, 1996]. The lake has a considerable natural water potential classifying it as the most important lake in the province of Khemisset [El Abidi et al., 2014]. This body of water is the essence of the existence of this natural and environmental space.

Therefore, the knowledge of the bacteriological properties of water resources dedicated to agricultural or tourist purposes is to appreciate its quality and identify its state of pollution. Indeed, the bacteriological analysis concerns the research and the enumeration of the germs indicators of bacteriological pollution at the level of the sample stations: namely the total aerobic mesophilic flora (TAMF) at 22 °C

and 37 °C, the total coliforms (CT) and fecal (CF), fecal streptococci (SF) and the anaerobic sulfito-reducers (ASR), *Staphylococcus aureus* (STA) and *Pseudomonas aeruginosa* (PSA)

The samples were taken during a hydrobiological cycle from October 2020 to September 2021 at four sampling stations, three surface sampling stations ST1, ST2 and ST3 (0 m) and a single station allowing sampling at 6m depth ST3 (6 m). The explanatory analysis of the data is based on descriptive, inferential and multivariate statistics.

MATERIALS ET METHODS

Study area and sampling stations

Lake Dayet Er Roumi (33° 45'N – 06° 12'W) is a zone of biological and ecological interest (SIBE) that extends over 2 km in length and from 400 to 700 m in width, the surface area of the water body is about 90 ha, with a maximum depth of about 14 m. It is the only natural permanent lowland lake in Morocco [AEFCS, 1996, 1996]. It is located at a distance of 15 km from the city of Khemisset, where it is administratively located (Figure 1).

To better understand the hydrobiological functioning of the lake system, the evolution of the bacteriological parameters of the waters lake Dayet Er Roumi was studied, at the level of four selected stations sampling and during an annual cycle, of the period going from October 2020 to September 2021, the choice stations was determined on the basis of the sources of pollution waters (Figure 1):

- Station 1 (ST1) – This station is located at the NE end of the lake where a drainage channel emerges from a marshy depression located 1–2 km to the NE of the lake called: the Daya of the frogs (a platform regularly flooded in winter and corresponding to the outlet of the lake).
- Station 2 (ST2) – located in the southwest of the lake next to the new Dar Eddaya hotel.
- Station 3 (ST3) – located in the centre of the lake and allows sampling at different depths:
  - ST3 (0 m) – located on the surface;
  - ST3 (6 m) – located at a depth of 6m.

Sampling, germs sought and methods of microbiological analysis

The sampling period was between October 2020 and September 2021. The water samples were collected monthly in 500 ml bottles that have been sterilised beforehand.

The transport to the laboratory of the sampling bottles was done in a cooler at low temperature (+

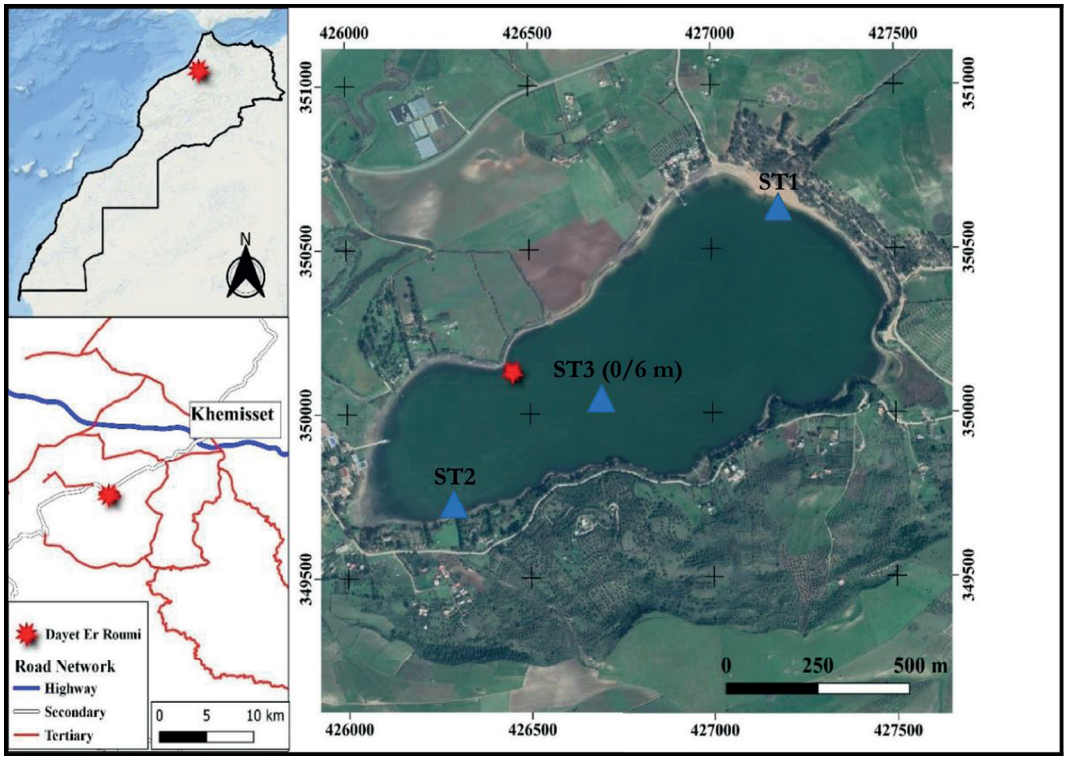

Figure 1. Map of sampling stations locations at Dayet Er Roumi lake

4 °C) to stop the metabolic activities of the organisms in the water. The analyses were carried out on the same day of sampling according to the appropriate Moroccan Standards (NM).

Total aerobic mesophilic flora

The total aerobic mesophilic flora is used as an indicator of overall pollution. It includes all microorganisms capable of multiplying in air and at a temperature of 37 °C for 48 hours or 22 °C for 72 hours. The enumeration of TAMF is carried out by incorporation in agar medium; this method is based on the incorporation of 1ml of sample in a sterile petri dish and then run the PCA medium, incubation at 37 °C for 48 hours and at 22 °C for 72 hours, all the colonies were counted [AFNOR, 1986].

Total coliforms

Coliforms are important fecal indicators because they are abundant in the feces of warm-blooded animals [Rodier et al., 2009]. The enumeration of total coliforms is performed by membrane filtration (porosity 0.45 µm). The analysis of water samples was performed by filtration of a volume of 100 ml. The membranes were deposited on Tergitol 7 and Triphenyl Tetrazolium Chloride (TTC) agar. After incubation at 37 °C for 24 hours, yellow colonies were counted [AFNOR, 1986].

Fecal coliforms

Fecal coliforms are also called thermotolerant coliforms, classified in the subgroup of total coliforms, and are capable of fermenting lactose at a temperature of 44 °C. The enumeration of fecal coliforms is done by the same method used for total coliforms, except that the incubation is done at 44 °C. In fact, the reading of the plates allows recognising the presence of coliforms by the following characteristics:

- Yellow, orange coloration of the colonies, resulting from the absence of reduction of TTC by the coliforms; in general, *Escherichia coli* cause a clearly orange coloration.
- Yellow halo, in the medium itself, under the membrane, around the previous colonies, corresponding to a fermentation of lactose by these colonies [AFNOR, 1986].

Fecal Streptococci

Fecal streptococci are often more responsive in the environment. Their survival rate in aquatic ecosystems is sometimes higher than that of fecal coliforms [Krumperman, 1983]. The analysis of water samples is done by filtration of a 100 ml volume. Fecal streptococci are counted on Slanetz and Bartley medium, after incubation at 44 °C for 48 hours, by counting all red, purple or pink colonies visible on the plate (TTC reduction) [AFNOR, 1986].

Sulphite-reducing anaerobes (Clostridium)

The enumeration of Clostridium is carried out on the SPS medium (Sodium Sulphite-Cysteine PolymixineSulphite). The method consists in placing a test tube of 12 mm diameter inside a tube of 25 mm diameter in order to have a thin crown favoring anaerobia. The stock solution is activated by a heat treatment at 80 °C for 10 min. The heat treatment destroys the vegetative forms and activates the Clostridium spores. The tubes are incubated at 37 °C for 24 to 48 hours. Only the colonies surrounded by a black halo of important size, due to the reduction of Sulphite with production of a black deposit of iron sulphide, will be counted [AFNOR, 1986].

Staphylocoque aureus (STA)

Staphylococcus aureus (STA) are gram-positive cocci bacteria, possessing catalase and giving a strong positive reaction to coagulase. The method used for this analysis is the membrane filtration method. After filtration of the water to be analyzed, the membrane is deposited on Chapman selective agar medium. This allows the colonies of Staphylococcus aureus to grow on the medium after incubation at 37 °C for 24 to 48 hours.

Pseudomonas aeruginosa (PSA)

Pseudomonas aeruginosa (PSA) are gram-negative, oxidase-positive bacteria. For their research, the NF T90-421 technique was applied. The method used for this analysis is the membrane filtration method. After filtration of the water to be analyzed, the membrane is deposited on the selective medium Cetrimide. This allows Pseudomonas aeruginosa colonies to grow on the medium after incubation at 42 °C for 24 to 48 hours. The media used and the culture conditions for the different germs are shown in Table 1.

Table 1. Germs sought in water with their culture media used and their incubation conditions

Germs sought in water	Culture media	Incubation condition	
		Temperature (°C)	Time (H)
Total aerobic mesophilic flora at 22 °C	PCA	22	72
Total aerobic mesophilic flora at 37 °C	PCA	37	48
Total coliforms	Tergitol + TTC	37	24
Fecal coliforms	Tergitol + TTC	44	24
Fecal Streptococci	Slanetz et Bartly	37	48
Sulfite-reducing anaerobes	TSC	37	48
Staphylocoque aureus	Chapman	37	48
Pseudomonas aeruginosa	Cetrimide	42	48

Data analysis

In order to appreciate the relationships between the different bacteriological variables on the one hand, and to study the typology of Dayet Er Roumi waters on the other hand, we used a combination of statistical methods. The first statistical approach was based on descriptive statistics, the second on using analysis of variance (ANOVA) and the last one was represented by the analysis in principal components (PCA). Thus, the analysis of the data recommended for this work is based on descriptive, inferential and multidimensional statistics.

The statistical processing is carried out by the software SPSS 25.0 and the graphic representations are designed under Excel 2016.

RESULTS AND DISCUSSION

Descriptive and inferential analysis

According to the test of homogeneity of variances, the spatial statistical analysis of the results showed that the contents of the bacteriological parameters surveyed, are significantly homogeneous, having p>α=0.05. In relation to the

Table 2. Test of homogeneity of variances at α = 0.05 of spatiotemporal variability of bacteriological parameters

Bacteriological parameters	Spatial				Temporal			
	All stations				Monthly			
	Levene's statistics	ddl1	ddl2	Signification	Levene's statistics	ddl1	ddl2	Signification
TAMF 22	.666	3	44	.578	4.290	11	36	.000
TAMF 37	.490	3	44	.691	4.802	11	36	.000
TC	2.501	3	44	.072	16.949	11	36	.000
FC	.296	3	44	.828	6.141	11	36	.000
FS	.556	3	44	.647	1.667	11	36	.122
SRA	.501	3	44	.684	5.345	11	36	.000
STA	.357	3	44	.785	8.495	11	36	.000
PSA	1.263	3	44	.299	14.468	11	36	.000
Bacteriological parameters	Type of sampling				Seasonal			
	Levene's statistics	ddl1	ddl2	Signification	Levene's statistics	ddl1	ddl2	Signification
TAMF 22	.028	1	46	.867	17.361	3	44	.000
TAMF 37	.340	1	46	.563	2.970	3	44	.042
TC	.518	1	46	.475	3.212	3	44	.032
FC	.512	1	46	.478	2.039	3	44	.122
FS	.021	1	46	.885	2.182	3	44	.104
SRA	.580	1	46	.450	.834	3	44	.483
STA	.340	1	46	.563	.341	3	44	.796
PSA	1.328	1	46	.255	3.377	3	44	.027

temporal analysis (monthly), the variability of the bacteriological parameters is significantly heterogeneous $p<\alpha=0.05$, except for the FS. As for the temporal analysis (seasonal), the variability of bacteriological parameters is significantly heterogeneous, having $p<\alpha=0.05$, with regard to TAMF 22, TAMF 37, TC and PSA and significantly homogeneous ($p>\alpha=0.05$), for FC, FS, SRA and STA (Table 2).

Total aerobic mesophilic flora

The results showed that the average annual TAMF levels at 22 °C, at the different stations of Dayet Er Roumi waters, are high compared to those of TAMF at 37 °C (Table 3). This finding implies that bacterial contamination of human or animal intestinal origin is more important than environmental or other sources of pollution.

Spatially, Levene's homogeneity of variance test ($p> 0.05$), ANOVA, and Tukey's post-hoc test stipulate that the variability in TAMF content at 22 °C and 37 °C is statistically insignificant, expressing that the water resources are homogeneous.

As for the temporal analysis, the variability of TAMF levels at 22 °C and TAMF at 37 °C was statistically significant at $p<0.05$. The Tukey's post-hoc test for multiple comparison, was able to shade the wet season (winter and spring) and dry season (summer and autumn) having a significant difference. Moreover, Figure 2 perfectly illustrates that the values recorded in dry season are significantly higher than those in wet season. This could be explained by the increase in temperature, the decrease in the amount of water received by the Dayat and the intensity of human and animal activity in the dry season.

The values recorded at the level of the study area are more significant than those recorded at the level of the waters of the Hassan Addakhil dam of Errachidia [Ouhmidou, 2015] and corroborate those reported by Khayri for the waters of the same study area [Khayri, 2015].

Total coliforms (TC)

The results showed that the total coliform contents vary between a maximum of 62 005 CFU/100 ml recorded at station ST2 in the month of May and a minimum of 15 CFU/100 ml recorded at station ST3 (0 m) in the month of March (Figure 3 and Table 4).

Spatially, Levene's homogeneity of variance test ($p> 0.05$), ANOVA and Tukey's post-hoc test explain that the variability of the total coliform content is statistically insignificant, which expresses that the water resources are homogeneous.

Table 3. Variation of TAMF 37 °C and TAMF 22 °C of the waters of the lake Dayet Er Roumi during the period from October 2020 to September 2021

Station	TAMF 22 (CFU/1 ml) (A)			TAMF 37 (CFU/1 ml) (B)			Amean / Bmean
	Max	Min	Mean±SD	Max	Min	Mean±SD	
ST1	134.10^3	220	12 615±38 303	7.10^3	28	2 413±2 401	5.23
ST2	282.10^3	228	29 640±80 368	31.10^3	33	4 448±8 659	6.66
ST3 (0 m)	260.10^3	50	27 941±74 875	25.10^3	6	3 532±7 110	7.91
ST3 (6 m)	346.10^3	170	33 772±99 023	72.10^3	8	7 343±20 511	4.60

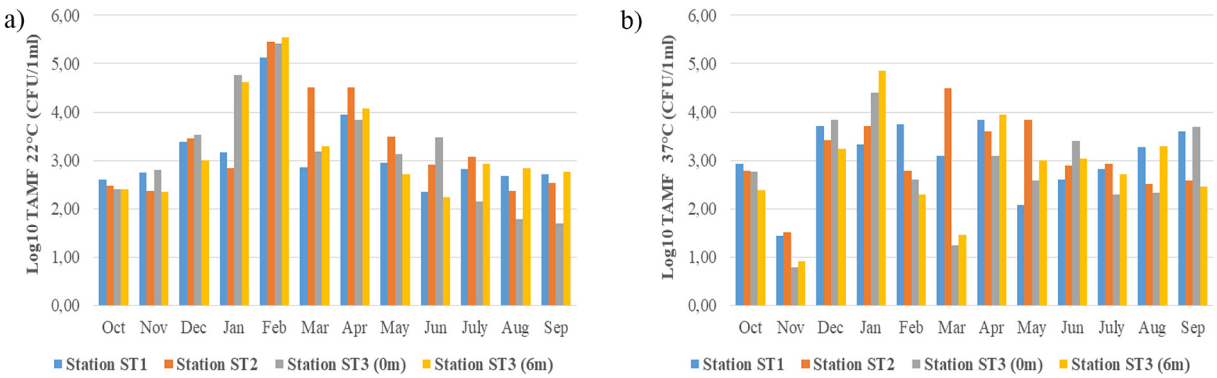

Figure 2. Spatial and temporal variation of TAMF at 22 °C (A) and TAMF at 37 °C (B) of Dayet Er Roumi lake waters during the period from October 2020 to September 2021

Table 4. Variation of total coliforms in Dayet Er Roumi lake water during the period from October 2020 to September 2021

Index (CFU/100ml)	Stations			
	ST1	ST2	ST3 (0 m)	ST3 (6 m)
Max	25 420	62 005	26 660	26 535
Min	995	1 020	15	45
Mean	10 240.08	15 474.17	10 281.58	8 922.92
Standard deviation	8 118.20	17 389.78	9 561.18	9 063.67

As for the temporal analysis, the variability of the total coliform content is statistically insignificant at $p>0.05$, which means that there is no significant difference between the water contamination.

Compared to the Moroccan quality standards for surface water that could be used for drinking water production, the overall quality of Dayet Er Roumi water is average to poor [Water quality standards, 2002ab].

Fecal coliforms (FC)

According to the obtained results, it can be said that the distribution of fecal coliforms is almost uniform throughout the year with a maximum of 4350 CFU/100 ml recorded at station ST1 in the month of April and a minimum of 0 CFU/100 ml recorded at station ST3 (6 m) in the month of January (Figure 4 and Table 5).

Spatially and temporally, the variability of total coliform levels is statistically insignificant at $p>0.05$ which expresses that the water resources are homogeneous.

Fecal Streptococci (FS)

The distribution of fecal Streptococci is almost irregular throughout the year with a maximum of

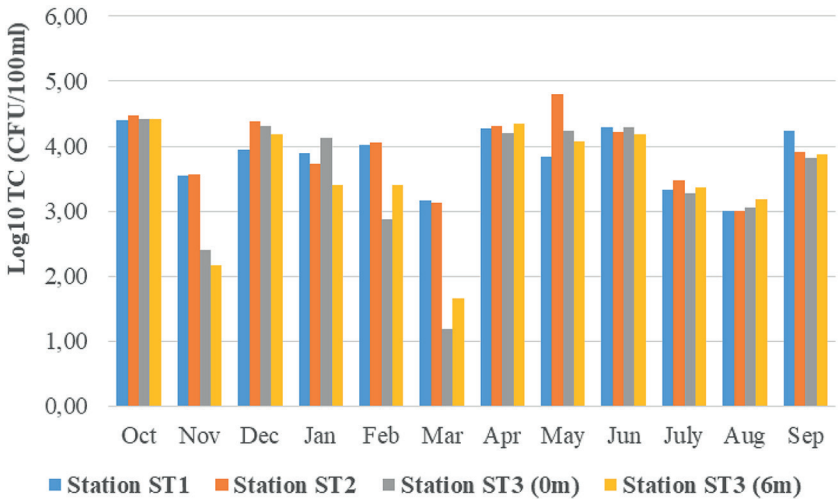

Figure 3. Spatial and temporal variation of total coliforms in Dayet Er Roumi lake during the period from October 2020 to September 2021

Table 5. Variation of fecal coliforms in the waters of Lake Dayet Er Roumi during the period from October 2020 to September 2021

Index (CFU/100 ml)	Station			
	ST1	ST2	ST3 (0 m)	ST3 (6 m)
Max	4 350	3 510	2 553	3 576
Min	1	14	2	0
Mean	449.75	770.50	509.00	699.75
Standard deviation	1 231.58	1 256.59	844.48	1 265.11

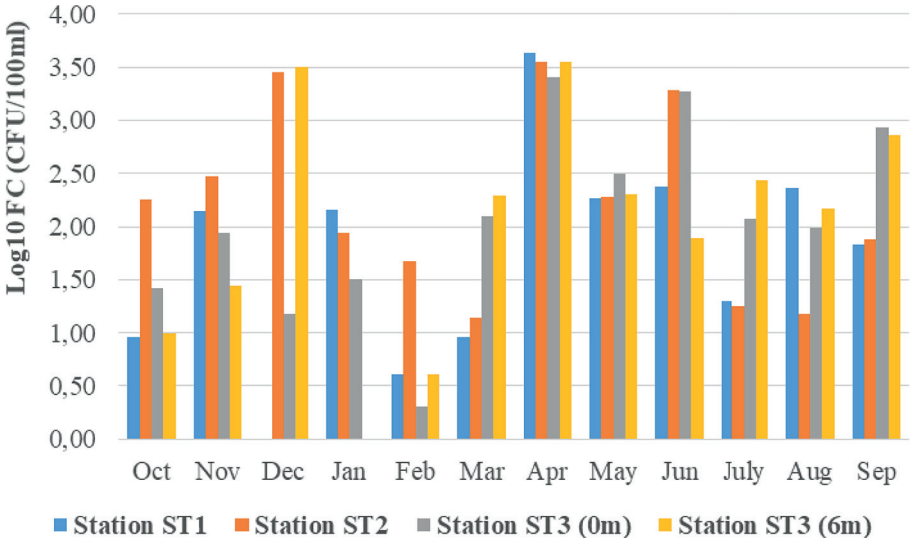

Figure 4. Spatial and temporal variation of faecal coliforms in the waters of Lake Dayet Er Roumi during the period from October 2020 to September 2021

16 350 CFU/100 ml recorded at station ST2 in October and a minimum of 0 CFU/100 ml recorded at all stations ST1, ST2, ST3 (0 m) and ST3 (6 m), respectively during the months of August, February/June, November/February and October/November (Figure 5 and Table 6).

Spatially and temporally, the variability of fecal Streptococcus levels is statistically insignificant at $p>0.05$ which expresses that the waters of Dayet Er Roumi are subject to contamination of fecal origin throughout the year, including intense human activity (swimming and tourism)

Table 6. Variation of fecal Streptococci in the waters of Lake Dayet Er Roumi during the period from October 2020 to September 2021

Index (CFU/100ml)	Station			
	ST1	ST2	ST3 (0m)	ST3 (6m)
Max	2 168	16 350	3 580	2 500
Min	0	0	0	0
Mean	373.75	1 874.08	908.83	499.50
Standard deviation	755.66	4 769.37	1 118.52	750.73

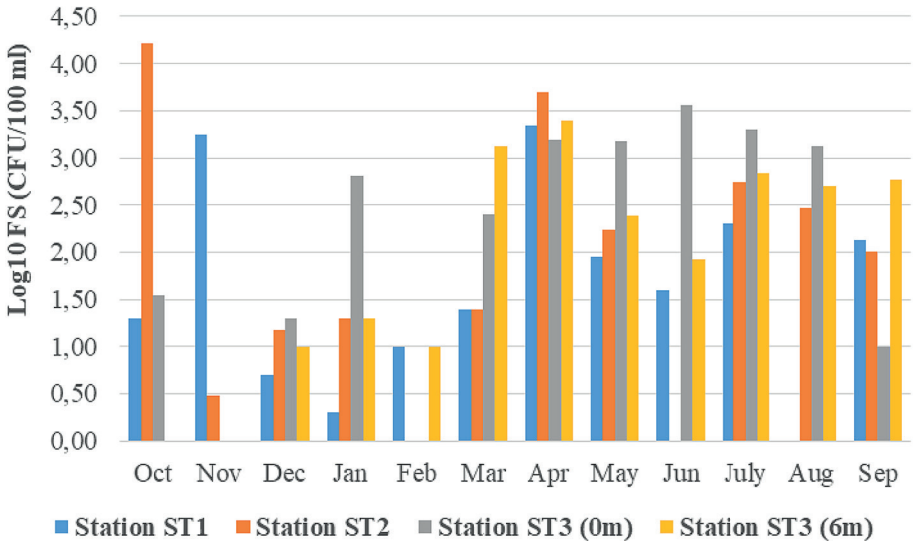

Figure 5. Spatial and temporal variation of fecal Streptococci in the waters of Lake Dayet Er Roumi during the period from October 2020 to September 2021

and animal excrement (grazing and migration of birds). These results obtained may indicate, by their presence, the existence of dangerous pathogens [Cabane, 2007], also viruses [Bitton, 2005a].

According to the Moroccan Water Quality Standard [Water quality standards, 2002ab], the quantity of FS exceeds 10 000 CFU/100 ml, it varies between 0 and 16 350 CFU/100 ml which gives it a very poor quality.

Sulphite-reducing anaerobes (SRA)

Sulphite-reducing anaerobes can survive longer in water than other indicator organisms of fecal pollution (coliforms and streptococci) [Regnault, 1990; Aulicino et al., 2005; Rodier et al., 2009]. Therefore, they are considered as indicators of past fecal contamination [AFNOR, 1986].

Temporally (Figure 6), the average content of Sulphite-reducing anaerobes ranged from 1 CFU/20 ml, recorded at station ST3 (0 m) during the month of November, to $13 \cdot 10^3$ CFU/20 ml, recorded at station ST3 (6 m), during the month of April. The increase of clostridium with depth, is in perfect agreement with its anaerobic life style.

According to the spatial plan, the results of bacteriological analysis show that the variability of the annual average content of SRA is not significant (Table 7).

Staphylocoque aurueus (STA)

The temporal evolution of *Staphylococcus aureus* is approximately regular during all months. In addition, Levene's homogeneity of variance test ($p<0.05$) states that the variability of STA content in Dayet Er Roumi water is statistically significant. In a second round, Turkey's post-hoc test does not indicate any significant correlation of the variability of the STA content of the waters according to the seasons.

Indeed, the average STA content oscillates between 871 CFU/100 ml, recorded at station ST1, and 2 428 CFU/100 ml, recorded at station ST3 (0 m), with a maximum content of 22680 CFU/100 ml recorded in June (Figure 7).

According to the spatial plan, the results of bacteriological analysis show that the variability

Table 7. Variation of sulphite-reducing anaerobes in Dayet Er Roumi lake waters during the period from October 2020 to September 2021

Index (CFU/20 ml)	Station			
	ST1	ST2	ST3 (0 m)	ST3 (6 m)
Max	520	490	950	13 000
Min	8	15	1	2
Mean	142.83	158.75	167.17	1 180.17
Standard deviation	179.34	177.27	275.63	3 723.77

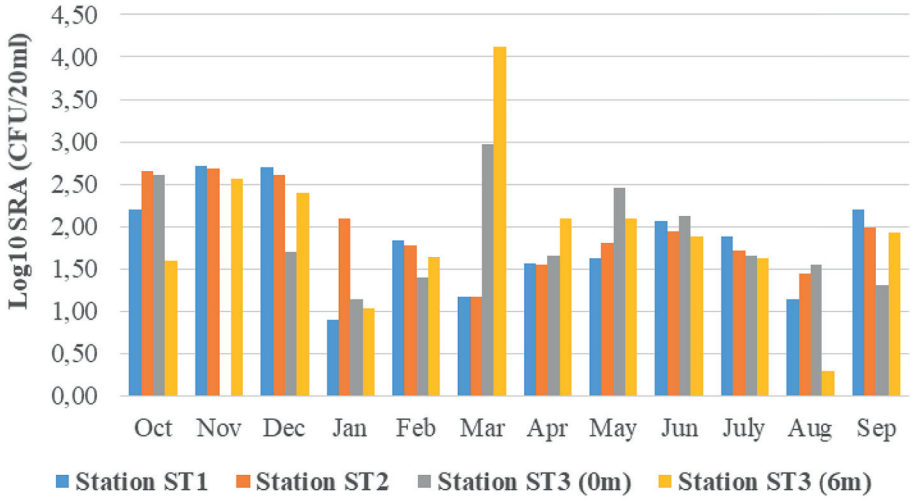

Figure 6. Spatial and temporal variation of Sulphite-reducing anaerobes in Dayet Er Roumi lake waters during the period from October 2020 to September 2021

Table 8. Variation of *Staphylococcus aureus* in the waters of Lake Dayet Er Roumi during the period from October 2020 to September 2021

Index (CFU/100 ml)	Station			
	ST1	ST2	ST3 (0 m)	ST3 (6 m)
Max	1 710	7 380	22 680	5 010
Min	155	165	130	38
Mean	871.42	1 397.92	2 428.17	1 292.83
Standard deviation	513.28	1 955.72	6 387.71	1 742.01

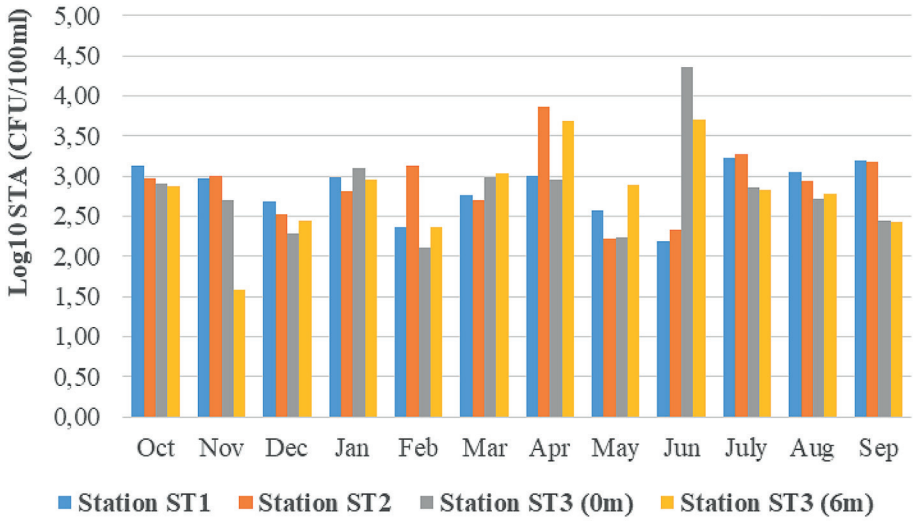

Figure 7. Spatiotemporal variation of *Staphylococcus aureus* in the waters of Lake Dayet Er Roumi during the period from October 2020 to September 2021

of the annual average STA content is not significant (Table 8).

Pseudomonas aeruginosa (PSA)

Pseudomonas aeruginosa (PSA) is one of a large group of free-living bacteria that are ubiquitous in the environment mainly in wastewater, surface water, water intended for human consumption (public distribution system water and packaged water), recreational water, inadequately treated whirlpool and spa water, or distilled water [Mena and Gerba, 2009]. It is an indicator bacterium for water pollution.

Levene's test of homogeneity of variance ($p<0.05$) states that the variability of PSA content in Dayet Er Roumi water is statistically significant. Indeed, the average content of PSA oscillates between 14 321 CFU/100 ml, recorded at station ST3 (6 m), and 16 091 CFU/100 ml, recorded at station ST2, with a maximum content of 33 600 CFU/100 ml recorded in October (Figure 8).

According to the spatial plan, the results of bacteriological analysis show that the variability of the annual average content of PSA is not significant (Table 9).

Table 9. Variation of *Pseudomonas aeruginosa* in Dayet Er Roumi lake waters during the period from October 2020 to September 2021

Index (CFU/100 ml)	Station			
	ST1	ST2	ST3 (0 m)	ST3 (6 m)
Max	32 123	29 760	30 521	33 600
Min	2 050	3 725	308	160
Mean	14 351.92	16 091.25	15 328.00	14 321.67
Standard deviation	9 406.80	7 817.55	9 345.36	9 469.42

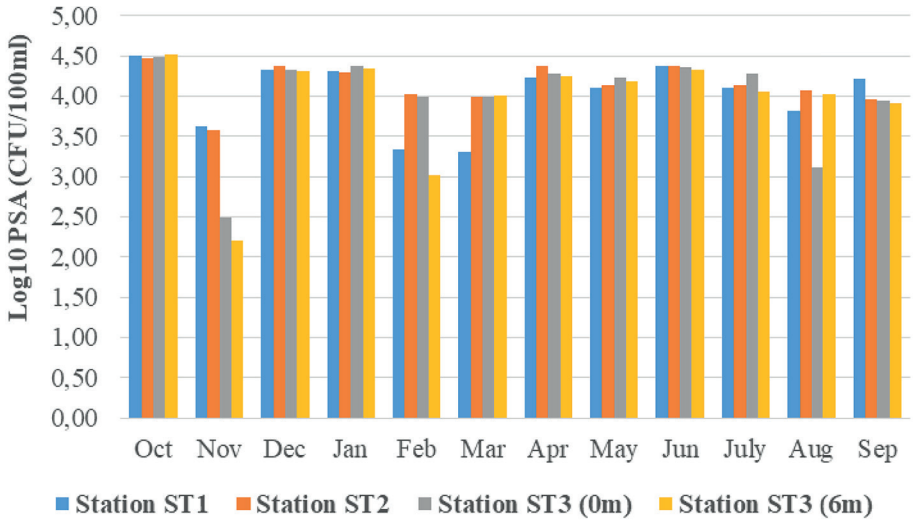

Figure 8. Spatial and temporal variation of *Pseudomonas aeruginosa* in Dayet Er Roumi lake waters during the period from October 2020 to September 2021

Multidimensional and typological analysis

The multidimensional analysis of the data matrix of the bacteriological parameters thus measured made it possible to visualise the spatiotemporal covariation, to know the global links between the various parameters and to establish a spatio-temporal typological structure (or structures).

Correlation matrix

Examination of the multiple correlation matrix for all stations (Table 10) illustrates that (i) TAMF 22 correlates with TAMF 37 (ii) TC correlates with TAMF 37 and PSA (iii) FC correlates with FS and STA (iv) SRA correlates poorly with all bacteriological parameters.

Table 10. Multiple correlation of bacteriological parameters for all stations

Bacteriological parameters	TAMF 22	TAMF 37	TC	FC	FS	SRA	STA	PSA
TAMF 22	1							
TAMF 37	.380**	1						
TC	.056	.557**	1					
FC	-.223	-.028	.246	1				
FS	-.092	.089	.110	.390**	1			
SRA	-.151	-.296*	-.035	.145	.212	1		
STA	.021	.204	.151	.227	.446**	.010	1	
PSA	.013	.540**	.567**	.205	.290*	.172	.380**	1

Note: **. The correlation is significant at the 0.01 level (bilateral); *. The correlation is significant at the 0.05 level (bilateral).

Table 11. KMO index and Bartlett's test of the matrix of bacteriological parameters

KMO and Bartlett's test		
Kaiser-Meyer-Olkin measure of sampling adequacy		.595
Bartlett's test of sphericity	Approx.Chi-square	93.729
	Df	28
	Bartlett's signification	.000

KMO index and Bartlett's test

Table 11 expresses the value of the KMO index, which makes it possible to evaluate the ratio of correlations between the parameters on the one hand, and partial correlations on the other. It thus reflects the uniqueness of the contribution of each parameter. In the case of the selected iteration, data matrix (8 parameters × 48 individuals), the value of the KMO index is good (Table 11).

As for Bartlett's test of sphericity, it tests the null hypothesis that all correlations are equal to zero. For the test to be sensitive, its value must be less than 0.05, thus allowing the null hypothesis to be rejected. In the considered case, the test is very significant (Table 11).

Principal component analysis

The principal component analysis of the bacteriological results of the eight parameters observed in the waters of Dayet Er Roumi has highlighted two factorial axes with the initial eigenvalue >1 that can explain 53.92 of the total variance of the parameters studied (Table 12).

Table 12. Total explained variance of bacteriological results of Dayet Er Roumi lake waters

Component	Initial eigen values			Extraction sums of squared loadings		
	Total	% of variance	% cumulative	Total	% of variance	% cumulative
1	2.521	31.514	31.514	2.521	31.514	31.514
2	1.792	22.405	53.919	1.792	22.405	53.919
3	1.004	12.555				
4	.907	11.343				
5	.698	8.730				
6	.494	6.174				
7	.347	4.342				
8	.235	2.936				

Table 13. Correlation matrix of the PCA without rotation of the bacteriological parameters of Dayet Er Roumi lake waters

Component	PSA	TC	TAMF 37	STA	FS	TAMF 22	SRA	FC
PC1	0.828	0.728	0.681	0.594	0.536	0.111	0.053	0.431
PC2	-0.027	-0.234	-0.61	0.224	0.517	-0.63	0.594	0.546

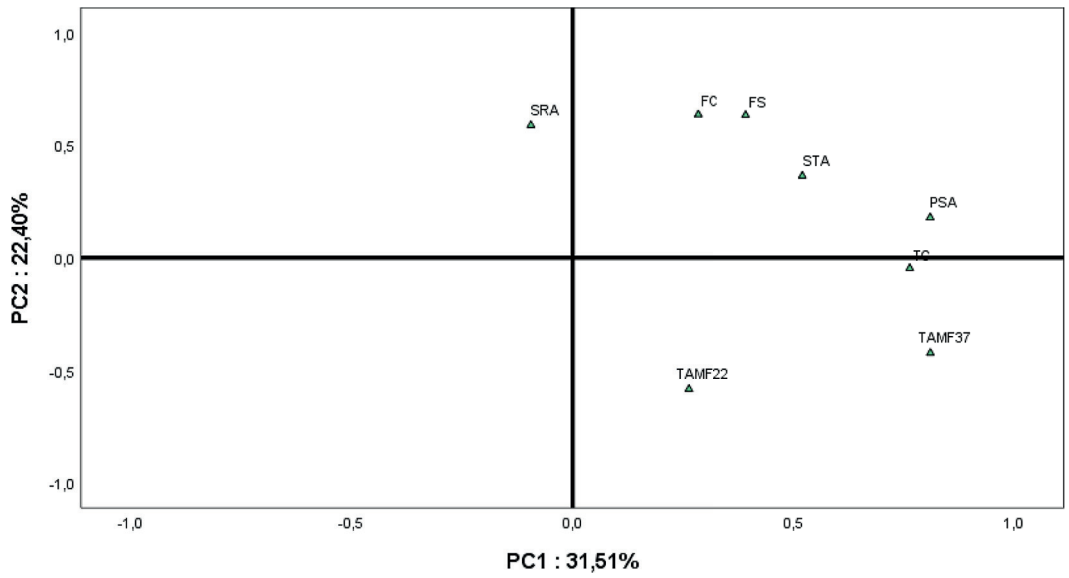

Figure 9. Graphical representation of the bacteriological parameters of Dayet Er Roumi lake water in relation to the factorial axes

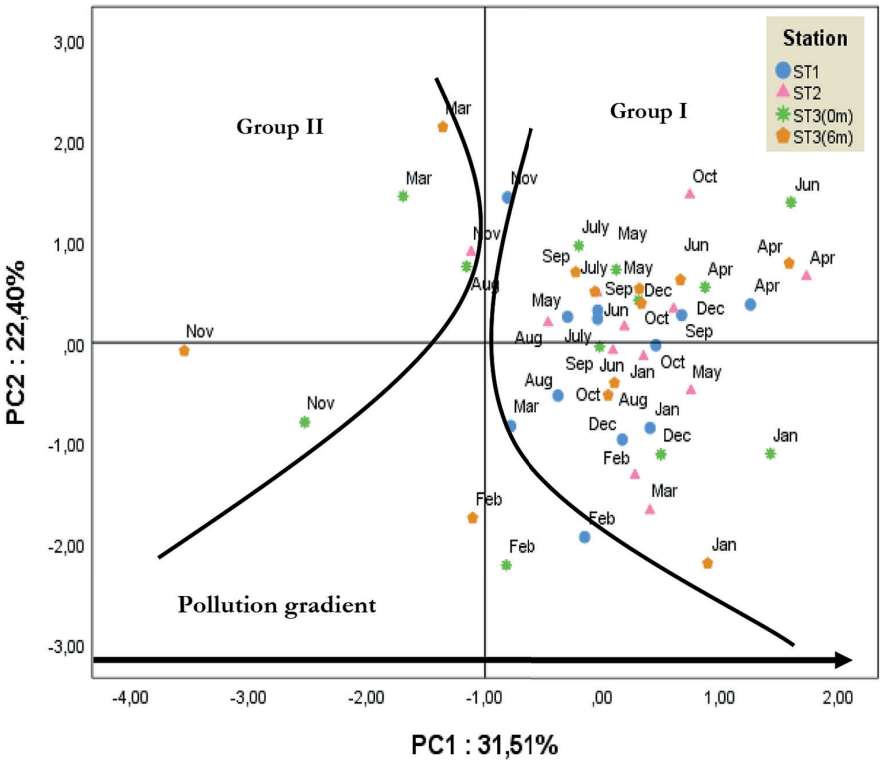

Figure 10. Spatio-temporal graphical representation of individuals (observations) in relation to the factorial axes

The PCA matrix without rotation was able to show that 31.51% of the total variance is explained by the PC1 factorial axis and 22.40% is explained by the PC2 factorial axis with an absolute value inertia >0.3 (Hair et al., 2014). Thus, PSA, TC, TAMF 37, STA, and FS are positively correlated with the PC1 factor axis, TAMF 22 is negatively correlated with the PC2 factor axis, and SRA and FC are positively correlated with the PC2 factor axis (Figure 9 and Table 13).

The analysis of the dispersion of the parameters and individuals (observation) represented by the two-dimensional PCA made it possible to distinguish two groups (Figure 10):

Group I – consisting mainly of stations ST1 and ST2 (positively correlated with the factorial axis PC1). This component shows variables that are mostly dependent on anthropic activity, especially human [Elhatip et al,. 2008; Liu et al,. 2003; Omo-Irabor et al,. 2008], and testifies to a recent fecal contamination [Cabane, 2007].

Group II – indicates that bacteriological contamination is very low during the winter period at all sampling stations, particularly at stations ST3(0 m) and ST3(6 m). The decrease of the bacterial load is favoured mainly by the absence of anthropic activity in winter.

CONCLUSIONS

The examination and the qualitative and quantitative follow-up of the bacteriological parameters allowed confirming that the waters of Dayet Er Roumi are subjected to a strong pressure generated by the discharges of domestic waters of the neighbouring agglomerations and also of the activities of natural, agricultural and tourist origin.

Indeed, the correlation matrix of the studied variables showed: (i) a correlation between PSA, CT, FMAT 37, STA and SF. This correlation is one of the essential characteristics of eutrophic environments characterised by the abundance of nutrients [CEAEQ, 2000]. (ii) Stations ST1 and ST2 have the same bacteriological characteristics, and they are experiencing a recent contamination of fecal origin due to the marked presence of total germs, total coliforms and fecal coliforms [Cabane, 2007].

In addition, the microbiological content of Dayet Er Roumi waters is higher than the Moroccan Water Quality Standard [Water quality standards, 2002ab], and that the decrease of the bacterial load is mainly favored by the absence of anthropic activity in winter.

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