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Evaluation of the quality of swimming water in the Gulf of Skikda (Algeria)

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Abstract

The aim of this study is to evaluate the bacteriological and physicochemical quality of the swimming waters of the Skikda region, a very touristic area known for its many beaches which are frequented during the summer period, through the water analysis of ten stations. Because the destination "sea" is far ahead of all the others (mountain, desert, museum, etc) in Algeria, where during the summer season, swimming is the most practiced recreational activity; the quality of swimming water is therefore an essential factor for the tourist development of coastal communities. This monitoring program focused on monitoring water quality during two summer seasons. The analyses concern the quantification of fecal contamination bacteria (total and thermo tolerant coliforms, *E. coli* and fecal streptococci), as well as the determination of certain physico-chemical parameters (electrical conductivity, pH, salinity, etc.). In view of the results, we can suppose the existence of a pollution having various origins at the levels of the different sites studied. In fact, for 9 out of 10 sites, we have average fecal streptococcal levels well above current standards (less than 100 FS/100 ml).

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Introduction

Water is a factor in the spread of many pathogenic and non-pathogenic micro-organisms, monitoring and control of the microbiological quality of swimming waters is an essential element in the preservation of public health; Although its importance may seem less important than that of feedwater; But also an important element of tourism development.

Euripides said "the sea cures all the evils of mortals"; However, strong urbanization, tourism and the democratization of aquatic activities have resulted in an increase in the number of visitors to the Mediterranean coast and thus a deterioration in the quality of coastal waters.

This study concerns the monitoring of the bacteriological and physicochemical quality of the swimming waters of the Gulf of Skikda through the analysis of the waters of a ten stations.

Materials and methods

Study area

The wilaya of Skikda is located in the north-east of Algeria bordering the Mediterranean Sea and has a coastaline of over 140 km long.

Our study area includes two municipalities and extends about twenty kilometers, it includes, to the east, the beaches of Filfila and Ben M'hidi about 15 km and to the West, a road of approximately 3 Km from beaches (Fig. 1).

Fig. 1. Location of the study area and sampling sites, Gulf of Skikda, Algeria.

In addition, the Gulf of Skikda is a point of discharge for many wadis : the main is wadi Safsaf which flows into the center of the gulf but there are also two secondary wadis at Filfila.

Sample Collection

Sampling, transport and analysis of seawater samples were carried out according with the guidelines for the monitoring of the quality of swimming waters.

This monitoring program was conducted during two summer seasons (April 2015-September 2016). The collected data were measured in each sample of seawater taken per month and per site.

The Experiments

The Analysis include quantification of fecal-indicator bacteria (total and the rmotolerant coliforms, *E. coli* and fecal streptococci) using the method of the enumeration in liquid medium by determining the most probable number (MPN); As well as on the determination of certain physico-chemical parameters (Electrical conductivity, pH, etc.).

The health status of swimming water is assessed based on the results obtained and compared with the threshold values for the quality of the bacteriological and physico-chemical criteria presented in Executive Decree No. 93-164. Moreover, in order to compare the averages of the different physicochemical parameters measured between the ten sites, we used the test of the analysis of variance in a criterion of classification (ANOVA), fixed pattern.

Results and discussion

Physicochemical parameters

As regards the average results recorded for the various physicochemical parameters, we find that these are in adequacy with the quality standards required for swimming waters by the standards in force (Table 1).

Table 1. Average results of physico-chemical parameters measured.

parameters / Site	T (°C)	pH	Salinity	Conductivity (mS/cm)
Site 1 «la jetée »	23,108	7,971	36,161	55,915
Site 2 «château-vert »	22,931	7,966	36,708	56,061
Site 3 «paradis »	23,269	8,086	36,731	55,985
Site 4 «bikini»	23,069	8,052	36,638	56,277
Site 5 «molo»	22,923	8,077	37,1	56,269
Site 6 «poste 2 »	23,446	8,117	36,592	56,008
Site 7 «poste 3 »	23,615	8,094	36,592	55,823
Site 8 «poste 5 »	23,561	8,108	36,608	55,869
Site 9 «poste 6 »	23,461	8,088	36,631	56,015
Site 10 «poste 7 »	23,538	8,079	36,661	55,785

Table 2. Results of the analysis of variance (ANOVA) of fixed patterns in comparisons between the sites; for each variables, average values were considered. Abbreviations: ddl = degrees of freedom; SCE = sum of squared deviations; CM = mean square; Fobs = F value Fischer.

Variables	Sources of variation	Ddl	SCE	CM	F_{obs}
T (°C)	Sites	9	8,345	0,927	0,1056 ns
pH	Sites	9	0,33	0,04	0,354 ns
S (‰)	Sites	9	5,973	0,664	0,886 ns
Conductivity (mS/cm)	Sites	9	3,32	0,369	0,885 ns
CT (/100ml)	Sites	9	$1,504.10^8$	$1,67.10^7$	1,814 ns
CF (/100ml)	Sites	9	$2,197.10^7$	$2,44.10^6$	0,72 ns
E.C (/100ml)	Sites	9	$2,2.10^7$	$2,44.10^6$	0,76 ns
SF (/100ml)	Sites	9	$7,56.10^7$	$8,4.10^6$	1,424 ns

Bacteriological analyses

The temporal variation of the concentrations of the different germs indicates that they fluctuate in the same way, showing their predominance during the months of August 2015 and September 2016 for total and thermotolerants coliforms; and during July 2015 and September 2016 for *E. coli* and fecal streptococci (Fig. 2).

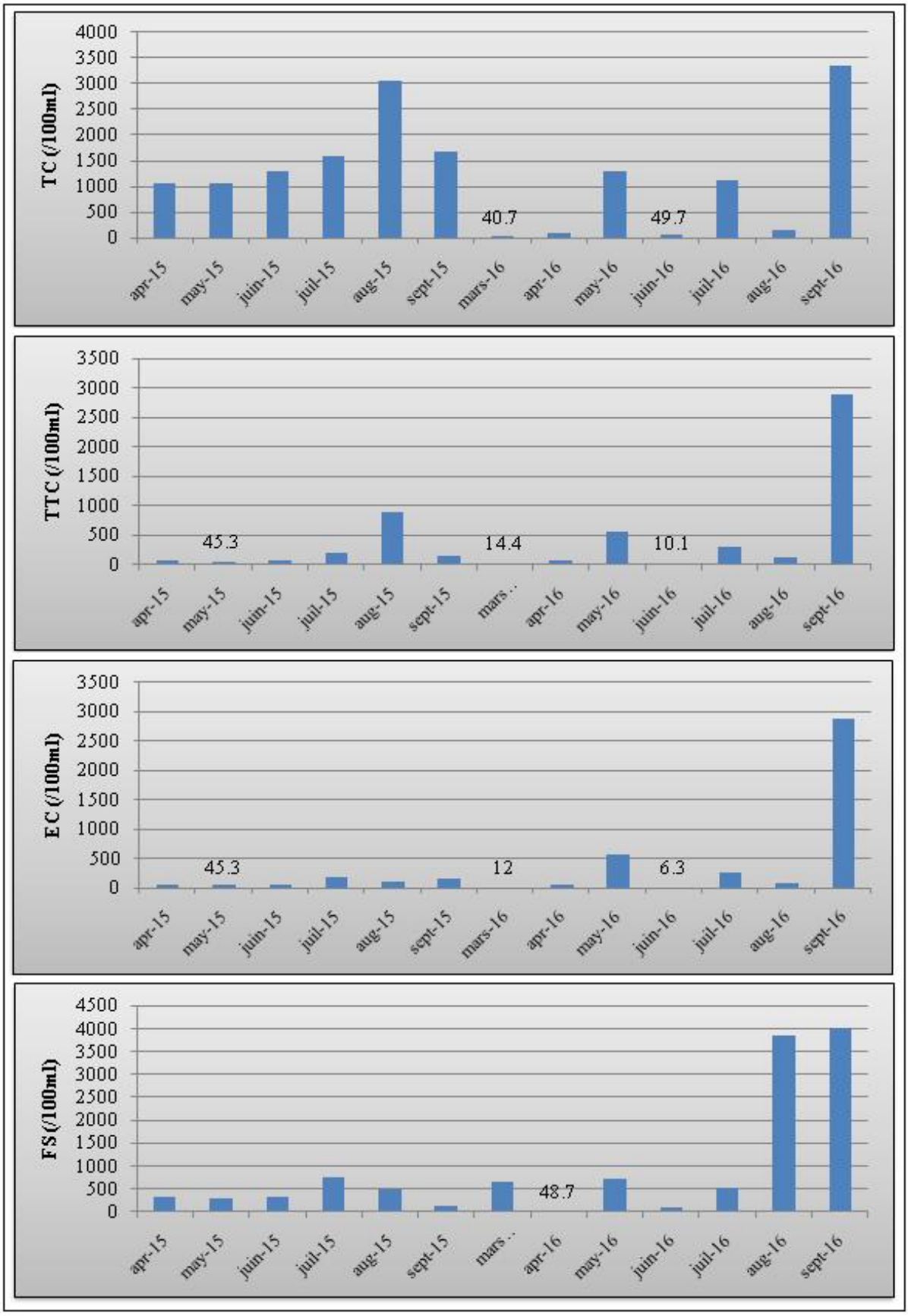

Fig. 2. Temporal variation of germs recorded during the study period.

TC: total coliforms; TTC: thermotolerant coliforms; EC: *E. coli*; FS: fecal streptococci.

This may be justified by the frequentation rates of beaches that were low due to fasting (Ramadan); as well as the climatic conditions recorded during the month of September, which have resulted in an increase in beach frequencies and the discharge of rainwater directly into the sea without treatment, high flows from urban wastewater and wadis, agitation of water etc. (Mazières, 1963).

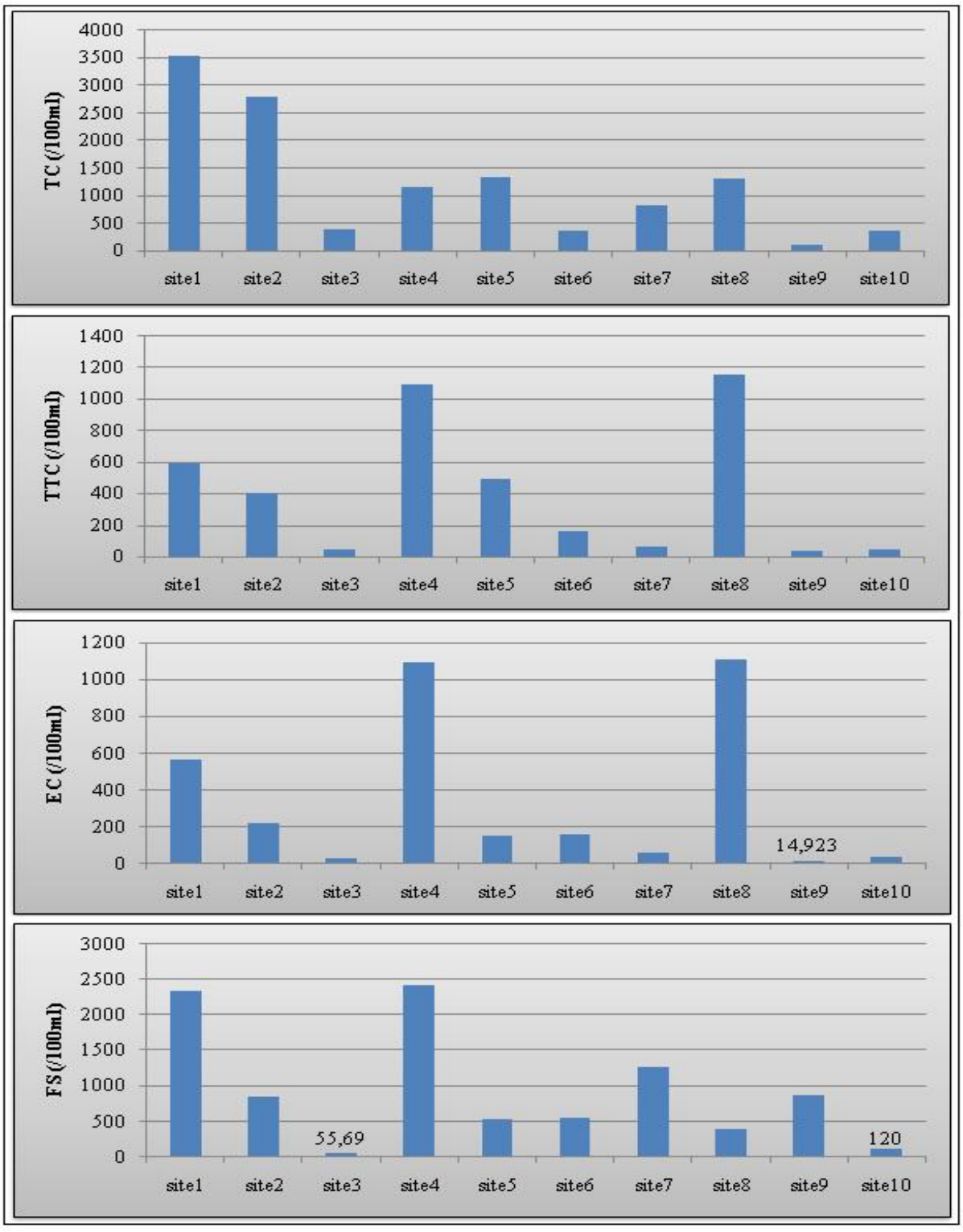

Fig. 3. Spatial variation of germs recorded during the study period.

TC: total coliforms; TTC: thermotolerant coliforms; EC: *E. coli*; FS: fecal streptococci.

Moreover, this fluctuation can be justified by several phenomena. Indeed, the fate of enteric bacteria in seawater is conditioned by a number of parameters specific to the environment, as physical factors (temperature, absorption/adsorption, dispersion, dilution, sedimentation, light (bactericidal radiation at shallow depths only)) (Carlucci and Pramer, 1959; Brisou, 1968; UNEP / WHO, 1983; Pommepuy *et al.*, 1991, Gourmelon, 1995); or chemical factors (salinity (selection factor), dietary deficiencies in vitamins, fasting, dissolved oxygen, etc) (Carlucci and Pramer, 1959; Brisou, 1968); and biological factors (microphagic plankton or adsorbent, benthos and nekton (macrophage-plankon), vital competition, bacteriophages, etc). (Brisou, 1968) and Oger *et al.*, 1983, Gourmelon, 1995).

All of these factors act together; either simultaneously or in successive steps in time and space, in order to reduce the number of bacteria or even eliminate them.

The spatial variation of the concentrations of the different germs sought allows us to observe that, overall, the average results in total coliforms and thermotolerants recorded are in adequacy with the quality standards required for swimming waters. However, analysis of total coliforms only allows to assess the quality of water only moderately; it is only indicative because of the great heterogeneity of species grouped under this term, some are of fecal origin and may reflect fecal pollution of water, but others are naturally found in soil or vegetation. (Rodier, 2005); Nowadays, only the detection of thermotolerant coliforms and specifically *E. coli* and intestinal enterococci in water must seriously let suspect fecal contamination, since these are considered as the most reliable indicators of enteropathogenic agents, and therefore the best way to detect recent fecal contamination for E. coli and old for intestinal enterococci. (Payment and Hartemann, 1998; Scientific Panel on Water, 2003).

For the 4th and 8th sites (beaches "bikini" and "poste 5"), the recorded rates are higher than the limit values for the average concentrations of *E. coli*; moreover, we can note that the average concentrations of fecal streptococci are all above the norms recommended by the Algerian legislation (except for site 3, "paradis beach") (Fig. 3). The results obtained show an old fecal contamination of the water, and therefore a poor bacteriological quality.

ANOVA variance

The results of the analysis of the univariate ANOVA variance for the four measured physico-chemical variables allow us to note the absence of significant differences between the waters of the ten sites studied (Table 2). The same is true for bacteriological parameters.

This confirms our previous observations on the equivalence of the swimming waters of the different sites studied.

Conclusion

Thus, in view of the results of physicochemical analyses, the swimming waters of the different sites studied are good given the Algerian standards, the results are not above the normal values for swimming waters. However, when we consider the bacteriological analyses, these waters show results, depending on the months and the sites; although in standards, a relatively high coliform and streptococcal levels; allowing us to suggest the existence of a kind of pollution, of various origins (mainly urban waste, stormwater runoff flowing into the sea without treatments), present at all sites more or less obvious.

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