

Monitoring of Physicochemical and Microbiological Quality of Taghazout Seawater (Southwest of Morocco): Impact of the New Tourist Resort “Taghazout Bay”

Imane Lamine^{1*}, Aicha Ait Alla^{1,2}, Mohamed Bourouache², Abdellatif Moukrim¹

¹ Laboratory Aquatic Systems: Marine and continental ecosystems; Faculty of Sciences, PB 8106, Ibn Zohr University, Agadir, Morocco

² Laboratory of Microbial Biotechnology and Plant Protection, Faculty of Sciences, PB 8106, Ibn Zohr University, Agadir, Morocco

* Corresponding author's e-mail: imane.lamine@edu.uiz.ac.ma

ABSTRACT

The marine environment plays a major socio-economic role in the Agadir region (south-west Morocco). This area, which hosts important fishery resources, is currently not spared from the pollutants produced in the course of agricultural, domestic, industrial and tourist development. The aim of this study is to assess the impact of the Taghazout bay tourist resort on the bacteriological and physicochemical quality of the coastal waters of Taghazout. The seawater samples were collected between March 2016 and March 2018 at three sampling sites (S1, S2 and S3) in order to monitor the concentrations of fecal coliforms (FC), fecal streptococci (FS) and total germs (TG). The results of physicochemical parameters show seasonal fluctuations influenced by climatic factors. The spatio-temporal monitoring of the bacteriological parameters shows that the average total germ count is 127.05 CFU/100 ml, 39.61 CFU/100 ml for fecal coliforms and 15.21 CFU/100 ml for fecal streptococci. The values of FC80, FC95 and FS90 do not exceed the guide values of the Moroccan standards. This classifies the Taghazout beach in category A (good quality of bathing water). The monitoring analysis recorded by the Pearson correlation test between the environmental parameters and the level of fecal bacteria showed that there was a significant positive correlation between the FC concentrations and rainfall; the FS concentrations showed significant positive correlations with all the environmental parameters while the TG concentrations indicate no correlation with them. The fecal contamination parameters should be routinely monitored for improving the environmental conditions of coastal cities. This must be the case for the Taghazout coastline where a regular monitoring program must be established to evaluate the impact of the new tourist resort “Taghazout bay” on the environmental quality of this ecosystem.

Keywords: seawater, fecal coliforms, fecal streptococci, physicochemical quality, Taghazout Bay, Agadir, Morocco.

INTRODUCTION

In the last years, economic development and the growing urbanization have continued to increase environmental pollution. In fact, human activities generally contribute to a consumption of natural resources and a modification in the functioning of ecosystems (Scheffer *et al.*, 2001; Adger *et al.*, 2005; Bennett *et al.*, 2005; Carpenter *et al.*, 2006). The marine environments, and more specifically the coastal ones, are exposed to constant changes of physical, chemical and

bacteriological origin (Alain and Roger, 2004). Thus, the quality of the marine environment is a key public concern. The seawater quality can be affected by fecal contaminations. The bacteriological examination is the most accurate way to detect recent, and potentially dangerous, fecal pollution so as to assess the water quality from a sanitary point of view with a precision, which is not possible by the current chemical analyses (Chahlaoui, 1996).

Several authors highlighted the importance of using microorganisms in the improvement of

water quality as well as their correlation with the environmental factors (Mimouni *et al.* 2002, Noble *et al.*, 2003, Elmanama *et al.* 2005, Bou-Mhandi *et al.* 2007, Ibarluzea *et al.* 2007, Setti *et al.*, 2009, Simeonova *et al.*, 2010). In fact, like all countries, Moroccan coastal regions use their marine environment as a recipient of their domestic and industrial wastewater.

For instance, the Bay of Agadir; the first tourist destination in the country, has not been spared from pollution problems due to various human activities (port complex, sewage water). This environment has been the subject of several studies dealing with various levels of ecosystem organization as well as different biological, chemical and biochemical parameters (Id Halla *et al.*, 1997, Najimi *et al.*, 1997, Moukrim *et al.*, 2000, El Hamidi *et al.*, 2003, Moukrim *et al.*, 2004, Ait alla *et al.*, 2006, Azdi *et al.* 2006, Benomer *et al.* 2006, Mouneyrac *et al.*, 2006, Anajjar *et al.*, 2008, Bergayou, *et al.*, 2009, Agnaou *et al.*, 2014, Nadir *et al.*, 2015).

Currently, the Agadir bay is facing a rapid growth in the number of tourism projects and resorts. Among the region's flagship projects, the new tourist-resort, "Taghazout bay" can be mentioned. This seaside resort is built, 15 km north of the city of Agadir, along the coast of Taghazout, internationally known for its seaside tourism and nautical sports (e.g. surfing, sailing). The "Taghazout Bay" resort extends over an area of 615 ha in front of a coastline of 4.5 km. However, the installation of this station at the Taghazout coasts will likely have an impact on the condition of this coastal ecosystem.

This study aims at assessing the condition of this ecosystem through the monitoring of physicochemical and bacteriological quality of Taghazout seawater. Standardized methods of conventional microbiology were used for the enumeration of fecal indicator bacteria.

MATERIALS AND METHODS:

Study sites:

In order to assess the physicochemical and bacteriological quality in the Taghazout coasts as well as determine the relationship between these parameters, three sampling sites were selected along the Taghazout coast. The choice of these three sampling sites was based on their position

exposed to any contamination that can be caused by the touristic project.

The first site S1 is located south of the Taghazout Bay resort (30.525577, -9.692692) and is located near the tourist-campground (Atlantica Parc Imourane, 14 km from Agadir), the second one S2 is located in front of the tourist-station (30.518996, -9.689528) and the third one S3 in the North of Taghazout Bay resort with two rainwater drainage pipes (30.510092, -9.687156) (Figure 1).

Sampling

The monthly sampling of seawater was carried out at the three sites during the period from March 2016 to March 2018. One liter of seawater was collected at low tide from each site at 9 or 10 a.m. This water was collected at a depth of 50 cm in a sterilized and labelled bottle. The collected samples from the field trips were transported to the laboratory in a cooler at 4–6°C.

Physicochemical analysis

In order to assess the variation of the physicochemical parameters of seawater during the sampling period, the following parameters were measured in situ: temperature, conductivity, salinity and total dissolved solids TDS were measured using the Thermo Scientific Orion Star™ A222, and dissolved oxygen (DO) content by means of the Thermo Scientific Orion 3-Star plus device. For pH, we used the pH meter (HI-9024 Hanna instruments) which can be read to the nearest 1/100th of a unit.

The rainfall values were provided by the Water Department of the Regional Office for Agricultural Development (ORMVA) of Souss Massa, Ministry of Agriculture and Maritime Fisheries, Kingdom of Morocco.

Bacteriological analysis

The bacteriological analysis focused on the enumeration of fecal indicator bacteria (FC and FS) and total germs (TG) using the membrane filter technique on millipore membranes (0.45 µm) (RODIER *et al.*, 1997):

- Total germs (TG) according to the AFNOR Standard NF EN 26461–2 ISO 6461–2 (July 1993).
- Fecal coliforms (FC) as described by AFNOR Standard NFENISO9308–1 (September 2000).

- Fecal streptococci (FS) AFNOR NF ISO 7899–2 standard (August 2000).

The results are expressed in colony-forming units per 100 ml (CFU/100 ml).

Statistical analysis

The relationship between the fecal bacteria and other environmental variables was analyzed using Pearson correlation test. Additionally, analysis of variance (ANOVA) was conducted to compare the changes in the coastal water quality caused by bacterial indicators. A three-way ANOVA test was used to compare fecal bacteria concentrations among months, sampling locations, and years using the Statistica 6.0 software with a significance level of $p < 0.05$.

RESULTS

Physicochemical parameters

The Figure 2 shows temporal variations of seawater physicochemical parameters in the three sites during the study period (March 2016-March 2018).

The temperature presents a seasonal profile similar at the three sites (Figure 2a), the higher values were recorded during August of both years with 24.5°C and 26.6°C, respectively, while the lower values were observed during the February of both 2017 and 2018 (14.9 and 16°C respectively).

The temporal variations in pH of seawater (Figure 2b) shows that the pH values recorded range between 7.04 in winter and 8.17 in summer;

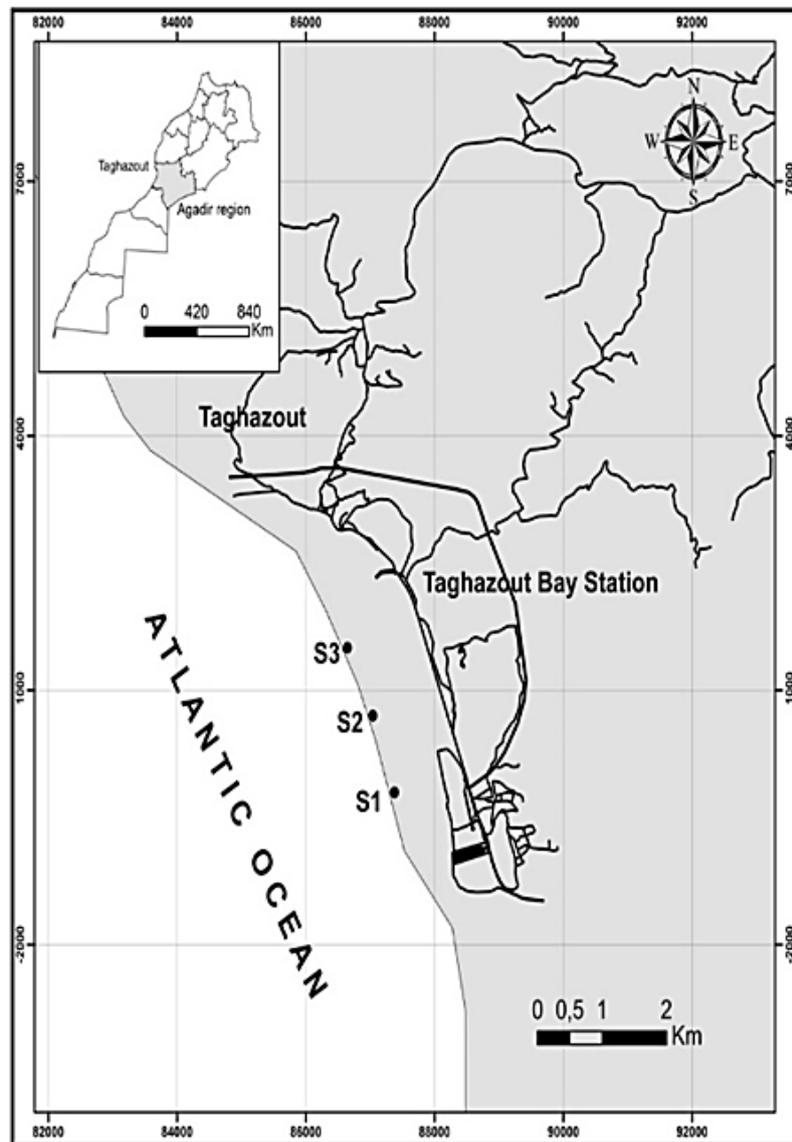


Figure 1. Location of the studied sites

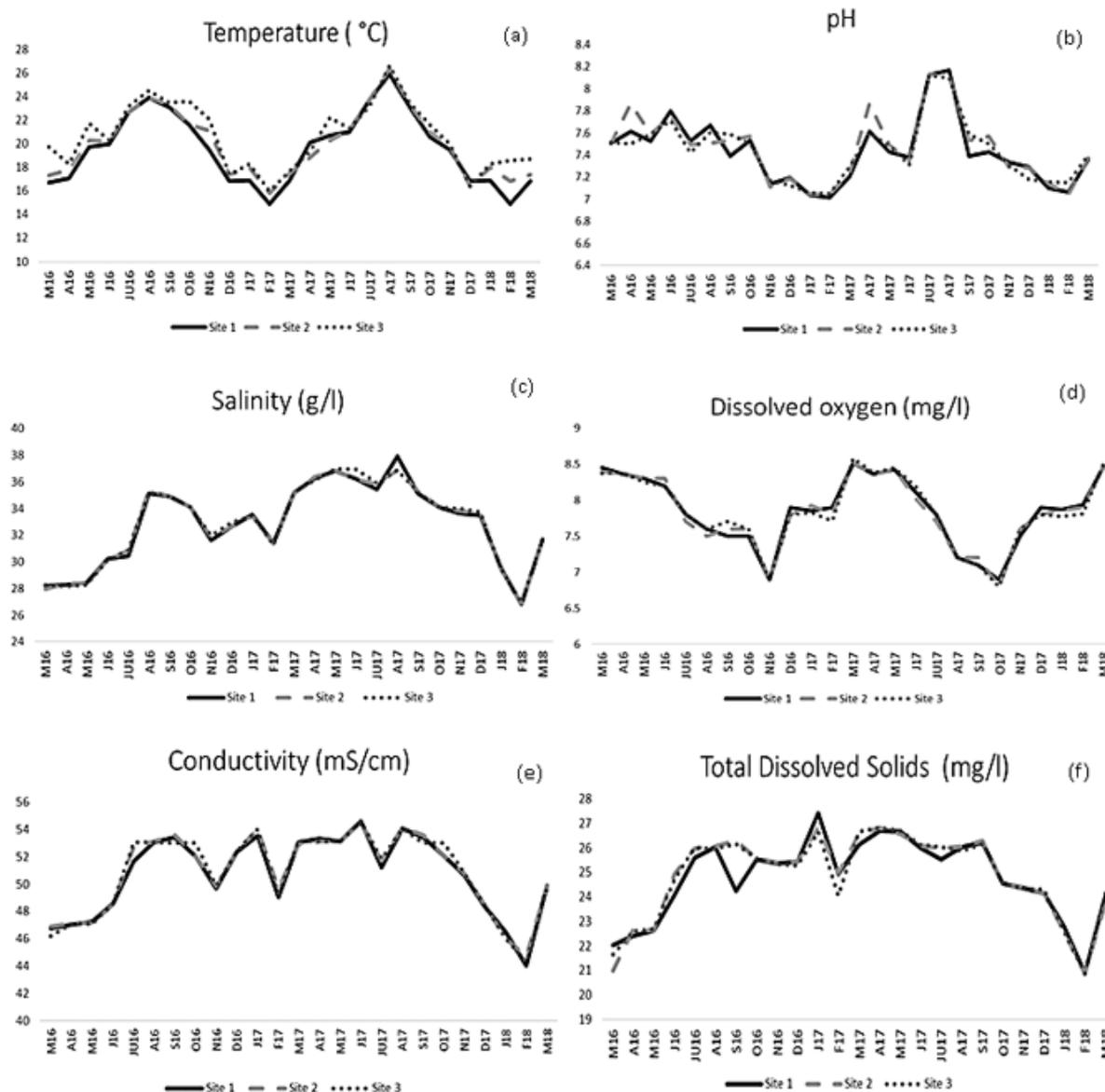


Figure 2. Seasonal evolution of physicochemical parameters during the sampling period

this result fluctuates around the optimal seawater pH (8.2), indicating the buffer effect of the sea. The highest pH values were detected in S3, and the lowest in S1.

Salinity and electrical conductivity of the seawater of Taghazout coasts show a significant temporal variation (Figure 2c, e), the highest values were detected in August 2016 and 2017, and they are 35.2 and 37.9 g/l for the salinity, and 53 and 54 ms/cm for the conductivity, respectively. In turn, the minimum values were recorded in February 2017 (Salinity = 26.9 g/l; conductivity = 44.2 ms/cm).

During the study period, the annual dissolved oxygen cycle showed a minimal value of 6.9 mg/l in November 2016 and 2017, and a maximal value in March (8.3, 8.2 and 8.5 mg/l) (Figure 2d).

The TDS rates recorded show temporal fluctuations at the three sites (Figure 2f), with a maximal value of 27.41 mg/l in January 2017 and a minimal one ranging from 20.8 to 21 mg/l in March 2016 and February 2018, respectively.

The results shown in Figure 3 show that the highest means of precipitations were recorded between November 2016 and February 2017 with the values of 165.7 and 283 mm, respectively.

The variance analyses of physicochemical parameters indicate that there are no significant differences between the sites and the years ($p > 0.05$), except for the salinity that showed a significant difference ($p < 0.05$) between the values recorded in 2016 and 2017.

Bacteriological parameters

The results of bacteriological analysis performed on seawater of Taghazout coast during the period from March 2016 to March 2018 are presented in Figures 4a, 4b and 4c.

Figure 4a shows that the FC concentrations are higher in S1, compared to other sites. The highest concentration was recorded in March 2016 at S1 (232.33 CFU/100 ml), while the lowest concentration was observed in October 2016 at S3 (2.57 CFU/100 ml).

With regard to fecal streptococci concentrations, it can be noted that they are relatively higher at S1 and S2 rather than S3 (Figure 4b). The highest concentration was recorded in February 2017 (80 CFU/100 ml), while the lowest concentration was observed in May 2016 (0.33 CFU/100ml).

The results of total germ count at the three study sites (Figure 4c) show relatively higher values at S3 and S1 compared to S2. The maximum concentration of TG was observed in July 2017 at S3 (300 CFU/100 ml) and the minimum concentration in October 2016 at S2 (25 CFU/100 ml).

The results obtained from the bacteriological analysis revealed seasonal variations in the concentrations of FC, FS and TG; thus, we notice that the highest concentration of FC were observed during the warm season (219 CFU/100 ml) and the cold season (152.67 CFU/100 ml), while high concentrations of TG (300 CFU/100 ml) and FS (80 CFU/100ml) were found in warm and cold season, respectively.

The mean total germ count is 127.05 CFU/100ml, 39.61 CFU/100 ml for fecal coliforms and 15.21 CFU/100 ml for fecal streptococci in the seawater of Taghazout. However, the analysis of variance pertaining to bacteriological parameters shows that the sampling site has no significant effect ($P > 0.05$). However, there is a highly significant difference between months ($P < 0.001$).

Pollution origin

Quantification of fecal contamination flora (Table 1) allowed us to monitor the evolution of the ratio fecal coliforms/fecal streptococci (FC/FS) at the three studied sites. The ratios found are between 2 and 4, indicating a mixed contamination of predominantly anthropogenic origin. This result is probably related to the large number of tourists visiting Taghazout in summer and during the surf season, as well as the use of animals in touristic attractions (camels, horses...), which may constitute a potential source of contamination for this site.

Regarding the seawater taken from the three sites on Taghazout beach, the values of FC80, FC95 and FS90 are provided in Table 2. Compared with the Moroccan standards (NM 03.7.200), they do not exceed the guide values (i.e. FC80 = 100 FC/100 ml, FC 95 = 2000 FC/100 ml and FS90 = 100 FS/100 ml), which allows us to classify this bathing area as category A and consider it of good quality for swimming.

Relationship between environmental and bacteriological parameters of seawater

The correlations between environmental (T° , pH, TDS, SAL, CDT and OD) and bacteriological parameters of seawater (FC, FS and TG) are detailed in Table 3.

The environmental parameters were not significantly correlated with FC and GT concentrations except for the rainfall which has a significant positive correlation with the FC concentrations ($r = -0.2859$, $p = 0.022$). The FS concentrations have significant positive correlations with all the environmental parameters: temperature ($r = 0.4198$, $p = 0.001$), pH ($r = 0.4936$, $p = 0.000$), TDS ($r = 0.4956$, $p = 0.000$), Salinity ($r = 0.4712$, $p = 0.000$), conductivity ($r = 0.4683$, $p = 0.000$), dissolved oxygen ($r = 0.5025$, $p = 0.000$) and rainfall ($r = 0.4621$, $p = 0.000$).

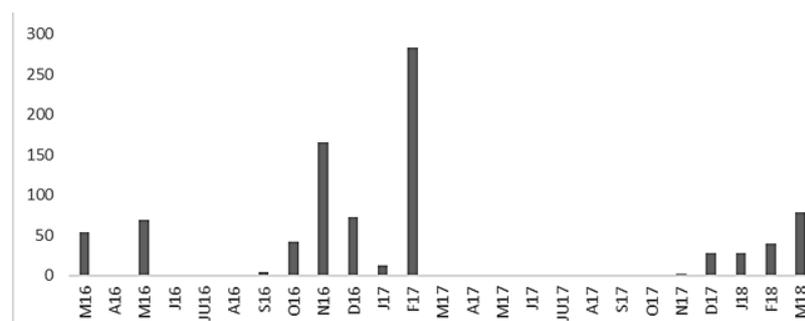


Figure 3. Monthly variations in mean rainfall in the region of Agadir (Rainfall data were obtained from the Hydraulic Basin Agency of AGADIR)

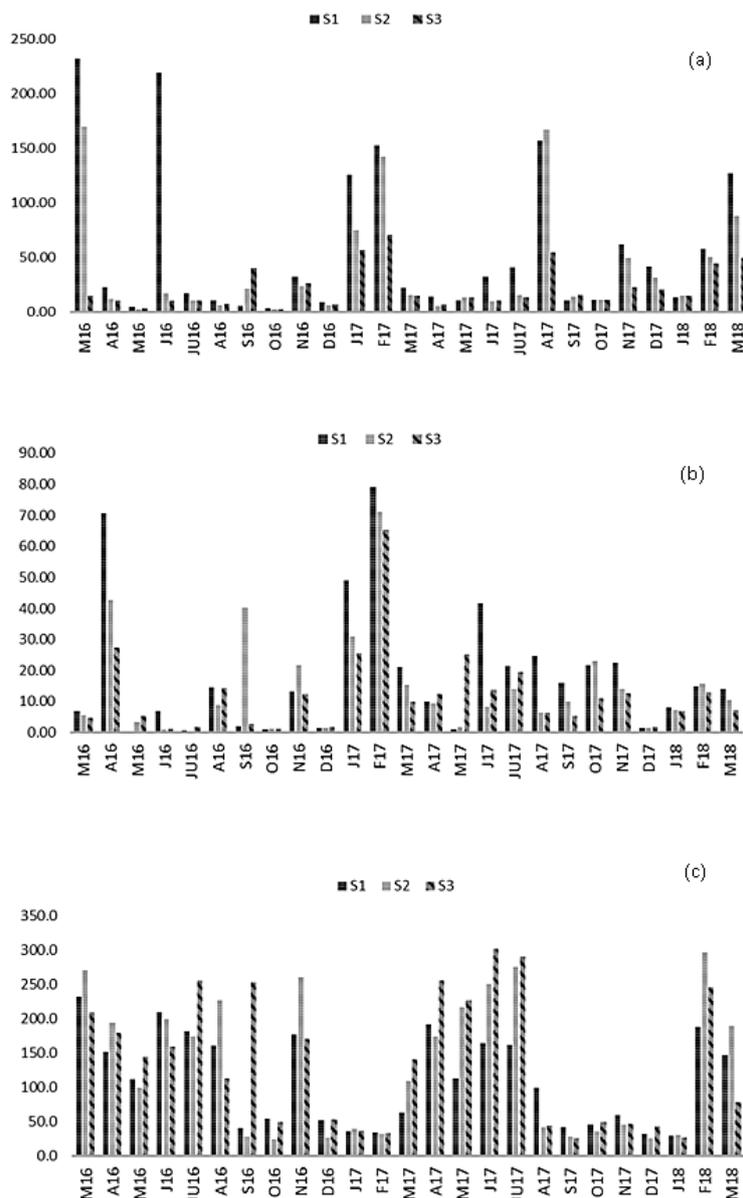


Figure 4. Spatio-temporal fluctuations of fecal bacteria concentrations: 4a) Fecal coliform FC, 4b) fecal streptococci FS, 4c) Total germ TG.

Table 1. Origin of pollution according to the ratio fecal coliforms/fecal streptococci (FC/FS)

Sites	FC/FS	Type of contamination
S1	3.09	Mixed contamination predominantly human
S2	2.67	
S3	1.79	

Table 2. Values of FC80, FC95 and FS90 parameters in seawater at the three sites on Taghazout beach

Sites	FC80 (UFC/100ml)	FC95 (UFC/100ml)	FS90 (UFC/100ml)
S1	45	54	16
S2	31	37	13
S3	17	21	11

DISCUSSION

This study examined the influence of environmental parameters on the abundance of fecal indicator bacteria. Such information is very useful for predicting the effects of climate change on the concentrations of these bacteria and,

consequently, on the seawater quality. The results of environmental parameters survey revealed seasonal variations. During the study period, the seawater temperature showed a similar annual variation in the three sites with a minimum recorded in winter and a maximum in summer. These variations are correlated with the meteorological

Table 3. Relationship between fecal bacteria and other environmental variables using Pearson correlation test

	T°	pH	TDS	Salinity	Conductivity	OD	Rainfall
FC	0.0549	0.1245	0.0937	0.0701	0.0359	0.1328	0.2859
	p=0.667	p=0.327	p=0.462	p=0.582	p=0.778	p=0.295	p=0.022
FS	0.4198	0.4936	0.4956	0.4712	0.4683	0.5025	0.4621
	p=0.001	p=0.000	p=0.000	p=0.000	p=0.000	p=0.000	p=0.000
TG	-0.0838	-0.0381	-0.0962	-0.1506	-0.1893	-0.039	-0.1427
	p=0.510	p=0.765	p=0.449	p=0.235	p=0.134	p=0.759	p=0.261

conditions recorded during the study period. Thus, the recorded water temperatures indicate normal to good water quality. The pH shows also an increase in summer and a decrease in winter; high pH values may be caused by spring planktonic blooming, which is responsible for the reduction in acidity because of an unbalanced pH buffer with chlorophyll levels (Id Halla, 1997), while the low pH values may be related to the rainfall period (280 mm) which is the source of a massive input of continental waters loaded with suspended matter (Regragui, 1991).

Salinity and conductivity also indicate an increase in summer and a decrease in winter. In fact, the increase of atmospheric temperature in summer generates seawater evaporation, which subsequently leads to an increase of salinity and conductivity (Ben Charrada et al., 1997). On the other hand, the rainwater carried by the Oueds and discharged into the sea is the reason of seawater dilution and – consequently – the reduction of salinity and conductivity.

The annual cycle of dissolved oxygen concentration is similar in the three studied sites, with a decrease in autumn and an increase in winter. Generally, the dissolved oxygen will be affected by water temperature, tides and water depths (Kaumadi et al., 2017). The winter seems to slightly improve the oxygen content of seawater, limiting the bacterial growth and therefore minimizing the oxygen consumption. According to Khattabi (2002), the dissolved oxygen content is the result of a large number of biotic and abiotic factors; it depends on the biological activity of the environment, i.e. the balance between photosynthesis – respiration, winds and temperature.

The spatio-temporal evolution of fecal bacteria concentrations revealed a seasonal pattern in the three studied sites. Thus, our results show the highest concentration of FC and FS during the cold season, coinciding with a heavy rainfall of about 280 mm (Figure 3). Numerous studies have shown that the detection of bacterial and

viral indicators can be influenced by precipitation (Lipp et al., 2001; Rose et al., 2001; Boehm et al. 2002; Ackerman and Weisberg, 2003; Morisson et al. 2003; Howard et al., 2003; Shehane et al. 2005; Papastergiou et al., 2009, Zhang et al. 2013, Eregno et al., 2016; He et al. 2019). Similarly, Mok et al., (2016) reported that relatively high FC and FS concentrations were detected in the samples taken immediately after heavy rainfalls in the Jaranman-Saryangdo area of Korea.

On the other hand, the high concentrations of TG and FC were recorded during the warm season; this could be explained by the increase in temperature and the sunshine duration. These factors encourage the multiplication of bacteria and their enrichment by physical phenomena such as adsorption, biological activation, dilution, dispersion and sedimentation (Rodier et al., 1996). Furthermore, the high touristic activity in the summer season and the installation of Taghazout Bay resort around this area may constitute a source of potential contamination of the seawater.

With regard to the FC80, FC95 and FS90 values, we found that they do not exceed the guide values of Moroccan standards. This classifies Taghazout beach in category A (Good quality of bathing water).

Similar results have been reported by Mimouni et al., (2002) in Taghazout coastline with values higher than ours (FC80 =55 UFC/100 ml, FC95 =120 UFC/100 ml, FS90 =40 UFC/100 ml); however, they still remain in compliance with the guide standards. A concordance exists between our results on the classification of this beach and those provided by the National Laboratory of Studies and Monitoring of Pollution under the Secretary of State in Charge of Sustainable Development (2015/2016). The latter considers the Taghazout beach of good quality for bathing (class A) in 2016. However, there is a discrepancy between our results in 2017 and the Analytical Report (2017 Edition), as it considers the Taghazout beach of medium quality (Class B). This would

be explained by the fact that the sampling time and dates are different.

However, even if the bacteriological analysis of Taghazout coast seawater meet standards, a relatively high rate of coliforms and streptococci was observed, thus allowing us to suggest the existence of pollution from several sources (principally urban waste and rainwater runoff into the sea without treatment) present at the three sites, although less obvious.

The results from the correlation test between the environmental parameters and the level of fecal bacteria showed a significant positive correlation between the FC concentrations and rainfall. The FS concentrations showed significant positive correlations with all the environmental parameters while the TG concentrations indicate no correlation with them.

A similar study was conducted in the eastern Aegean Sea, by Kacar et al., (2017). According to their results, there was a negative correlation between environmental parameters and the level of fecal bacteria, but no significance was recorded using the Pearson correlation test. They also found that higher indicator bacteria ratios were determined during the periods of intense rainfall and low temperature. Chigbu et al., (2004) also reported that FC levels exhibited a positive relationship with rainfall in the Mississippi Sound. Previous studies also reported the increase of total coliforms and *E. coli* in seawater after rainfall events (Haramoto et al., 2006; Surbeck et al., 2006). According to Setti et al., (2009) rainfall was the only explanatory environmental variable showing a linear relationship with the presence of *Salmonella* in coastal waters of Agadir. However, Sampson et al., (2006) found no association between the rainfall amount and bacterial concentrations at any of the 15 beaches along Lake Superior in Wisconsin.

Factors such as pH, temperature, solar (UV) radiation, predation, osmotic stress, nutrient deficiencies, particulate levels, turbidity, oxygen concentrations, and microbial community composition contribute to bacteria inactivation once they reach receiving waters (Mancini 1978, Davies-Colley et al. 1994, Fujioka et al. 1981, Berry and Noton 1976, Kapuscinski and Mitchell 1980, Auer and Niehaus 1992, Johnson et al. 1997, and Gerba and Bitton 1984).

Rosenfeld et al., (2006) found that the load of fecal contamination indicator bacteria are not only related to temporal or spatial variability in their sources but also to the conservative behaviour

of these bacteria, and the fact that each bacterial type dies at a different rhythm, This rate of disappearance of bacteria from the ocean depends on environmental factors such as temperature, salinity, nutrient concentration, predation, presence or absence of bacterial toxins, solar radiation, coagulation, flocculation, and particle adsorption, all of which have an impact on the ultimate death of the bacteria.

CONCLUSION

This study provided the data on the bacteriological quality of Taghazout coastal waters. At this area, we have recorded a relatively high level of bacteria (fecal coliforms and total germs), which reflects the risks for people frequenting this area, especially during summer season. The results of the bacteriological analysis show that the seawater in the studied areas complies with the Moroccan standards and can be classified as category A (Good quality of bathing seawater).

However, a tourist complex will be built at this site; therefore, it is necessary to accompany this development project with regular monitoring of the quality of water in order to control the pollution sources, thus ensuring a good biomonitoring of this ecosystem.

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