





## The microbiological quality of bathing waters in the city of Tangier

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### ABSTRACT

In Morocco, 60% of wastewater from coastal cities is discharged into the sea without any prior treatment. These marine discharges pose a threat to human health (swimming, water sports, fishing) and animal health (exploitable marine resources). The present study was conducted to assess the bacteriological quality of bathing waters at Sidi Kacem Beach in Tangier, Morocco. The bacteriological analysis focused on pollution indicator germs, including fecal coliforms (*E. coli*) and fecal streptococci. The analyses showed that the frequency of exceeding the mandatory limit for *Escherichia coli* and fecal streptococci was over 100%, indicating poor water quality for swimming, classifying this area as Class D. All nine stations, deemed non-compliant for swimming during this season, are influenced by wastewater discharges and experience a high concentration of swimmers, combined with inadequate hygiene infrastructure. Bathing waters are generally classified into four categories, with categories A and B being compliant, and categories C and D not meeting the standards.

**Keywords:** *Escherichia coli*, fecal streptococci, beaches, Tangier, Morocco

### INTRODUCTION

Morocco has a vast maritime territory: the Mediterranean and Atlantic coasts, which are subject to the ever-increasing demographic pressure of urban agglomerations and the influence of various industrial, port and tourist activities. In addition, it receives inputs from river and stream watersheds, as well as a large proportion of urban and industrial wastewater. From an environmental point of view, these ecosystems play a predominant role, providing numerous biological and ecological functions [Hughes et al., 1997]. However, these ecosystems are subject to strong anthropogenic pressures [Duarte et al., 2015], which weaken them and can lead to a loss of biodiversity, ecosystem functions and water quality [Braatz et al., 2006; Cochard et al., 2008].

The deterioration of coastal ecosystems also entails a public health risk in the context of bathing activities, as a result of altered microbiological water quality. Indeed, numerous epidemiological studies have confirmed that contact with recreational waters contaminated with faecal matter poses health risks for users [Fleisher et al., 1998; Shuval, 2003].

The Boukhalef – Tangier Step is designed to treat all wastewater generated by the Tangier free zone. During the rainy season and in the event of flooding, the Tangier plant is the collection point for the city's stormwater network. Wastewater from the Boukhalef Step and stormwater overflow, runoff and drain into a daya, which finally drains to Sidi Kacem beach.

The aim of this study is to assess the microbiological quality of seawater at Sidi Kacem beach in Tangier during the summer season, which is

the receiving environment for Step discharges, by testing for fecal coliforms and fecal streptococci using bacteriological analysis. The results of this study give an indication of the quality of these bathing waters, and enable us to envisage responsible measures linked to the use and protection of these sources

## MATERIAL AND METHODS

### Study area

The city of Tangier is located in the extreme north of the Kingdom (Figure 1). It is bordered to the east by the city of Tetouan, to the south by the province of Assilah, to the north by the Mediterranean Sea, and to the west by the Atlantic Ocean. Tangier’s strategic position at the crossroads of trade winds, as the closest outpost to Europe, and a junction between Africa, Europe, and the Middle East, has made it an ideal location to host the

new export free zone. Its population is estimated at 947.000 inhabitants (according to the 2014 national census) (Table 1).

### Sample collection

To conduct this study, seawater samples were collected between May and September 2023 (Table 2) from Sidi Kacem Beach in Tangier to assess concentrations of fecal coliforms (FC) and fecal streptococci (FS). For each monitoring point, regulations require at least one sample to be taken twenty days before the summer season and one sample every fifteen days during the summer season. However, if the bathing sites were compliant during the previous two years, it is permissible to take only one sample per month.

In order to better assess the bacteriological characteristics of the bathing waters at Sidi Kacem Beach, our work was carried out at nine representative points: MP1, MP2, MP3, MP4, MP0, MP1’, MP2’, MP3’, and MP4’ (Figure 2), as follows:

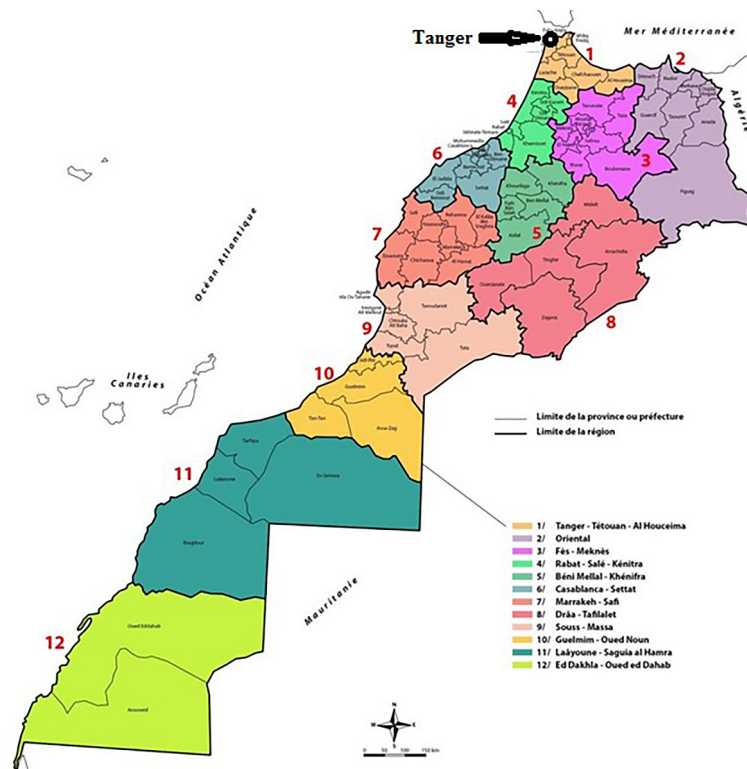


Figure 1. The geographic location of Tangier in Relation to Morocco

Table 1. Population growth in the Tangier-Asilah Region

Region	1982	1994	2004	2014
Tangier-Asilah	436 227	627 963	777 000	947 000

Note: RGPH 1982-1994-2004-2014.

**Table 2.** Sample collection schedule

Saisons	Sampling dates,
Before the summer season	01/05/2023
	15/05/2023
	30/05/2023
During the summer season	15/06/2023
	30/06/2023
	15/07/2023
	30/07/2023
	15/08/2023
	30/08/2023
	15/09/2023



**Figure 2.** Sampling points for bathing waters at Sidi Kacem, the receiving environment for treated wastewater from the Boukhalef Treatment Plant in Tangier (www.maps.Google.fr)

- Confluence Point: MP0: this is the point where the wastewater from the treatment plant (STEP) meets the bathing waters at Sidi Kacem Beach (10 samples and analyses in total for each study point).
- Confluence to the South: MP1 (1 km), MP2 (2 km), MP3 (3 km), and MP4 (4 km).
- Confluence to the North: MP1' (1 km), MP2' (2 km), MP3' (3 km), and MP4' (4 km).

## RESULTS AND DISCUSSION

### Fecal coliforms

The species most commonly associated with this bacterial group is *Escherichia coli* (*E. coli*), and to a lesser extent, some species

from the genera *Citrobacter*, *Enterobacter*, and *Klebsiella* [Elmund et al., 1999; Canada Health, 1991; Edberg et al., 2000]. However, *E. coli* accounts for 80 to 90% of the thermotolerant coliforms detected [Edberg et al., 2000; Barthe et al., 1998]. Although the presence of fecal coliforms typically indicates contamination of fecal origin, some fecal coliforms are not of fecal origin but rather come from water enriched with organic matter, such as industrial effluents from the pulp and paper industry or food processing [Barthe et al., 1998; WHO, 2000]. The importance of detecting these coliforms as indicator organisms lies in the fact that their survival in the environment is generally similar to that of pathogenic bacteria, and their density is usually proportional to the level of pollution caused by fecal matter [Ceaq, 2000].



## Confluence point

This point, located in an urban area, experienced significant pollution, with an average of 19.647 CFU/100 ml, linked to the malfunctioning of the nearby wastewater treatment plant. As a result, the swimming site was closed.

- 1 km from the confluence, North and South: the frequency of exceeding the mandatory limit for *Escherichia coli* is over 100%, indicating poor water quality for swimming, classifying this area as Class D.
- 2 km and 3 km from the confluence, North and South: the values obtained far exceed the mandatory limits for *Escherichia coli*. These results can be explained by the presence of several wastewater outfalls in the immediate vicinity of this beach.
- 4 km from the confluence, South: the Sidi Kacem beach is bordered to the south by a natural area, distant from urban zones and potential sources of pollution associated with them. Additionally, it is a site for temporary to long-term camps (up to 5 months) and lacks public sanitation facilities, which poses bacteriological contamination risks from human waste. The sanitary control sample from August 30 revealed the presence of 3.800 CFU/100 ml of *Escherichia coli*. All other samples taken during the 2023 season were compliant. This pollution episode is likely linked to the absence of toilets and the uncontrolled waste dumping by the numerous

site occupants (Figure 3). It is noteworthy that bacterial pollution by *E. coli* is higher at Sidi Kacem beach, which aligns with the discharge volumes from the Boukhalef wastewater treatment plant (STEP) (Figure 4).

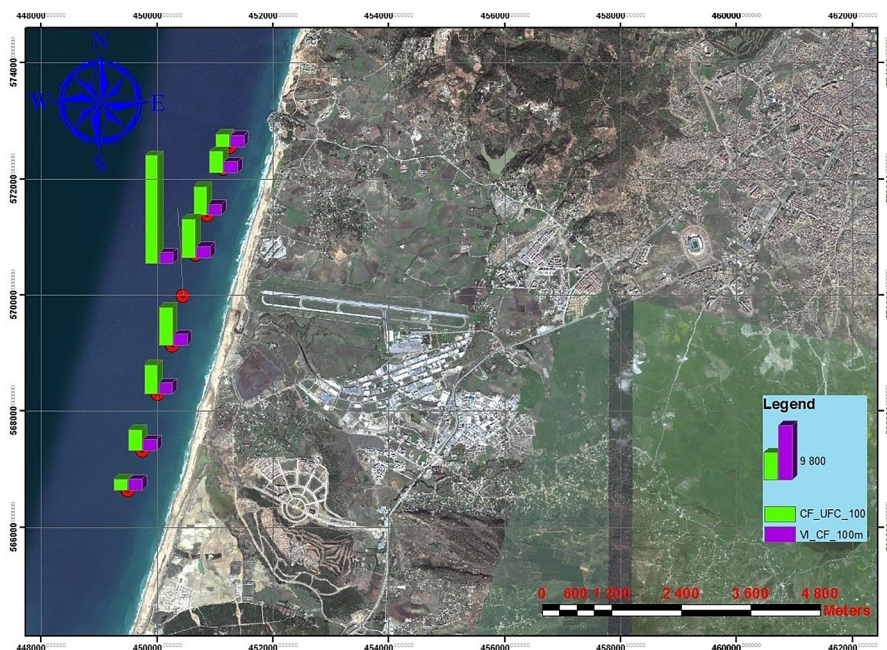
- 4 km from the confluence, North: the values obtained exceed both the quality guideline for bathing water (100 CF/100 ml) and, in most cases, the mandatory standard (2000 CF/100 ml). The August 30, 2023 sample indicated poor water quality for swimming (Table 3 and 4).

## Fecal streptococci

Fecal streptococci are largely of human origin [Clausen et al., 1977; Gleeson et al., 1997]. However, some bacteria classified in this group can also be found in animal feces or on plants. Nevertheless, they are considered indicators of fecal contamination [Geldreich et al., 1969; Leclerc et al., 1982] and their main significance lies in their resistance to desiccation [Leclerc et al., 1982].

As a result, they provide additional information about pollution. The identification of fecal streptococci gives important confirmation of the fecal nature of the contamination [WHO, 1993].

The mandatory values are the limits not to be exceeded. As for fecal streptococci (FS), we observed that their average concentration in the studied stations is around 1776 CFU/100 ml,



**Figure 3.** Average concentration of fecal coliforms in the bathing waters of Sidi Kacem, Tangier

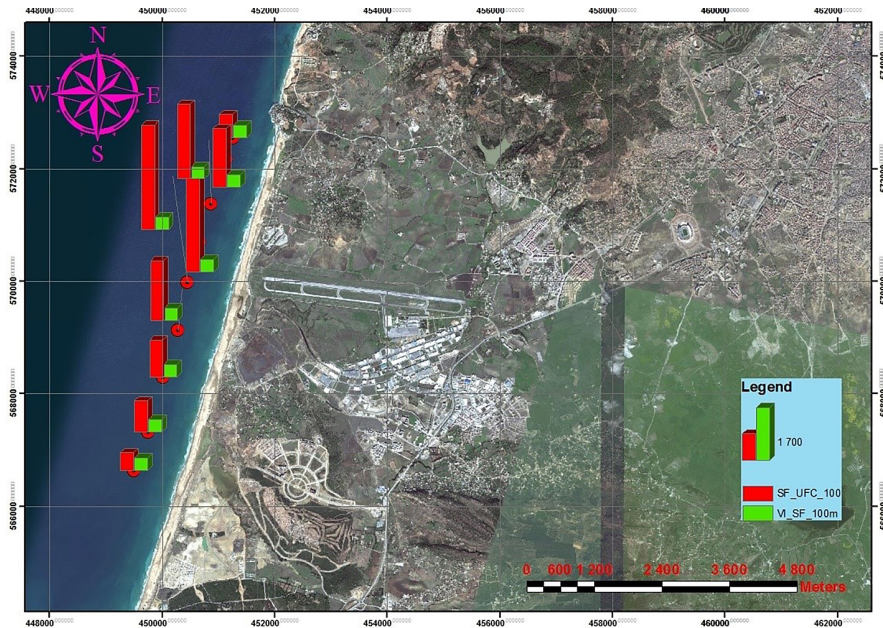


Figure 4. Average concentration of fecal streptococci in the seawater at Sidi Kacem Beach, Tangier

Table 3. Variations in *E. coli* concentrations per 100 ml in bathing waters

Sampling		Confluence to the south				Confluence MP0 (0 km)	Confluence to the north			
		MP4 (4 km)	MP3 (3 km)	MP2 (2 km)	MP1 (1 km)		MP1' (1 km)	MP2' (2 km)	MP3' (3 km)	MP4' (4 km)
Before the summer season	01/05/2023	1600	3100	4050	6000	19000	6400	4040	3050	1580
	15/05/2023	1740	3267	4000	5030	17400	5900	4400	3210	1700
	30/05/2023	1990	3400	4800	6300	18600	6100	4730	3360	2410
Summer season	15/06/2023	1860	3354	4890	6900	18000	6800	5100	3410	2090
	30/06/2023	1940	3901	6100	7050	10400	7180	5900	3890	1900
	15/07/2023	1800	4000	5220	7100	23150	7280	5300	4010	2920
	30/07/2023	2000	4800	5900	6800	12100	6470	6000	4690	2130
	15/08/2023	1890	4600	6111	8100	27000	7900	6050	4700	2190
	30/08/2023	3800	4200	5890	7500	29000	7750	5870	4500	3900
	15/09/2023	2000	4050	5800	8090	21820	8240	5000	4420	2200
Moyenne		2062	3867	5276	6887	19647	7002	5239	3924	2302

Table 4. Variations in average fecal coliform concentrations in seawater for bathing

Distance	To the north (CF/100ml)	To south (CF/100ml)	Point of confluence	Guideline values per 100 ml	Mandatory values per 100 ml
1 km from the confluence	7002	6887	19647	100	2000
2 km from the confluence	5239	5276			
3 km from the confluence	3924	3867			
4 km from the confluence	2302	2062			

**Table 5.** Variations in average fecal streptococci concentrations in seawater for bathing

Distance	To the north (SF/100ml)	To the south (SF/100ml)	Point of the confluence (SF/100ml)	Guideline values per 100 ml	Mandatory values per 100 ml
1 km from the confluence	3000	1900	3345	100	400
2 km from the confluence	2389	1178			
3 km from the confluence	1870	992			
4 km from the confluence	743	570			

**Table 6.** Source of fecal contamination in seawater for bathing

Stations	CF/100ml	SF/100ml	R= CF/SF	Origin
Confluence point	19647	3345	5.87	Strictly human
1 km from the confluence to the north and south	6944.5	2450	2.83	Mixed with human predominance
2 km from the confluence to the north and south	5257.5	1783.5	2.94	Mixed with human predominance
3 km from the confluence to the north and south	3895.5	1431	2.72	Mixte à prédominance humaine
4 km from the confluence to the north and south	2182	656.5	3.32	Mixed with human predominance

with a maximum value recorded at the confluence point (3345 CFU/100 ml) and a minimum value recorded at the station located 4 km away from the confluence to the south (570 CFU/100 ml) (Table 5).

The results obtained all exceed the guideline value for bathing water quality (100 FS/100 ml) and the mandatory standard (400 FS/100 ml).

### Determination of the source of fecal contamination

The source of fecal contamination is determined by the quantitative ratio R: FC/FS. According to criteria defined by [BORREGO et al., 1982] the contamination is of animal origin if the ratio R is less than 0.7; it is of human origin if R is greater than 4. The contamination is mixed with animal predominance if R is between 0.7 and 1. This origin is uncertain if R is between 1 and 2, and it is considered mixed with human predominance if R is between 2 and 4 (Table 6).

Contamination levels can lead to the temporary closure of certain fishing areas or their downgrading, with negative repercussions on the local economy, a ban on marketing products, or, more chronically, the necessity for prior treatment.

### CONCLUSIONS

The assessment of the bathing water quality at Sidi Kacem Beach, Tangier, is based on the search for microbiological parameters, including fecal coliforms (*Escherichia coli*) and enterococci (Fecal streptococci), in accordance with national standards (NM 03.7.200), which are transposed from the European Directive (76/160/EEC) and the WHO/UNEP Guidelines applicable to the sanitary surveillance of marine bathing waters. Bacterial pollution of *E. coli* and fecal streptococci at Sidi Kacem Beach is significant, exceeding the guideline value for bathing water quality (100 SF/100 ml, 100 CF/100 ml) and, for most cases, the mandatory standard (2000 CF/100 ml and 400 SF/100 ml). This indicates poor water quality for swimming, classifying the beach as Class D. Our study is confirmed by analyses conducted by the Mohammed VI Foundation for the Protection of the Environment, under the effective presidency of Her Royal Highness Princess Lalla Hasna, on beaches in Morocco. Despite the efforts made at both the national and local levels, coastal management strategies have not achieved the expected objectives. The Blue Flag initiative has accelerated the upgrading of standards related to bathing water quality and has brought together a multitude of



institutional, private, and civil society actors who support coastal preservation.

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