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Sources of Bathing Water Pollution in the West Coast of Tangier, Morocco: Effects of Industrial Zones †

El Khalil Cherif [1,*], Farida Salmoun [1] and Nordine Nouayti [2]

[1] Department of Chemistry, Sciences and Technology Faculty, Abdelmalek Essaadi University, Tangier 90090, Morocco
[2] Research Team Water and Environment Management (G2E), National School of Applied Sciences, Abdelmalek Essaadi University, Al-hoceima 32003, Morroco
* Correspondence: c.elkhalil@uae.ac.ma; Tel.: +212-6663-90481
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Abstract: This study was carried out in the Boukhalef River which reaches the western coastal waters of Tangier, Morocco, loaded with wastewaters from two industrial zones: Tangier Free Zone and Gzenaya Zone. To understand the extensive impact of these industrial zones on Jbila and Sidikacem beaches located near the Boukhalef River mouth, water and sediment samples of the Boukhalef River were examined in terms of physical–chemical and heavy metal parameters, respectively. The results showed high values of conductivity (Cond), biochemical oxygen demand in five days (BOD5), and chemical oxygen demand (COD), which are the causes for the very bad quality status of the Boukhalef River waters. The application of principal component analysis on the heavy metal results of Boukhalef waters and sediments showed that samples were characterized by a load of heavy metals, seemingly of the same anthropogenic origin. This analytical survey demonstrated a relationship between the bathing water quality and industrial discharge. Indeed, industrial zones represent a strong source of pollution in the west coast of Tangier, Morocco.

Keywords: bathing waters; Boukhalef River; physical–chemical; heavy metal analysis

1. Introduction

The quality status of bathing waters in the Jbila beach is marked as momentarily polluted, and it is marked generally medium to momentarily polluted in the Sidikacem beach in the west coast of Tangier, Morocco [1], where riverine inputs come from the Boukhalef River. This status is a result of fecal contamination caused by industrial wastewaters drainage from the Tangier Free Zone and Qzenaya Zone, which reaches the bathing waters through the Boukhalef River [2–6]. Therefore, sustainable coastal water requires water resource control and continuous monitoring [7]. Hence, it is very important to evaluate the runoffs from the Boukhalef River, using water quality indicators such as physical–chemical and heavy metals parameters [8].

The aim of this study is to determine the source of bathing water pollution in the west coast of Tangier through (i) physical–chemical and heavy metal analyses of the Boukhalef River waters and sediments, and (ii) the use of multivariate statistical methods corresponding to the Principal Component Analysis (PCA).

2. Material and Methods

2.1. Study Area

The study area is located in north-western Morocco, occupied by the Boukhalef River which flows into the west coast of Tangier (Figure 1). Next to the Boukhalef River is a wastewater treatment station and two industrial zones (Tangier Free Zone and Gzenaya Zone), as well as areas with touristic and urban activities.

2.2. Methodology

Four samples were collected on 17 September 2017, from the waters and sediments of the Boukhalef River at the point of wastewater discharge from industrial activity into the river and into the Boukhalef River mouth in previously sterilized bottles of 500 mL.

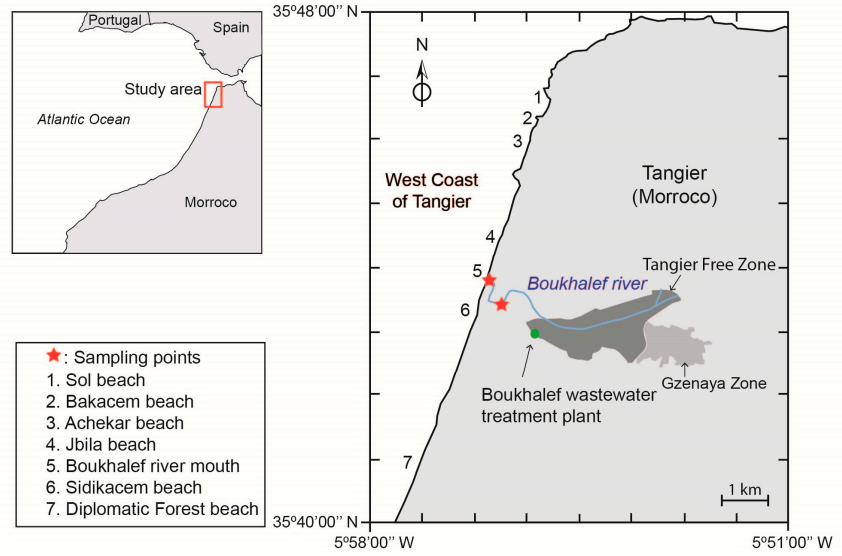

Figure 1. Study area in the west coast of Tangier, northern Morocco, with locations of two sampling points, beaches of the west coast of Tangier, the Boukhalef River, and the industrial zones.

The analyses of various physical–chemical parameters were carried out according to standard norms; NM ISO 10523 IC/NM 03.7.009 for the hydrogen potential (pH) and NM ISO 7888 2001 IC/NM 03.7.011 for electrical conductivity. These parameters were measured at the time of sample collection using a portable field thermometer, pH meter WTW 521, and conductivity meter LF 90, as well as biochemical oxygen demand in 5 days (BOD5) according to NF EN1899/NMISO6878 and chemical oxygen demand (COD) according to NF T 90-101/NM03.7.56. These parameters were determined by a colorimetric method using a UV/visible spectrophotometer PR 2800, suspended matter (SM) was evaluated according to Rodier [9].

The determination of heavy metals in waters and sediments of the Boukhalef River was carried out by Inductively Coupled Plasma Mass Spectrometry (ICP-MS) according to the Moroccan norms 03.7.120 (ISO 17294-1) and 03.7.121 (ISO 17294-2).

Multivariate statistics was used to identify trends, correlations, and events that may influence the distribution of heavy metal elements in western coastal waters of Tangier, computing a principal component analysis (PCA).

3. Results and Discussion

Physical–Chemical Analysis

The Boukhalef River waters surveys showed conductivity (Cond), chemical oxygen demand (COD), and biochemical oxygen demand in five days (BOD5) above the limit prescribed by the Ministry of Environment of Morocco (NM 03.7.200) (Table 1).

Table 1. The results of physical–chemical analysis of the Boukhalef River waters.

Samples	pH	Cond µS/cm	COD mg O2/L	BOD5 mg O2/L	SM mg/L
Sample 1	7.4	4015	800	320	410
Sample 2	7.46	4010	720	225	380

The Boukhalef River, which meets the Atlantic at Sidikacem beach, is polluted, showing high values of COD, BOD5, and Cond that reflect the amount of dissolved salts and substances in the water [10,11]. These loads can be attributed to industrial solid waste materials which are discharged into this river and transported into the ocean (Figure 1).

3.2. Heavy Metal Analysis

Multivariate analysis of heavy metals in the Boukhalef River waters and sediments showed that the first two factors represent 95.5% of the variance expressed (Figure 2). These factors combine the maximum of the variance expressed and were sufficient to accurately translate the information sought.

The analysis in space of the variables of the factorial plane F1–F2 made it possible to highlight two large groups of variables (Figure 2).

Group 1: Occupies the positive part of axis F1 and axis F2, and comprises the points of sediments 3 and 4. This class is characterized by pollution with iron (Fe), Pb, Ni, Se, Al, Hg, and Cd. This heavy load in these chemical elements seemed to be of anthropogenic origin, mainly due to household and industrial waste.

Group 2: Occupies the negative part of the F1 axis. It is represented by the water points 1 and 2. It is characterized by a weak mineralization with slightly elevated levels of Zn and Cu ions. Hence, all the water points studied met the recommended standards with the exception of two parameters, iron for both points and Al for the first point.

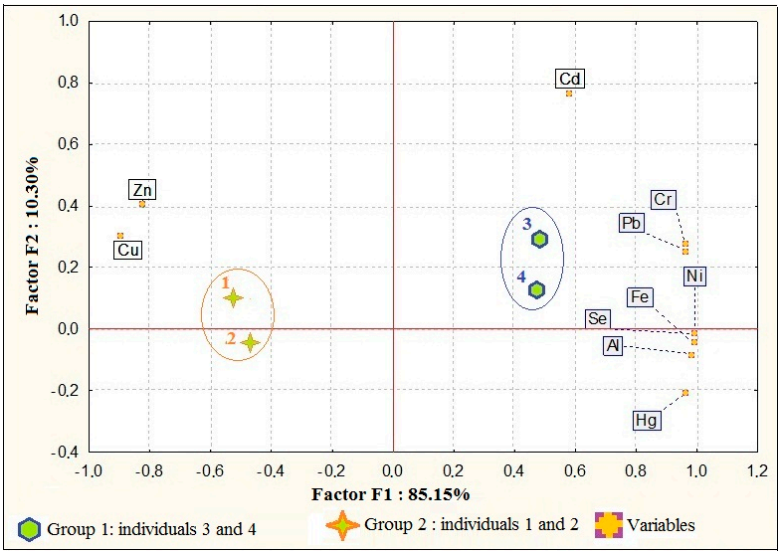

Figure 2. Projection and correlation circle of heavy metal data in Boukhalef River waters and sediments in the factorial plane F1 X F2.

Nonetheless, the results of PCA proved that these heavy metal concentrations came from the same source which, in this area, related to punctual and localized industrial wastewaters discharge in agreement with those found by Brahimi et al. (2015) [12] in the Za River, located in Oriental, Morocco, which is equally problematic to our study area.

The industrial activities near the Boukhalef River can explain the spatial presence of heavy metals in our study area, and, despite their rarity in nature and their high toxicity, reflect a wide application in the industry that contributes to dangerous contamination of surface waters.

4. Conclusions

The results of the present study showed a high physical–chemical pollution concentration in the Boukhalef River runoffs, which discharge into the ocean after running along a heavily industrialized area. In addition, the application of principal component analysis showed that the heavy metal load seemed to be of anthropogenic origin, which was demonstrated by the presence of liquid discharges in the Boukhalef River linked to the industrial zones.

In this study area, the collected data allowed us to better figure out the pollution dynamics along the Boukhalef River and confirmed the fact that Boukhalef River waters have a negative impact on the bathing water quality on the nearby beaches, Jbila and Sidikacem in particular. Furthermore, they confirmed the important role or rainfall events in driving physical–chemical and metal pollution into the coastal environment. However, this study proved that the industrial zones are the source of pollution of western coast waters of Tangier owing to the pumping of its wastewaters into the Boukhalef River.

Author Contributions: E.K.C. performed the experiments and led the writing of this paper. The first draft was written and then sent to F.S. for her comments and edits. E.K.C. and N.N. analyzed the data. F.S. and E.K.C. produced the final paper.

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Conflicts of Interest: The authors declare no conflict of interest.

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