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Physicochemical Assessment of Water Pollution in the Oued Beht River, Morocco

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ABSTRACT

This study's objective was to assess pollution by characterizing the urban wastewaters released in the Oued Beht of the town of Sidi Slimane using physio-chemical and microbiological methods. This study had two main goals: first, to address the question of how raw sewage should be treated; and second, to raise awareness about the contamination of the Oued Beht, a local source of irrigation. Water samples were collected and analyzed for temperature, salinity, pH, suspended particles, and the oxygen requirement of biological and chemical processes. According to physico-chemical tests, the average pH of the wastewater in the upstream and downstream locations is 7.63 and 7.72, respectively. The average electrical conductivity value ranged from 730 to 2210μS/ cm, and the measured values were determined to be between 6.5 and 8.5, which is the top limit for direct discharges. The biodegradability of these effluents was shown by the ratios DCO/BOD5, DBO5/DCO, and MES/DBO5, which also allowed for the selection of an appropriate treatment technique. The BOD5 ratios were 22 and 140mg/ L, while the COD ratio was 61: 316mg/ L. In fact, the data indicated that home effluents surpass the national rejection criteria. It necessitates the involvement of the appropriate authorities to maintain environmental protection, public health, and the installation of an effective sewage treatment plant to guarantee sustainable development.

INTRODUCTION

The shortage of clean water is a persistent and increasingly serious problem in both developing and developed countries **(Au *et al.*, 2023)**. Clean water is essential for human beings **(Al-Mayyahi *et al.*, 2023; Lachheb *et al.*, 2024a)**. Countless raw water sources contain harmful microorganisms or other substances, making the water unfit` for human consumption **(Lotfi *et al.*, 2020a; Amri *et al.*, 2022; Sobhani Alves *et al*., 2023; Sobhani & Alinavaz, 2023; Lachheb *et al.*, 2024b)**. Treatment processes must eliminate these organisms and substances to make colloids in the water fit for domestic use. Raw water treatment brings together a number of integrated processes in a plant called a treatment plant to produce water of the desired quality **(Lotfi *et al.*, 2020b; Au *et al.*, 2023)**. Used water discharged from different industries, particularly the dye industry, generates a product called effluent (wastewater). The effluent contains a number of pollutants that alter the water in ways that have a negative impact on both health and the environment **(Basaleh *et al.*, 2021; Ait Messaad *et al.*, 2022a; Aydin-Kandemir & Demir, 2023; Chakit *et al.*, 2024)**.

Groundwater contaminated by microbiological, parasitological, virological, and physicochemical agents causes serious public health issues **(El-Naqa *et al.*, 2007; Eblin *et al.*, 2014; Asfers *et al.*, 2016a; Ait Messaad *et al.*, 2022b)**. In fact, the primary cause of death and illness globally is the use of non-potable water. The use of non-potable water is thought to be the cause of 88% of diarrhea cases reported globally, and poor or inadequate hygiene is the cause of 1.5 million fatalities annually, particularly in children **(Prüss-Üstün *et al.*, 2008)**. Urban agriculture is one of the industries that has the potential to affect the quality of the water and soil when it drains out in delicate ecosystems like surface water aquifers and permeable soils. Wastewater discharged from homes and businesses can also contaminate surface waters, which can seep into groundwater and change its composition **(Prüss-Üstün *et al.*, 2008)**. Agriculture is known to be a significant source of pollution and has the potential to harm the quality of water by mixing into the eutrophication of lakes and reservoirs (caused by phosphate and nitrogen) and the nitrate contamination of groundwater **(Asfers *et al.*, 2016b; Bensalah *et al.*, 2021; Bensalah *et al.*, 2023; Bibi *et al.*, 2023; Bolan *et al.*, 2023; Brantley *et al.*, 2023)**.

Our research focused on a physicochemical comparison between the waters of Oued Beht river, which are upstream from the city of Sidi Slimane wastewater release, and the waters of the same Oued, which are downstream from these discharges. It should be mentioned that untreated wastewater is released into the Oued. Determining the load is necessary to evaluate the effect of the discharges on Oued Beht water quality.

These results emphasize how crucial it is to take action to stop and minimize the water pollution, especially in places where urban agriculture is practiced and where human activity can significantly affect the quality of the water. To protect the environment and public health, a call for sustainable agriculture methods and integrated water resource management has emerged.

MATERIALS AND METHODS

1. Study area

Study area selected for the study is the city of Sidi Slimane, situated 70 kilometers away from Kenitra, on the border of the Gharb plain. It serves as the district's capital. The condition of the water has an impact on the area's climate. There is an occurrence of 445mm of rain on average. The average temperature during the winter season is 10°C, while in July and August it reaches 45°C. The southwest portion of the Sebou basin contains the Oued Beht watershed, which is situated in northwest Morocco. A perennial river of considerable force, Oued Beht rises from the study area Atlas and is a left tributary of Oued Sebou. It gets tributaries from Kharouba, Bouaachouch, El Kell, Ouchkat, Berrajline, D'kor, and Chébilia along its path **(Diara *et al.*, 2019)**.

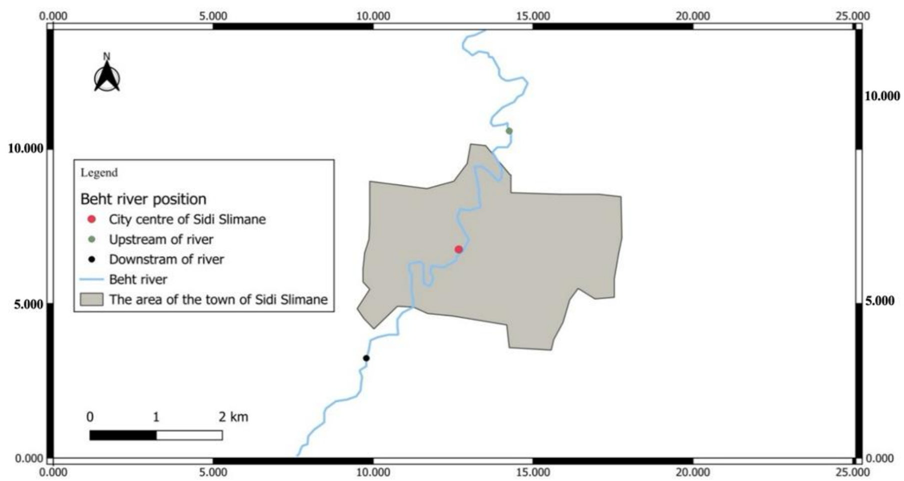

Fig. 1. Images of the area of the town of Sidi Slimane operational to date

The Oued Beht watershed spans over 4500km² in northwest Morocco, and its yearly average flow is estimated to be 410 million cubic meters. As seen in Fig. (1), QGIS (Quantum GIS) is an open-source geographic information system (GIS) program that facilitates the management, analysis, and visualization of spatial data. The upstream and downstream river collection sites were depicted on this map.

2. Methods

Pre-sampling site (upstream): This is the Oued Beht receiving environment, which is situated upstream of the city of Sidi Slimane wastewater discharge.

Contamination location (downstream): Here, wastewater discharged from Oued Beht encountered the following downstream contamination.

Water samples were gathered and transported to the lab for analysis. The Rodier method, a reputable and well-established technique for analyzing water quality, was used for the analyses. This approach can measure a variety of parameters, including temperature, salinity, pH, suspended particles, and the oxygen requirement of biological and chemical processes. These factors are crucial for determining the quality of the water and identifying pollutants.

The analysis study findings were contrasted with Morocco's requirements for direct discharges. These guidelines specify the allowable limits for each metric to safeguard human health and the environment. The data can be compared to these requirements to ascertain whether the wastewater emissions exceed permitted thresholds or conform with existing regulations.

RESULTS

1. Physical-chemical characteristics

The average biochemical oxygen demand after five days (BOD5) values for Oued Beht's upstream and downstream stations were recorded as 22 and 140mg/ L, respectively (Table 1).

The wastewater discharged into Oued Beht has a high level of contaminants and organic matter degradation, which can be the reason for the increase in biochemical oxygen demand (BOD5) after five days, which was detected at the downstream station. The chemical oxygen demand (COD) values obtained at the upstream and downstream sites were 61 and 316mg/ L, respectively.

The quantities of suspended particles considerably surpass the 80mg/ L threshold, set in the surface water’s quality guidelines, both upstream and downstream of the wastewater discharges. These waters were rated as having a very low quality, according to this research. However, it is still far lower than the findings of an earlier study.

Table 1. Evaluation of Oued Beht wastewater parameters against standard limits for irrigation

Parameter	Amount	Aval.	Limit
Temperature (°C)	26.00	28.00	≤ 30 (direct rejection)
pH	7.63	7.72	6.5 – 8.5 (direct rejection)
Conductivity (µS/cm)	730.00	2210.00	≤ 2700 Acceptable for irrigation
DBO5 (mg/L)	22.00	140.00	≤ 200 Acceptable for irrigation
DCO (mg/L)	61.00	316.00	≤ 80 (very poor quality)
MES (mg/L)	45.00	162.00	≤ 50 (direct rejection)

Table (1) shows the suspended solid contents in the water samples from Oued Beht upstream and downstream stations being 45 and 162mg/ L, respectively. The substantial load of organic and mineral debris produced by the residents of the neighborhoods releasing their wastewater into the river is usually the cause of these high levels. Notably, these amounts were still below the reported levels.

It is also crucial to stressing that these values are far higher than the 50mg/ L allowed limit for direct discharges as per the guidelines issued by the Moroccan Committee for Standards and Norms (CNS).

2. Chemical pollution indices

Discharges containing organic substances consume the oxygen present in the receiving aquatic environment and, if too abundant, can kill fish by asphyxiation. Pollution by organic matter can be characterized by various parameters, including.

2.1 Organic pollution index (OPI)

$$OPI = \frac{(BOD_5 + COD)}{2} \quad (1)$$

This index assesses the organic load of wastewater.
Upstream: OPI = (22 + 61) / 2 = 41.5
Downstream: OPI = (140 + 316) / 2 = 228

2.2 Water quality index (WQI)

These are often supplemented by various ratios and evaluated in relation to the full flow of the watercourse. Wastewater quality parameters generally include BOD5 and COD.

$$WQI = 100 - (0.18 * COD + 0.32 * BOD_5 + 0.21 * TSS + 0.16 * Conductivity + 0.13 * pH) \quad (2)$$

This index provides an overall assessment of water quality.

Upstream: WQI = 100 - (0.18 * 61 + 0.32 * 22 + 0.21 * 45 + 0.16 * 730 + 0.13 * 7.63) = 82.91

Downstream: WQI = 100 - (0.18 * 316 + 0.32 * 140 + 0.21 * 162 + 0.16 * 730 + 0.13 * 7.72) = 52.13

2.3. BOD5/COD ratio

Wastewater can be divided into two categories: biodegradable and non-biodegradable. Calculating the biodegradability coefficient of raw water effluents defines the biodegradability of the effluent. The BOD5/COD ratio calculates it and depends on the nature and origin of the wastewater, which may be domestic or industrial.

This ratio assesses the biodegradability of organic matter.

Upstream: BOD5/COD Ratio = 22 / 61 = 0.36

Downstream: BOD5/COD Ratio = 140 / 316 = 0.44

The closer the ratio is to 1, the more biodegradable the organic matter.

2.4 Water pollution index (WPI)

Surface water is becoming increasingly polluted. They contain millions of tons of pollutants formed by chemical waste from our industries, agriculture, and everyday activities.

$$WPI = (2 * BOD_5 + 3 * COD + 2 * TSS) / (2 + 3 + 2) \quad (3)$$

This index combines multiple parameters to provide an overall assessment of pollution.

Upstream: WPI = (2 * 22 + 3 * 61 + 2 * 45) / (2 + 3 + 2) = 44.67

Downstream: WPI = (2 * 140 + 3 * 316 + 2 * 162) / (2 + 3 + 2) = 212.67

A higher WPI value indicates higher pollution levels.

2.5 General quality index (GQI)

Water quality is characterized by the various substances it contains, their quantity, and their effect on the ecosystem and human beings. The concentration of these various elements determines the quality of the water and suitability for a particular use **(Ramkumar *et al.*, 2013)**.

$$GQI = \sum \frac{C_i}{n \times L_i} \quad (4)$$

Where, Ci is the concentration of parameter i, Li is the regulatory limit, and n is the number of parameters.

Since the pollution index approach makes use of a number of water quality parameters, measuring pollution requires calculating the average of the full Ci/Li value. However, if one of the Ci/Li numbers is more than 1, this value will not be important. Hence, the maximum Ci/Li number needs to be included in this index. River A body of water will be even more contaminated if the values of Ci/LiR and Ci/LiM are greater than 1.0. If these values are higher than 1.0, the designation for that body of water will be more contaminated.

Upstream: GQI = (26/30 + 7.63/8.5 + 730/2700 + 22/- + 61/80 + 45/50) / 6 = 0.74

Downstream: GQI = (26/30 + 7.72/8.5 + 730/2700 + 140/- + 316/80 + 162/50) / 6 = 1.41

A GQI value closer to 1 indicates better water quality.

3. Bacteriological quality

3.1 Well contamination levels

The analysis of total coliforms indeed reveals a significant health impact of the discharges from Oued Beht on the nearby groundwater. These results, complementing the physicochemical study, underscore the importance of taking swift action to address this situation (Table 2).

Table 2. Descriptive statistics of total coliform and fecal coliform (CFU/100ml)

Variable	Observations	Minimum	Maximum	Average	Standard deviation
Total Coliform	6.000	0.000	7.10^4	$6\ .10^4$	423.563
Fecal Coliform	6.000	0.000	11.10^4	5.10^4	4.980

High values of 70,000 CFU/100 ml signify the level of fecal pollution in the groundwater.

- Total coliform concentrations, which are markers of contamination, point to a serious health danger.

Source of the Contamination:

The most likely cause of this high level of microbiological pollution is groundwater seepage and wastewater from Oued Beht. The reason for the hazardous levels of Total Coliforms in the wells is the Oued gets untreated discharges directly from the city of Sidi Slimane.

Health risks: These water are unsafe for human consumption because of the large amount of total coliforms, which are frequently of fecal origin. The inhabitants in the vicinity are also seriously at risk for serious health problems when these waters are used for home purposes.

Management strategies must take into account

- Prior to dumping into Oued Beht, a wastewater treatment system must be established immediately.
- Measures must be taken to clean up the groundwater and keep it from seeping in.
- It is important to conduct routine monitoring of well waters' microbiological purity.

3.2 Fecal coliforms/Total coliforms ratio

The approximate source of the microbial contamination was identified using the following formula:

Fecal Coliforms / Total Coliforms in the Report

Report = 5.104 CFU/100ml / 6.104 CFU/100ml = 0.83 using the data that was provided.

A report with a value close to 1 denotes recent fecal contamination, supporting the theory that Oued Beht wastewater is directly responsible.

3.2 Fecal contamination index

The bacteriological quality index (BQI) is a synthetic index used to assess the general bacteriological quality of river water. The index takes into account four types of water use and the criteria associated with them are raw water supply for drinking purposes, including swimming and water sports; protection of aquatic life; and protection of water bodies against eutrophication.

The concentrations of both total and fecal coliforms are combined in the FCI (Fecal Contamination Index) to generate an overall microbiological quality score.

FCI was calculated as follows:

$$FCI = 100 - \left(0.75\ x\ log10(Total\ Coliforms) + 0.25\ x\ log10\ (Fecal\ Coliforms)\right) \quad (5)$$

FCI = 100 - (0.75 x log10 (6,104) + 0.25 x log10(5,104)) using the provided data.

48.25 is the FCI, or 100 - (0.75 x 4.78 + 0.25 x 4.70).

These waters have extremely low microbiological quality, making them unsafe for home use and inappropriate for ingestion, as shown by the Fecal Contamination Index (FCI), which was calculated as 48.25.

DISCUSSION

The findings indicated that the water temperature in the city of Sidi Slimane varies between 26 and 28°C both upstream and downstream of Oued Beth. The upper limit for direct discharges into the receiving environment is recorded below the critical threshold of 30°C as a maximum value. Moreover, the recorded readings below 30°C are regarded as a boundary value suggestive of water meant for irrigation.

The wastewater at the upstream and downstream sites has an average pH of 7.63 and 7.72, respectively. These readings suggested the pH of the water was fairly neutral. Additionally, the measured values were found in the range of 6.5 to 8.5 as the upper limit for direct discharges.

The wastewater at both the upstream and downstream sites has an average electrical conductivity value ranging from 730 to 2210µS/ cm. Based on the organic and mineral load produced by the urban population, these results show a considerable difference in mineralization between the upstream and downstream locations (Table 1). Moreover, these releases show noticeably greater amounts than comparable research carried out in Sfax (Tunisia). These numbers were still lower than those stated elsewhere.

Furthermore, these wastewater samples were suitable for crop irrigation by comparing the electrical conductivity values of the water between the upstream and downstream stations of Oued Beht in the city of Sidi Slimane with the irrigation water quality standards. Additionally, the average values were recorded as 2700µS/ cm less than the limit for direct discharges.

The analysis of these pollution indices derived from the physicochemical data of Oued Beht provides additional and in-depth insights into the impact of untreated wastewater discharges from the city of Sidi Slimane. The organic pollution index (OPI) clearly demonstrated a significantly higher organic load downstream (228) compared to upstream (41.5), indicating a strong impact from the discharges. The water quality index (WQI) decreases from 82.91 upstream to 52.13 downstream, confirming a significant deterioration in overall water quality due to the discharges. The BOD5/COD ratio, higher downstream (0.44) than upstream (0.36), suggested that organic matter becomes more biodegradable due to wastewater inputs.

Furthermore, the water pollution index (WPI) and general quality index (GQI) reach values of 212.67 and 1.41, respectively, downstream compared to 44.67 and 0.74 upstream, confirming the high pollution caused by direct discharges. These indices collectively indicated a considerable negative impact of untreated effluents on the physicochemical quality of Oued Beht, underscoring the urgent need for implementing wastewater treatment systems before their release into the natural environment.

Total coliforms have traditionally been used as indicators of microbial water quality due to their indirect association with fecal contamination. They are defined as rod-shaped bacteria that can be aerobic or facultative anaerobes and possess the enzyme β-galactosidase, enabling them to hydrolyze lactose at 35°C. The predominant genera included in this group are Citrobacter, Enterobacter, Escherichia, Klebsiella, and Serratia **(Guamri & Belghyti, 2010)**.

With a few rare opportunistic pathogenic bacteria and a few *Escherichia coli* strains, the great majority of species in this group are non-pathogenic and do not directly endanger human health **(Guamri & Belghyti, 2010)**. The primary characteristic that sets these bacteria apart from other enterobacteria is their capacity to ferment lactose.

Fecal coliforms, a subtype of total coliforms, are capable of fermenting lactose at 44.5°C. They are also referred to as thermotolerant coliforms (Table 3). *Escherichia coli* is the species most frequently linked to this group of bacteria, with several species from the genera Citrobacter, Enterobacter, and Klebsiella also being somewhat connected **(Edberg *et al.*, 2000; Jaber *et al.*, 2017)**. Fecal coliforms are typically indicative of fecal contamination, but it is crucial to remember that some coliforms come from sources of organic matter-enriched water, like food processing or industrial effluents from the pulp and paper industry **(Rodier *et al.*, 2009)**.

In fact, calling them "fecal coliforms" is not as appropriate as calling them "thermotolerant coliforms" **(Lotfi *et al.*, 2020b)**. Both people's and animals' intestines contain bacteria called thermotolerant coliforms, and their presence in water can signal recent or close contamination in terms of both time and space. Thermotolerant coliforms are less resistant to water than fecal streptococci. Their discovery in water may indicate the existence of more diseases, which may be more hazardous but more difficult to identify.

It is important to remember that the presence of thermotolerant coliform bacteria does not always mean that the bacteria are dangerous; rather, it suggests that there may be microbiological contamination. This paper presented the findings of an analysis of thermotolerant coliform bacteria found in water. These data may be used to assess potential health risks associated with water consumption and provide information on the microbiological quality of the water **(Jaber *et al.*, 2017)**.

Poor bacteriological quality, which confirms substantial health hazards, is indicated by an IQB below 60. Given these concerning findings, immediate action must be taken to treat wastewater before discharge, shield groundwater from contaminated infiltrations, and maintain routine water quality monitoring. In order to successfully minimize the long-term environmental and health effects of discharges from the city of Sidi Slimane into Oued Beht and the groundwater, a suitable depollution system must be established.

CONCLUSION

Comprehensive analysis of Oued Beht's physicochemical and microbiological quality, as well as the surrounding groundwater, revealed the main detrimental effects of Sidi Slimane untreated wastewater discharges. The physicochemical parameter investigation showed that the water quality of Oued had significantly declined downstream of the discharges. The organic load has increased noticeably, the water quality index has decreased, and multiple parameters of discharge standards have been exceeded. According to these findings, the waters from the two study stations upstream and downstream are between "poor" and "very poor" in quality, which could have negative effects on the aquatic ecosystem and its users. Massive fecal pollution of the groundwater has also been brought to light by the analysis of bacteriological contamination indicators, particularly for the wells downstream of the Oued. The report, being near to 1, along with the high amounts of both total and fecal coliforms, points to recent fecal contamination that is probably related to wastewater infiltration. The very low bacteriological quality index confirms that these waters are unfit for consumption and dangerous for domestic use.

Given these alarming results, urgent measures are necessary to treat wastewater before discharge, protect the aquifer from polluted infiltrations, and ensure regular monitoring. Establishing an adequate depollution system is an absolute priority to effectively limit the environmental and health impact of Sidi Slimane discharges on Oued Beht and the groundwater in the long term.

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