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Effect of the Depollution Project on The Physico-Chemical and Bacteriological Quality of Rabat's Coastal Waters

Youssef Idrissi[1*], Soraya EL Hamdouni[1], Essediya Cherkaoui[1], Mohamed Khamar[1], Abderrahman Nounah[1]

[1] Civil Engineering and Environment Laboratory (LGCE), Materials, Water and Environment Team, Higher School of Technology of Sale, Mohammed V University in Rabat, Morocco

* Corresponding author's e-mail: idrissi.job1@gmail.com

ABSTRACT

Morocco's Atlantic coast, faces significant anthropogenic disturbances, leading to pollution in its waters used for various purposes. The primary objective of this study is to shed light on how the depollution project, a crucial part of the Bouregreg valley development plan, has influenced the coastal area of the city. This has been achieved through a comprehensive analysis of the water quality, focusing on both physico-chemical characteristics and bacteriological aspects. Thirteen specific physico-chemical parameters and fecal pollution indicators were meticulously monitored along the coastline. The goal was to gain insights into how water quality has changed over time and across different locations. The results of this investigation have revealed the substantial impact of the Wastewater Treatment Plant (WWTP) on the area, with varying degrees of efficiency observed, such as 63.04% for turbidity, 52.21% for BOD_5, and 40% for organic matter.

Keywords: coastline, waste water treatment plant, wastewater, littoral

INTRODUCTION

The problem at hand is the urgent need for Moroccan authorities to address the significant discharge of untreated wastewater. This issue is driven by key factors, including the need to adopt solutions used in other countries (United Nations World Water Assessment Programme, 2017), increased wastewater production due to population growth and changing lifestyles (El Haite H, 2016), and the potential health and environmental risks associated with untreated domestic wastewater, containing pathogens like bacteria, viruses, and protozoa (Bonetta et al., 2022). Neglecting wastewater treatment (Ziliotto et al., 2023), can harm ecosystems and human well-being, (Ouro-Sama et al., 2014).

In response to coastline pollution, the "Rabat city of light, Morocco's capital of culture" program (Oualalou F, 2019) initiated coastline depollution project, a vital component of the Bouregreg valley development project (Mouloudi H., 2009), and The national program for liquid and wastewater purification (PNA) (Mohamed et al., 2018). This involved intercepting discharges and installing pumping stations. Now, all domestic wastewater undergoes treatment at the pre-treatment station before being released into the ocean via a 2 km Rabat-side outfall (Ait hmeid H., 2015). This plant serves as a key environmental mechanism, ensuring compliance with standards, enhancing the Atlantic coastline and Bouregreg estuary's value, and improving bathing water quality (CID consulting, engineering and development, 2017). The treatment system relies on a wastewater pre-treatment plant with a 6 m^3/s capacity (2013) (CID consulting, engineering and development, 2017). The primary objective of this research is to assess the impact of the WWTP on the ocean water quality in the surrounding area.

MATERIALS AND METHODS

Study zone

The city of Rabat is located on the Atlantic coast with an area of 118.5 km² in northwest Morocco, 40 km south of Kénitra and 87 km northeast of Casablanca (Oualalou F., 2019). The Rabat prefecture is made up of two communes: Touarga and Rabat. The Rabat prefecture is the densest in the Conurbation, with an average density of 54 inhabitants per hectare, and an urbanization rate of 100%. Rabat's population declined between 2004 and 2014 (General Directorate of Local Authorities, Minister of the Interior. 2015). The slowdown in population growth can be explained by (Planning High Commission, Kingdom of Morocco. 2014):

- a positive natural balance despite falling fertility,
- a net migration deficit.

The city's climate is Mediterranean, with four distinct seasons. Winters are cool and rainy, with night-time lows that can dip below 5°C, or even reach 0°C, and pleasant days of around 17°C. Frosts are relatively rare. Summers are very hot, with temperatures sometimes exceeding 35°C. On the other hand, nights are always cool, and the humidity of the ocean air is clearly felt (Oualalou F., 2019).

The city belongs to the sub-humid bioclimatic domain, and the average annual rainfall is 555 mm (Oualalou F. 2019). Annual sunshine duration is 2916 hours, while average annual precipitation is 76 days, concentrated between October and April. Snowfall is rare (Oualalou F., 2019). In the study area, the coastline is subject to significant pressure and degradation due to socio-economic activities (National laboratory for pollution studies and monitoring, 2021 & 2023). The discharge of domestic and industrial waste directly into the sea was without any prior treatment, resulting in coastal degradation, and there were six discharge points spread along the coastal zone (Mansoum et al., 2016) (Fig. 1).

Generally speaking, surface water, soil, and groundwater are polluted when untreated wastewater is discharged into the environment. The quality (and therefore availability) of freshwater supplies can be affected by the diluted wastewater that is discharged into aquatic receiving environments (sea, wadi, and lake). (Joshua N et al., 2017). The consequences can be classified into three categories (CID consulting, engineering and development 2017):

- reduced water quality has negative health effects,
- degradation of water resources and ecosystems has caused negative environmental effects,
- economic activities could be affected in a potential manner.

Sampling

To assess the physico-chemical and bacteriological quality of Rabat's coastal waters, we designated three sampling sites. Samples were collected throughout all four seasons over the course of one year (Autumn-Winter 2021/

Figure 1. Wastewater discharges along the Rabat coastline

Spring-Summer 2022), as well as prior to the construction of the WWPT in 2013. The choice of sampling sites was based on factors such as accessibility, ease of sampling, and the proximity of these stations to previously identified sources of pollution. The three sites selected were: (Fig. 2)

- R1: opposite the L'OCEAN district, near the CHOUHADA cemetery,
- R2: opposite the YACOUB-EL MANSOUR neighborhood,
- R3: opposite the HAY-FATH district.

The above parameters were determined according to the methodology given in the study (Rodier et al., 2009) (Table 1).

The measurement of trace metals (Cd, Cr, Cu, Fe, and Pb) in raw wastewater is done at the Centre National de la Recherche Scientifique et Technique (CNRST) in Rabat.

However, the study of bacteriological water quality in the coastal zone concentrated on the determination and quantification of faecal coliforms (FC) and faecal streptococci (FS), as they are recognized as indicators of recent fecal contamination and facilitate the identification of the source and origin of pollution (Chahouri A., 2021).

Enumeration of these bacteriological parameters was carried out using the MPN (most probable number) method, in which a series of tubes containing selective media for CF and SF were inoculated with appropriate decimal dilutions of the sample to be analyzed (Karioun M.A., 2021).

Statistical analysis

To study the evolution of different parameters over space (along the coastline) and time (in different seasons). A statistical study was carried out using SPSS (Statistical Package for the Social Sciences). The results were analyzed using PCA principal components analysis and ANOVA at 5% where the statistical difference was significant, and a comparison of multiple averages was carried out using Tukey's test.

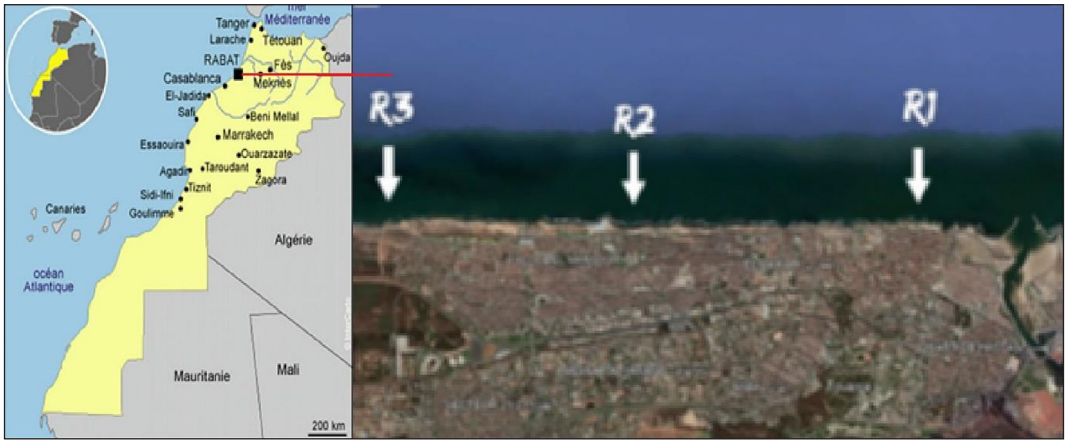

Figure 2. Sampling station locations

Table 1. Equipment used to measure physicochemical parameters

Parameters	Equipment used to measure
Temperature	206 Lutron pH meter fitted with a temperature probe
pH	
Electrical conductivity	WTW LF90 conductivity meter
Turbidity	HACH 21009 turbidity meter
Suspended solids	Filtration a volume of wastewater on a cellulose filter (0.45 microns)
COD	Oxidation, in an acid medium with an excess of potassium dichromate at a temperature of 148°C, of oxidizable matter under the conditions of the dosage in the presence of silver sulfate as catalyst and mercury sulfate as complexing agent.
BOD_5	Respiratory method using a WTW OxiTop BOD
Ortho-phosphates	Colorimetric phosphomolybdic complex method
Nitrates	Spectrophotometric method (sodium salicylate), while chlorides are measured using Mohr's method

RESULTS AND DISCUSSION

Using ANOVA to better analyze the average of the various parameters measured after the implementation of the WWTP (2021/2022), we observe that these values are statistically significant (Sig < 0.05) due to the climatic conditions related to the season (Transboundary diagnostic analysis of the Canary Current Large Marine Ecosystem, 2016) and also to the cyclic variation of sea levels (Boudet L., 2017) (Fig. 3). Except for organic matter (F=1,387; Sig=0,315), turbidity (F=1,152; Sig=0,386), orthophosphates (F=1,131; Sig=0,393) and nitrates (F=2,554;

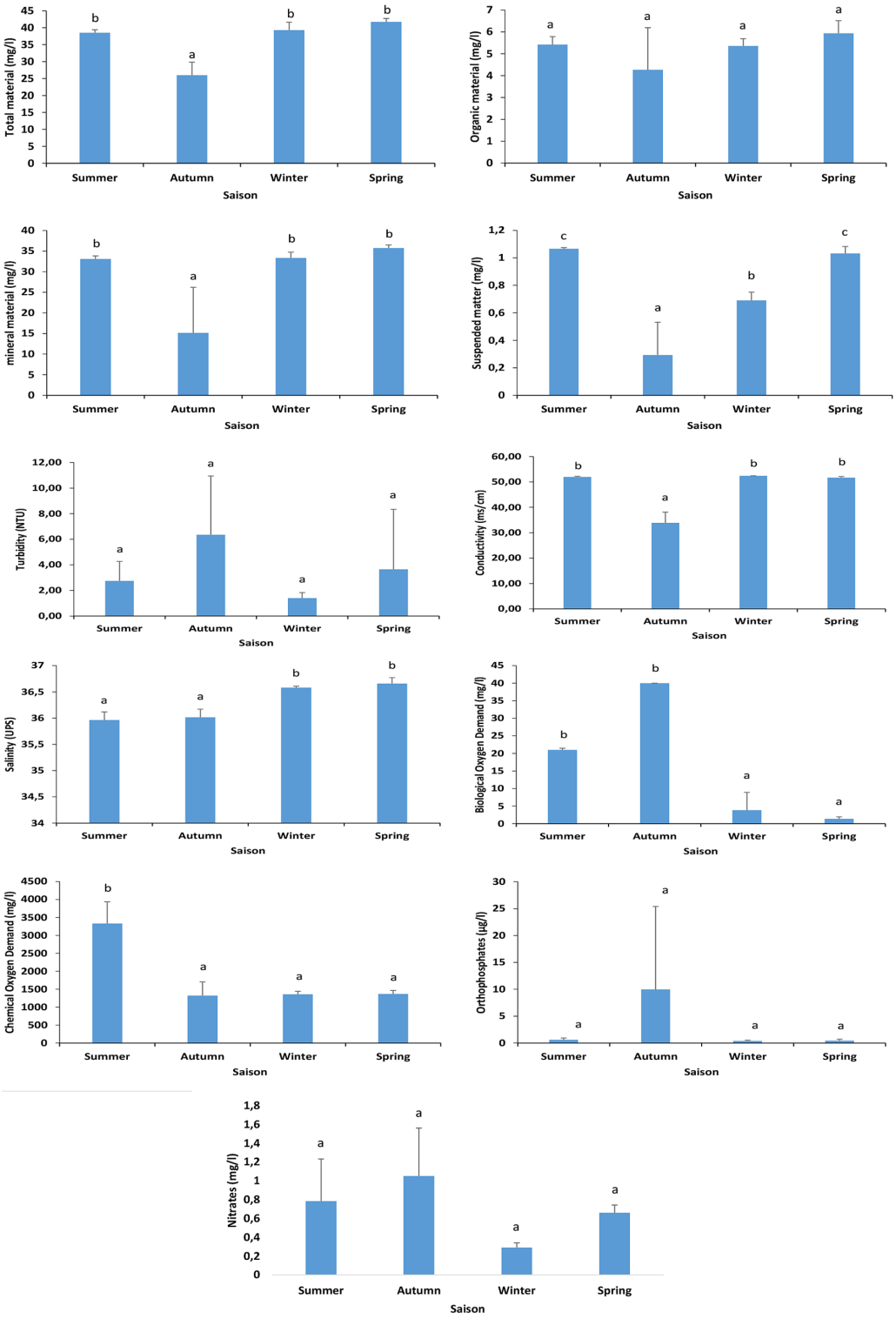

Figure 3. Seasonal trends in averages for various physico-chemical parameters (2021/2022)

Sig=0,129), these parameters are more impacted by the composition of wastewater discharged previously (Kanbouchi et al., 2014).

The difference in station averages for the various parameters is statistically insignificant (Sig > 0.05) with a factor of 0.05 < F < 1.244. This can be interpreted by the fact that the difference between the concentrations of the various characteristics along the city's Littoral is negligible, which is explained by the effect of the WWTP on the quality of the littoral waters, given that previously the concentration of several elements varied from one station to another while depending on their proximity to the liquid discharges (Drissi A., 2012).

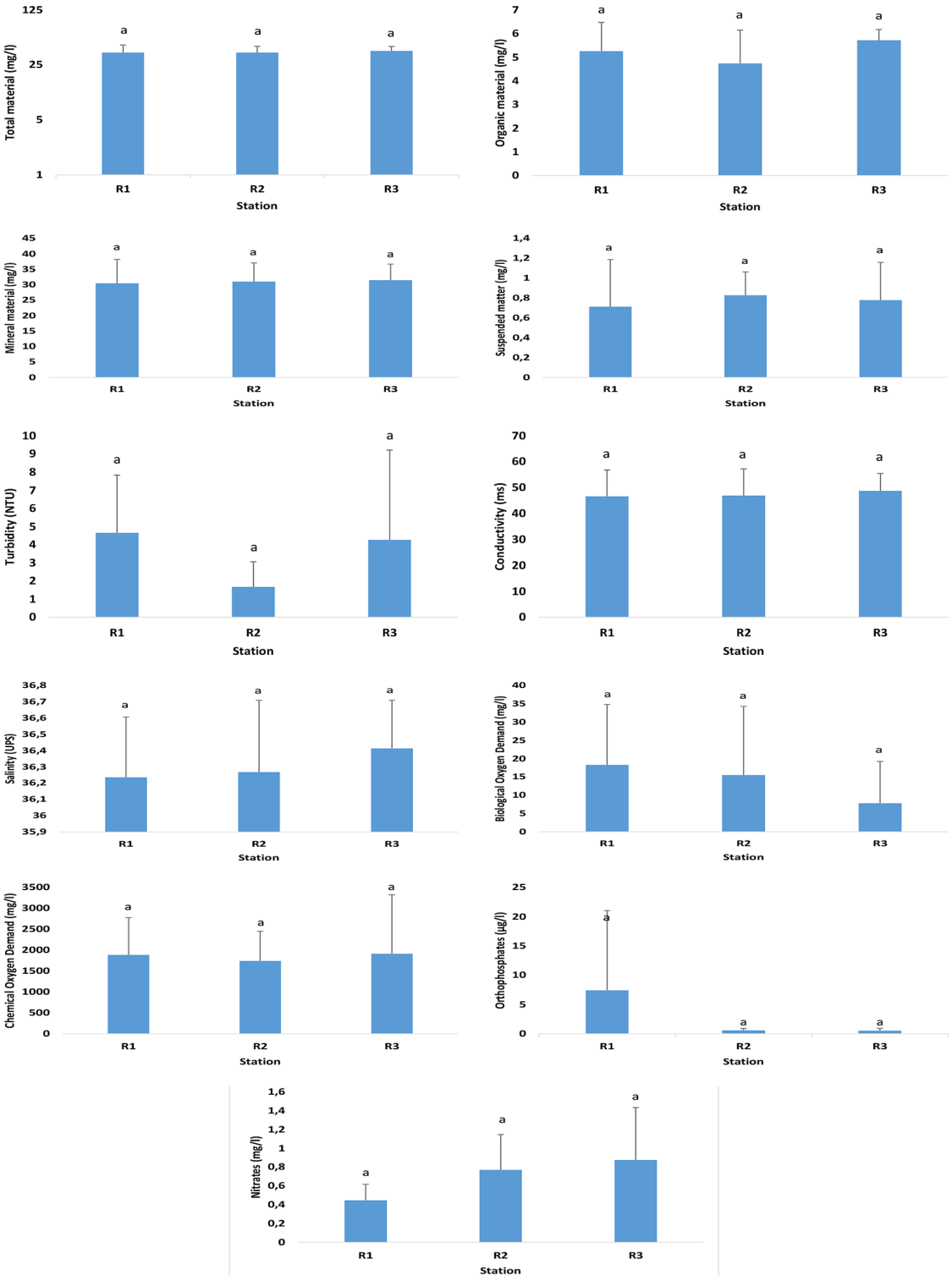

Figure 4. Trends in averages for various physico-chemical parameters by site (2021/2022)

At bacteriological level, we note that the evolution of fecal coliforms and fecal streptococci are (indicators of fecal pollution) according to season is significant, however, depending on the site, the difference is not significant (0.743<Sig<0.930; 0.073<F<0.308) (Fig. 4). The measured values of fecal pollution indicators at the sites studied show a trend that is not significant, with a maximum average value for fecal coliforms at R3 = 1.2 10^9 CF/ml and a minimum average value at R1= 6.15 10^8 CF/ml.

Fecal Streptococci have a maximum average value at R2 = 1,10^5 SF/ml and a minimum average value at R1= 2.3 10^4 SF/ml. The evolution of fecal pollution indicators in our study by season shows a highly significant difference, with a maximum recorded value for fecal coliforms in Spring (2.3 10^9 CF/ml) and a minimum value in Winter (1.3 10^5 CF/ml). On the other hand, for fecal streptococci, a maximum value of (2 10^5 SF/ml) and a minimum value of (34 SF/ml). Coastal waters contain certain heavy metal elements in fairly low concentrations, ranging from Mn = 0.015 mg/l to Zn = 0.2 mg/l (Fig. 5).

To assess the impact of the WWTP, we chose to compare the averages with studies conducted before the WWTP's operation (2013) done by Materials, Water and Environment Team (LGCE), which utilized the same sampling stations and employed the same methods. We note that at the time, the difference between the averages of the concentrations of the various physicochemical elements was not significant, except for that of organic matter (Sig <0.05).

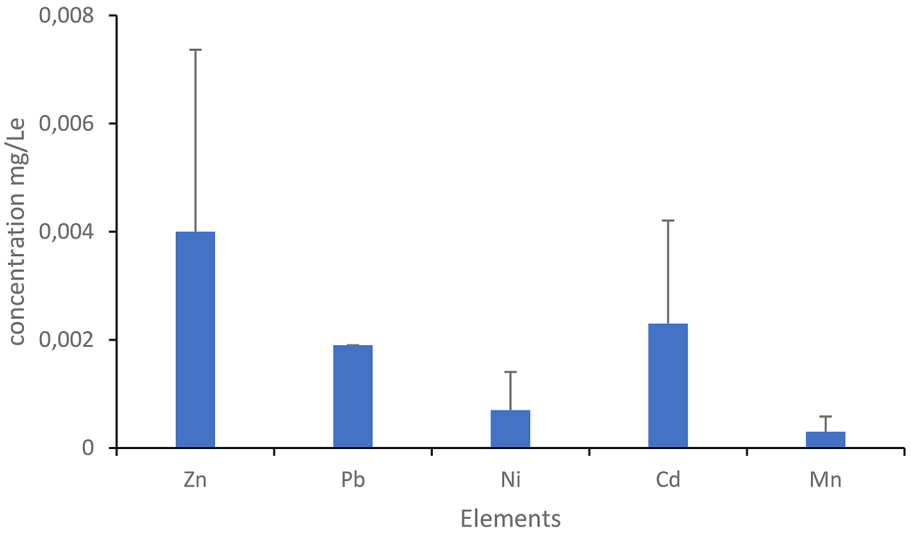

Figure 5. Metallic element concentrations

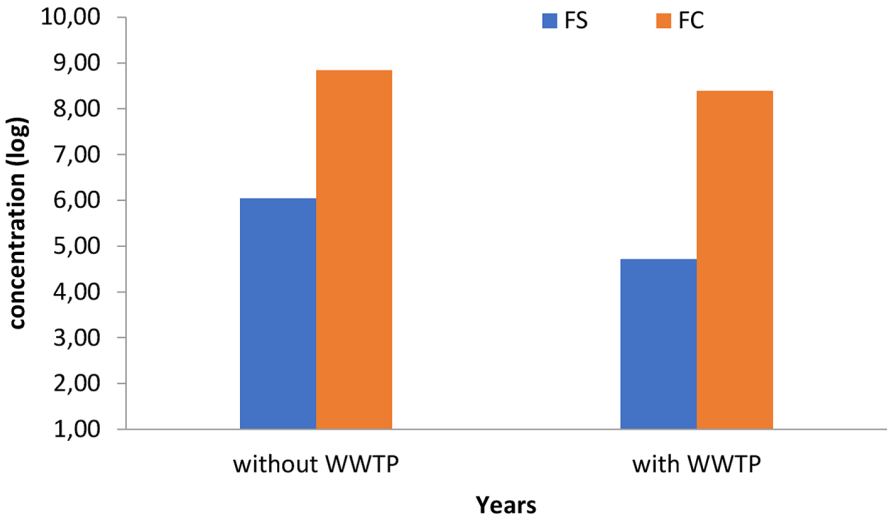

Figure 6. Trends in average fecal pollution indicators with and without WWTP

Table 2. Comparison of some physicochemical elements before and after the start of WWTP

Parameters	2013/14			Average	2021/22			Average	Effeciency ratio
	R1	R2	R3		R1	R2	R3		
pH	7.78	8.195	8.14	8.038	7.485	7.5725	7.705	7.588	5.61%
Turbidity NTU	8.8	5.34	14.55	9.563	4.6575	1.675	4.27	3.534	63.04%
Conductivity ms	53.58	54.525	55.425	54.510	46.65	46.925	48.79	47.455	12.94%
Orthophosphates µg/l	3.325	3.85	2.625	3.267	7.428075	0.5989	0.5371	2.855	12.61%
BOD mg/l	30	35	30	31.667	18.3	15.5	11.6	15.133	52.21%
Total matter mg/l	39.621	40.041	40.949	40.204	35.72688	35.74125	37.5875	36.352	9.58%
Organic matter mg/l	14.666	6.113	5.674	8.818	5.265	4.74375	5.72875	5.246	40.51%

The averages of the various parameters measured before the WWTP show a variation between sites, which can be justified by the fact that the values are impacted by the existence of liquid discharges and the degree of toxicity of the latter. On the other hand, the averages of the values after the WWTP show a stability along the coastline. The installation of the pre-treatment plant has had a positive impact on most physicochemical and bacteriological parameters. Efficiency levels vary between 63.04% for turbidity, 52.21% for BOD_5 and 40% for organic matter. With regard to fecal pollution indicators, there was a slight decrease in FC and FS. (Fig. 6)

CONCLUSIONS

The negative impact on the physico-chemical properties of the marine environment, such as water clarity, dissolved oxygen levels disrupt the delicate balance of the ecosystem. These disruptions can lead to the decline of marine life, affecting fisheries, tourism, and recreational activities along Rabat's coastline. Furthermore, the presence of pathogenic microorganisms in the wastewater raises public health concerns, potentially leading to related healthcare costs.

Despite not yet reflecting a complete transformation, the depollution efforts have shown a discernible positive trend over a decade. The once-polluted coastal waters have demonstrated signs of improvement, a testament to the project's effectiveness and authorities' commitment. These initial enhancements signify a critical step in the right direction,

Moreover, incorporating secondary and tertiary treatment processes elevates wastewater purification to an advanced level. These stages frequently employ specialized technologies like advanced oxidation or membrane filtration, capable of eliminating even minute contaminant traces. This rigorous approach to wastewater treatment not only demonstrates environmental responsibility but also guarantees the highest quality standards for potential reuse, effectively reducing health and environmental hazards.

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