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Impact of Environmental Pollution on Wetlands: A Case Study - Polluted Water of the Merja of Fouarat; A Model

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ABSTRACT

Wetlands are crucial for biodiversity and are highly productive ecosystems, as they involve a variety of biological and non-biological factors in their functioning. Understanding these systems requires, in addition to other characteristics, a physical and chemical description of their waters, as well as an analysis of the specific structure of the species inhabiting these environments. This study focused on describing the marshy waters of Merja of Fouarat, which is registered under the Ramsar Convention. The lake consists of three parts, each varying in size and flood duration. The results revealed that the organic pollution index for this environment is very high. Based on these findings, the researchers recommended the preservation of the area due to its significant ecological and environmental importance.

INTRODUCTION

Wetlands are considered one of the natural resources that effectively contribute to meeting many present needs and achieving future challenges **(Were *et al.*, 2019; Slim, 2021)**, necessitating their maintenance, development, and rational investment for the benefit of social, economic, and environmental balances in service of sustainable development. The reality of wetlands in Morocco poses many challenges that intensify with the continued threats to this resource **(Rachid & Hafid, 2024)**. Merja of Fouarat is one of the wetlands abundant in Morocco in general, and the Western region in particular. It is considered one of the ecologically and biologically important wetlands **(Lahrouz *et al.*, 2011)**, classified on the list of ecologically important wetlands globally. In addition to its strategic location and ecological significance, Merja of Fouarat is a pillar of local development **(Slim *et al.*, 2023)**.

The Merja of Fouarat is a wetland area with a width ranging between 100

and 200 meters, and the submerged area is estimated at about 502,00 hectares, which is less than half of what it was about half a century ago **(Lahrouz *et al.*, 2011)**. In addition to the Sidi Bougaba Lake Reserve and the Merja Zerga, the springs reserve is another witness to the freshwater wetlands along the Atlantic coast of the Kingdom of Morocco. Most of them have been subjected to drying out due to natural factors such as consecutive periods of drought or human factors such as the construction of dams on some of the valleys that were their main source, or their use as land for the cement expansion of the neighboring cities **(Lahrouz *et al.*, 2011)**.

Furthermore, the area of Marjat of Fouarat is located within the region of Kenitra, known for a suitable climate but characterized by disturbances resulting from the Mediterranean climate, which is subject to the influence of humid and dry desertic maritime factors. This has made the region of Kenitra distinguished by the presence of two contrasting seasons: a humid and rainy season characterized by low temperatures and an increase in precipitation, extending from the end of the autumn season to the beginning of the spring season, and a hot and dry season characterized by high temperatures and little to no precipitation, coinciding with the beginning of June and continuing until the end of September **(Dadoun, 2012)**.

In terms of vegetation, the Fouarat region is characterized by the presence of Eucalyptus trees. The region is home to seventeen types of aquatic plants, seven of which are considered rare to very rare in Morocco **(Hammada *et al.*, 2004)**. The area also supports significant animal biodiversity and serves as an important breeding site for migratory birds and fish, including species at risk of extinction, such as the European eel (*Anguilla anguilla*).

As for ecological importance, the Merja of Fouarat is considered a haven for continental and migratory birds, some of which are very rare or threatened with extinction. The marsh is considered a habitat for bird nesting, a winter refuge, and a resting place for 57 species of birds **(Lahrouz *et al.*, 2011)**. Due to its strategic location as a hub for bird migration, the Fouarat marsh has been a significant sanctuary for thousands of migratory birds during the winter, where they find suitable conditions for resting and breeding at times, making it a wetland area of biological and ecological importance since 1996, according to the classification of the High Commission for Water, Forests, and Combating Desertification. It was also classified within the Ramsar list in 2018.

However, reducing the area by drying its water for tourism development has resulted in a reduction in the water volume in the area. Similarly, unsustainable agriculture, water extraction, as well as untreated liquid and solid waste disposed of by neighboring industrial companies, have polluted the waters of Merja of Fouarat.

As a result, and despite its ecological importance, the waters of Merja of Fouarat are still being polluted, which necessitates the intervention of responsible authorities to protect them. Thus, the objective of this work was to evaluate the pollution status of the waters of the Merja of Fouarat, according to the organic pollution index.

MATERIALS AND METHODS

- **Geographic location**

The Merja of Fouarat is located in the northeast of the city of Kenitra, between the longitudes 34°14'51"N and 06°31'33"W. It is bordered to the south by residential neighborhoods, and to the north by the neighborhoods of Essam, Al-Bustan, Al-Hajj Mansour, and the rural communities of Fouarat, as it has become surrounded by the urban center of the city of Kenitra from all sides.

- Physical and chemical description of the spatial change in water quality in the Merja of Fouarat.

1. Selection of study sample

The description of the studied aquatic environment focused on 7 stations (S1, S2, S3, S4, S5, S6 and S7) distributed to cover the main heterogeneity of the environment (Fig. 1). The choice of these stations took into account the duration of the impoundment of the site, the abundance of its aquatic vegetation, its depth, and the apparent degree of water salinity. Thus, the 7 selected stations belong to various hydrological facies such as fresh water, salt water, temporary water, and permanent water, and this was done during the period from March 15 to June 20, 2023.

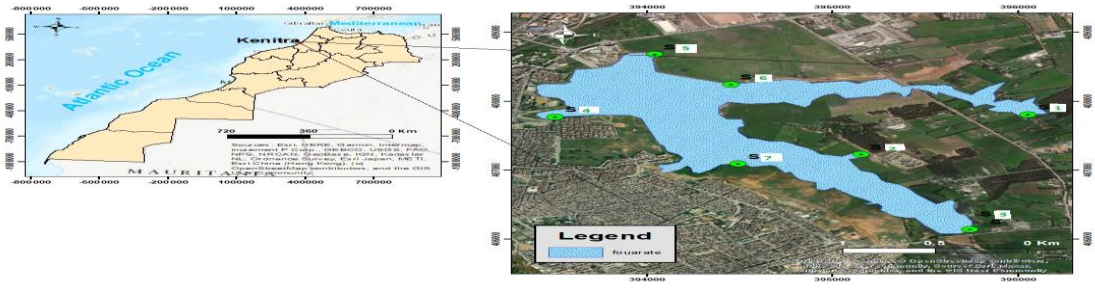

Fig. 1. Geographical location of Merja of Fouarat study sample **(Slim *et al.*, 2023)**

2. Study tools

At each of the stations studied, the 7 physico-chemical parameters, namely temperature, acidity, conductivity, chloride, nitrate, ammonium, and biological

oxygen demand were measured using electronic equipment or by volumetry. The water temperature was measured with a mercury thermometer graduated in tenths of a degree Celsius. The pH was measured using an Orion Research, Ionalyser model 607 pH meter with an Orion pH 91-05 specific electrode. Additionally, conductivity was measured using a conductivity meter. The biological oxygen demand was measured using a BOD meter. A volume of water corresponding to the estimated range of BOD5 in relation to the COD of the same sample was poured into a brown glass flask containing a magnetic stir bar. Two pellets of caustic soda (NaOH) were then added to the rubber stopper. The caustic soda serves to absorb the CO2 produced during the oxidation of organic matter. The amount of oxygen is recorded every 24 hours by the OxiTop^{R} over a period of 5 days. The BOD5 expressed in mg O2/l was obtained by multiplying the recorded value on day 5 by a factor determined according to the range of COD.

The parameters such as ammonium ions, nitrates, and nitrites were measured by photometry using the Palin Test DR 7500 Photometer, with pre-dosed reagents.

The **Leclercq (2001)** method was used to determine the water trophic index and its classification, and the Excel program was used to process and analyze field and statistical data.

3. The organic pollution index (IPO)

The organic pollution index (IPO) was defined by **Leclercq (2001)** as the average sum of the organic variable species present in the water. Table (1) shows the concentration ratio of each variable. (mg/l).

Table 1. Water organic pollution index (IPO) **(Leclercq, 2001)**

Variable **Class**	**DBO5 (mg/l)**	**NH4+ (mg/l)**	**NO3- (mg/l)**	**IPO quality class**
5	< 2	< 0.1	0.005	4,6 - 5,0
4	2 – 5	0.1– 0.9	0.006 – 0.01	4,0 - 4,5
3	5.1 – 10	1–2.4	0.011 – 0.05	3,0 - 3,9
2	10.1 – 15	2.5 – 6.0	0.051 – 0.15	2,0 - 2,9
1	> 15	> 6	> 0.15	1,0 - 1,9

(5) No organic pollution, (4) low organic pollution, (3) moderate organic pollution, (2) high organic pollution, (1) very high organic pollution.

RESULTS

1. The spatial change data for the physicochemical variables of the water at the studied stations

The analysis of the Fig. (2) shows that there was a varying difference in the depth of the marsh water from one station to another, reaching a maximum of 250 centimeters at the seventh station, which is a permanent station, and a minimum of 45 centimeters at the first station, which is a temporary station, while it changes to varying degrees at the remaining stations.

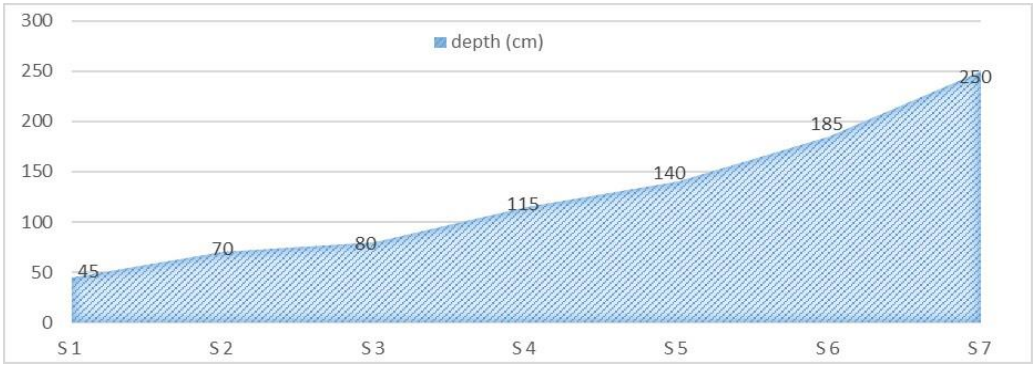

Fig. 2. Changes in the depth of the studied stations water

Regarding the studied water temperature element (Fig. 3), the statement shows the rate of changes in the water temperature according to the studied stations. The results show that the highest average temperatures range between 26.4 and 30.9°C, with the highest value at the first station and the lowest at the fifth station. The lowest temperatures range between 11.9 and 13.2°C, with the highest at the first station and the lowest at the seventh station.

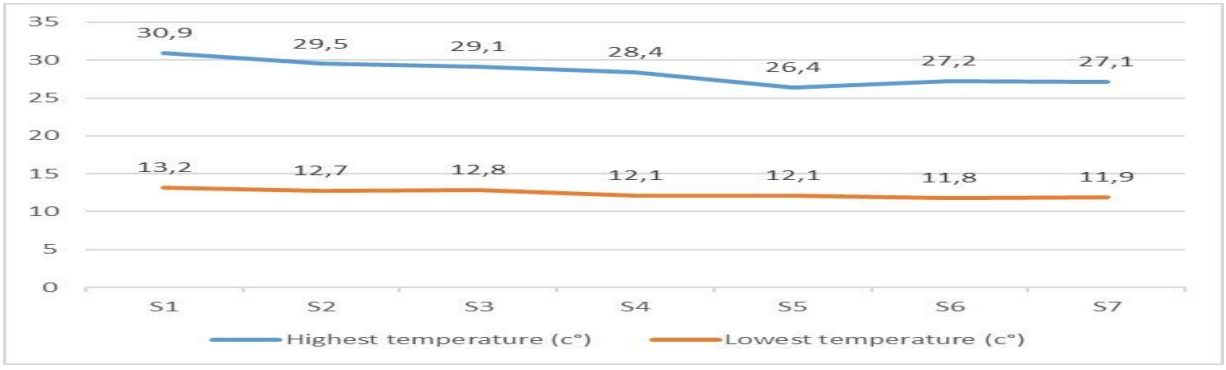

Fig. 3. Changes in the temperature of the water at the studied stations

- **The acidity of water or the hydrogen ion concentration pH**

The data clearly show that the pH values of the water in the studied area are slightly alkaline, ranging from 7.2 to 8.2. The highest pH value was recorded at the fifth station, while the lowest was observed at the third station (Fig. 4). This measurement helps estimate the strength of water's acidity or alkalinity by determining the concentration of hydrogen ions present in the water.

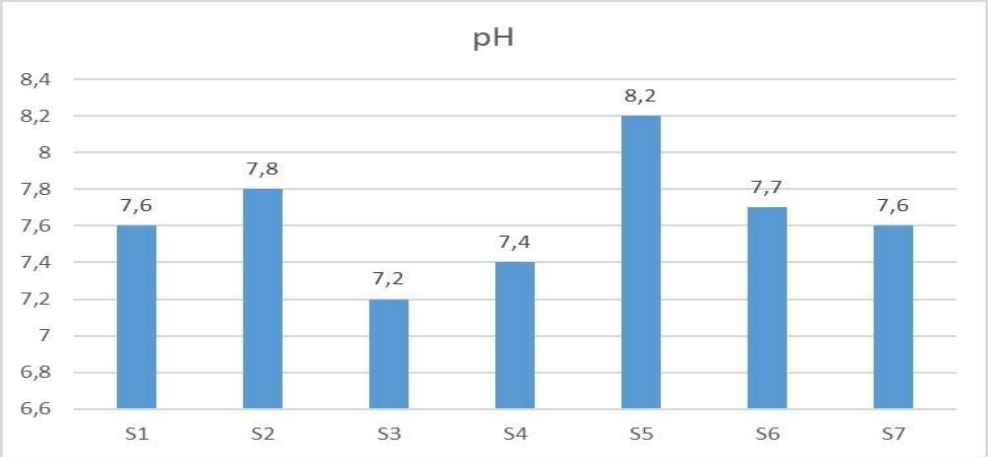

Fig. 4. Changes in the pH of the water at the studied stations

The electrical conductivity, as indicated by the data, reaches its maximum at the fifth station, followed by first station, while it is lower in the other areas (Fig. 5). Higher conductivity values indicate a higher salinity level in the water, which results from the dissolution of salts in the water.

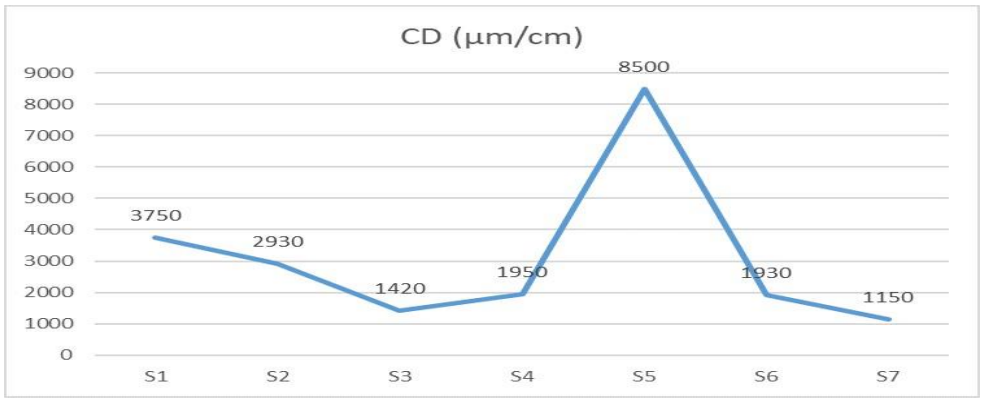

Fig. 5. Changes in the conductivity of water at the studied stations

Through the analysis of the data, it is noticeable that the rate of changes for both nitrate and ammonium remained very low in the water levels of all studied areas, while it was very high for chloride and biological oxygen demand, reaching its maximum for the fifth area (Fig. 6).

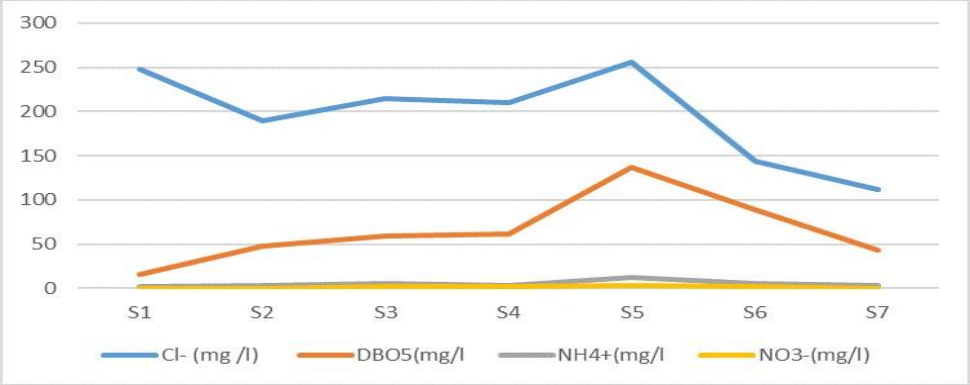

Fig. 6. Variations of chloride, nitrate, ammonium, and biological oxygen demand in the water of the studied stations

- **The organic index of the water in the studied area**

Table (2) shows the value of the organic trinity index for the water of the studied areas, as the research results showed that the organic trinity index in the water samples of the third area was high (IPO = 2), while it was also high at the first, second, fourth, fifth, sixth, and seventh areas, ranging between 1 and 1.66.

Table 2. Organic trinity index for the water of the studied areas

Station	The variable and its classification							
	DBO5 (mg/l)	Class	NH4+ (mg/l)	Class	NO3- (mg/l)	Class	Pollution index IPO	The meaning of the pollution index
S1	15,88	1	1,87	3	0,5	1	1,66	Very high
S2	47,22	1	3,58	2	0,1	2	1,66	Very high
S3	59,62	1	5,62	4	1,95	1	2	high
S4	61,45	1	2,64	2	1,83	1	1,33	Very high
S5	136,6	1	12,1	1	2,6	1	1	Very high
S6	88,64	1	5,56	2	2,1	1	1,33	Very high
S7	43,71	1	3,62	2	0,15	2	1,66	Very high

DISCUSSION

Several factors intersect, including natural ones such as climate changes, including temperature rise and consecutive years of drought **(Stern, 2007; Loudière & Gourbesville, 2020)**, on one hand, and human factors **(El Guamri, 2009)** on the other, such as reducing the area, and discharging untreated domestic, industrial, and agricultural solid and liquid waste, leading to the deterioration of the water quality of the Merja of Fouarat. This represents one of the environmental impacts suffered by these wetlands. In this context, the results of this research showed that the physical characteristics of the water of the studied stations, related to temperature, vary from one station to another, given that the stability of the temperature is an important factor in maintaining the ecological balance and the continuity of the life of living organisms **(Kovaleva, 2023; Ugureanu, 2023)**. Thus, any sudden change in temperature leads to an imbalance in aquatic ecological systems **(Haddad & Ghoualem, 2014)**.

On the other hand, water temperature is among the important environmental factors that increase the viscosity and solubility of gases in water, as well as the breakdown of soluble salts **(Ershadnia *et al*., 2023)**. It also contributes to chemical reactions and the development and growth of aquatic organisms **(Makhoukh *et al*., 2011)**.

Furthermore, the results of the chemical analysis of the water from the studied stations varied from one station to another. The acidity level of the stagnant water is all basic but with different values, reaching its maximum at the fifth station with a value of 8.2 and its minimum at the third station with a value of 7.2. This is attributed to the origin of the water in the area. In general, the modification of water acidity is associated with the loss of carbon dioxide. It is also worth noting that the pH value is an indication of the solubility of organic matter in water **(Slim, 2021)**.

As the same results showed, an extreme diverse difference was detected in the concentrations of dissolved substances, as the research results showed that the nitrate values were deemly weak in all samples, ranging from 0.05mg/ L recorded at the first station to 1.95mg/ L recorded at the third station. This is the result of the oxidative bacterial breakdown of organic matter on the one hand, and the result of compound agricultural fertilizers on the other, as it is considered a contributing factor to the deterioration of water quality **(Chapman & Kimstach, 1996)**. Additionally, the values of ammonium concentration ranged from 1.87mg/ L at the first station to 12.1ml/ L at the fifth station.

Natural water or wastewater always contains ammonia, which is a biodegradable natural product of organic ammonium (proteins, amino acids, etc.). However, the ammonium content in natural water should be relatively low

because ammonia oxidizes to nitrite and nitrate **(Bouamrane, 2008)**. On the contrary, research results have shown a very significant increase in the concentration of chloride ions compared to nitrate and ammonium. The maximum was reached at station five with a value of 256mg/ l, and the minimum was at station seven with a value of 112mg/ l. This can be explained by the presence of chloride ions in natural water abundantly in the form of mineral salts, such as sodium chloride (NaCl) and potassium chloride (KCl) **(Lakhili *et al*., 2015)**.

From another perspective, the measurement of biological oxygen demand allows for the assessment of the content of biodegradable organic matter in water, and therefore, to some extent, its quantity or degree of pollution **(Lakhili *et al*., 2015)**. The research results showed that the biological oxygen demand ratio over 5 days was low at the first station at a rate of 15.88mg/ l and high at the fifth station at a rate of 136.6mg/ l. This can be interpreted as the oxidation of biodegradable compounds by microorganisms leading to oxygen consumption, or due to seasonal factors **(Rabeea *et al*., 2020)**. Therefore, the environment exerts a specific biological-chemical demand on oxygen **(Lakhili *et al*., 2015)**.

As the results of this research showed that the organic pollution index for the studied water samples falls within the category of very high pollution. This is due to the untreated liquid and solid waste discharged by the neighboring population **(EL Guamri *et al*., 2007; Chahboune *et al*., 2012)**, which includes the areas of Mekhalef, Wafaa, Oulad Arefa, Haj Mansour, Amal, Rahma, Rabie, Sakania, Dyour El Shaabi, and Essam, as well as the adjacent industrial units, namely: the Setexam industrial unit for industrial products, the Mafaco industrial unit for textile manufacturing, the CMCP industrial unit for paper manufacturing, concrete factories, chemical and semi-chemical product factories, liquid fuel stations, and vehicle washing/lubrication stations **(El Guamri. 2003)**. The pollution index reached category 1, but the pollution index recorded an increase compared to the results of studies conducted by **Fadli (2000)**, **Houssaini (2005)** and **Rai (2012)**.

In comparison between the quality of the water of the Marja of Fouarat and Oued Sebou, it is evident that the water of the two regions is classified as highly polluted, as the average pollution index for the water of the Marja stations is 1.52 and 1 for the water of the Oued Sebou stations, as confirmed by the study of **Ouzemri (2021)**.

CONCLUSION

The Merja of Fouarat remains a wetland and an ecological system at risk of imbalance due to various factors, including climate change, such as rising temperatures and decreased precipitation. While these natural factors contribute to the deterioration of the marshland, they can be mitigated through natural renewal processes. However, human activities are the primary drivers of the ecosystem's decline. The water level in the Merja has decreased due to water drainage and its conversion into cement structures. The remaining water is experiencing a significant rise in salinity, exacerbated by pollution from solid, liquid, and gaseous waste. Ultimately, humans, who are a part of nature, have become both its adversary and their own.

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