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Assessment of the physicochemical and bacteriological quality of oueds Fez and Sebou downstream of Fez after the launch of the wastewater treatment plant: impact on health, Morocco

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Abstract

The main objectives of this study is to assess the quality of surface waters in Oued Fez and Sebou River downstream the city of Fez, to see the impact on health of the wastewater treatment plant (WWTP) subsequently to his launching . The results of the study show that the physicochemical and bacteriological quality of the different sites from where the samples were taken does not always correspond to Moroccan surface water standards. On the contrary, sampling sites in downstream of the wastewater treatment plant are slightly close to meeting those standards. Nevertheless, Oued Fez surface water prior to WWTP and Sebou River downstream from the confluence are chemically and bacteriologically contaminated. They are characterized by high turbidity, high content in suspended substances, namely nitrites and orthophosphates, and high microbial contamination by fecal coliforms FC, Escherichia coli EC and Intestinal Enterococci IE. It is clear that Oued Fez and Sebou River have both been exposed to anthropogenic hazards. The use of water derived from these water courses or from wells in the area may expose local population to serious health threats, due to numerous water uses, which requires more interest and further studies.

1. Introduction

Water is a major factor in human life. Nevertheless, it may also constitute a source of diseases. With the progress achieved and the technological developments attained, urban and industrial wastewater produced by the city of Fez are seriously leading to a high pollution of Oued Fez and Sebou River. Several studies have been conducted on the properties of water in Oued Fez and Sebou River [1- 4]. Most of those studies detected a surface water contamination in both water courses downstream from Fez, related to the demographic growth and the accelerated progress of the vital social and economic sectors of agriculture and industry in this region [5].

The setting up of a sewage treatment plant is the best remedy of the phenomenon, and the adequate solution to ensure a good hygiene of the environment. Today, the city of fez is endowed with a wastewater treatment plant WTTP, considered the most important environmental project at the national and regional levels.

Indeed, prior to the setting up of this plant, the city, with its 1 million population and an annual volume of wastewater reaching 57 million m³, accounted for 40% of pollution in Sebou, which induced a high degradation of water quality, as well as a deterioration of health conditions and hygiene in Fez and central Sebou population. The yearly losses were estimated at more than MAD 1 billion [6]. Another study, carried out on Sebou River, evaluated the economic losses due to water pollution at MAD 2 billion (€ 180 million) per year [7].

This huge project constitutes an important component of the liquid sanitation system that shall allow an extensive improvement of the environment quality through the elimination of olfactory nuisances, and the reduction of greenhouse gas emissions, contributing thus to urban and agricultural development of Fez.

The present paper ought to be an initial step for studies on the evolution of the Physico-chemical and bacteriological quality of surface waters in Sebou River and Oued Fez downstream from Fez, after the start of the WWTP, becoming operational at the end of 2014, with a view to ensuring water security for the purposes of sustainable development and public health.

2. Material and Methods

2.1. Geographic location of the area of study

Oued Fez and the Sebou River were impacted by the discharge of untreated sewage, and contaminated water sources are major cause of water borne diseases of public health importance [8]. So insufficient treatment seem to be associated with self-reported diseases [9], drawing on the geographic location of the area of study, we have recorded an epidemiological evolution of major water-borne diseases, during the last years, both in Fez and the governorate of Moulay Yaacoub (Figure. 1, 2).

The city of Fez is situated in Fez-Meknes Region, at the north-center of Morocco. It is bordered by the governorates of Sefrou, Taounate and Moulay Yaacoub (Figure. 3), and characterized by a hydrology based on Oued Fez, running from west to east, starting from its springs in Ras El Ma till Oued Sebou. Fez activated sludge WWTP is 10 km from Fez, on the territory of the rural commune of Ain Kansara (Governorate of Moulay Yaacoub). Moulay Yaacoub is a health resort located on the hills to the north-west of Fez, in Fez-Meknes Region.

2.2. Status of water-related diseases in Fez city and the governorate of Moulay Yaacoub

In the Governorate of Moulay Yaacoub (Figure. 1), during the last thirteen years, 69 cases of typhoid, and 100 cases of viral hepatitis were reported. In Fez (Figure. 2), 629 cases of typhoid, and 551 cases of viral hepatitis were reported [10].

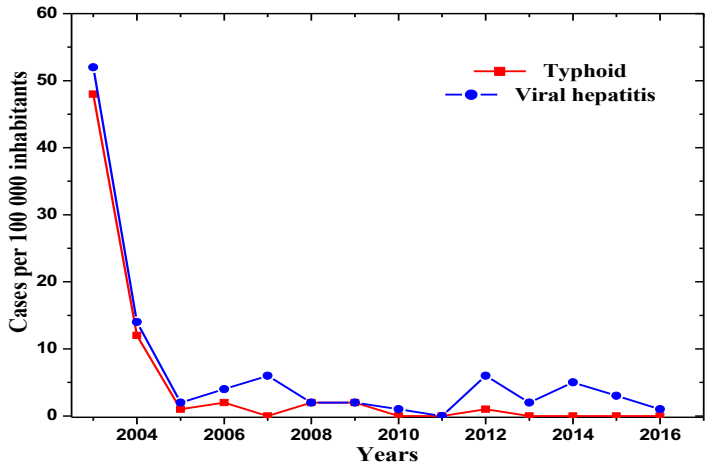


Figure 1: Evolution of water born diseases in the Governorate of Moulay Yaacoub 2004-2016.

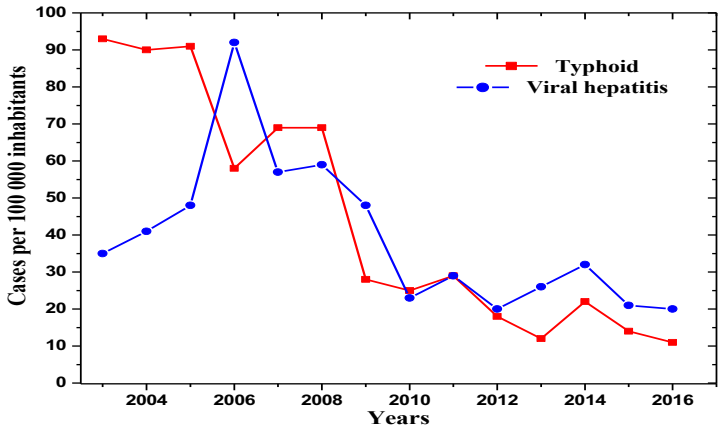


Figure 2: Evolution of water born diseases in the city of Fez 2004-2016.

Based on the figures 1 and 2, collected data regarding water born diseases during the last years show a strong decreasing tendency of cases at an annual average of 55 and 46 cases respectively in Fez city, the same regression being recorded in Moulay Yaacoub, with 6 and 8 cases respectively.

Prior the start of the WWTP becoming operational at the end of 2014, the reduction of water-borne diseases during the last years, is explained by endeavors deployed by the government in this area, example:

- Dechromatation station, operational since 2003, Chromium is one of the toxic metals [11];
- National Environnemental Action Plan (PANE). Established in 2004 as part of UNDP's Capacity 21 program to strengthen the institutional capacity of developing countries, it should be noted that the city of Fez also had a much deteriorated sewage system causing serious problems [12];
- Publication of Decree n°. 2-04-553 of 24 January 2005 on spills, runoff, discharges, direct or indirect deposits in surface or underground waters [13];
- Establishment of the surface water quality grid By the Committee Specifications and Standards." This grid is a national tool to standardize And to unify the assessment of the water quality of Rivers, lake and reservoirs 2007[14];
- Global National Environmental Charter as part of the sustainable development process Excerpt from the Speech from the Throne, July 2009 [15];
- Increase in the rate of access to sanitation services to 54.84% in 2010, Today, Morocco has 80 biological wastewater treatment plants in operation [16];
- Publication of Specific Rejects Limit Values (VLSR), in October 2013 to the official bulletin (BO) [17];

Although these efforts cannot account for the huge change in the occurrence of both diseases, which requires further studies and research to repel those diseases, and to ensure the achievement of sustainable development.

3. Study area

Sebou River is one of the largest Moroccan rivers, stretching over 600 km from its source in the Middle Atlas to the Atlantic Ocean. This river plays a vital role in supplying its watershed area with water for drinking, irrigation as well as for industrial uses. It originates in the Middle Atlas mountain range at 2030 m of altitude, and flows over 600 Km into the Atlantic Ocean. Its watershed, located at the north-west of Morocco between parallels 33°-35° north latitude and 4°15'-6°35' west longitude, stretching over nearly 40000 Km². It is bordered to the north by the southern front range of the Rif Mountains, to the south by the Middle Atlas, to the east by Fez–Taza corridor, and the Atlantic Ocean from the west .The city of Fez is responsible for 40% of the total impact on water quality of Sebou River [18]. The canning and yeast factories also represent a non- negligible contribution of organic pollution of Sebou River [19].

Oued Fez is the main water body in Morocco crossing the city of Fez, with a SW-NE direction, crossing the city of Fez and its old Medina on a 24-km stretch, before joining Sebou River. It takes its source from the big source (Ras al-Ma), where it is fed by very important sources (Ain Ras El Ma, Atrous, Bergama, Sennad...) [20].

This water courses visible at the location of Ras El Ma domain. It is characterized by a permanent flow. Its main course is 33 km long and its catchment area is 615 km^2 [21]. All of Fez's sewage (estimated at 200,000 m3 per day in 2004 [2]) is flushed directly into nearby watercourses.

This includes industrial effluents generated by many industries, including tanneries, oil mills, metal works, potteries and wastewater from the textile industry, which is rated as the most polluting among all industrial sectors [22], using various pollutants (eg degradable organics, surfactants, metals and dyes) [23], which induces serious degradation of quality. Therefore, considerable amounts of chemicals, among which are chromium and ammonium in addition to organic matter, are present in the river [24, 25].The sub-basin of Fez alone generates 40% of pollution [18].

4. Sampling sites

In the rural area of Kansara, field visits enabled us to identify the number of water points and their nearby environment over the whole Sebou and Oued Fez watershed, samples were taken in stable hydrological conditions one times per month during spring and summer time of 2015 at five sampling sites (Figure. 3).

- S1: (34°04'49.0"N+4°55'50.0"W) Upstream the discharges of Fez before the WWTP;
- S2: (34°04'43.1"N+4°56'13.8"W) Downstream the WWTP;
- S3: (34°04'34.3"N+4°55'13.9"W) Located in the confluence (Oueds Sebou-FEZ);
- S4: (34°04'49.0"N+4°54'53.1"W) Located in Sebou downstream of the confluence (Oueds Sebou-FEZ);
- S5: (34°04'10.2"N+4°55'04.0"W) Located in Sebou upstream the confluence (Oueds Sebou-FEZ).

- **5. Experimental Protocol**
- *5.1. Physicochemical results*
- Grab samples were manually collected at approximately 20 cm below the water surface using previously the flasks the 1 L high-density polyethylene (HDPE).

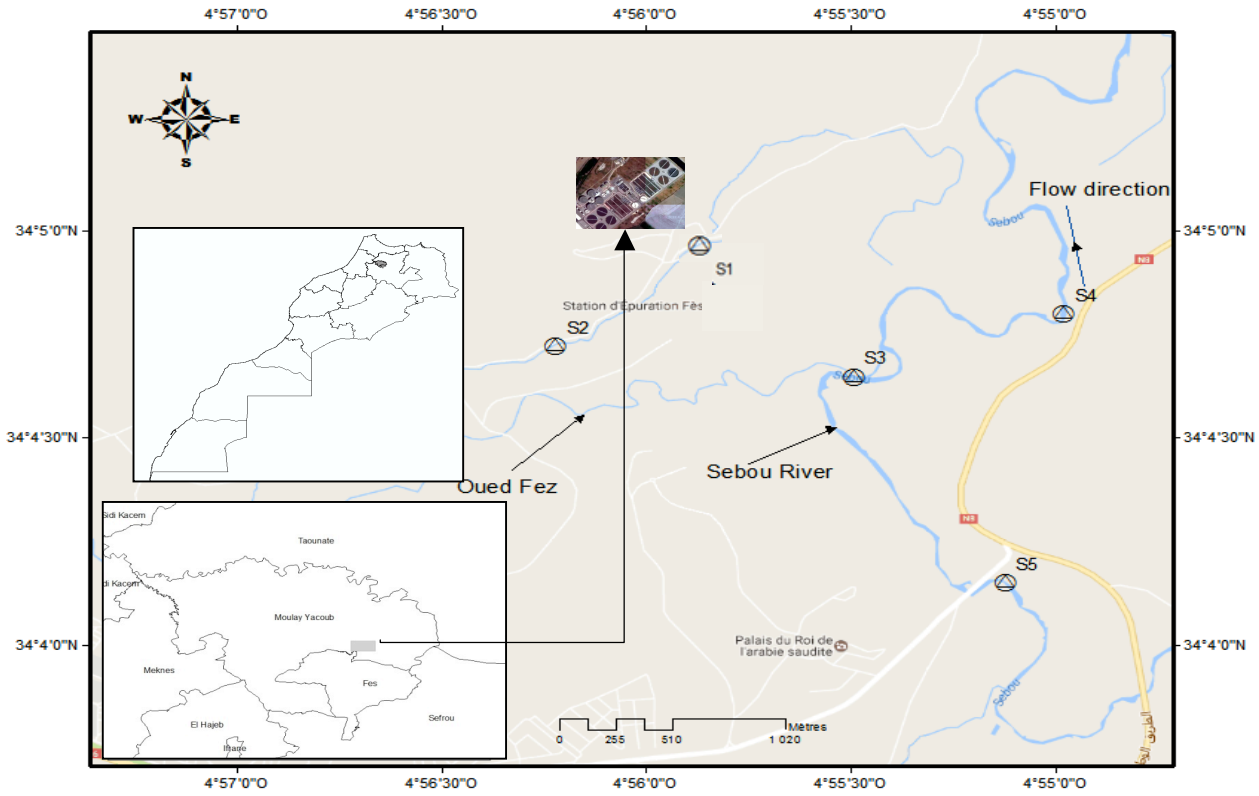


Figure 3: Overview of the study area, Location of sampling sites in the Sebou River and Oued Fez Rivers.

The flasks were thoroughly cleaned and rinsed with distilled water. At the time of in-situ sampling, the previously washed flasks were rinsed three times with river water before sample collection [26]. Samples were carefully labeled and transported from the sampling site to the laboratory.

The tests were performed according to the methods of the methods described by Rodier [27] Measurements of the Physico-chemical parameters (temperature, pH, dissolved oxygen and electric conductivity (EC)) were performed in situ with a multi-probe (Consort C561 Portable) calibrated before each campaign, and the turbidity with a turbidimeter Type HACH-Model 2100P.

Physico-chemical tests concerned the following parameters: boron, silicate, orthophosphate, iron, aluminum, nickel, ammonium, chlorides, nitrites, and sulphates are performed accord in to DUNOT standards 9th edition by Rodier [27].

5.2. Bacteriological parameters

The counting of indicator bacteria of fecal contamination FC, Escherichia coli EC and Intestinal Enterococci IE was realized by the method of multiple tube fermentation MPN using special statistical tables (Mac Crady). Water samplers used for bacteriological tests were taken in compliance with the protocol as described below: Sampling was performed using borosilicate glass vials carefully pre-cleaned with distilled water. The cleaned and rinsed vials were then sterilized in an autoclave at 120°C, and pressured at 120 kg/cm^{-2}for 30 minutes. Water samples were tested in compliance with the appropriate Moroccan standards [28].

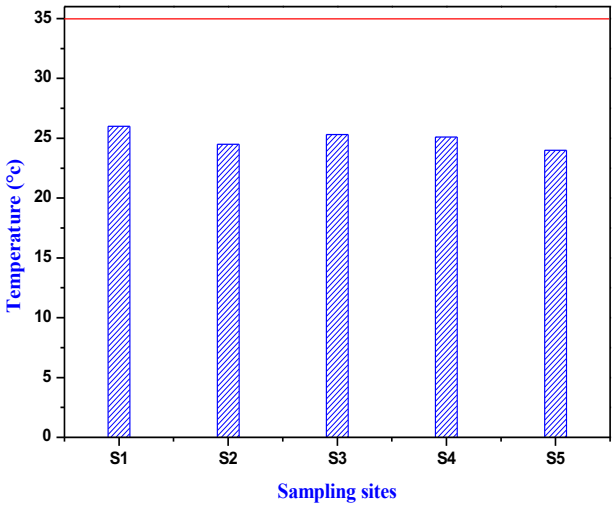
After storing water samples each in an appropriate 500mL vial, they are labeled and conserved in a cooler at a maintained temperature between 0 and 4°C. then they are transferred to the laboratory with a sampling sheet indicating all required data, mainly the sampling site and date, as well as sanitary conditions in the sampling sites.

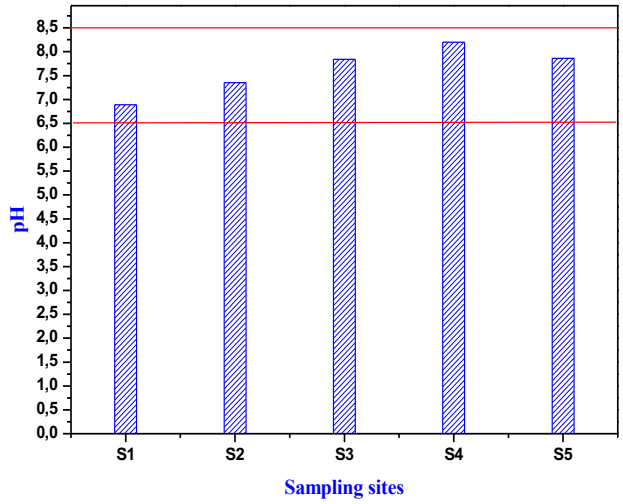
6. Results and discussion

6.1. Physico-chemical parameters

The results of the Physico-chemical and bacteriological tests (mean values), are represented in figures with standards (red line) below for each sampling site. All results will be discussed according to the Decree on Moroccan Standards which sets the surface water quality standards (MSSW) [28].

Temperature is a major factor in the quality of aquatic ecosystems (Figure. 4); it has an influence on many physical, chemical and biological processes [29]. In the study area, it was noticed that there were no great temperature variations from one site to another. The values obtained are between 24 °C as minimal value and 26°C as maximum value recorded at the level of the Sebou river, and 24.6 °C as minimal value and 24.8°C as maximum value recorded at the level of the Oued Fez. This temperature is deemed favorable to the development of bacteria, parasites, mosquito larvae and other microbial germs. The confirmed values (< 30°C) rank these waters within the range of good quality.





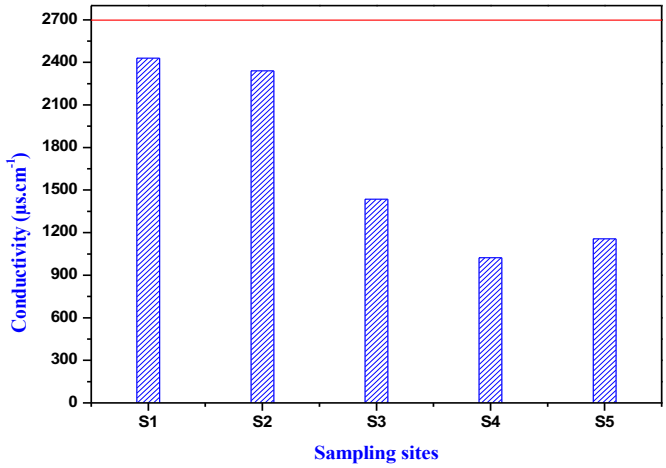
The pH of water affects most of water chemical and biological mecanisms. It can also be influenced by acid precipitation, biological activity and certain industrial releases [30]. (Figure.5) No significant variations were noticed in water pH values in the sites object of study with a minimum of 6,3 in S1,due to the presence of high organic matter contents, and a maximum of 8,3 in S4. The obtained pH values are acceptable and meet

Figure 4: Evolution of temperatures in the different sites water.

Figure 5: Evolution of pH in the different sites water.

Moroccan directives on the classification of surface waters.

Electric conductivity indicates water capacity to conduct an electric current. Therefore, it represents the mineralization rate of water [29]. In the sites selected for the study (Figure. 6), conductivity was significant in



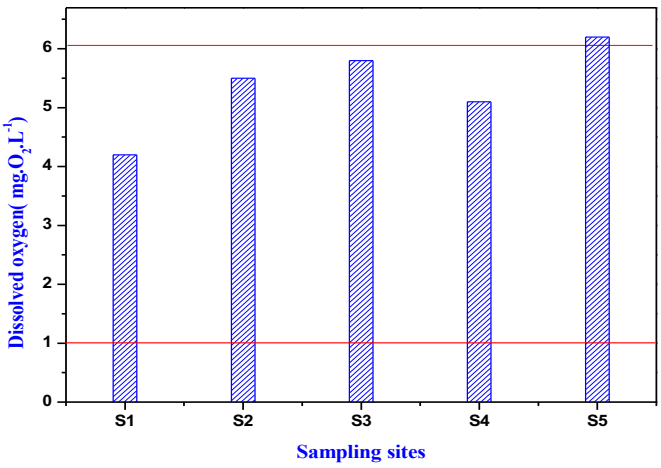


Figure 6: Variation of the conductivity for the different sampling sites Water.

Figure 7: Variation of dissolved oxygen for the different sampling sites.

S1 and S2, and weak in S3, S4 and S5. According to Moroccan surface water classification, the obtained values (<2700 µs.cm-1) position these waters within the range of good quality.

As for dissolved oxygen is one of the parameters most sensitive to pollution, because a dissolved oxygen level that is too high or too low can harm aquatic life and affect water quality. The obtained values dissolved oxygen (Figure. 7), are acceptable and meet Moroccan directives on the classification of surface waters. Usually one can rank these waters within the range of good quality.

In the figure 8 the studied samples presented a high concentration of boron in site1 (Figure.8), which positions these waters in the range of poor quality. Whereas waters in sites S2, S3, S4 and S5 are weakly boron-loaded due to WWTP treatment. These three sites present acceptable content in boron, meeting Moroccan surface water directives.

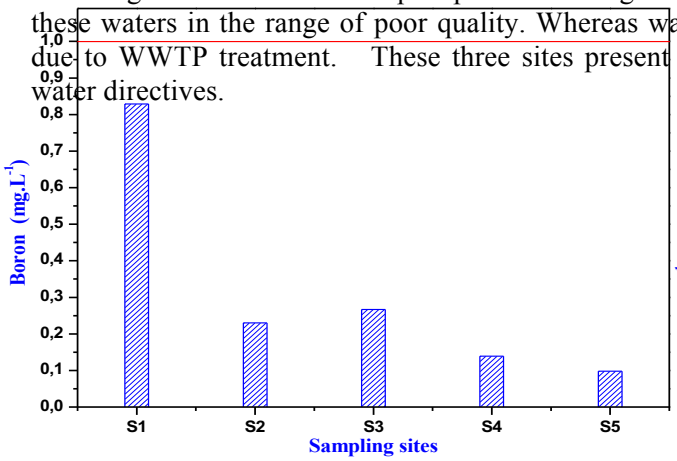


Figure 8: Boron concentration in the different sampling sites water.

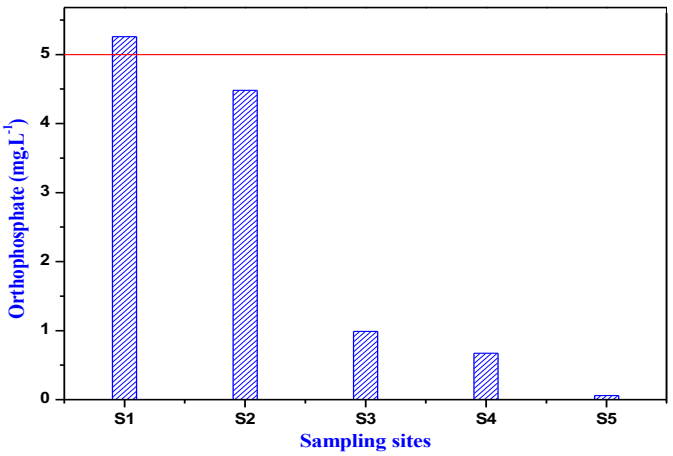


Figure 9: Concentration of orthophosphate in the different sampling sites.

Knowing that orthophosphates are primarily the result of household agricultural and industrial activities, and also of agricultural run-off in lands with phosphate fertilizers content. In Oued Fez (S1, S2) (Figure.9), maximum values obtained position these waters in the range of poor quality. Whereas S3, S4 and S5 present acceptable content meeting Moroccan surface water directives.

Turbidity is the measurement of water clarity. The obtained values of the turbidity (Figure. 10) aren't below the standard; it's acceptable and meets Moroccan directives on the classification of surface waters. Usually one can rank these waters within the range of good quality.

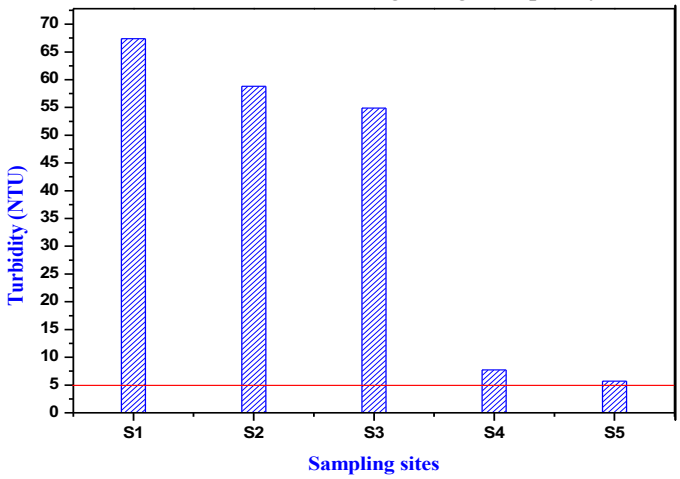


Figure 10: Variation of Turbidity in the different sampling sites water.

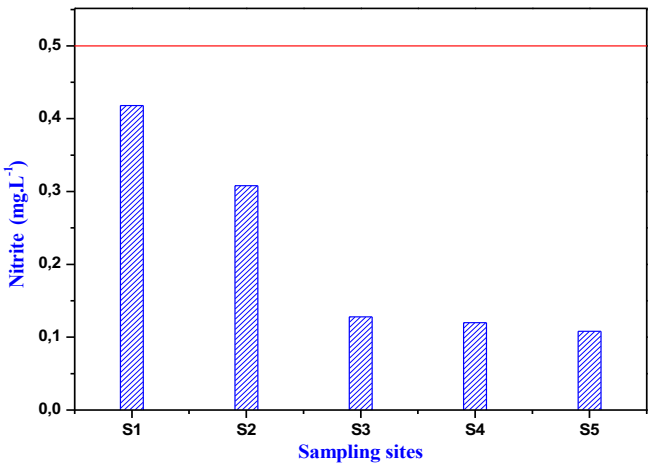


Figure 11: Concentration of Nitrites in the different sampling sites.

Nitrites NO_2^- (Figure. 11) can be toxic to the human body. Their presence in significant quantity esdecreases water quality. Nitrites toxicity is highly significant due to their oxidizing power. In this case, nitrites content varies between 0,108 to 0,418 $mg.L^{-1}$, which positions these waters in the range of good quality. The excessive value in S1 water may be attributed to agricultural and household activities, and positions these waters in the range of poor quality.

Ammonium (Figure.12) constitutes the product of the final reduction of nitrogenous organic substances and inorganic matter in waters and soil. It also originates from living organisms' excretion and waste reduction and biodegradation, in addition to household, industrial and agricultural origins. This element is present in low rates

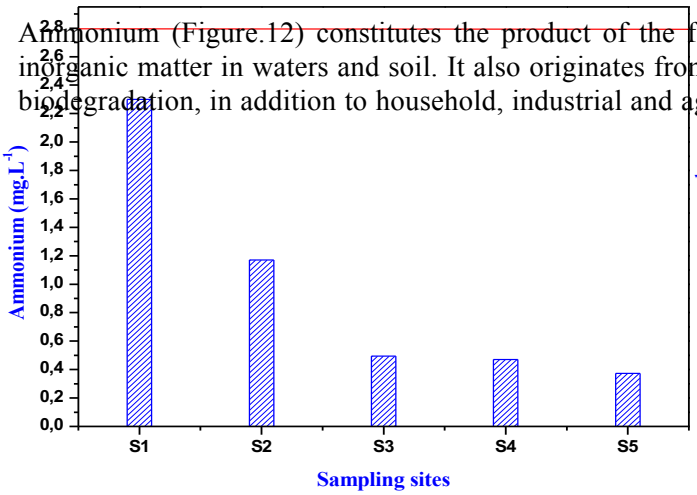


Figure 12: Ammonium concentration in the different sampling sites.

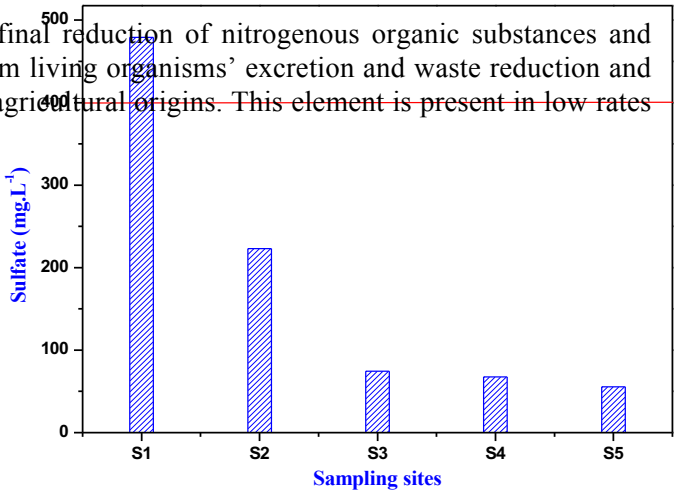


Figure 13: Concentration of Sulphates in the different sampling sites.

in sites S3, S4, S5.

Concerning sulfates, the values of this parameter (Figure.13) in studied waters vary from 55, 55 and 479, 2 $mg.L^{-1}$. The high contents of this parameter are noticed in polluted waters. The high contents may also be attributed to agricultural activities, positions these waters in the range of poor quality.

Chlorides (Figure.14) are largely spread in nature, generally in the form of sodium and potassium salts (NaCl)

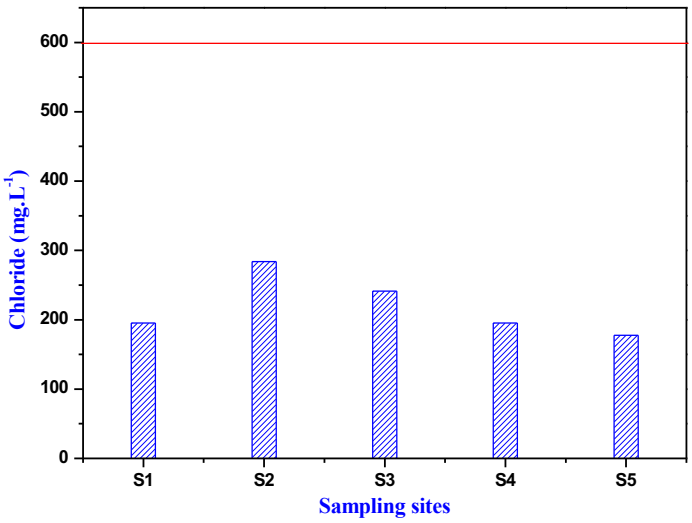


Figure 14: Chlorides concentration in the different sampling sites.

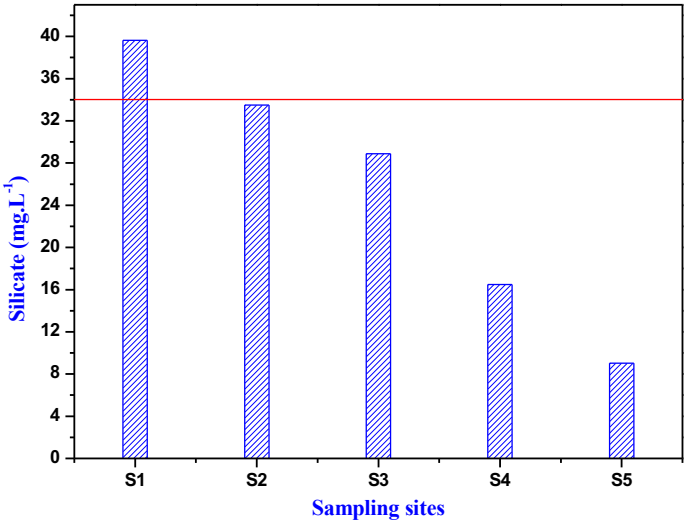


Figure 15: Concentration of Silicates in the different sampling sites.

and (KCl). They are often used as a pollution index. Content in chlorides is at its good in site S1, also that in the other sites. This which positions these waters in the range of good quality.
The silicates concentration (Figure.15) rates in the studied sites are low in sites S4 and S5, and high in sites S1, S2 and S3, meeting Moroccan surface water directives. High contents of this parameter are noticed in polluted waters, due to the high importante of silicates for industrial and geochemical activities, which positions these waters in the range of poor quality. Water in the studied sites, have acceptable values **of iron, nickel, aluminum and sulphates,** meeting Moroccan standards of water classification.

6.2. Bacteriological results

Results obtained show that the sampling sites S1, S2, S3, S4 (Figure.16) have presented high concentration rates of fecal coliforms, Escherichia coli and intestinal enterococci. This can be explained by a very important human activity in the neighboring area, and a human or animal fecal pollution. In conformity with Moroccan classification, the obtained values position these waters in the range of poor bacteriological quality. Oued Sebou S5 presented a minimum value of fecal coliforms, Escherichia coli and intestinal enterococci. The regulatory framework of surface water ranks Oued Sebou water in the range of good quality.

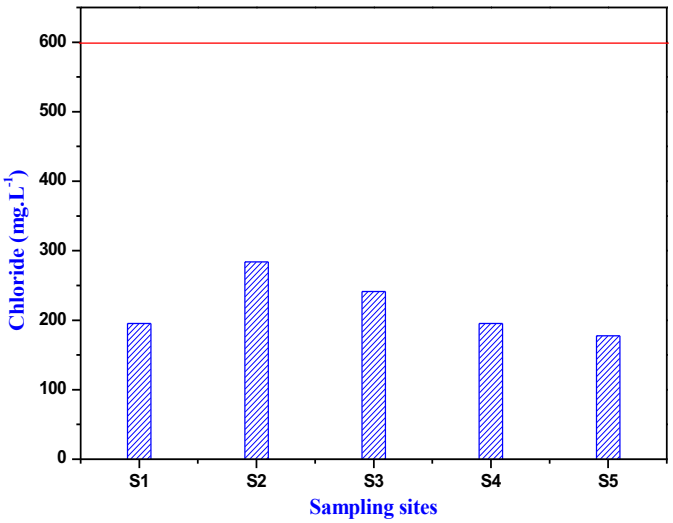


Figure 14: Chlorides concentration in the different sampling sites.

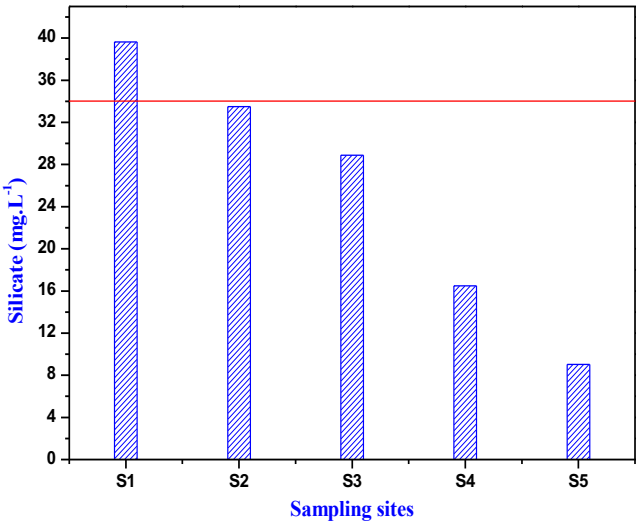


Figure 15: Concentration of Silicates in the different sampling sites.

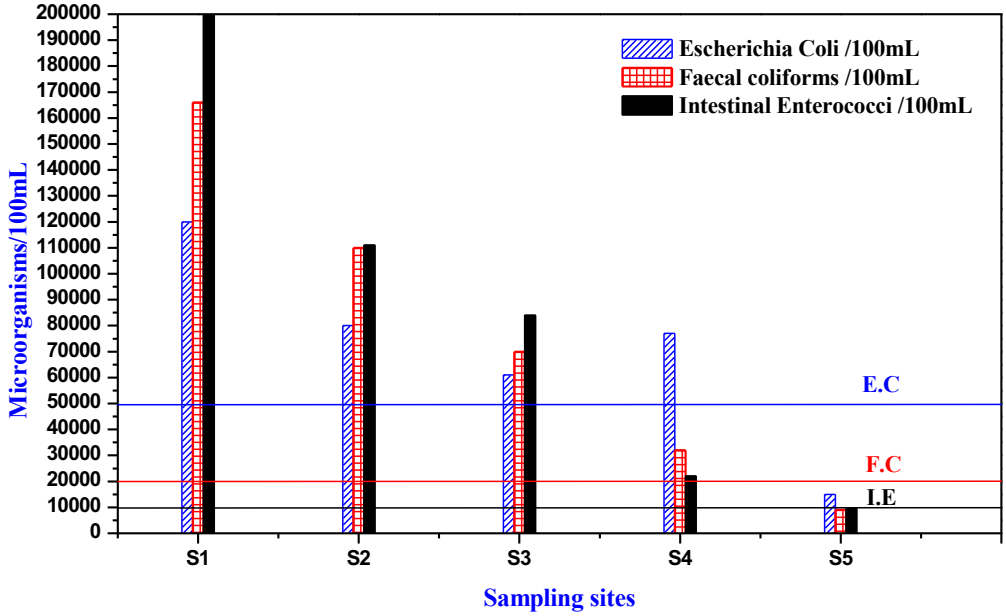


Figure 16: Bacteriological concentration in the different sampling sites.

The entirety of surface and waste waters in Fez might engender a detrimental impact on the lives and health of fauna and flora, and cause the transmission of several water-born infectious and parasitic diseases, mainly: typhoid, viral hepatitis, and food intoxications, due to the consumption of market gardening products.

Table 1: Result of different sampling sites according with the Moroccan standards of the quality, concerning the classification of surface waters.

Sites	S1	S2	S3	S4	S5
Temperature (°C)					
pH					
(Dissolved oxygen($mgO_2.L^{-1}$)					
Conductivity ($\mu s.cm^{-1}$)					
Turbidity (NTU)					
Chlorides ($mg.L^{-1}$)					
Sulphates ($mg.L^{-1}$)					
Nitrites ($mg.L^{-1}$)					
Ammonium ($mg.L^{-1}$)					
Aluminum ($mg.L^{-1}$)					
Iron					
Boron ($mg.L^{-1}$)					
Silicates ($mg.L^{-1}$)					
Orthophosphates ($mg.L^{-1}$)					
Escherichia Coli /100mL					
Fecal coliforms /100mL					
Intestinal Enterococci/100mL					

- Blue : excellent water quality;
- Green : good water quality;
- Orange : average water quality;
- Violet: poor water quality.
- Red: very poor water quality.

According to the classification only some points have a good quality to excellent.

6.3.

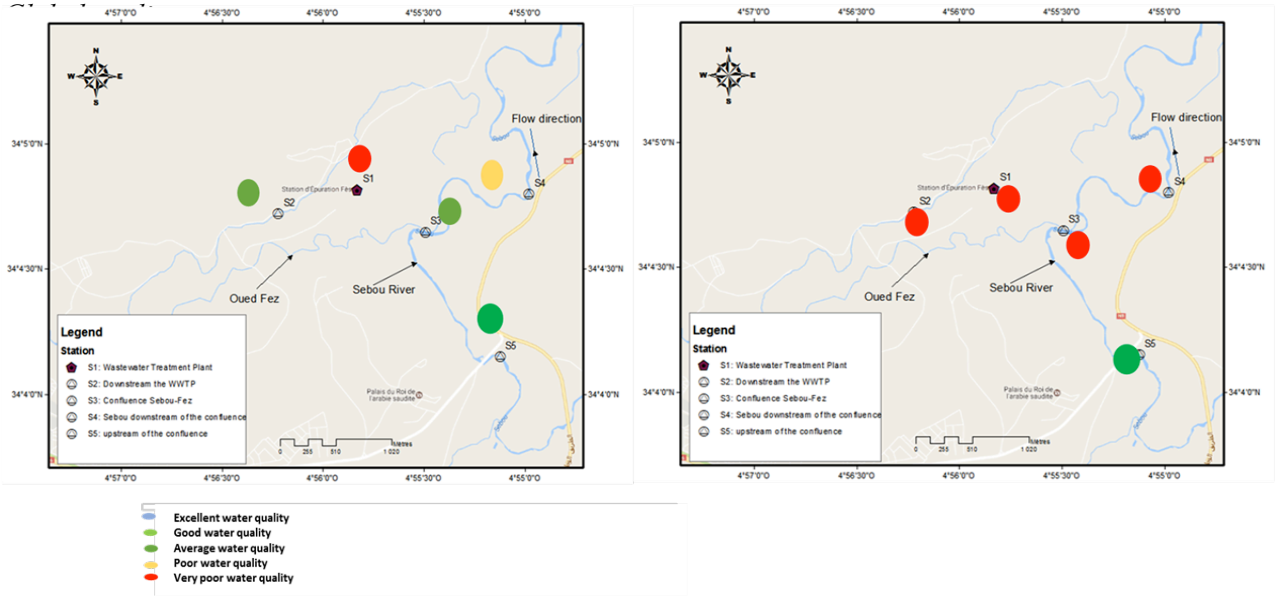


Figure 17: Classes of global quality Physico-chemical at the sampling station levels.

Figure 18: Classes of global quality Bacteriological at the sampling station levels.

In the (figure.17) the global quality Physico-chemical at the sampling stations levels presented, an improvement after WWTP treatment. But site 4 remains polluted due to agricultural activities in this area, positions these waters in the range of poor quality. As to in the (figure.18) the Spatial-temporal map shows that, in spite of the treatment of WWTP, the bacterial load is strong at of most of the sampling sites. Since nitrogen and phosphorus of secondary effluent of the WWTP must be eliminated in order to avoid any risk of eutrophication [30], and thereafter Bacterial proliferation.

We propose to add an advanced treatment accomplished by a variety of methods such as coagulation sedimentation, filtration, reverse osmosis, and extending secondary biological treatment to further stabilize oxygen-demanding substances or remove nutrients.

Conclusion

The objective of setting up the wastewater treatment plant is to reduce organic matter rates, and to eliminate pathogenic organisms, so that water can be reused or released into the environment with the least harmful consequences, thereby improving water quality in Sebou River and Oued Fez. The different results clearly show the positive effect of the wastewater treatment plant by minimizing the polluting load just after site 1, of same in by minimizing the Waterborne Diseases based on collected data; from health delegations. The Sebou River, upstream from Fez, showed a low-pollution status. On the other hand, high levels of major ions were found in Fez River (Oued Fez) and Sebou River downstream Fez River inputs, due to the discharge of urban and industrial untreated and hugely polluted wastewaters, before the launch of the wastewater treatment plant. Among contaminants, metals are of particular concern because of their toxicity, abundance and environmental persistence and their possible bioaccumulation [30]. The analysis of water quality downstream the city of Fez and around the Wastewater Treatment Plant has been carried out. The data is compared with standard parameters prescribed by Moroccan standards.

The analysis indicates that surface water located in Sebou upstream the confluence (Oueds Sebou-FEZ) and around the wastewater treatment plant is suitable for drinking, agricultural and industrial use. In general, it is not harmful to human beings, whereas some samples need pre-treatment before use.

This study aims to enable:

- Epidemiological researchers and water treatment authorities to forge scientific cooperation ties on mutually agreed projects that respond to national research priorities in both fields; In order to combat the most declared waterborne diseases, and carry out awareness programs near the most polluted streams.
- Assessment of concentration levels for other pollutants (eg pesticides, etc.) to obtain a more complete picture of the pollution problem, which could lead to the introduction of treatment technologies.
- Work towards multidisciplinary research in the field of epidemiology and quality management of wastewater treatment.
- Make computer contacts to link the quality of treatment of the studied waters with the reduction of the rate of the most frequent waterborne diseases. Indeed, it is a system that plays an important role in monitoring the preservation of population health and the quality of the aquatic environment.
- Thus, there is an obligation to implement tertiary treatment and to choose the process (s) that are most suitable for the desired re-use and the quality of the effluent at the station exit.

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