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Physico-chemical characterization of the coastal waters of the city of Sidi Ifni (Morocco)

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Abstract

Our work is a contribution to assessing the health of the marine ecosystem of the city of Sidi Ifni, not yet studied and some sites still receive untreated wastewater.Six samplings campaigns were conducted during January-June 2015 in Mirleft, Cheikh and Sidi Ifni wastwater treatment plant(Step)sites. Our results showed an real disruption of physicochemical parameters measured in coastal waters (T°C, pH, Dissolved O_2, Salinity, Conductivity, Turbidity, Salinity, Chlorides, Sulfates, Phosphorus, Ammonia Nitrogen, Nitrate and Nitrite), and especially in sites that receive untreated wastewater from Sidi Ifni coasts (Cheikh and Step sites) compared to the reference site Mirleft.Our study also highlighted the impact of this disruption and requires the strengthening of the surveillance of the coast of Sidi Ifni in the framework of a monitoring strategy and effective prevention against marine pollution.

1. Introduction

In Morocco, the marine environment constitutes a very important pole of economic and social development. With its wealth, it currently occupied an important place in the national economy. Moreover, this sector constitutes reservoir of food resources contributing significantly to the increase in the rate of national self-sufficiency. However, this strategic ecosystem has become the privileged receptacle of pollution because of the anthropogenic development witch discharge wastewaters in many points of marine coasts. Such situation requires the establishment of a sustainable strategy for monitoring and protecting the environment. Indeed, preserving the environment and its resources are considered one of the priorities of scientists and managers of marine environment.

For this, several approaches are currently used, including the use of conventional physico-chemical methods. This physicochemical approach, essential for the qualitative and quantitative assessment of pollutants in the various compartments of the environment (water, sediment and organisms), was used in this study to contribute to the assessment of the health status of the Marine ecosystem of the Sidi Ifni region. This marine ecosystem, not yet studied, receives untreated wastewater in several sites.

2. Materiels and Methods

2.1. Studied and sampling sites

Our study was conducted in three sites representative of Sidi Ifni’s coastline (Figure 1): *i)* Mirleft site (S0) (Coordinated : 29°58’41.68’’N, 10°07’40.82’’W) , which is considered as reference site, located at 30 Km to the north of Sidi Ifni, far from any source of pollution, *ii)* Cheikh Sidi Ali Ifni (S1) (Coordinated : 29°38’70.55’’N, 10°17’29.54’’W) located at the entrance of Sidi Ifni at the rejection of the oued Sidi Ifni and receives untreated wastewaters of the city and *iii)*station of wastwater epuration (S2) (Coordinated : 29°34’20.80’’N, 10°20’12.13’’W) which receives treated wastewaters of a part of Sidi Ifni city.

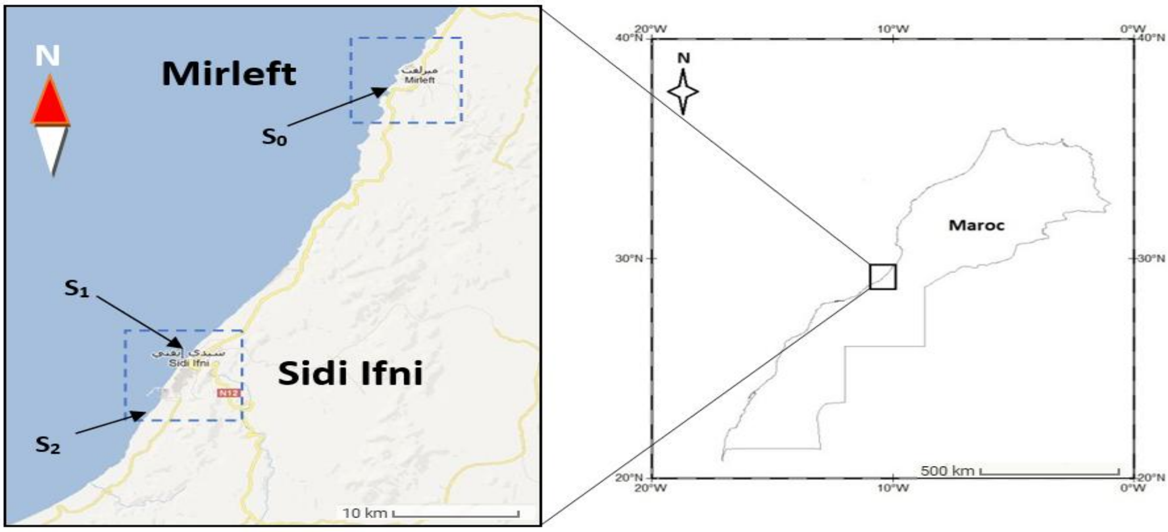

Figure 1 : Map of sampling sites in coastline of Sidi Ifni : Mirleft site (S0), Cheikh Sidi Ali site (S1) and Sidi Ifni wastewater treatment plant (S2)

2.2. *Mode of sampling*

Marine water was sampled monthly in each site between January and June 2015, according technical recommendations of Rodier [1].

2.3. *Methods of analysis*

The quality of marine water was evaluated by the determination of the following physicochemical parameters : Temperature (T °C), pH, Dissolved O_2, Salinity, Conductivity, Turbidity, Salinity, Chlorides, Sulfates, Phosphorus, Ammonia Nitrogen, Nitrate and Nitrite (Table 1). These parameters were measured according methods described by Rodier [1] and Aminot & Chaussepied [2].

Temperature, pH, Dissolved O_2 and Salinity were measured *in-situ*, during the sampling campaigns, using the portable devices of a multi-parameter probe while the other analyzes were carried out in the laboratory.

Tableau 1 : Methods of analysis of physico-chemical parameters [1]

Parameter	Methods of analysis	Parameter	Methods of analysis
Temperature	Thermometer	Total hardness	Complexometry
pH	pH-meter	Chlorure	Titrimetry
Dissolved O_2	Oxymeter	Sulfate	Spectrophotometry
Turbidity	Turbidimeter	Phosphore	Colorimmetry
MES	Filtration system	Ammonia Nitrogen	Colorimetry
Conductivity	Conductimeter	Nitrite	Colorimetry
Salinity	Salinometer	Nitrate	Colorimetry

2.4. Statistical Analysis

The results for the physico-chemical analysis, mentioned above, are represented by the mean ± standard error of the mean (mean ± E).They are analyzed using analysis of variance (ANOVA) to analyze the effects of the factors "site" and "month of sampling". Significant differences were established at the $p < 0.05$ level according to the LSD test for the multiple comparison between the variations during the study months of the different parameters. The interpretation focused on the determination of Pearson's correlation coefficients and Principal Component Analysis (PCA). The statistical analysis was performed using the Statistica software (Statsoft Version 10)

3. Results and discussion

3.1. Temperature

During the study period, the temperature of the sea water has a similar profile in the three sites studied, with low temperatures during April, while the high temperatures are recorded in May and June 2015 (Figure 2). These variations must be correlated with those of the air temperature and the climate of the Sidi Ifni region where the marine environment responds to variations in weather conditions [3]. This variation would be linked also to the seasons. Moreover, the slight increase throughout the study period in the Cheikh site is likely related to wastewater discharged to the site and which is relatively hotter than seawater [4, 5]. This phenomenon has already been observed in the Temara region [5] and in the Bay of Agadir [6, 7].

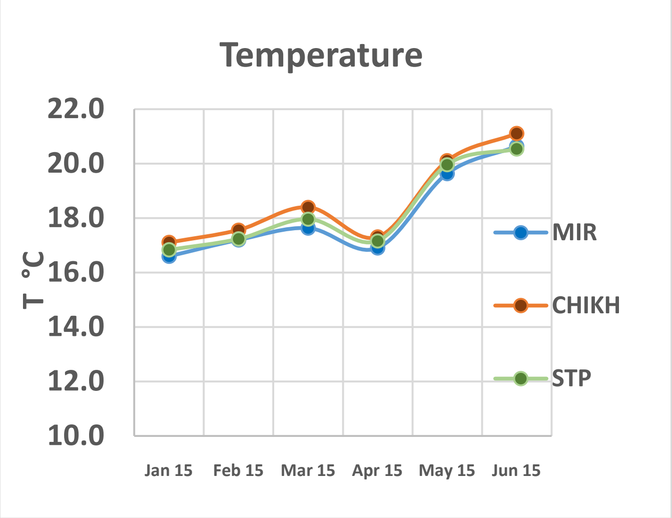

Figure 2 : Evolution of temperature in seawater at sites: Mirleft (MIR), Cheikh (point of discharge of untreated sewage: CHIKH) and point of discharge of water treated by Sidi Ifni wastwater treatment plant(STP)

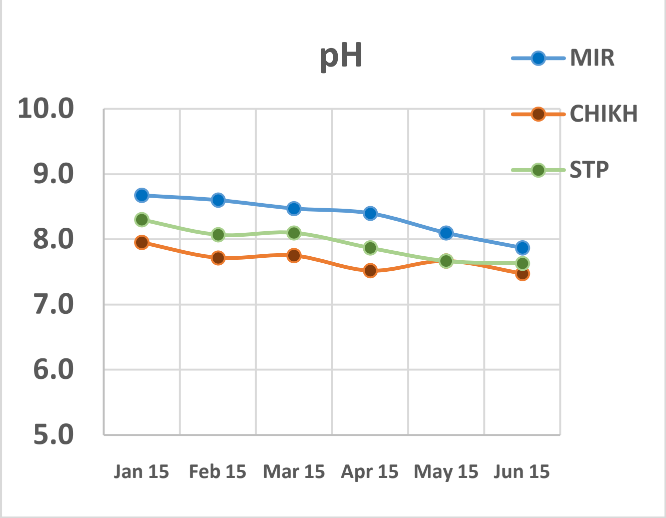

Figure 3 : Evolution of pH in seawater at sites: Mirleft (MIR), Cheikh (point of discharge of untreated sewage: CHIKH) and point of discharge of water treated by Sidi Ifni wastwater treatment plant (STP)

3.2. pH

The pH of the seawater shows a close seasonal profile in the three sites studied. However, the values appear to be lower in the Cheikh and Step sites compared to the Mirleft site (Figure 3). The decrease in pH in these sites would probably be linked to the inputs of sewage which contribute to an acidification of the sea water in these stations. This phenomenon has also been described in the region of Anza which receives domestic and industrial wastewater in the Bay of Agadir [6, 7, 9].

3.3. Dissolved oxygen

The dissolved oxygen analyzes performed on the seawater samples show a similar seasonal pattern in the all studied sites. The highest values were recorded in winter (January, February, March) and lower values in spring (April, May and June) (Figures 4).

Concentrations of dissolved oxygen in seawater appear to be significantly higher in the Mirleft and Step sites compared to those observed at the Cheikh site. This result shows the pollution potential of wastewater discharge into the environment.

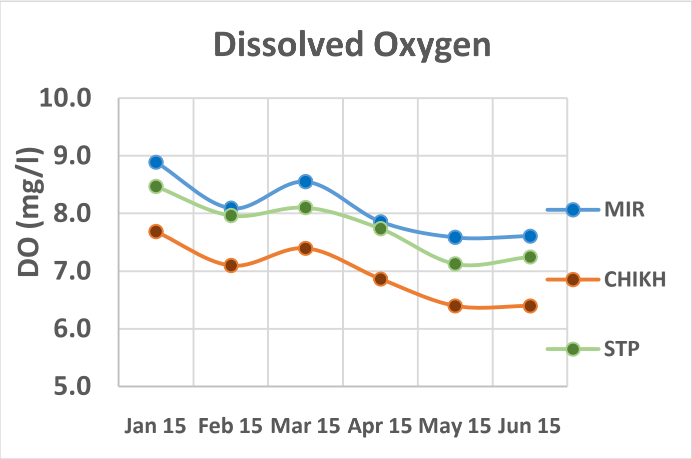

Figure 4 : Evolution of dissolved oxygen in seawater at sites: Mirleft (MIR), Cheikh (point of discharge of untreated sewage: CHIKH) and point of discharge of water treated by Sidi Ifni wastwater treatment plant(STP)

Indeed, the recorded anoxia would probably be due to inputs from wastewater that are rich in organic fillers and chemical and biological products that consume oxygen in the environment [10]. While the oxygen levels, which are higher in the Mirleft and Step sites, are related respectively to the absence or reduction of pollution at these sites. These conditions are favored by the significant hydrodynamics of these sites which enrich the medium with oxygen under the effect of agitation of seawater [5].

3.4. Turbidity (NTU) and suspended matter (MES)

The results of the monitoring of the turbidity of the sea water revealed very diversified concentrations. The evolution of this parameter follows a seasonal profile in the studied sites. The values appear to be higher at the Cheikh site compared to the other sites, and particularly at the Mirleft site (Figure 5).

The same profile were observed during the monitoring of suspended matter (SS). Indeed, there is a strong correlation between these two parameters, since the increase in turbidity is always accompanied by an abundance of suspended matter (Figures 5 and 6).

The increase recorded at these two parameters could probably be related to the inputs of wastewater discharged at the Mirleft and Step site. Moreover, the coincidence of samplings with a rainy season (Communication of the Meteorological Services of Sidi Ifni) in the region would probably be at the origin of the recorded winter increase and to the contribution by the waters of leaching of land trained by oueds in the region.

On the other hand, the decrease of these parameters should be related to the upwelling currents that begin in March and reach their maximum level in July and August.

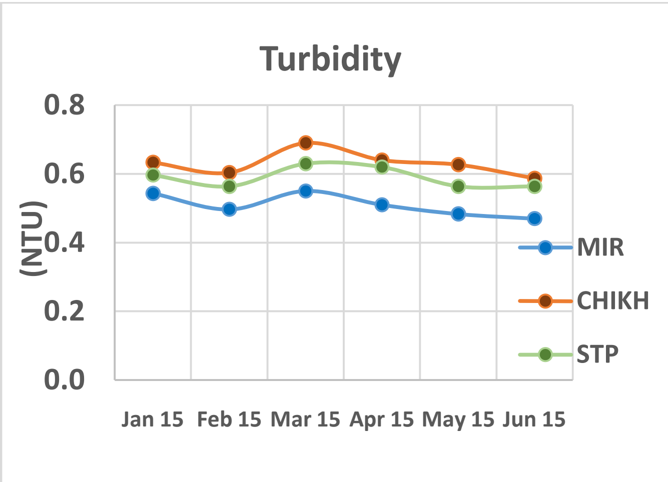

Figure 5 : Evolution of turbidity in seawater at the sites: Mirleft (MIR), Cheikh (point of discharge of untreated sewage: CHIKH) and point of discharge of water treated by Sidi Ifni wastwater treatment plant(STP)

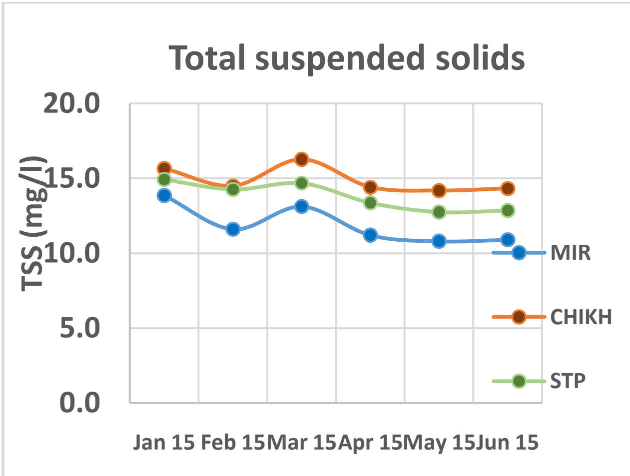

Figure 6: Evolution of suspended solids (MES) in seawater at the sites: Mirleft (MIR), Cheikh (point of discharge of untreated sewage: CHIKH) and point of discharge of water treated by Sidi Ifni wastwater treatment plant(STP)

3.5. *Conductivity and salinity*

During the study period, variations in electrical conductivity and salinity show the same seasonal pattern of profiles enregistred in the studied sites. Mean values of electrical conductivity range from 40.14 mS / cm (± 0.05) to 53.23 mS / cm (± 0.1). The salinity ranged from 25.28 g / l (± 0.03) to 33.41 g / l (± 0.1) (Figures 7 & 8).The variations of these two factors must be related to evaporation and precipitation in the Sidi Ifni region. Indeed, the decline in salinity recorded in March could be explained by the input of rainwater. The increase in atmospheric temperature, in May, would lead to an evaporation of the seawater, which would be the cause of the augmentation of these factors. The slight decrease recordred in the Mirleft site could be explained by the process of dilution by the wastewater discharged into this site. Similar results have been reported on the coast of Temara [5, 12] and Anza [6, 7, 9].

3.6. Total hardness

Figure 9 showed that, during the study period, the profile of the total hardness (Ca^{2+}, Mg^{2+}) of seawater is nearly the same in the three study sites. The first month showed very high concentrations, while the opposite was observed during the last month of study (Figure 9).The increase in the total hardness of the seawater would probably be related and especially during the summer to the supply by the oueds and outfalls of the leaching waters of the calcareous soils in the region. However, the decrease of this parameter in May could be correlated with upwelling currents, which include the deep mineral-rich waters responsible for maintaining the ions expressed in the total hardness of the water [13].

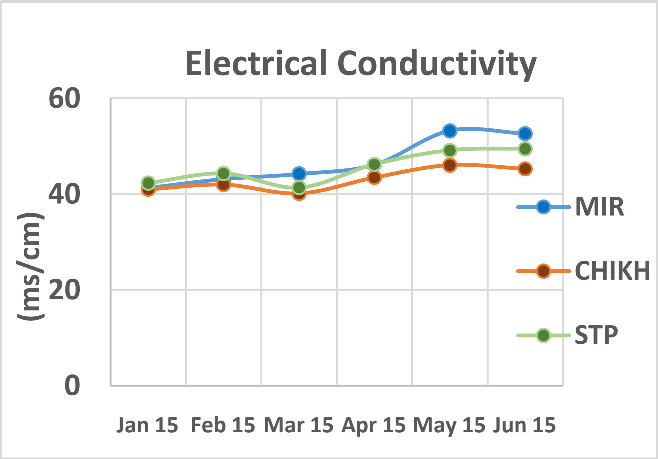

Figure 7 : Evolution of the electrical conductivity in seawater at the sites: Mirleft (MIR), Cheikh (point of discharge of untreated sewage: CHIKH) and point of discharge of water treated by Sidi Ifni wastwater treatment plant(STP)

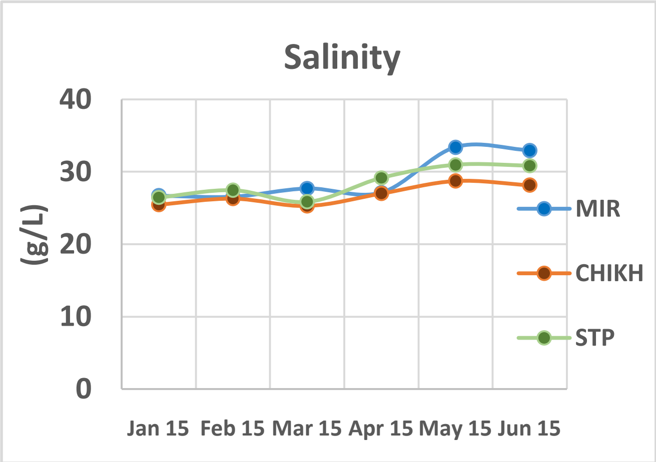

Figure 8 : Evolution of salinity in seawater at the sites: Mirleft (MIR), Cheikh (point of discharge of untreated sewage: CHIKH) and point of discharge of water treated by Sidi Ifni wastwater treatment plant(STP)

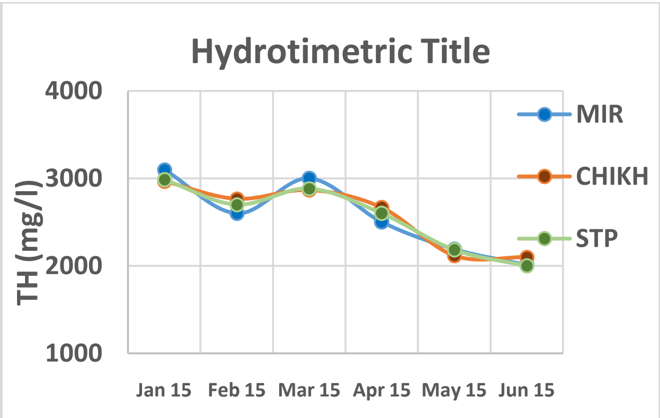

Figure 9: Evolution of total hardness in seawater at the sites: Mirleft (MIR), Cheikh (point of discharge of untreated sewage: CHIKH) and point of discharge of water treated by Sidi Ifni wastwater treatment plant(STP)

3.7. *Chlorures*

The evolution of the chloride content in marine water shows a slightly different profile between the study sites. Indeed, in all sites it has lower values in winter compared to spring (Figures 10).

The comparison between studied sites revealed higher concentrations of chloride ions in the sea water taken from the Cheikh and Step sites compared to those of the Mirleft site. This difference could result from the non-negligible contribution of chemicals, and in particular domestic detergents in the waste water discharged at these two sites. The seasonal profile presented a slight decrease in April which must be correlated to storm water inputs, which could lead dilution of the chloride level in seawater.

3.8. *Sulfates*

The sulfate concentrations follow-up in Mirleft, Cheikh and Step sites show a similar profile during the study period. The minimum values are recorded in February while the maximum values are observed in May. The inter-site comparison revealed an increase in the concentration of sulphates in the seawater collected respectively from the Cheikh sites and Step compared to the Mirleft site. This difference would probably be related to the polluting load of the wastewater (Figure 11).

3.9. *Phosphore total*

Analysis of total phosphorus on seawater samples from the sites studied revealed significantly higher concentrations at the Cheikh and Step sites compared to the Mirleft site. The mean values obtained ranged from 0.65 mg/l (± 0.01) to 1.134 mg/l (± 0.01) with a minimum recorded at the Mirleft level in January and a maximum found at the Cheikh site in June 2015, (Figure 12). This increase is mainly due to inputs of wastewater discharged into these stations and which would contribute much of the organic phosphorus that would come from waste protein metabolism and its elimination in the form of phosphates in the urine by humans and Detergents [14].

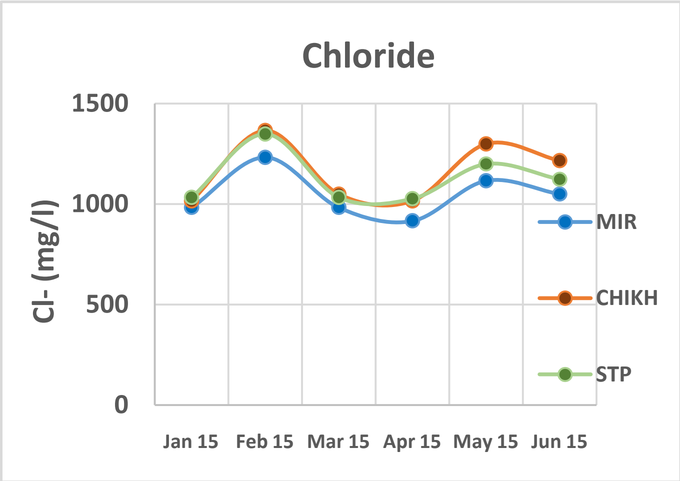

Figure 10 Evolution of chloride ions in seawater at the sites: Mirleft (MIR), Cheikh (point of discharge of untreated sewage: CHIKH) and point of discharge of water treated by Sidi Ifni wastwater treatment plant (STP)

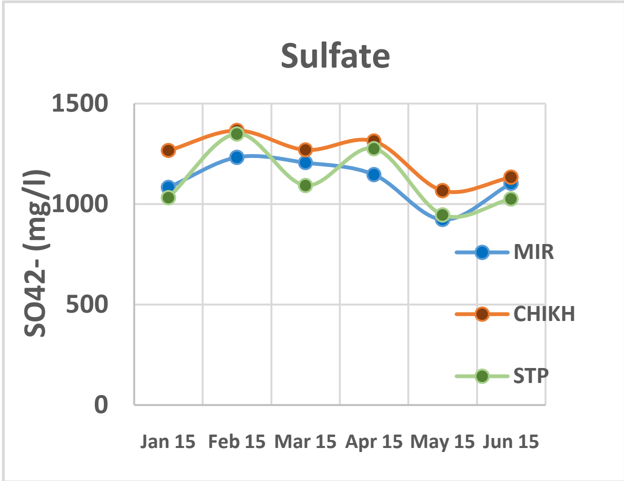

Figure 11 : Evolution of sulfate ions in seawater at the sites: Mirleft (MIR), Cheikh (point of discharge of untreated sewage: CHIKH) and point of discharge of water treated by Sidi Ifni wastwater treatment plant(STP)

3.10. Ammonia nitrogen

Monitoring of ammonia nitrogen in seawater samples from the Mirleft, Cheikh and Step sites shows varying concentrations between sites. Mean values ranged from 0.35 mg/l (± 0.01) to 2.41 mg/l (± 0.02), while low values were obtained in the spring at the Mirleft site, while the high values were detected at the Cheikh and Step sites in winter season (Figure 13).

This increase in sites receiving wastewater is likely related to the inputs of wastewater discharged to these sites [9], while the increase observed in the seasonal profile at the reference site level (Mirleft) would be linked to upwellings that contribute to nutrient enrichment in coastal areas [11].

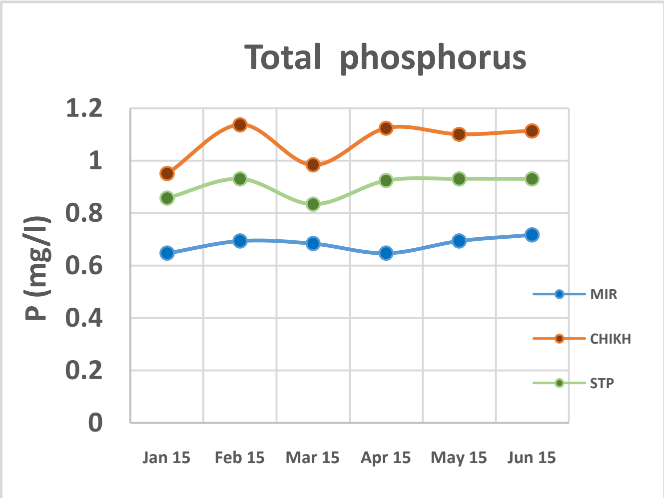

Figure 12 : Evolution of total phosphate in seawater at the sites: Mirleft (MIR),), Cheikh (point of discharge of untreated sewage: CHIKH) and point of discharge of water treated by Sidi Ifni wastwater treatment plant(STP)

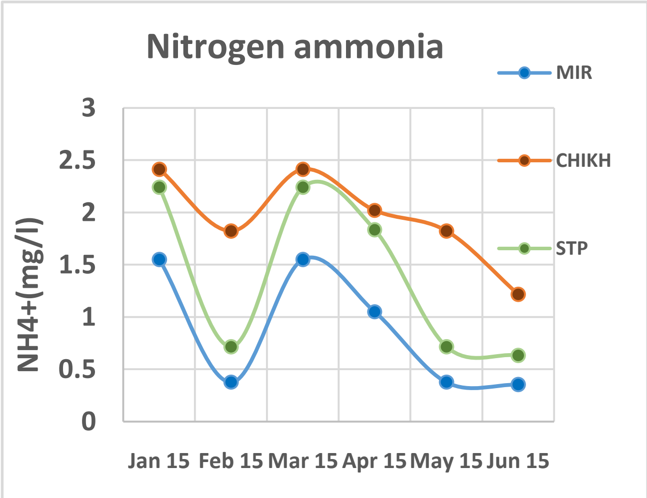

Figure 13 : Evolution of ammonia nitrogen in seawater at the sites: Mirleft (MIR),), Cheikh (point of discharge of untreated sewage: CHIKH) and point of discharge of water treated by Sidi Ifni wastwater treatment plant(STP)

3.11. Nitrites and nitrates

The values recorded in study sites show similar variations in nitrite and nitrate concentrations during the study period. However, nitrite and nitrate levels remain higher in the Cheikh and Step sites compared to the Mirleft site. The maximum values were detected in winter (Figures 14 and 15).

This results show the intense nitrifying activity that takes place in the marine environment in studied sites. Laporte et al. [15] have shown in an experiment laboratory that the organic matter is rapidly mineralized and ammoniacal nitrogen is oxidized to nitrous nitrogen and nitric nitrogen. Therefore, the wastewater discharged sites could be enriched by nutrient salts which are normally requied for the growth of plants in the littoral zone and become so factors of eutrophication in some sensitive sites. Indeed at the Cheikh site in particular, low levels of dissolved oxygen are recorded.

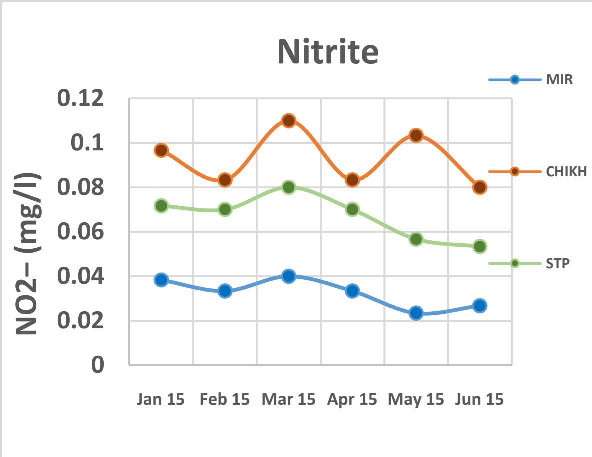

Figure 14 : Evolution of nitrites in seawater at sites: Mirleft (MIR), Cheikh (point of discharge of untreated sewage: CHIKH) and point of discharge of water treated by Sidi Ifni wastewater treatment plant (STP)

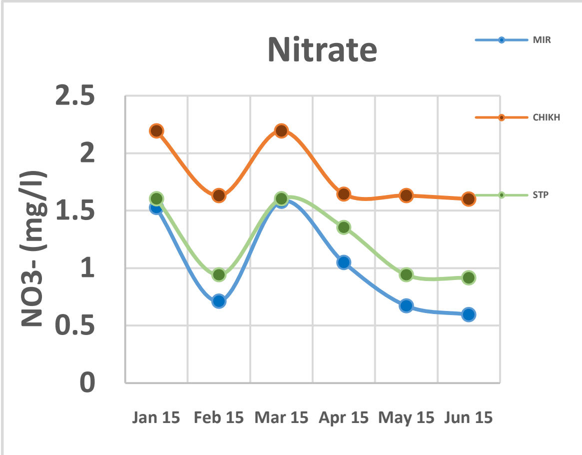

Figure 15 : Evolution of nitrates in seawater at sites: Mirleft (MIR),, Cheikh (point of discharge of untreated sewage: CHIKH) and point of discharge of water treated by Sidi Ifni wastewater treatment plant (STP)

This could probably be explained by a strong microbiological activity, which is at the origin of the oxidation of the organic matter brought by the wastewater. In this regard, Ballay [16] showed that the oxidation of an effluent containing 30 mg/l of ammoniacal nitrogen borrows about 140 mg/l of oxygen from the receiving medium.

In addition, comparatively, the nitrate values recorded during the two months of study are higher than those of nitrites recorded in seawater at all sites. These low nitrite concentrations could be explained by the fact that nitrite ion is an intermediate between ammonium and nitrates and is unstable in the presence of oxygen [17].

3.12. Statistical analysis and data correlation

The study of the correlation between the physicochemical parameters analyzed gives information about the degree possible associations between them (Table 2).

Table 2: Correlation matrix between the physicochemical parameters measured during the study period (January to June 2015) in the coastal waters of the sites: Mirleft (MIR), Cheikh (point of discharge of untreated sewage: CHIKH) and point of discharge of water treated by Sidi Ifni wastewater treatment plant (STP)

(T: Temperature, OD: Dissolved Oxygen, CE: Electrical Conductivity, Sal: Salinity, Cl: Chlorides, MES: Suspended Solids, TH: Total hardness, P: Total phosphorus, SO4: Sulfates, NO3: Nitrates, NO2: Nitrites NH4: Ammonium)

Pearson correlation with *: p <

	T°	EC	Sal	Cl^-	P	NO_2^-	SO_4^{2-}	TH	Turbidity	NO_3^-	TSS	pH	DO	NH_4^+
T°	1,000													
EC	0,666***	1,000												
Sal	0,663***	0,938***	1,000											
Cl^-	0,290*	0,071	0,065	1,000										
P	0,249	-0,230	-0,197	0,473***	1,000									
NO_2^-	-0,027	-0,563***	-0,508***	0,224	0,809***	1,000								
SO_4^{2-}	-0,506***	-0,556***	-0,553***	0,154	0,337*	0,366*	1,000							
TH	-0,861***	-0,824***	-0,752***	-0,308*	-0,162	0,217	0,453***	1,000						
Turbidity	-0,166	-0,612***	-0,531***	0,038	0,687***	0,875***	0,382**	0,367**	1,000					
NO_3^-	-0,307*	-0,767***	-0,692***	-0,185	0,479***	0,781***	0,374**	0,586***	0,820***	1,000				
TSS	-0,261	-0,775***	-0,679***	0,079	0,626***	0,871***	0,411**	0,539***	0,866***	0,884***	1,000			
pH	-0,602***	-0,222	-0,227	-0,316*	-0,834***	-0,551***	-0,043	0,532***	-0,440***	-0,177	-0,287*	1,000		
DO	-0,653***	-0,268*	-0,234	-0,446***	-0,775***	-0,463***	-0,007	0,660***	-0,291*	-0,085	-0,112	0,874***	1,000	
NH_4^+	-0,436***	-0,753***	-0,680***	-0,268	0,420**	0,748***	0,339*	0,646***	0,825***	0,932***	0,837***	-0,120	0,026	1,000

0.05; **: p <0.01; ***: p <0.001

Table 2 shows the correlations between the various physicochemical parameters measured in the coastal waters of Sidi Ifni. Several significant correlations could be identified and showed the good correlation between salinity (Sal) and electrical conductivity (CE). These significant links can be attributed to the increase in temperature. However, there was a significant negative correlation between the group (CE and Sal) and the ions (SO_4^{2-}, NO_2^-, NO_3^- and NH_4^+) and turbidity and suspended solids (MES). Moreover, the parameters of Turbidity, MES, Cl^-, SO_4^{2-}, NO_2^-, NO_3^- and NH_4^+) are strongly correlated with total phosphorus, which is both negatively associated with dissolved oxygen and pH. Finally, a significantly negative correlation was obtained between chloride ions and total hardness (TH) parameters, dissolved oxygen and pH.

In order to establish a relationship between the different physicochemical parameters and evaluate the effect of anthropogenic activities on the quality of the coastal waters of Sidi Ifni, a statistical treatment by Principal Component Analysis (PCA) was applied to all the parameters measured during our study period. This method is widely used to interpret hydrochemical data [18], [19], [8].

Multivariate analysis showed that 79.43% of the variance was expressed. The projection of variables on the factorial planes has two poles (Figure 16): *i)* The F1 plane showing 48.68% of the variance and expressing an axis characterizing the mineralization of the waters by the leaching of the geological formations. This is determined by electrical conductivity, salinity, turbidity, sulphates, nitrates, nitrites, ammonium ions and water hardness, and *ii)* the factor plane F2 representing only 30.75% of the information and considered as an axis characterizing urban pollution by domestic wastewater. This is determined by pH, dissolved oxygen, temperature, chlorides and total phosphorus (Figure 16)

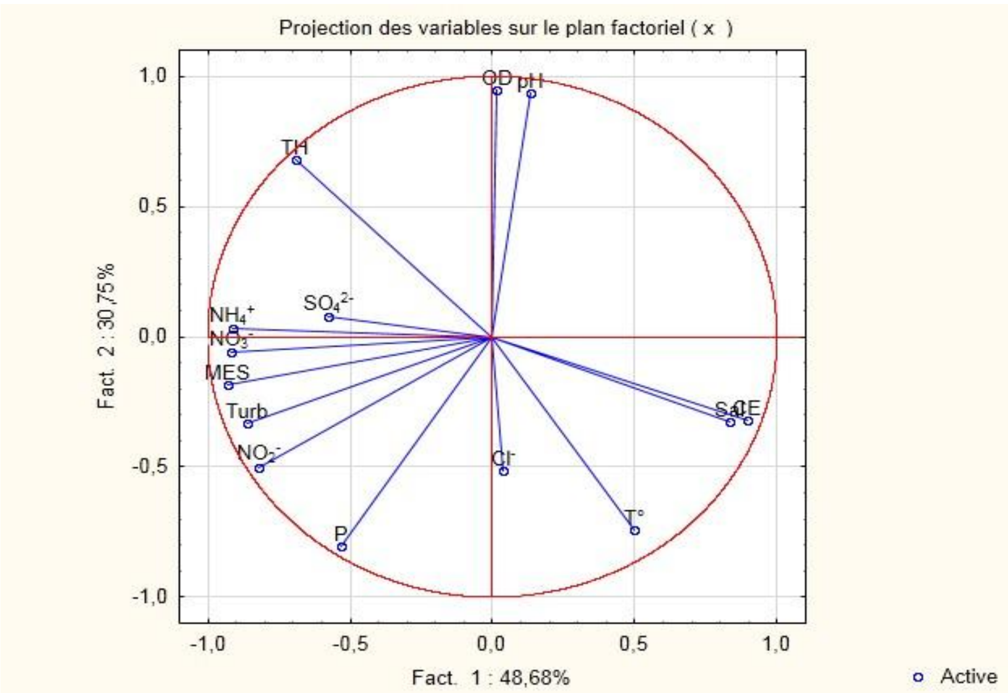

Figure 16: Representation of the physicochemical parameters in the coastal waters of the sites: Mirleft (MIR), Sheikh (point of discharge of untreated sewage: CHIKH) and point of discharge of water (T: Temperature, OD: Dissolved Oxygen, EC: Electrical conductivity, Sal: Salinity, Cl: Chlorides, MES: Suspended solids, TH: Total hardness, P: Total phosphorus, SO4: Sulfates, NO3: Nitrates, NO2: Nitrites NH4: Ammonium)

4. Conclusion

Spatio-temporal monitoring of the physicochemical quality of water at the coastal area of the marine ecosystem of Sidi Ifni constitutes a preliminary contribution to the knowledge of Moroccan South Atlantic ecosystems and particularly that of Sidi Ifni coast, which has never been studied.

The analyzes carried out in this study (*T°, pH, O_2 dissolved, Turbidity and Suspended matter, Conductivity, Salinity, Total hardness, Chlorides and Sulfates, Total phosphorus, Ammoniacal nitrogen, Nitrites and Nitrates*) allowed to make a diagnostic about the physico-chemical health of this marine ecosystem. They revealed a real disturbance of the physical and chemical characteristics of this ecosystem and particularly at the site of Cheikh comparatively to the Mirleft site. The Cheikh site shows an anoxia especially during winter and spring with high levels of nutrients indicating a tendency towards eutrophication.

In the light of these results, monitoring of Sidi Ifni coasts is essential by effective development of means of preventing pollution. On the other hand, in the long term, we must think of treating the entire city's wastewater before rejecting it in the marine environment or finding an alternative of its reuse.

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