RESEARCH ARTICLE

ANALYSIS OF THE PHYSICOCHEMICAL AND MICRO BIOLOGICAL PARAMETERS CHARACTERIZING THE QUALITY OF THE WATERS OF THE OULADINE LAGOON (CÔTE D'IVOIRE)

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Abstract
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The objective of this study was to determine the effect of anthropogenic pressures on the quality of water in the Ouladine lagoon, located in Grand-Bassam, through the analysis of physicochemical and microbiological parameters. Hydrological parameters were measured and water samples collected at ten stations. Ammonium, nitrate, nitrite, total nitrogen, orthophosphate, total phosphorus, BOD_5 and bacteria were measured in the sampled water, allowing their quality to be assessed.

The average values obtained for the hydrological parameters were 9.38 for pH, 31.71°C for temperature, 20.54μS/cm for conductivity, 11123.23 mg/L for TDS, and 12.31 mg/L for salinity. The average concentrations of chemical parameters are equal to 8 mg/L for BOD_5, 34.35 mg/L for total nitrogen, 0.40 mg/l for orthophosphate, 1.13 mg/L for total phosphorus, 0.18 mg/L for ammonium, 0.009 mg/L for nitrite and 9.53 mg/L for nitrate. Salmonella and Escherichia coli were not observed in the waters of the Ouladine lagoon. Total coliforms and enterococci have concentrations that vary respectively between 300 and 16700 CFU/100 ml and from 0 to 590 CFU/100 ml.

The intensity of pollution varies from moderate to strong.

The waters of the Ouladine lagoon would be mostly suitable for recreational activities.

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Introduction:-
The Ouladine lagoon is located in Grand-Bassam in the southeast of Côte d'Ivoire, between altitude 5°12'26" North and longitude 3°45'28" West. This lagoon is separated from the atlantic ocean by a narrows and bar. It is of significant interest to the local population as well as to third-year undergraduate students in Earth Sciences at Félix Houphouët-Boigny University. Indeed, the Pachymelania genus living in this body of water is used by teachers at

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the Earth Sciences and Mineral Resources Training and Research Unit to enhance their students' understanding of Dolo's law. As a source of sustenance, it offers significant fishing opportunities, thus contributing to the local economy and providing food resources for residents. Furthermore, its calm and shallow waters make it an attractive place for swimming and leisure activities, attracting residents and visitors seeking relaxation and entertainment. The sands dredged from the Ouladine lagoon are used in the construction of roads and housing. Despite its socio-economic importance, this lagoon is facing increasing anthropogenic pressure, which is manifested by a significant loss of the surrounding mangroves due to urbanization and the reception of waste water without any treatment. These pressures could negatively impact the quality of its ecosystem, compromising the ecological services it provides, thus threatening local economic and recreational activities (Ouattara and Cecchi, 2019; Egnankou and al., 2023; Mevanly and al., 2024). Several studies have been carried out to understand the functioning of this lagoon (Keumean and al., 2010; Koffi and al., 2016; Keumean and al., 2020; Djogli and al., 2024). However, it has not been possible to assess the capacity of the Ouladine lagoon to fully play its role. The objective of this present study is to undestand the impact of physicochemical and microbiological parameters and to evaluate the effect of anthropogenic pressures on the quality of the waters of the Ouladine lagoon.

Material and methods:-
Determination of physicochemical parameters:
Salinity, TDS, pH, conductivity, and temperature values were measured using a multi-parameter system after calibration. Water samples were collected from different parts of the lagoon. A survey was conducted on the anthropized part of the Ouladine's lagoon. Ten stations were visited. Physicochemical parameter measurements and water samples were taken at a depth of 0.5 meters. Microbiological analyses were performed using the membrane filtration method (Clark and al., 1951; Goetz and al., 1951; CEAEQ, 2013; CEAEQ, 2016a; CEAEQ, 2016b; Ane and al., 2020). Ammonium, nitrite, nitrate, orthophosphate, total phosphorus, BOD_5 and total nitrogen were measured in the water samples collected (AFNOR, 2001; Rodier and al., 2009; CEAEQ, 2014).
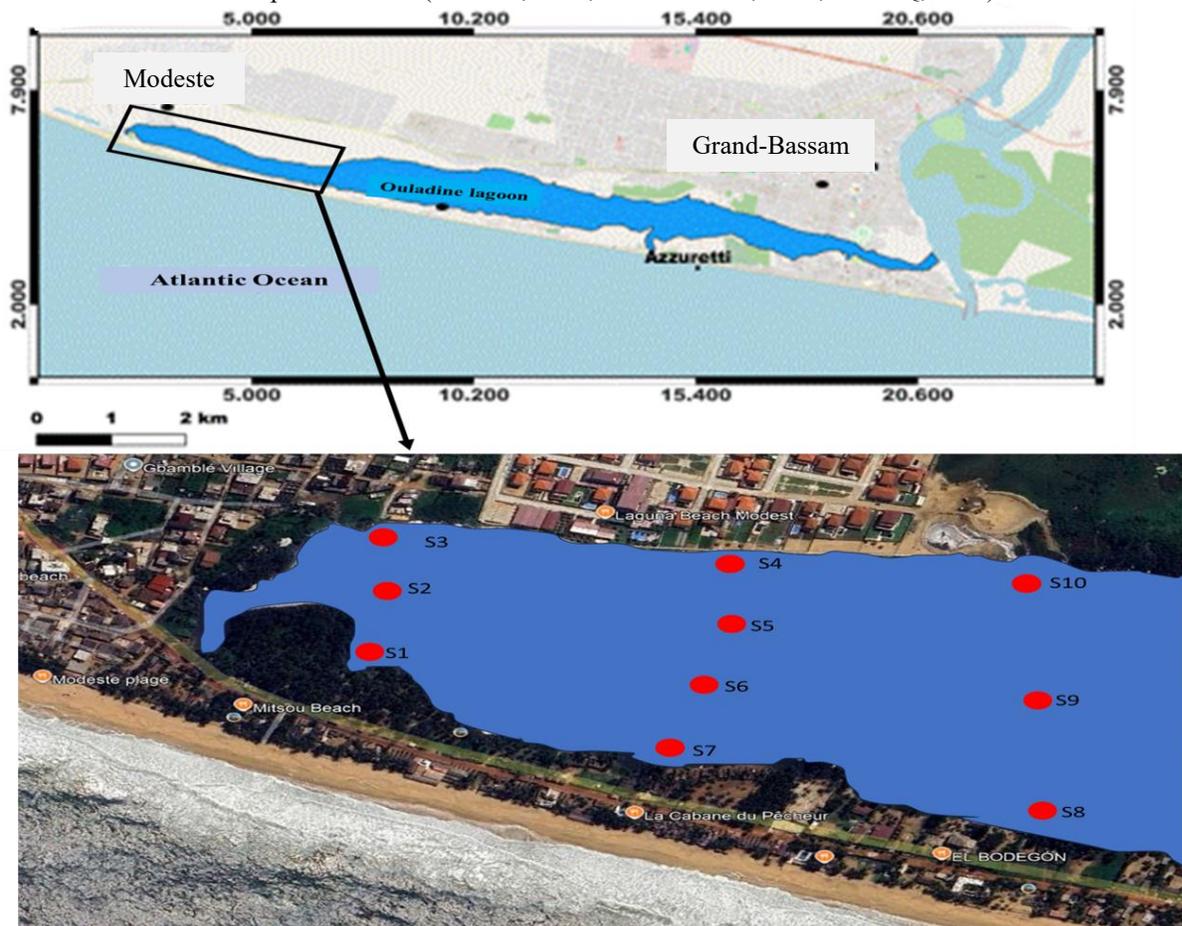

Figure 1. Location of stations

Water quality assessment:-
The suitability of the Ouladine lagoon waters for swimming is determined by comparing microorganism levels and physicochemical parameters with reference values (SEQ-Eau, 2003). The level of water quality degradation is obtained by interpreting the organic pollution index values (Leclercq and Maquet, 1987; Leclercq, 2001).

Results :-
Spatial evolution of physico chemical parameter values :
pH values ranges between 9.31 and 9.51, with an average of 9.38. Stations S6 and S9 have the highest pH values. Water temperatures ranges from 31.22 to 32.09°C. The average value is 31.71°C. Stations S2 and S3 have the lowest temperatures, and stations S1, S6, S8, and S9 have the highest temperatures. Conductivity has values ranging from 19.29 to 21.80 μS/cm, with an average value of 20.54 μS/cm. The lowest conductivity values are found at stations S3 and S6. TDS concentrations are between 9,673 and 15,700 mg/L. The extreme TDS levels are obtained at stations S3 and S4 respectively. The average TDS is 11123.23 mg/L. Salinity levels varies from 9.34 to 13 mg/L ; with an average value of 12.31 mg/L (Figure 2). BOD levels ranges from 7 to 10 mg/L.

The average BOD_5 is 8.6 mg/L. S1 and S3, located at the west of the Ouladine's lagoon, have high BOD_5 levels. Total nitrogen concentrations in the waters of the Ouladine lagoon fluctuate between 21.5 and 37.75 mg/L. The average concentration is 34.35 mg/L. Orthophosphates have concentrations that vary between 0.96 and 0.05 mg/L. High concentrations are observed at stations S2 and S10. Between these two stations, there is an area in which the waters are weakly enriched in orthophosphate. The average orthophosphate concentration in the waters is 0.40 mg/L. Total phosphorus levels in the waters of the Ouladine lagoon fluctuate from 2.71 to 0.27 mg/L, with an average value of 1.13 mg/L. Total phosphorus levels have the same spatial distribution as orthophosphates. High concentrations are observed at stations S2 and S10.

The waters in the area between the two stations are less rich in total phosphorus. Ammonium levels varies from 0.116 to 0.466 mg/L. Stations S3 and S6 have high ammonium levels. The other stations have low ammonium concentrations. The average ammonium content is 0.18 mg/L. The minimum nitrite concentration is 0.006 mg/L and the maximum concentration is 0.015 mg/L. High concentrations are observed at stations S2 and S10. The other stations have waters with low nitrite enrichment. Nitrate concentrations are between 7.9 and 10.6 mg/L ; with an average of 9.53 mg/L (Figure 3). Their variation allows the water body to be divided into three parts. The first has waters withlow nitrate content (S3, S6 and S9). The second zone consists of waters with medium nitrate concentration (S7, S8 and S10). The third part is formed by stations with high nitrate levels (S1, S2, S4 and S5).
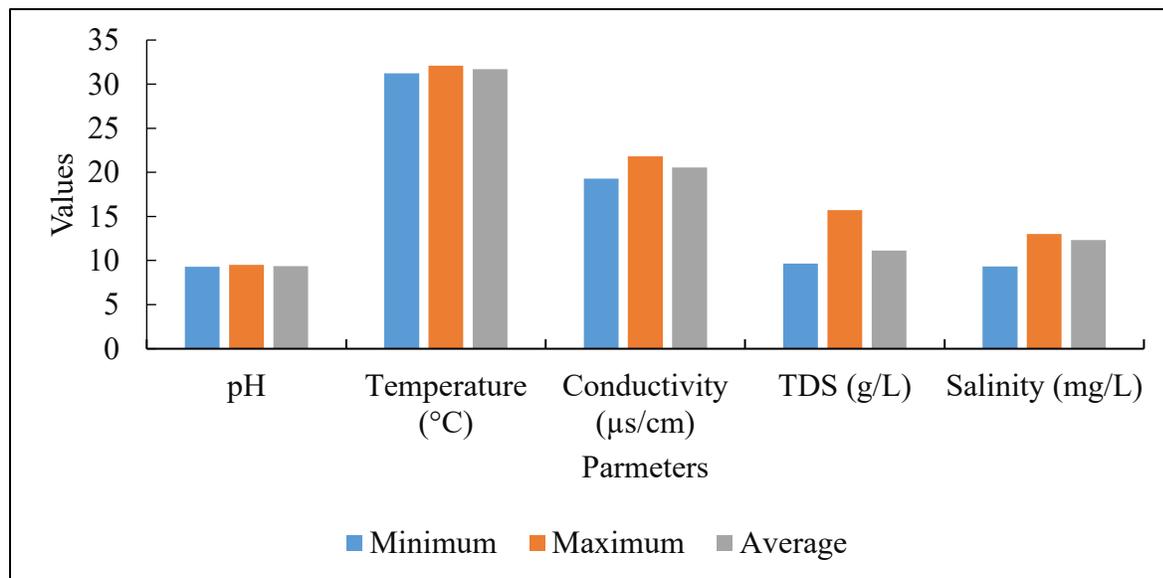

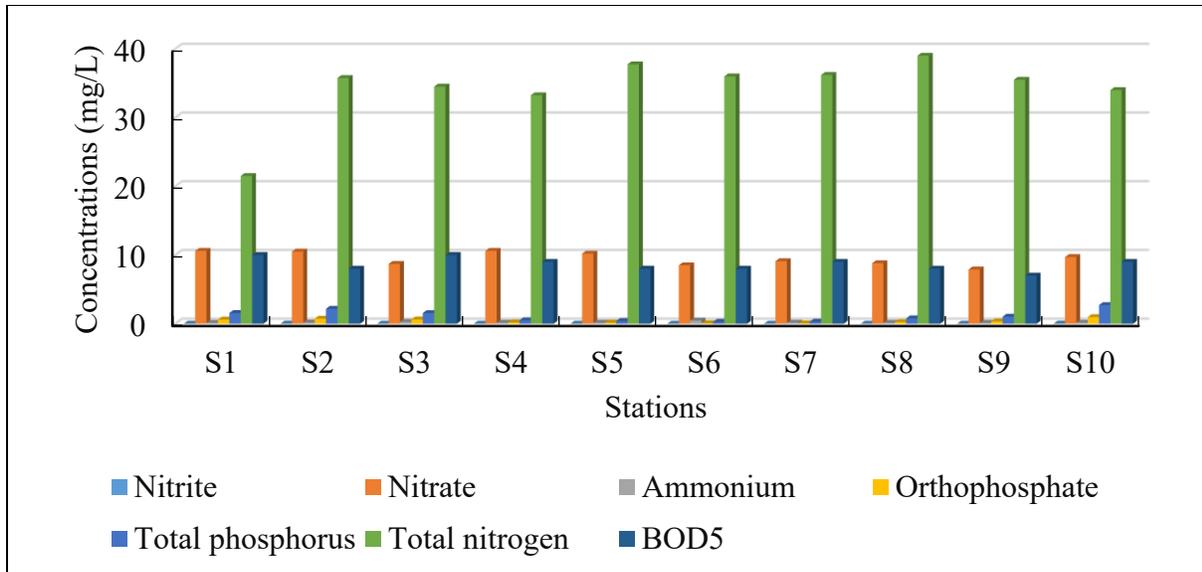**Figure 2. Characteristics of hydrological parameters**

Figure 3. Chemical levels in the Ouladine lagoon

Water quality and suitability for recreation:

Escherichia coli and Salmonella were not observed in the water samples. Total coliform concentrations ranged from 300 to 16,700 CFU/100 ml. The highest concentrations were observed at stations 2 and 8. Stations S1 in the southeast, S6 in the center, S7 in the south, and S9 and S10 in the west recorded low total coliform concentrations. The average concentration was 4,850 CFU/100 ml. Enterococcus levels fluctuated between 0 and 590 CFU/100 ml. The waters at stations S4 and S10 did not contain enterococci. High enterococcus levels were recorded at stations S1 and S10. The average concentration was 96 CFU/100 ml.

The organic pollution index values ranges from 2.75 to 3.75. Pollution intensity ranges from moderate to severe. Only station S10 indicates severe pollution. The other stations are moderately polluted. Total coliform and enterococci concentrations in the water samples distinguishes between very good, good, and poor-quality water for recreational use (Table 1). Based on total coliform levels, 80% of the stations have water suitable for recreational activities. Enterococcus levels indicate recreational suitability for 90% of the water samples.

Table 1. Suitability of water for recreation

	Total Coliforms (CFU/100 ml)			Enterococci (CFU/100 ml)		
	Very good 500	Good 10000	Bad >10000	Very good 100	Good 200	Bad >200
S1		●				●
S2			●	●		
S3		●		●		
S4		●		●		
S5		●		●		
S6		●		●		
S7	●			●		
S8			●		●	
S9		●		●		
S10		●		●		

Discussion:

The electrical conductivity of the waters of the Ouladine lagoon varies between 19.29 µS/cm and 21.80 µS/cm, with an average of 20.54 µS/cm. This variation in conductivity is thought to be influenced by several factors such as marine water's infiltration, dilution by precipitation, and fresh water or waste water inputs. The average conductivity is 26.87 µS/cm in the Ono's lagoon (Gboko and al., 2018). The difference in conductivity between these lagoons is thought to be related to the environment in which they are located (anthropogenic pressure, rainfall, rivers). The average pH is 9.38 in the Ouladine lagoon. In the Grand-Lahou's lagoon, pH values are around 8.46 in the dry season (Konan and al., 2013). The pH in the Ouladine's lagoon is higher than in the Grand-Lahou's lagoon.

This could be explained by significant underground infiltration of marine waters in the dry season in the Ouladine's lagoon compared to the Grand-Lahou's lagoon. The average concentration of ammonium in the waters of the Ouladine's lagoon is 0.18 mg/L or 180 µg/L. 15 years ago, studies indicated an average concentration of 69 µg/L (Keumean and al., 2010). The current high ammonium content is thought to be due to increased anthropogenic pressure, the destruction of mangroves, and the lack of treatment of waste water and rain water before its discharge into the Ouladine's lagoon. Total coliforms were measured in the waters of the Ouladine's lagoon. It's presence in the lagoon waters does not necessarily indicate poor water quality.

Coliforms are bacteria naturally present in the environment. The high concentration of total coliforms and enterococci in stations 2 and 8 could be explained by the discharge of domestic waste directly or indirectly into the waters by the population at these stations. The areas indicated correspond respectively to the fishermen's embarkation and disembarkation quay (S1) and the bathing area (S8). The bacteria arrive in the lagoon waters through the discharge of untreated domestic waste water (Niamien-Ebrottie and al., 2008). Salmonella is absent in the waters of the Ouladine's lagoon. The same is true for the waters of the Aghien's lagoon. They do not contain bacteria of the genus Salmonella (Traoré and al., 2012). This observation highlights the low level of anthropogenic pressures exerted on these bodies of water. Indeed, these waters are currently protected from the heavy discharge of domestic and industrial waste water.

Conclusion:

The study analyzing the physicochemical and microbiological parameters of the Ouladine's lagoon made it possible to assess the quality of water in this hydrosystem. The hydrological parameters ranged from 9.31 to 9.51 for pH, from 31.22 to 32.09°C in temperature, from 19.29 to 21.80 µS/cm in conductivity, from 9673 to 15700 mg/L in TDS, and from 9.34 to 13 mg/L in salinity. The concentrations of chemical parameters range from 7 to 10 mg/L in BOD_5, from 21.5 to 37.75 mg/L for total nitrogen, from 0.05 to 0.96 mg/L in orthophosphate, from 0.27 to 2.71 mg/L for total phosphorus, from 0.116 to 0.466 mg/L in ammonium, from 0.006 to 0.015 mg/L in nitrite and from 7.9 to 10.6 mg/L in nitrate.

Salmonella and Escherichia coli are absent from the waters of the Ouladine's lagoon. Total coliforms and enterococci were abundant in the southeast and southwest of the lagoon respectively. They have low concentrations in the center of the water body. The pollution index ranges from 2.75 to 3.75, indicating a moderate to severe pollution level. The waters of the Ouladine's lagoon can be of very good, good, or poor quality for recreational use. The waters in the swimming areas and the fishing boat dock are not suitable for recreational use.

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