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Analysis of Total Hydrocarbon Content in Sediments and Physicochemical Parameters of Waters in Adiopodoume Bay (Ebrie lagoon, Cote d'Ivoire)

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ABSTRACT

The Ebrie lagoon is a vast brackish body of water on the Ivorian coast, subject to strong anthropogenic pressures. Of all its bays, the one of Adiopodoume seems to be protected from the effects of these activities. The studies carried out about total hydrocarbons missed this bay over thirty years ago. The current study was conducted to determine the concentration levels of total hydrocarbons in the sediments of the bay of Adiopodoume and the evolution of hydrological parameters. This study required the measuret of pH, conductivity, ORP, dissolved oxygen, TDS, and salinity at 10 stations using a multiparameter. 10 sample sediments were also collected. After freeze-drying the sediments, the hydrocarbons were extracted using appropriate solutions. The total hydrocarbon content was obtained by GC-MS analysis. The average values of the physicochemical parameters are: 8.1 for pH, 11.35 mV for ORP, 7.3 mg/l for dissolved oxygen, 40.20 mS/cm for conductivity, 16.82 g/l for TDS, and 22.73 ‰ for salinity. Hydrocarbons were detected only at stations A4, A8, and A10. The average content is 0.3033 mg/kg. The hydrocarbons are likely from urban activities and discharges due to lagoon transport and the amount of organic matter contained in the sediments. The absence of hydrocarbons in some areas could be explained by sand dredging activities, the low level of organic matter in the sediments, and water movement orchestrated by the tide.

Keywords: evaluation, content, hydrocarbons, sediments, bay of Adiopodoume

INTRODUCTION

Oil, whose exploitation represens one of the pillars of the modern industrial economy, is a mixture of hydrocarbons and various organic residues. Its use as liquid fuels and input in the chemical production of polymers generates discharges into the aquatic environment (Boudreau et al., 2019). The Ebrie lagoon receives wastewater from the city of Abidjan without any prior treatment. These waters contain organic pollutants including hydrocarbons (Irie and al., 2024a) and pesticides (Irie and al, 2024b). The presence of hydrocarbons in this hydrosystem could be the cause of the degradation of sediment quality and negatively impact aquatic life. Aware of this danger, research work has been carried out on the Ebrie lagoon concerning total hydrocarbons (Marchand and Martin, 1985). This work did not allow for sediment sampling in the bay of Adiopodoume. This bay, located in the northwest shore of the Ebrie lagoon, is considered to be one of its bays still preserved from the harmful effects of anthropogenic activities. It has an average slope of 1.77°, with depths ranging between 0 and 10.50 m, for an average of 2.50 m (Diangone and al., 2019). In order to contribute to the preservation of this bay, this study, which aims to determine the concentration level of total hydrocarbons (TH) in the sediments of the bay of Adiopodoume, was initiated. In parallel with this objective, measurements of the values of the physicochemical parameters of the bay's waters will be taken to analyze their spatial variation.

I. MATERIAL AND METHOD

I.1. Measurement of hydrological parameters and Sediment sampling

Measurements were taken on Monday, February 27, 2020, at ten (10) stations using a multi-parameter device (figure 1). A GPS was used to determine the geographical coordinates of the measurement stations for pH, oxidation-reduction potential (ORP), electrical conductivity (EC), dissolved oxygen (O2), total dissolved solids (TDS), and salinity. These measurements were taken in the water, at a depth of 0.5 meters.

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Sediment sampling was carried out using a Van Veen grab. In total, 10 sediment samples were collected at the same stations as the water samples (Figure 1). Once in the water, the grab closes upon contact with the bottom and scrapes the surface layer. The collected sediments are wrapped in aluminum foil, then numbered and stored in a cooler at 4°C.

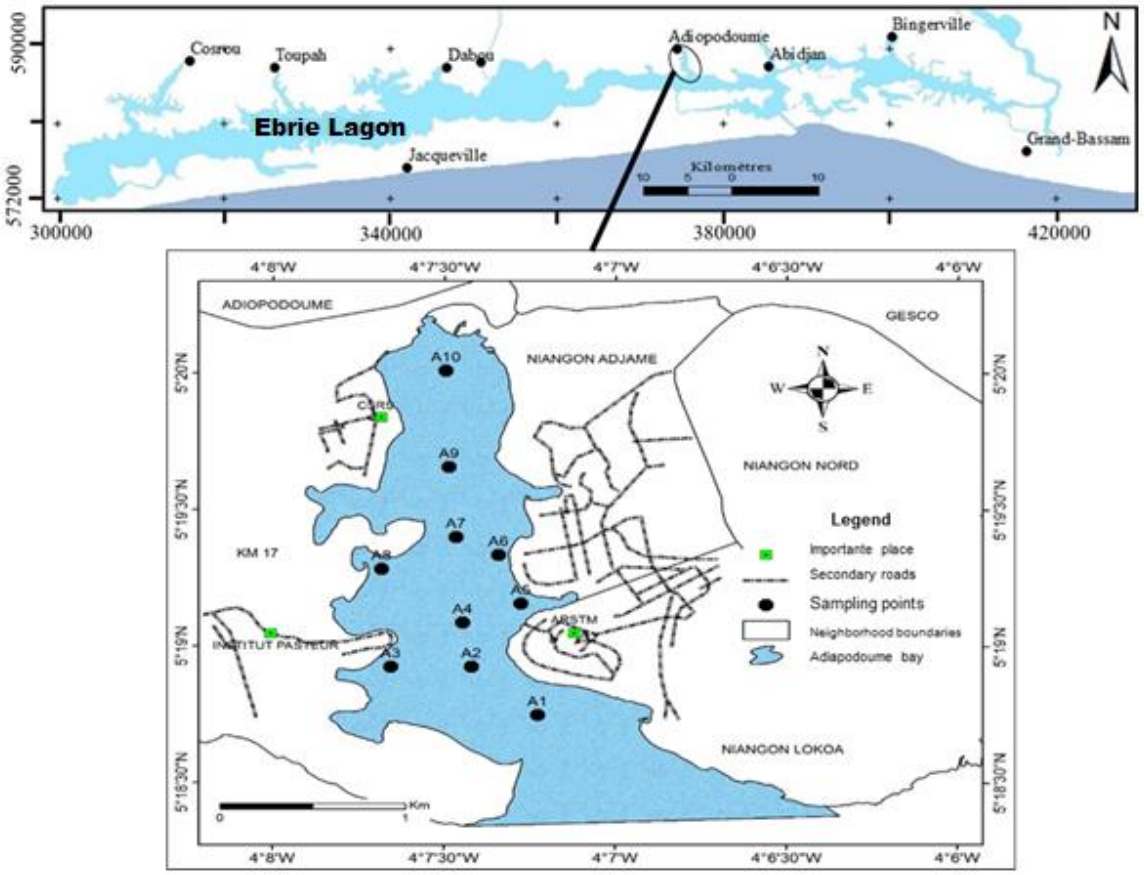

Figure 1. Location of measurement and sampling stations

I.2. Determination of the total hydrocarbon concentration in sediments

After extracting moisture from sediment samples by lyophilization, they are homogenized using an electric stirrer. 100 ml of dichloromethane is added to 50 g of prepared sediments for analysis. The mixture is agitated in an ultrasonic bath for 30 minutes. The resulting extract is filtered and evaporated. Sulfur is removed from the samples by repeated treatment of the extracts with mercury until the latter clarifies. The polar fraction is separated from total hydrocarbons using a preparative adsorption chromatography technique on a silica/alumina column. Compound elution is performed with varying concentrations of n-heptane. Total hydrocarbons and polar compounds are evaporated using a rotary evaporator. They are then recovered in vials (Le Dreau, Y., 1996; Mazouz and Smail, 1996; Asia and al., 2009; Asia, 2012). Total hydrocarbons are quantified by gas chromatography coupled with mass spectrometry (GC-MS). Analyses were performed in duplicate.

II. RESULTS

II.1.Variation of pH in the bay waters

pH values range from 7.3 to 8.9, with an average of 8.1. The lowest pH value (7.3) is measured at station A3. The highest pH value (8.9) is recorded in the East of the bay, at station A5 (Figure 2). The pH values indicate that the waters of this bay are alkaline.

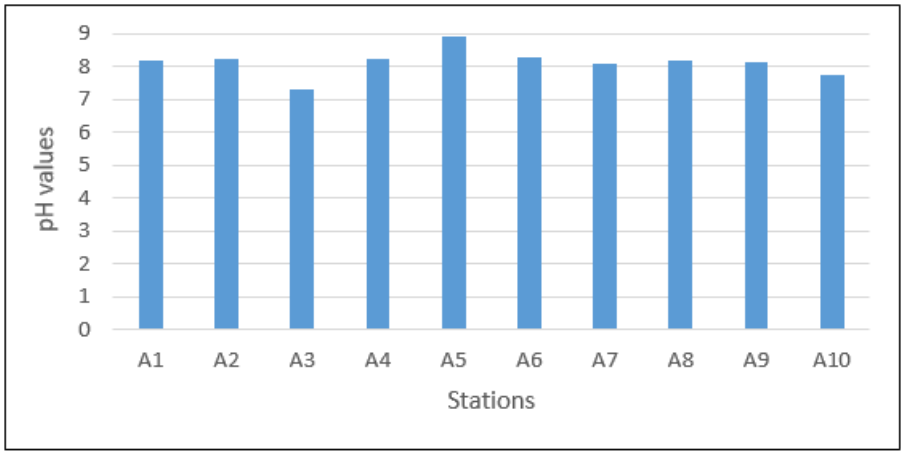

Figure 2: Spatial distribution of water pH values

II.2. Distribution of oxidation-reduction potential (ORP) values

The minimum and maximum ORP values are 9.4 and 16.4 mV respectively. The average value is 11.35 mV. The values are measured at station A7 for the lowest and A6 for the highest (Figure 3).

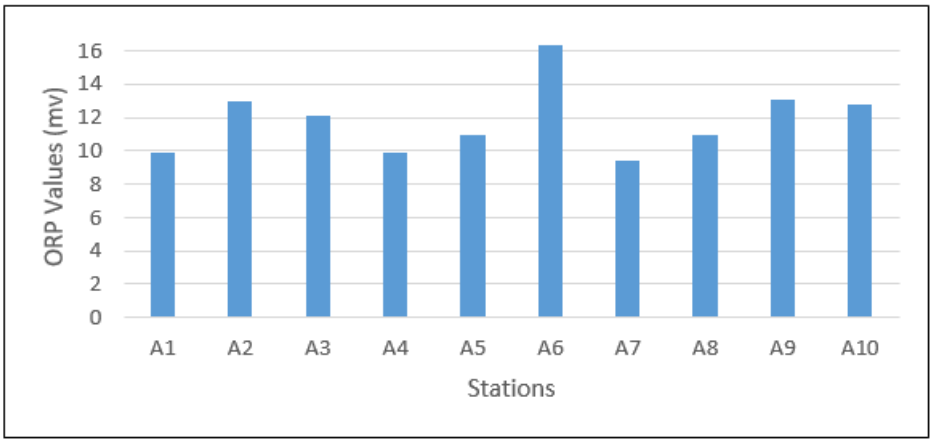

Figure 3: ORP values in the waters of Adiopodoume Bay

II.3. Evolution of the electrical conductivity values of the bay

The waters of Adiopodoume Bay have an average conductivity of 40.20 mS/cm. The minimum (24.31 mS/cm) and maximum (78.4 mS/cm) conductivity values are observed at stations A10 and A6 respectively (Figure 4).

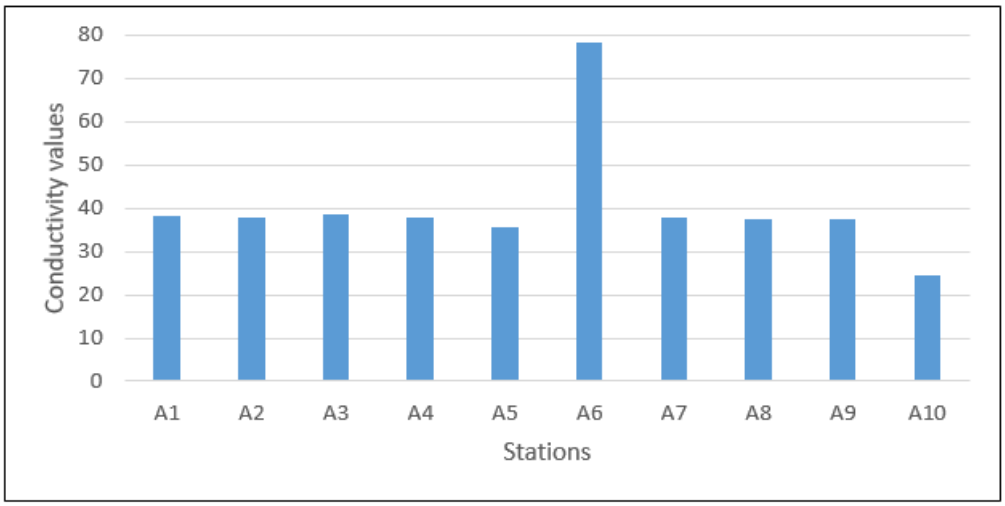

Figure 4: Fluctuation of conductivity values in the bay

II.4. Oscillation of Total Dissolved Solids (TDS) values

TDS values range from 18.96 g/l to 5.4 g/l, with an average of 16.82 g/l. The low value is observed at station A6 located in the East of the bay. Station A3, in the Southeast of the bay, records the highest value (Figure 5).

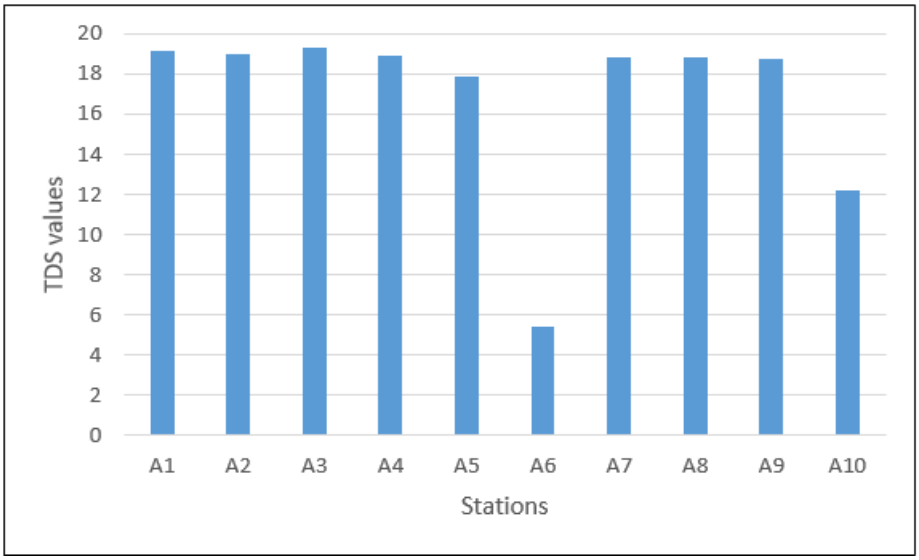

Figure 5: TDS values in Adiopodoume Bay

II.5. Evolution of salinity values in the bay

Salinity values range from 14.76‰ to 24.36‰. The average salinity is 22.73‰. At station A10, the observed salinity is very low compared to the salinity value observed at the other measurement stations. Station A3 located in the Southwest of the bay records the maximu salinity value (Figure 6).

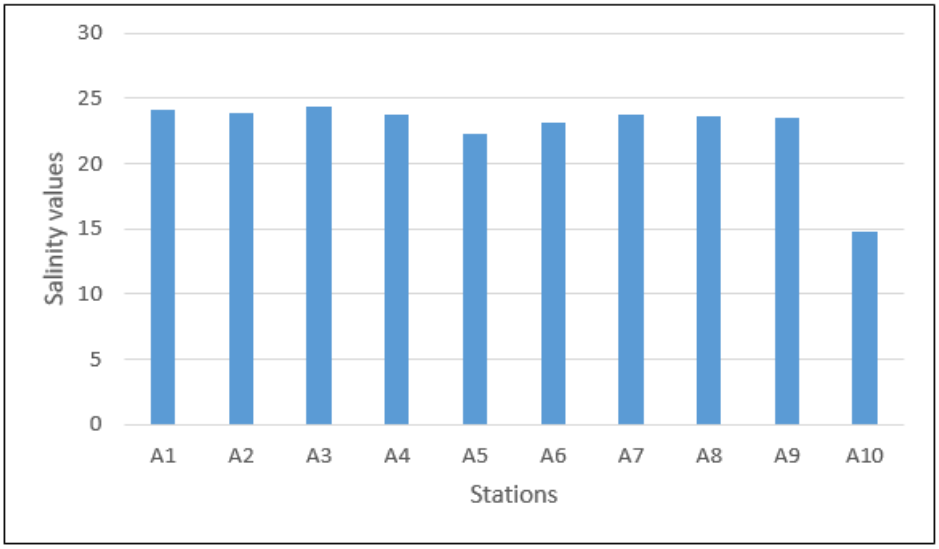

Figure 6: Distribution of salinity values in Adiopodoume Bay

II.6. Variation of dissolved oxygen in Adiopodoume Bay

The dissolved oxygen content is minimal at station A7 (4.17 mg/l) and maximal at station A6 (18.47 mg/l). The average is 7.3 mg/l. Oxygen levels are low in the North of the bay compared to the South (Figure 7).

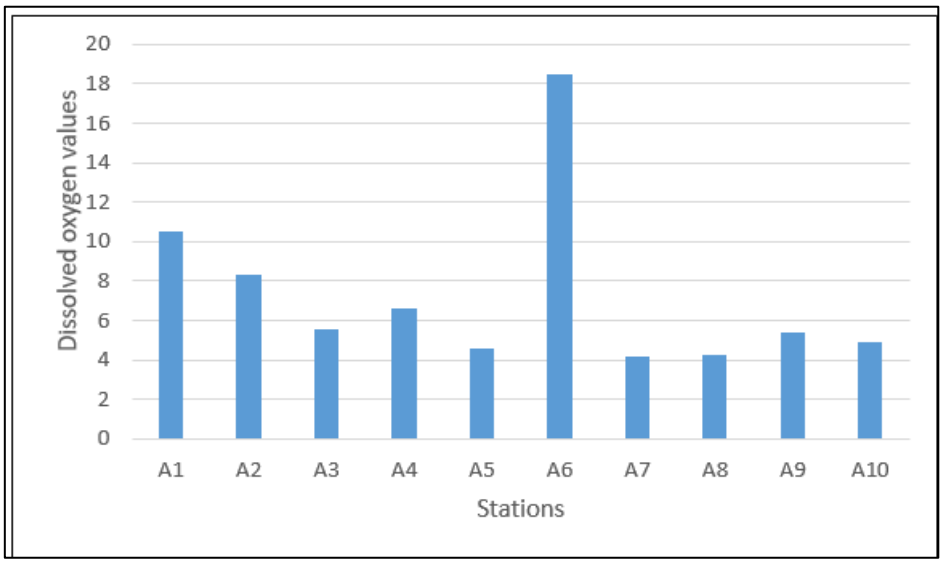

Figure 7: Evolution of dissolved oxygen levels in the bay

II.7. Total hydrocarbon (TH) concentration in sediments

Hydrocarbons are present in the sediments of three (3) sampling stations out of the ten (10) samples (Table I). These three stations are located in the Center for station A4 and A8 and A10 in the North of the bay.

Table I: Total hydrocarbon concentration (mg/kg) in sediments

Sample numbers	Total hydrocarbon	Total hydrocarbon	Moyen
A1	<0	<0	
A2	<0	<0	
A3	<0	<0	
A4	1,0003	1,0026	1,0014
A5	<0	<0	
A6	<0	<0	
A7	<0	<0	
A8	1,0079	1,0072	1,0075
A9	<0	<0	
A10	1,0349	1,0329	1,0339

III. DISCUSSION

III.1. Evolution of physicochemical parameters

The maximum values of salinity and TDS are observed at the same station (A3). The waters at station A3 are saltier because they would retain the oceanic waters that enter Adiopodoume Bay by passing through the main channel of the Ebrie lagoon. This intrusion of Atlantic Ocean waters into the bay occurs during high tide.

The average salinity in Adiopodoume Bay is 22.73‰. It is 30.4‰ for Billionaires' Bay (Inza and al., 2009). The salinity in Adiopodoume Bay is lower than that of Billionaires' Bay. These values being obtained in the same month (February), the distance of Adiopodoume Bay from the Atlantic Ocean compared to Billionaires' Bay could be the main cause of this difference.

Dissolved oxygen and redox potential follow the same evolution. They are minimal at station A7 and maximal at station A6. The high oxygen values at station A6 would be due to the activity of plants present on the banks of the bay in this area. They enrich the water with oxygen during photosynthesis.

The average dissolved oxygen value is 7.3 mg/l in Adiopodoume Bay and 5.5 mg/l in Biétry Bay (Amani et al., 2019). The waters of Adiopodoume Bay are more oxygenated than those of Biétry Bay. This difference in water oxygenation is likely due to an enrichment of Biétry Bay with oxidizable matter compared to Adiopodoume Bay. The chemical oxygen demand value is 750 mg/l in Biétry Bay (Amani and al., 2019) and 66 mg/l in Adiopodoume Bay (Irie and al., 2018).

III.2. Total hydrocarbons in Adiopodoume Bay sediments

Sediment samples A10, A8, and A4 are the only ones containing hydrocarbons in this study. The presence of hydrocarbons in these stations could be linked to their high organic matter content (Konan, 2021), the effect of urban discharges (Razika and al., 2013), and also hydrocarbon discharges from lagoon transport. The other samples do not contain hydrocarbons. This observation could be explained by the regular dredging of sediments in these areas, the low organic matter content of these sediments, and the hydrodynamics of the bay's waters under the influence of Atlantic Ocean waters. Adiopodoume Bay is connected to Ebrie Lagoon at its southern end. During the movements of the lagoon waters, sediments entering the bay will be swept away, and hydrocarbons will not have time to settle.

The average total hydrocarbon content in Adiopodoume Bay is 0.30 mg/kg. In Bietry Bay, the average content is 1365.75 mg/kg, while it is 191 mg/kg in Koumassi Bay (Marchand and Martin, 1985). The contents in the two bays are significantly higher than that of Adiopodoume Bay. This difference could be due to the effects of anthropogenic activities, which are likely stronger in Bietry and Koumassi Bays compared to Adiopodoume Bay. A large part of the banks of this bay is still covered by vegetation. In contrast, Koumassi and Bietry Bays are directly exposed to domestic and industrial discharges.

Conclusion

The objective of this study was to determine the concentration of total hydrocarbons in sediments and the variation in the values of physicochemical parameters of the water in the Adiopodoume Bay.

The values of the physicochemical parameters vary as follows: 7.3 to 8.9 for pH, 9.4 to 16.4 mV for ORP, 4.17 to 18.47 mg/l for dissolved oxygen, 40.20 to 78.4 mS/cm for conductivity, 5.4 to 18.96 g/l for TDS, and 14.76 to 23.88‰ for salinity. pH, conductivity, TDS, and salinity depend on the intrusion of oceanic waters into the bay. The evolution of dissolved oxygen and oxidation-reduction potential values is influenced by the amount of oxidizable matter in the water and the photosynthetic activity of plants.

The presence of total hydrocarbons was noted in three (3) out of ten sediment samples. The hydrocarbons from the three stations likely originate from urban discharges, the high level of organic matter in the sediments, and leaks due to lagoon transport. The absence of total hydrocarbons in the seven stations could be caused by sediment dredging activities, hydrodynamics, and the low level of organic matter in the sediments.

Author Contributions Statement

KANDO, IRIE and DAGNOGO participated in the fieldwork, data processing and writing of the article. The study was supervised by COULIBALY.

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Conflict of Interest Statement: All authors have nothing else to disclose.