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RESEARCH ARTICLE

SPATIO-TEMPORAL DYNAMICS OF ARSENIC CONTAMINATION OF SEDIMENTS IN IVORIAN COASTAL LAGOONS: THE CASE OF THE ABY LAGOON SYSTEM (ABYNORTH, TENDO)

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Abstract

Arsenic present in various components of lagoon ecosystems. This study aims at characterizing its distribution and identifying the factors influencing its mobility and bioavailability. Sediment samples were collected, prepared, and analyzed according to standardized protocols. Arsenic concentrations, measured by ICP-MS, were subjected to statistical analyses (ANOVA, t-test, correlation, etc.). The results revealed significant variability in arsenic concentrations in the sediments of the studied lagoons, with averages ranging from 9.13 mg/g in Tanoé lagoon to 27.16 mg/g in the bays of Tendo lagoon. They also showed seasonal and spatial variations in arsenic contamination, linked to the hydrological, geological and anthropogenic conditions of each site. Significant correlations were found between arsenic concentrations and environmental parameters such as salinity, transparency, conductivity and pH. These results contribute to a better understanding of the processes governing arsenic dynamics in coastal lagoons and underline the importance of considering seasonal variations and environmental conditions in sediment contamination studies.

Introduction:-

Arsenic is a metalloid that occurs naturally in the environment. It is increasingly recognized as a major contaminant of water, soil and sediment (Almelaand al., 2002), (Hussain and al., 2023). Emitted by a variety of anthropogenic activities, including mining, fossil fuel combustion, and fertilizer use, arsenic has significant toxic effects on human health and aquatic ecosystems (Cai and al., 2017 ; Khatun and al., 2022). In this context, macrophytes and fish, as living organisms within lagoon ecosystems, play a central role in the arsenic cycle (Hussain and al., 2023). They not only serve as indicators of arsenic contamination, but can also contribute to its mobility and bioavailability in the ecosystem (Ji and al., 2024). The Aby Lagoon is the largest lagoon body of water in Côte d'Ivoire. Due to its size, the biodiversity it shelters and the fisheries resources it provides, it constitutes an ecosystem of great ecological and economic importance on a national scale (Claon and al., 2022). However, this fragile ecosystem is under increasing anthropogenic pressure in various forms (Rahman and al., 2024). Indeed, gallopingurbanization along the

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riverbanks, especially around the city of Abidjan, leads to increased discharges of domestic wastewater, excessively enriching the lagoon with nutrients and pollutants (Koffiand al., 2013). In addition, the development of intensive agriculture in the watershed also generates significant inputs of fertilizers and pesticides that end up in the lagoon. Overfishing depletes fish stocks(Kinimo et al., 2018), . Fishing techniques, which are sometimes destructive, complete the degradation of the seabed. Finally, the presence of many petrochemical, agri-food and mining industries represents a permanent risk of accidental pollution or illegal dumping of waste (Fan and al., 2024). All these excessive inputs of nutrients and various contaminants (hydrocarbons, heavy metals, etc.) lead to asphyxiation and poisoning of lagoon organisms (Soro and al., 2023). Arsenic in particular, which occurs naturally in soils, can increase its concentration in water and sediment as a result of certain human activities (Liu and al., 2023). In the long term, the health and balance of the entire lagoon ecosystem is threatened. And in turn, the food, health and economic security of the local populations who depend closely on this lagoon is also compromised. A comprehensive and sustainable management of anthropogenic pressures is more necessary than ever for this lagoon (Kumar and Pati, 2022). The study aims to characterize the presence and distribution of arsenic in sediments of lagoon ecosystems during seasonal variations.

Claon, S.J., Kouassi, S.K., M'bassidje, S.A., Séri, L.K., Kouadio, L.K., Djaman, J.A., 2022. Exposure of Mercury from Gold Ming Area: A Case Study in Tendo and Aby Lagoon in Côte d'Ivoire. Journal of Environmental Protection 13, 613–627.
Monney, I.A., Etile, R.N., Ouattara, I.N., Kone, T., 2015. Seasonal distribution of zooplankton in the Aby-Tendo-Ehy lagoons system (Côte d'Ivoire, West Africa). International Journal of Biological and Chemical Sciences 9, 2362–2376.

Materials and Methods:-

Study area:-

Aby lagoon (5°05'–5°22' N and 3°16'–2°55' W) is located in West Africa, on the coast of the Gulf of Guinea between Côte d'Ivoire and Ghana. Aby lagoon covers 24.5 km and 56 km, respectively, from east to west with an estimated area of 420 km^2, while the Tendo lagoon is formed by the band from west to east and has a width of about 20 km. Aby and Tendo lagoons are located in an equatorial climate region with a climate composed of 4 successive seasons: 2 rainy seasons from May to July and from October to November and 2 dry seasons from August to September and from December to March/April (Claon et al., 2022).We indicated successively from north to south for Aby north and south lagoons, and from west to east for Tendo **(Figure 1).**

The north and south Aby lagoons will simply be called Aby throughout this study. Several towns, villages, and seasonal fishing camps exist around the Aby and Tendo lagoons. The population estimated to 30,000 (RGPH, 2014) are living around Aby and Tendo lagoons that constitute and provide a real source of food and living for these populations through fishing activities. Aby and Tendo lagoons are under the influence, respectively, of the Bia river whose watershed is estimated at about 10,000 km^2 with an average flow estimated at 300 m^3/s during rainy floods and the Tanoe river whose watershed is at about 16,074 km^2 with an average flow estimated at 142 m^3/s (Monneyandand., 2015).

These rivers are home to numerous gold deposits that have gradually developed over the years. Thus, artisanal and industrial gold mining around the Bia and Tanoe rivers fears that these rivers will serve as a pollution vector for heavy metals, especially mercury from gold-mining areas to its outlets in Aby and Tendo lagoons. Assessment of Aby and Tendo lagoon sediments' exposure to pollutants resulting directly or indirectly from gold-mining activities, namely, mercury, is a relevant indicator of this pollution. In addition to spatial, bathymetric, and hydrological variations, Aby and Tendo lagoons were influenced by the Bia and Tanoe rivers, respectively. Aby and Tendo lagoons are the estuaries of the Bia and Tanoe rivers, respectively.

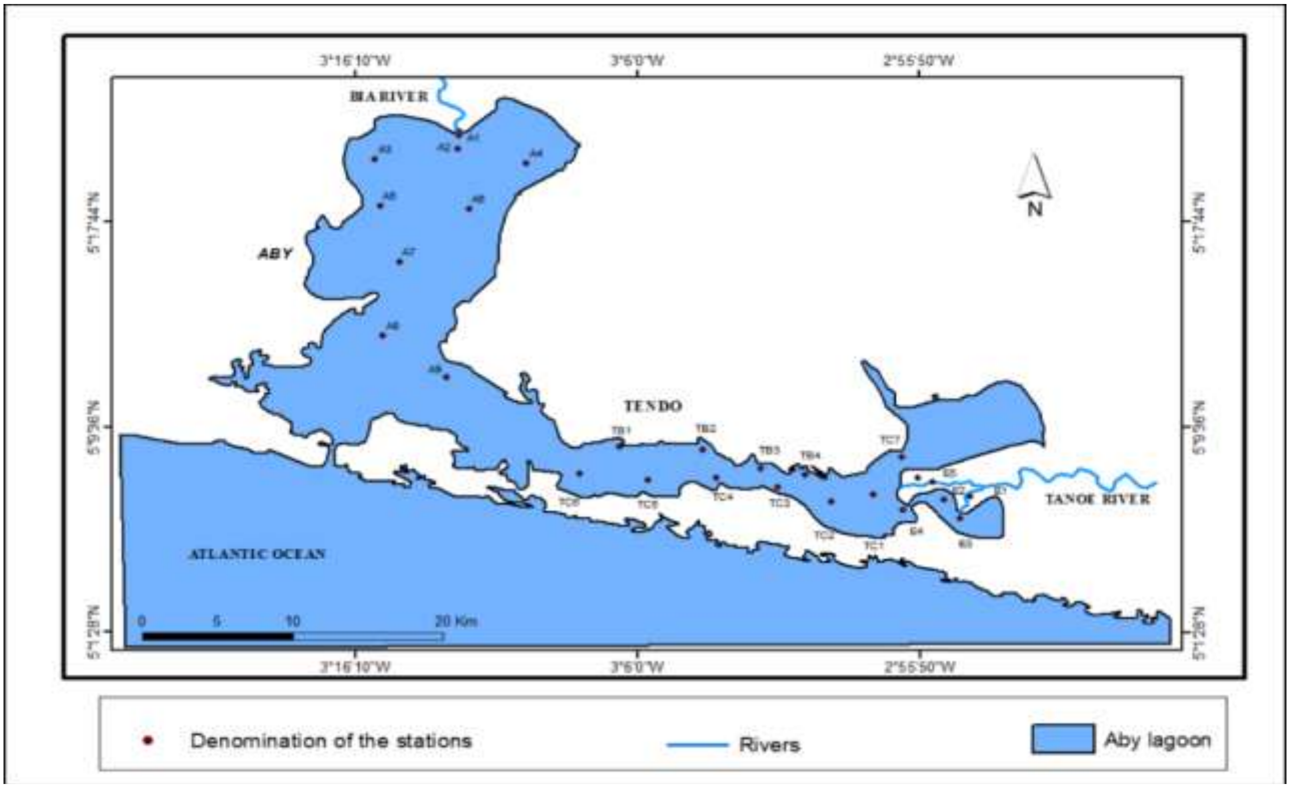

Figure 1:- Locations of sampling sites.

Sediment sampling:-
For each of the campaigns and at each station, sediment sampling was taken from the lagoon bottom. A total of four samples were taken, two of which were taken at the end of the major dry season (Ss1& 2) and two at the end of the major rainy season Sp1& 2.

In the water, in situ measurements of temperature, pH, conductivity, salinity and transparency were made at each point. A sample of water for the assessment of suspended solids (TSS) was carried out.

For points where bathymetry is greater than 6 m, two sets of measurements and samples were taken in the water column. The first at the surface (0.5 m) and the second at a depth of 1 m above the water-sediment interface. The points for which this double measurement was made are 7 in number, 4 of which are in the Tendo lagoon.

Sediment was collected from a core barrel. Once the core has risen to the surface, it is extruded. We collected the first five cm using a plastic spatula. Foreign bodies and organic detritus are removed manually. Finally, the sample is stored in a polyethylene bag after being perfectly homogenized and stored in the dark in a cooler. Transport to the laboratory is done within 24 hours of sampling

Sample Preparation:-
Sediment samples were air-dried, sieved through a 2 mm sieve and homogenized. Macrophyte and fish samples were washed in distilled water, dried at 60°C for 48 hours, and ground into a fine powder.

Sediment Mineralization:-
Sediments were digested using a mixture of nitric acid and hydrogen peroxide (HNO_3/H_{2O2}) according to the protocol described by Tseng *and al*. (Tseng and al., 1998). Approximately 0.25 g of dried, homogenized sediment was precisely weighed in a container. Subsequently, 8 mL of concentrated nitric acid was added to the container, which was hermetically sealed with a reflux column. A plastic gasket has been placed between the backflow column and the container to prevent evaporation. The tube containing the mixture followed the following protocol:

1. A first phase of microwave heating at 20 W for 5 minutes.

2. Chill for 5 minutes, followed by the addition of 2 ml of hydrogen peroxide (H_2O_2).
3. A second phase of microwave heating at 20 W for 5 minutes.

Finally, the mineralized was diluted with Milli-Q water in a volumetric borosilicate glass flask with a capacity of 50 ± 0.06 ml. The resulting mixture was then stored in the refrigerator in a polyethylene tube for further analysis.

Arsenic Determination :
The analyses were performed on the Perkin Elmer Elan® 6000 ICP-MS. The methodology used for the instrument optimization and analytical procedure was described by EPA Method 6020 published in 1998 for arsenic. The measurements were made in triplicate. Limits of quantification are between 0.1 and 1 µg/l. The limits may be higher when there is the presence of interference or memory effect, as in the case of arsenic.

Statistical analyses:-
Data were analysed using SPSS statistical software, and differences between sampling sites were assessed through a one-factor ANOVA. The main objective of this analysis was to compare arsenic concentrations in sediment between the different sampling sites. SPSS facilitated this comparison by providing appropriate statistical tools. Specifically, this software was used to perform a one-factor ANOVA, allowing it to be determined whether the discrepancies between sampling sites were statistically significant. This statistical technique tests the null hypothesis that the means between groups (sampling sites) are equal.

Expression of results:-
The formula for calculating arsenic levels in the samples was expressed as follows:

Arsenic content (mg/kg): $\frac{\boldsymbol{Arsenicquantity}}{\boldsymbol{Weightsample}} \times \mathbf{1000}$

1. The content in milligrams per kilogram (mg/kg)
2. Amount of arsenic measured during analysis (milligrams)
3. Dry weight test portion mass (kilograms).
4. The factor of 1000 is performed the conversions.

Results:-

Sediment concentrations:-
Concentrations of arsenic in sediments from Aby Lagoon are presented in Table 1. The overall average calculated over all campaigns was 19.97 mg As/kg, while the median was 13.97 mg As/kg. The results revealed significant variability in these concentrations. It should be noted that the presence of extreme values had a significant influence on the average. To better represent the central tendency, a truncated mean of 5%, excluding these extreme values, was calculated, resulting in an average of 16.86 mg As/kg. This variability in arsenic concentrations can be attributed to several factors. First, it could result from the geology of the sedimentary basin: the Aby Lagoon is located on a sedimentary basin formed by deposits of sedimentary and volcanic rocks. These rocks may contain arsenical minerals, such as slag, pyrite, and arsenopyrite (Coulibaly and al., 2019). Secondly, anthropogenic activities also play a major role: the Aby Lagoon is an industrialized area, with activities such as mining, agriculture and industry, which can contribute to the increase in arsenic concentrations in sediments (Togbeand al., 2019). These high concentrations of arsenic in the sediments of Aby Lagoon can have significant environmental and health implications. Arsenic, as a poison, can be toxic to plants, animals, and humans, potentially leading to diseases such as cancer, heart disease, and neurological diseases. Previous studies have also documented elevated concentrations of arsenic in sediments from Aby Lagoon. For example, a 2019 study found average arsenic concentrations of 20.4 mg As/kg (Kouassi and al., 2019), while another study conducted in 2018 reported mean arsenic concentrations of 17.9 mg As/kg (Kinimoand al., 2018).

Table 1:- Arsenic Concentrations in Aby Lagoon sediments.

Descriptive Statistics	As (mg/kg)
Mean (Standard Error)	19,97 (2,74)
95% CI of mean	14,52 – 25,42
Averagetruncated to 5%	16,86
Median	13,97
Standard Deviation	24,96

Min - Max	0.38 – 195.90
Interval	195,52
Interquartile Ranges	19,29
Asymmetry (Standard Error)	4,63 (0,26)
Flattening (Standard Error)	29,98 (0,52)

Figure 2 showed the concentrations of arsenic in the sediments of Aby Lagoon. These results showed that berries have the highest concentrations. The analysis of variance showed that the mean arsenic concentrations in the sediments of the bays, the AbyN lagoon and the Tanoé River were significantly different ($p < 0.05$). Arsenic concentrations in bay sediments were significantly higher than those of the AbyN Lagoon ($p = 0.08$) and the Tanoe River ($p = 0.01$). Arsenic concentrations in bay sediments averaged 10 mg/kg, compared to 4 mg/kg in the AbyN lagoon and 2 mg/kg in the Tanoé River. These results showed that berries are an important source of arsenic pollution in Aby Lagoon. Arsenic concentrations in bay sediments are more than twice as high as those in the AbyN Lagoon and nearly five times higher than those in the Tanoé River. Arsenic concentrations in bay and channel sediments did not differ significantly ($p = 0.26$). This suggests that the channel is not a significant source of arsenic pollution in Aby Lagoon.

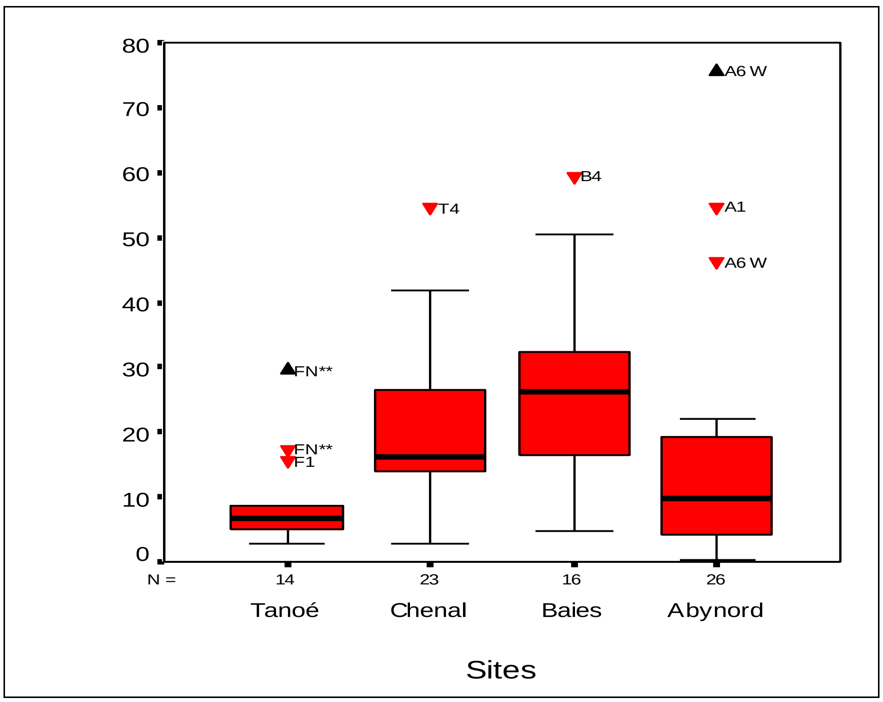

Figure 2:- Boxplots of arsenic concentrations in lagoon sediments: median, distant and extreme values.

Seasonal variations of arsenic in sediments:-

Table 2 illustrates the seasonal variations of arsenic in sediments. The analysis of arsenic concentrations in the sediments of the lagoons studied revealed significant variations. The Tanoé Lagoon had relatively low median values, indicating a moderate concentration of arsenic, but with notable variability. In contrast, the Tendo Channel Lagoon had higher median concentrations, particularly for Sp2, Ss1 and Ss2, with significant variability. Tendo Berries were distinguished by the highest median concentrations. This could suggest a potential build-up of arsenic. The AbyN Lagoon showed relatively low concentrations, but with significant variability. These variations revealed contrasting levels and seasonal dynamics of arsenic contamination between the different lagoon sites analyzed. The moderate concentrations recorded in the Tanoé Lagoon are consistent with the reference values reported in other West African regions with little anthropogenic activity (Osibanjoand al., 2011, Bodin and al., 2013), . The observed seasonal variability could be explained by seasonal hydrological changes affecting arsenic mobility (Bodin and al., 2013). The high median values found in the Tendo Channel Lagoon, especially during the long rainy season, probably indicate greater terrigenous inputs leaching the soils of the watershed and thus enriching the sediments with arsenic runoff (ELTurkand al., 2019 ; Kalita and al., 2019). The suggested sediment accumulation in Tendo Bays may be the result of anthropogenic contamination via urban and industrial discharges into the lagoon (Diop and al., 2015, N'guessan and al., 2009). Finally, the low and variable concentrations in the AbyN Lagoon raise questions about the particular dynamics of arsenic in this area, which would merit further investigation (Diop and al., 2015).

Table 2:- Medians and extremes of As concentrations in the Aby, Tendo, Tanoé and Sp 1&2 lagoons.

Sites	n	Statistics	Sp 1	Sp 2	Ss 1	Ss 2
Tanoé	**4**	Median.	18,10	6,86	5,25	7,45
		Min - Max	6,69 – 29,51	3,37 – 17,30	4,91 – 8,45	2,80 – 15,60
Chenal Having	**6**	Median	16,18	25,39	16,10	17,90 (43,16**)
		Min - Max	4,71 – 54,57	15,80 – 41,76	2,66 – 27,77	4,60 – 35,60
BerriesTendo	**4**	Median	21,70	23,28	32,35	21,20
		Min - Max	11,26 -30,06	12,87- 50,39	25,19 – 59,45	4,70 – 43,60
AbyN	**5**	Median	8,95	17,43	11,38	7,40
		Min - Max	0,38 – 54,69	0,87 – 46,17	4,29 – 20,17	1,40 – 75,60

Intra-seasonal variation of arsenic in sediments:-

Figure 3 shows the intra-seasonal variations of arsenic in sediments during the rainy and dry seasons. An analysis of the results reveals distinct trends for each lagoon. In the Tanoé Lagoon, arsenic concentrations were lower during the rainy season (Sp) and increased slightly during the dry season (Ss), suggesting possible accumulation of arsenic in sediments during this period.

On the other hand, in the Tendo Channel Lagoon, a significant increase in arsenic concentration was observed during the rainy season (Sp) compared to the dry season (Ss). These results would reflect an increased input of arsenic into sediments during the rainy season. For AbyN Lagoon, arsenic concentrations remained high throughout both seasons, but were more pronounced during the rainy season (Sp), suggesting a constant source of arsenic in this lagoon.

Indeed, the results highlight contrasting seasonal dynamics of arsenic contamination of sediments according to the lagoons studied. In the Tanoé Lagoon, the lower concentrations observed in the rainy season compared to the dry season correspond to the trends generally reported in the literature for West African lagoon environments (Bakary and al., 2015). These seasonal variations are mainly attributed to the phenomenon of dilution of lagoon waters by higher river inputs during the wet season, reducing trace element concentrations in the environment (Oura and al., 2022).

The seasonal increase in arsenic sediment content in Tendo Lagoon is likely the result of leaching from soils in the watershed by rainfall runoff. This phenomenon leaches and mobilizes more arsenic naturally present in the geological formations of the surrounding area. (Sharma and al., 2009, Marcellin and al., 2009; Tata and al., 2023). The consistently high arsenic concentrations in the Aby Lagoon and their seasonal peak during rainy periods can be explained by the existence of diffuse sources due to human activity in the vicinity of this lagoon surrounded by urban areas (Tastet and al. 2018; Diop and Megnan 2018). These results therefore highlight the complexity of the processes governing arsenic dynamics in these lagoon ecosystems and further comparative studies are still needed to elucidate the factors controlling the mobility of this contaminant.

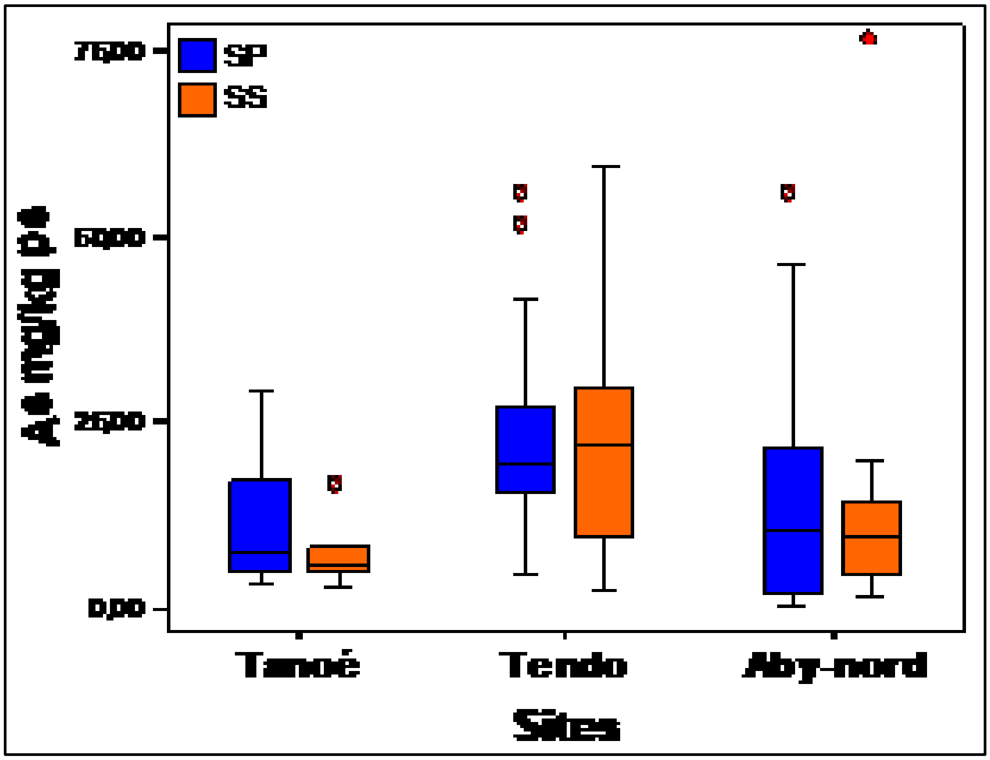

Figure 3:- Boxplots of arsenic concentrations in sediments during the rainy (Sp) and dry (Ss) seasons.

Spatial distribution of arsenic in sediments of the AbyN Lagoon, Tendo chenal and Bays, and the Tanoé River:-

Statistical parameters describing the distribution of arsenic concentrations in the sediments of the bays and channel of Tendo Lagoon have been presented in Table 3. The results showed that the average arsenic levels in the sediments were higher in the channel and bays than elsewhere in the lagoon. Although the means were relatively close, the median and 90th percentile calculated for the bays exceeded the values recorded in the channel. The mean obtained in the channel was strongly influenced by an extreme value of 195.90 mg As/kg dry weight. This was high in the mean although most of the concentrations measured in the channel were lower than the levels of sediments collected in the bays, as indicated by the other statistical parameters.

These results revealed higher levels of arsenic contamination in the sediments of the Tendo Lagoon Channel and Bays compared to those of the Aby Lagoon. This was consistent with trends typically observed between these lagoons by (Bédiaand al., 2017), with the former being subject to greater anthropogenic pressure overall (Bhuyanand al., 2024a, Bhuyan and al., 2024b).

To facilitate the comparison of the results, a 5% truncated mean approach, excluding the 5% of the lower and upper values, was adopted. The results showed 5% truncated averages of 26.62 mg As/kg for bays, 20.22 mg As/kg for the Tendo Lagoon channel, and 13.09 mg As/kg for AbyN Lagoon. These truncated averages provided a more stable representation of arsenic concentrations, allowing a more equitable comparison between different areas of the Tendo Lagoon as well as with the AbyN Lagoon. Indeed, the asymmetrical distribution highlighted (a positive asymmetry) linked to the presence of pollution hotspots is classic in this type of coastal environment affected by diffuse sources of metal contamination (Diop and al., 2015, Male and al., 2024).

The truncated average approach then makes it possible to move away from extreme values to obtain a more robust and comparable central estimate of pollution levels, as practiced by (Santos-Echeandíaand al., 2010a). It can be seen that this indicator shows an even more pronounced gap between the two lagoons.

The increased sediment contamination revealed globally in the Tendo lagoon would require further investigations to identify the responsible sources of arsenic and consider targeted remediation actions at this priority site.

Table 3:- Descriptive statistics of arsenic concentrations (mg As/kg) in sediments from different sites in Aby Lagoon.

Statistics	AbyN	Chenal Having	Baies Tendo	Tanoé
n	26	23	16	14
Average	15,34	27,21	27,16	9,13
95% CI of mean	8,16 – 22,52	10,41 – 44,01	19,37 – 34,95	4,97 – 13,29
Averagetruncated to 5%	13,09	20,22	26,62	8,34
Median	9,88	16,23	26,15	6,69
Standard deviation	17,78	38,85	14,62	7,20
90th percentile	48,72	49,45	53,11	23,41
Min. – Max.	0,38 – 75,60	2,66 – 195,90	4,70 – 59,45	2,80 – 29,51
Interval	75,22	193,24	54,75	26,71

Study of arsenic variability in sediments between the dry season and rainy season:- The variability of arsenic in sediment between the dry season (Ss) and rainy season (Sp) has been illustrated in Table 4. The results showed that the average arsenic was 10.73 in the AbyN lagoon during the rainy season, and 9.67 in the dry season. The t-test value was 0.479, with 16.97 degrees of freedom, and the p-value was 0.63.

In the Tanoé River, the average salinity was 7.64 in the rainy season and 6.04 in the dry season. The t-test value was 0.968, with 12 degrees of freedom, and the p-value was 0.35. Finally, in the Tendo Lagoon, the average arsenic was 19.45 in the rainy season, and 22.10 in the dry season. The t-test value was 0.405, with 29.57 degrees of freedom, and the p-value was 0.68.

Indeed, the results obtained indicated that the mean arsenic concentrations did not show statistically significant differences between the dry and rainy seasons within each study site, based on the t-tests performed ($p>0.05$). This contrasts with previous studies conducted in West African lagoons, which showed a marked decrease in arsenic during the wet season under the influence of freshwater inputs from rivers, as reported (Oura and al., 2022). This study was conducted in the Ebrié Lagoon, Côte d'Ivoire, and showed that mean arsenic concentrations did not show statistically significant differences between the dry and rainy seasons. The authors suggested that this could be due to the presence of local sources of arsenic, which are not affected by river freshwater inputs.

Table 4:- Results of the comparison of As concentrations between the rainy and dry seasons for different sites in Aby Lagoon.

Sampling sites	n	Rainyseason	Dry season	Student's Test		
				t	**ddl**	**p**
AbyN Lagoon	26	10,73	9,67	0,479	16,97§	0,63
Tanoe River	14	7,64	6,04	0,968	12	0,35
Lagune Tendo	38	19,45	22,10	0,405	§29.57§	0,68

Spatio-temporal evolution of arsenic in sediments as a function of sampling sites and stations

Lagune AbyN:-

Figure 4 showed arsenic concentrations in sediments during the rainy (Sp) and dry (Ss) seasons in Aby Lagoon. The results showed that during the rainy season (Sp), arsenic concentrations varied considerably between sampling stations. Some stations, such as A1 and A2, showed relatively low concentrations, while others, such as A3E, A3W, A4E, A4W and A5E, showed higher concentrations. There was a great deal of variability in arsenic concentrations within each station. In the dry season (Ss), arsenic concentrations appear to have been generally lower compared to the rainy season. However, there has always been significant variability in concentrations within each sampling station. Indeed, the peak of arsenic concentrations recorded during the rainy season at certain measurement points is consistent with the trends usually reported in West African estuarine and lagoon ecosystems (Diop and al., 2015). This seasonality would be linked to the increased leaching of soils drained by the watershed and the resulting mobilization of contaminants via fluvial inputs, as shown by (Santos-Echeandíaand al., 2010b) in the Canary Islands.

The significant intra-site variability highlights the complex nature of the mixing processes of water and sediment within the lagoon, leading to a heterogeneous distribution of contaminants (Diop *and al.*, 2015, de Souza *and al.*, 2024). The identification of critical points by a detailed mapping of arsenic concentrations at the lagoon scale thus seems essential for a good assessment of ecotoxicological risks and an appropriate management of the contamination of this sensitive ecosystem (Cai *and al.*, 2017, Rishan *and al.*, 2024).

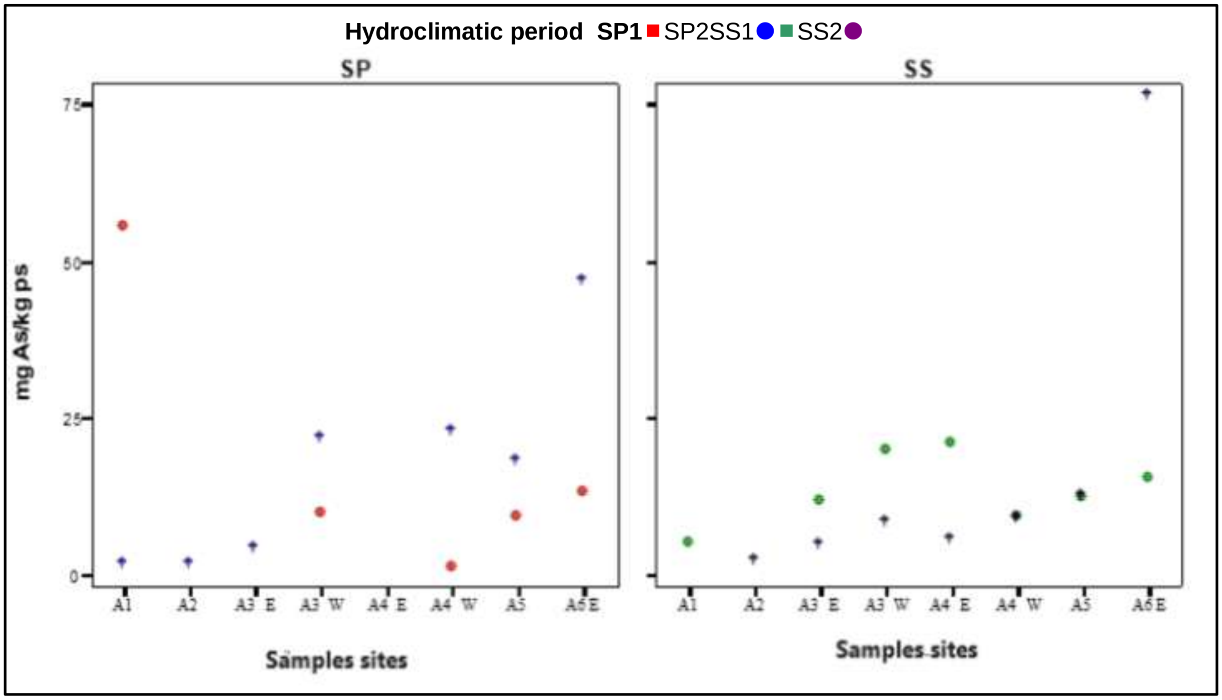

Figure 4:- Arsenic concentrations in sediments from AbyN to Sp and Ss from the mouth of the Bia River (A1) to the pass to the ocean (A6E).

Tendo Lagoon Bays:-

Figure 5 shows arsenic concentrations in sediments during the rainy (Sp) and dry (Ss) seasons. During the rainy season (Sp), arsenic concentrations varied considerably between sampling stations. Some stations, such as B1 and B2, showed relatively low concentrations, while others, such as B3 and B4, showed higher concentrations. There was a great deal of variability in arsenic concentrations within each station. In the dry season (Ss), arsenic concentrations appear to have been generally lower during the dry season compared to the rainy season. However, there has always been significant variability within each station. The results highlighted a complex seasonal and spatial dynamics of arsenic contamination within the Tendo Lagoon. The peak concentrations observed during the wet season at some measurement points (B3, B4) corresponds to trends reported in various estuarine environments in this region, such as Casamance (Diop and al., 2015) Gambia or Saloum. This seasonality would reflect an increased remobilization of arsenic present in the soils of the watershed, leached by runoff water to reach the lagoon via tributaries during flood periods. Intra-site variability highlights the likely influence of local sources of anthropogenic arsenic diffuse around the lagoon, such as urban and industrial effluents, leading to a heterogeneous distribution of sedimentary contaminants (Ahoussi and al., 2012); .

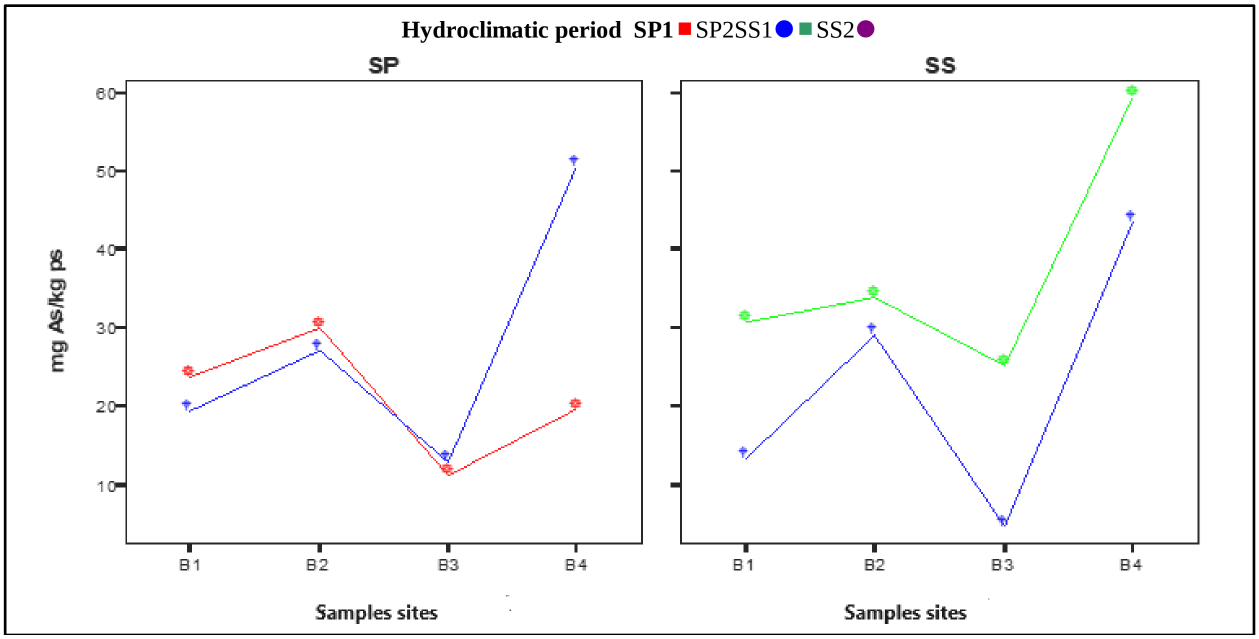

Figure 5:- Arsenic concentrations in the sediments of the bays of the Tendo lagoon from the river (B1) to the offshore pass (B4).

Tendo lagoon channel:-

Figure 5 presented an analysis of the scatter plots representing arsenic concentrations in the sediments of the Tendo Lagoon channel from the outlet of the river (T1) to the offshore pass (T6). During the rainy season (Sp), arsenic concentrations varied considerably between sampling points. Some stations, such as T1 and T2, showed relatively low concentrations, while others, such as T5 and T6, showed higher concentrations. There was a great deal of variability in arsenic concentrations within each station. In the dry season (Ss), arsenic concentrations appear to have been generally lower during the dry season compared to the rainy season. However, there has always been significant variability within each station. The results revealed a complex longitudinal and seasonal dynamics of arsenic contamination in the Tendo Lagoon channel. The decreasing gradient of concentrations from the outlet of the river (T1) to the ocean pass (T6) observed in the dry season is consistent with classical distributions along the fluvio-estuarine continuum (Zhang and al., 2014). This gradient generally reflects a decrease in trace element inputs from the fluvial source with increasing salinity downstream. On the other hand, the inverted profile recorded during the wet season suggests diffuse inputs along the lagoon line, masking the marine influence and leading to the increase in levels downstream (T5, T6). This could come from leaching from urbanized soils in the nearby watershed, enriching surface water with arsenic and other metal pollutants during the rainy season (Hussain and al., 2023).

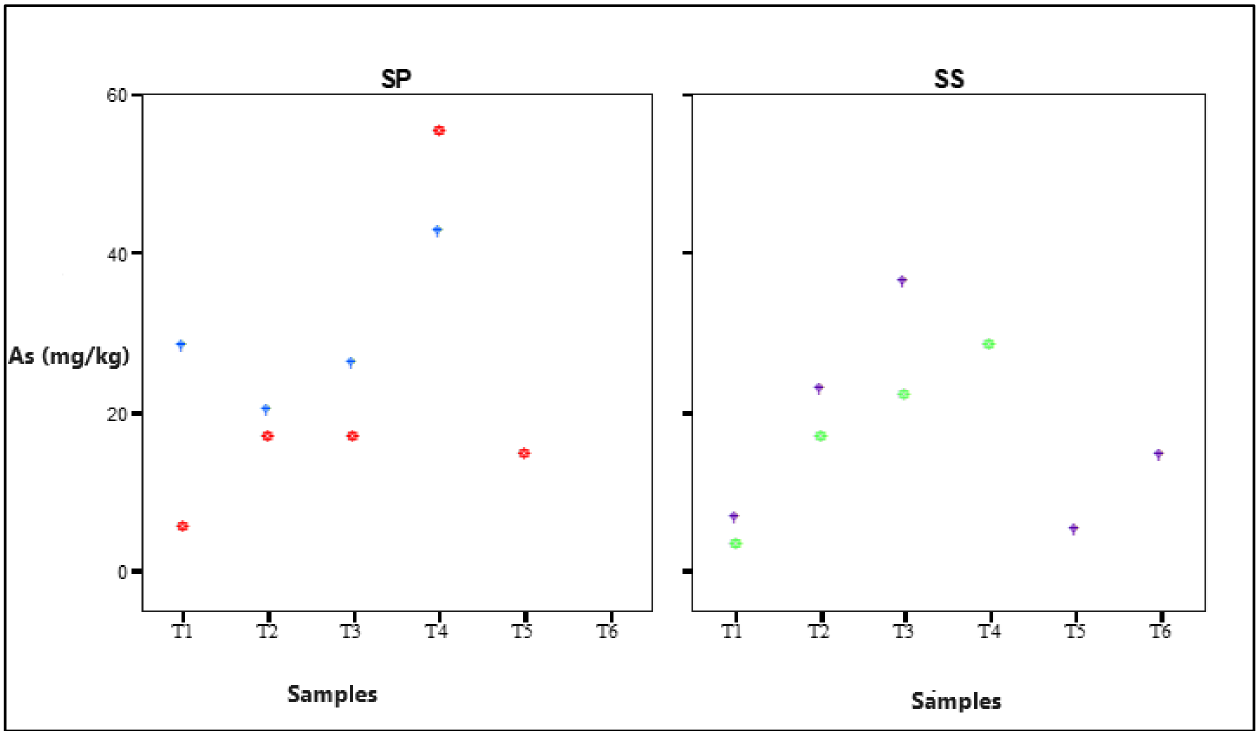

Figure 6:- Arsenic concentrations in sediments in the Tendo Lagoon channel from the outlet of the river (T1) to the offshore pass (T6).

Tanoe River:-

Figure 7 shows the concentrations of arsenic in the sediments of the Tanoé River from the inland stations to the outlet of the Tendo Lagoon. The results showed, during the rainy season (Sp), a high variability in arsenic concentrations between sampling points. Some stations, such as F1 and F2, had relatively low arsenic concentrations, while others, such as F3 and FN***, had higher arsenic concentrations. There was a great deal of variability in arsenic concentrations within each station. In the dry season (Ss), arsenic concentrations generally appear to be lower compared to the rainy season. However, there is still significant variability within each station. The higher concentrations found upstream (F3, F4) during the rainy season likely reflect enrichment related to the leaching of naturally occurring arsenic from soils in the watershed of this river (Budhosand al. 2019). Indeed, the increased mobility and transport of this metal contaminant by runoff during flood periods is a widely documented process (Du Laing and al. 2009; Rieuwerts and Farago 2016). The significant intra-site variability also highlights the possible role of anthropogenic point sources along the river, such as discharges from industrialized or urbanized areas (Bastami and al., 2015).

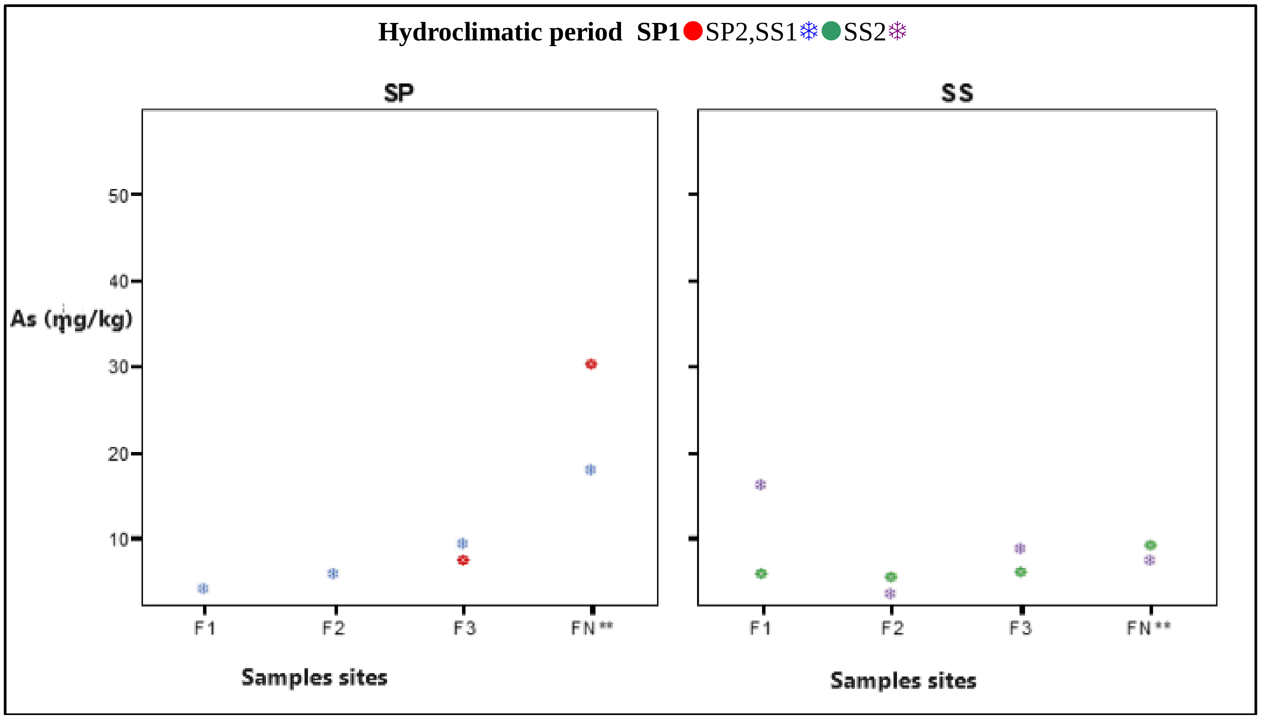

Figure 7:- Concentrations of As in the sediments of the Tanoé River, from the inland stations to the outlet of the Tendo Lagoon. (FN**: northern outlet of the Tanoé River).

Influence of physicochemical parameters on arsenic concentrations in sediments: -

Table 5 presented the results of the correlation analysis between arsenic (As) concentrations and different environmental variables in the AbyN and Tendo lagoons, as well as in the two lagoons as a whole (ABY). In the AbyN lagoon, a moderate positive correlation was observed between arsenic concentrations and parameters such as salinity, transparency, conductivity, and pH. These results are consistent with an earlier study by Lee and al. (2006) which also reported a positive correlation between salinity and arsenic levels in lagoon sediments. These observations suggest that these environmental variables may influence the distribution of arsenic in this lagoon.

Of particular interest is the positive correlation with transparency, indicating that low visibility conditions in water may be associated with higher arsenic concentrations. This original result deserves further investigation, as recommended in the case of heavy metal contamination (Sundarayand al., 2011).

In Tendo Lagoon, a significant and positive correlation was observed between arsenic concentrations and conductivity, as well as pH. This suggests that water conductivity and acidity may be factors influencing the presence of arsenic in the sediments of this lagoon, consistent with the work of Williams and al. (2009), . These results underscore the importance of understanding the chemical composition of water in the assessment of arsenic concentrations, as demonstrated by Bundschuh and al. (2021) recently in their comparative study of different aquatic environments.

Table 5:- Results of the Spearman correlation test between arsenic in sediment and physicochemical parameters in water.

Physico-chemicalparameters	Aces in AbyN			The dans HAVING			As Ensemble ABY		
	Coeff.	Say.	N	Coeff.	Say.	N	Coeff.	Say.	N
Salinity	0,393	0,164	14	0,305	0,204	19	0,099	0,521	44
MY	-0,282	0,215	21	-0,264	0,224	23	-0,202	0,107	65
Transparency	0,496	0,072	14	0,289	0,229	19	0,251	0,100	44
Conductivity	0,385	0,175	14	0,519	0,023	19	0,259	0,090	44
pH	0,119	0,608	21	0,420	0,046	23	0,272	0,029	65
Temperature	-0,035	0,880	21	0,415	0,049	23	-0,032	0,802	65

Conclusion:-

This study characterized arsenic concentrations in sediments from the Aby, Tendo, Tanoé and Bia lagoons, Côte d'Ivoire, taking into account seasonal and spatial variations. The results showed that arsenic concentrations were higher in the bays and channel of Tendo Lagoon, indicating high anthropogenic contamination, while AbyN Lagoon and Tanoé River had moderate concentrations, reflecting a geological influence. Arsenic concentrations also varied seasonally, with peaks during the rainy season in the Tendo Lagoon, suggesting significant terrigenous inputs, and during the dry season in the Tanoé Lagoon, reflecting possible sediment accumulation. These results contribute to a better understanding of the factors influencing the presence of arsenic in coastal lagoons, an element that is potentially toxic to human health and aquatic ecosystems. In perspective, the analysis of the chemical forms of arsenic in sediments, to assess its bioavailability and mobility. In addition, an assessment of the ecotoxicological risks of arsenic to living organisms, such as macrophytes and fish, which play a key role in the arsenic cycle. Finally, the identification of the sources of arsenic responsible for the contamination, using isotopic or geochemical tracing tools, in order to propose appropriate management measures.

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