Determination of the radioactive nature of the sediments of the bays of the Ebrié lagoon of Abidjan (Ivory Coast)

Abstract

In Ivory Coast, the lagoonsrepresent the transit point for the majority of continental inputs. They are thusincreasinglyvulnerable and theirecological balance israpidlymodifiedunder the influence of certain natural or anthropogenicfactors.

The objective of thisstudyis to evaluate the level of presence of lead 210 in sediments.
The sedimentsweresampledduring the campaigns of the National Water Quality Observation Network on the bays spread over thirteenstudy sites. Thesesampleswеredried, crushed, sieved, mineralizedwithstrongacidsthenanalyzed by alpha spectrometry. The highest lead-210 activitieswereobtained in the bays of Koumassi 1 (228.57 ± 12.21 Bq/kg) and Marcory (198.91 ± 9.46 Bq/kg). However, no seasonal variation in lead-210 contamination of sediments in the bays of Abidjan wasobserved. Wewish to extendthisstudy to otheraquatic matrices.

Keywords: bays, mineralization, Lead 210, Radioactivity, sediment, alpha spectrometry.

1. Introduction

With the evolution of time, itisbecoming more necessary to take an increasinginterest in the study of marine and lagoonecosystemsthrough the determination and quantification of toxic radioactive contaminants resultingfromhumanactivities. At the level of theseecosystems, the conditions influencing the precipitation, adsorption or desorption of elementsvaryrapidly [**1**]. In Ivory Coast, the lagoonsrepresent the transit point for the majority of continental inputs. Theythusbecome more and more vulnerable and theirecological balance israpidlymodifiedunder the influence of certain natural or anthropogenicfactorssuch as leaching water from agricultural areas, industrial effluents and residues and significanturbanwastedischarges [**2**]. In the Abidjan area whichcovers a large part of the Ebrié lagoon, almost all the researchcarried out has focused on the evaluation of the concentration of heavymetals [**3, 4**]. On the other hand, studiesrelating to the analysis of toxicradionuclidessuch as lead 210 (^{210}Pb) and polonium 210 (^{210}Po) originatingfromanthropogenicactivities are verylimited. The determination of ^{210}Pb

through^{210}Po seemsvery important to us becauseitprovides us withuseful information on the state of radioactive contamination of waterwaysimpacted by humanactivities.

This presentworkaims to know for the first time the activity of ^{210}Pb in the sediments of the bays of the Ebrié lagoon of Abidjan (Ivory Coast) from 2015 to 2016.

2. Material and Methods

2.1. Study site

With an area of 566 km^2, the Ebrié lagoonconstitutes the largestlagoonenvironment in Côte d'Ivoire and the largestcoastalecosystem in West Africa [5, 6]. It occupies a large part of the Ivoriancoastline and extends over 130 km along the coastlinebetween 3°40' and 4°50' West longitude and 5°20' and 5°10' North latitude. The Ebrié lagoonis 7 km wide and itsaveragedepthisestimated at 4.8 m withsomedeeppitsexceeding 20 m in the urban area of Abidjan [**7, 8]**. The lagoon system isseparatedfrom the Atlantic Ocean by a sandycoastalbarrier 8 km thick. It has communicatedwith the Atlantic Oceanpermanentlysince the opening of the Vridi Canal in 1950 (**Figure 1**). The Ebrié lagoon system isinfluenced to the west by the Agnéby and to the east by the Comoé and Mé rivers. It is made up of numerous bays whichoccupyalmost a fifth of the total surface area [**9**]. The sediments of the lagoon system are fed by the riverswhich flow intoit and by the runoff water on the banks [**10**]. Around Abidjan the lagoon bays are also dumping grounds for urbanwaste. Thesesediments are made up of an organic fraction and a mineral fraction with variable grain size [**10, 11**].

Source: Open Map Street

KC: Octobre 2022

Figure 1. Sediments sampling sites

2.2. Location of sampling sites

The sampling sites are sites referenced as part of monitoring activities for the quality of receivingenvironments (RNO-Ebrié lagoon). The GPS (Global Positioning System) coordinates of the sampling stations are grouped in **Table 1.**

Table 1. Coordinates of lagoon RNO sampling stations

Stations	GPS Coordinates	Stations	GPS Coordinates
Bay of Yopougon	05°18,316N 04°03,917W	Bay of Marcory	05°18,837N 04°00,003W
Bay of Azito	05°17,821N 04°04,740W	Baie de Chenal Est	05°19,298N 03°59,483W
Bay of Banco	05°19,691N 04°01,969W	Bay of M'badon	05°19,955N 03°55,737W
Bay of Biétry 1	05°16,752N 04°00,098W	Bay of Anna	05°19,166N 05°54,007W
Bay of Biétry 2	05°16,081N 03°58,539W	Bay of Koumassi 1	05°17,882N 03°56,090W
Bay of Cocody	05°19,677N 04°00,833W	Bay of Koumassi 2	05°16,863N 03°56,719W
Bay of Koumassi 3	05°16,457N 03°55,801W		

2.3. Material

The analyzeswerecarried out using the followingproducts:distilled water, hydrochloricacid (degree of purity 37%; PANREAC), nitricacid (degree of purity 65%, PANREAC), hydrofluidricacid (degree of purity 20%; PANREAC), water oxygenated (degree of purity 20%; PANREAC), ascorbicacid (SCHARLAU).

The technicalequipmentiscomposedof:heating plate (STUART), silver disk (for self-deposition), glassware, ORTEC alpha spectrometer (for the analysis of ^{210}Pb).

2.4. Sampling and physicalprocessing

The samplesweretakenaccording to the scheduledefined as part of the RNO-sedimentactivities. Samplesweretakentwice a yearduring the twoyearsdevoted to the study. Sampling wascarried out in the months of April and October due to seasonal variations, at the

water-sediment interface of the Ebrié lagoon in an area of 1000 cm^2, using a grablevy. The samplestakenweredried in an oven at a temperature of 60°C for 06 days, thenground in an agar mortar, sievedusing a 45µm sieve and stored in vials.

2.5. Determination of ^{210}Pb activities

The methodused in thisstudyisthatestablished by the National Center for Energy, Nuclear Sciences and Techniques of Rabat and used by Béa et *al.* [**12**].

The chemicaltreatment of the sampleswascarried out by mineralizationwithconcentratedacids (HCl, HNO_3, HF) and H_2O_2. For eachseries of analyses, a blanksample (distilled water) and a referencematerialwith PT code IAEA-TEL 2018-03 (Sample 4), resultingfrom an inter-comparisonexerciseorganized by the International Agency of Atomic Energy (IAEA), wereused to validate the results. A quantity of 0.25 g of eachsedimentsamplewascollected and plottedwith 300 µg of a ^{209}Po solution (0.188 ± 0.004 Bq/g).

Self-depositionwascarried out on a silver diskimmersed in the solution and left for deposition for 6 hours on a hot plate at 90°C with constant stirring. After 6 hours of self-deposition, the diskwasremoved, thenwashedwithdistilled water and air dried.

The diskwasthencounted by placingit in a silicone surface barrier alpha detector for counting.

The activitywithitsuncertaintywerecalculated as follows:

$$\mathbf{Ae} = \frac{(\mathbf{Se}-\mathbf{SBdFe})\times\mathbf{mt}\times\mathbf{At}}{(\mathbf{St}-\mathbf{SBdFt})\times\mathbf{me}} \text{ (I) et } \mathbf{i_A} = \mathbf{Ae}\sqrt{\mathbf{0,00023} + \frac{\mathbf{1}}{\mathbf{Se}} + \frac{\mathbf{1}}{\mathbf{St}} + (\frac{\mathbf{Et}}{\mathbf{AAt}})^{\mathbf{2}}} \text{ (II)}$$

Or

A_e:Sampleactivity (Bq/g)

i_A:uncertainty about the activity

A_t : Tracer activity (Bq/g)

S_e : Peak surface of the radioelementconsideredcontained in the sample

S_t : Tracer peak area

S_{BdFe} : Surface of the peak of the background noise correctedwith respect to the counting time, corresponding to the emissionenergy range of the radioelement of the sample

S_{BdFt} : Surface of the peak of the background crudecorrectedwith respect to the counting time, corresponding to the emissionenergy range of the tracer

m_e : Sample mass (g)

m_t: Tracer mass (g)

E_t : Error on current tracer activity

A_{At} : Current tracker activity.

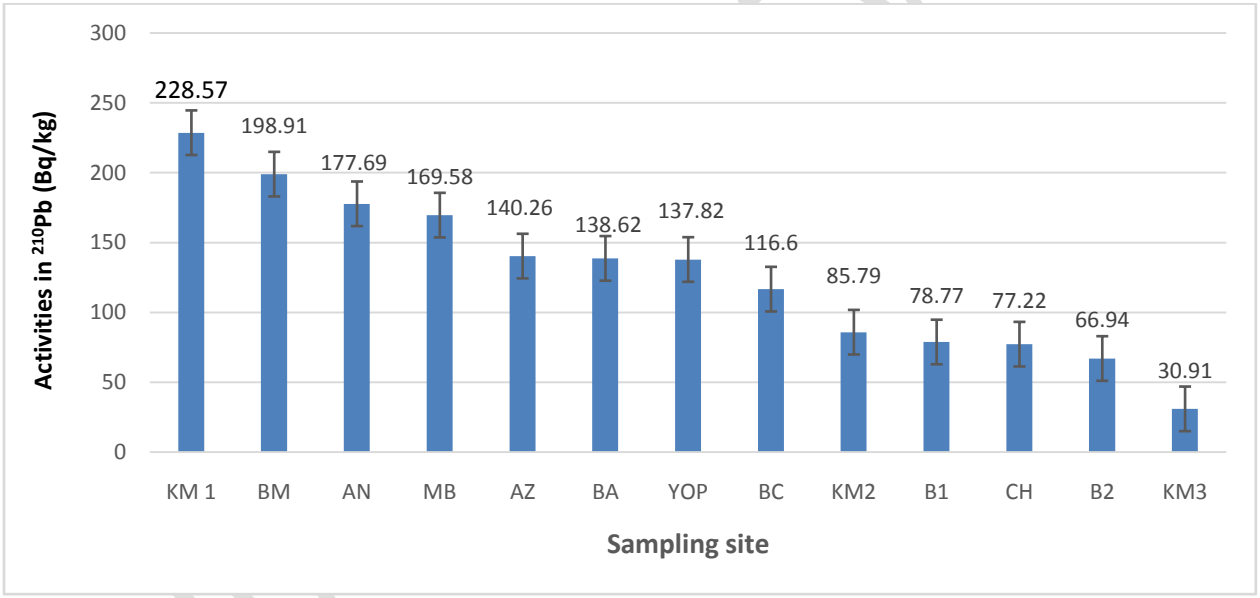
2.6. Statisticalanalysis

The Kruskal Wallis and Mann Whitney tests wereused to compare the ^{210}Pb activitiesobtained in the bay sediments. If $P < 0.05$, the differenceissignificant.

3. Results and discussion

3.1. Level of presence of ^{210}Pb in the sediments of the bays of Abidjan

The resultsrecorded in **Figures 2** to **4**clearly show that the different bays studied all contain the radioelement^{210}Pb. The activities of ^{210}Pb varyfrom one bay to another (**Figure 2**). The lowestactivityisobserved in Koumassi Bay 3 (30.91 ± 3.43 Bq/kg), while the highest value isobtained in Koumassi Bay 1 (228.57 ± 12.21 Bq/kg).



KM1: Koumassi 1 Bay; **BM:** Marcory Bay; **AN:** Anna Bay; **MB:** M'BadonBay; **AZ:** Azito Bay; **BA:** Banco Bay; **YOP:** Yopougon Bay; **BC:** Cocody Bay; **KM2**: Koumassi 2 Bay; **B1**: Biétry 1 Bay; **CH:** Chenal Est Bay; **B2:**Biétry 2 Bay; **KM3:**Koumassi 3 Bay

Figure 2. ^{210}Pb activity in bayssediments

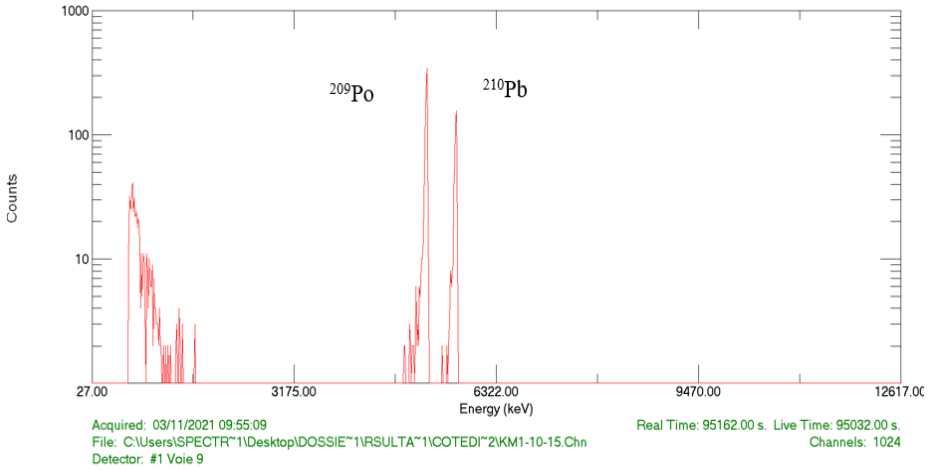


Figure 3. Alpha emissionspectra of tracer ^{209}Po and ^{210}Pb in the KM1 sediment

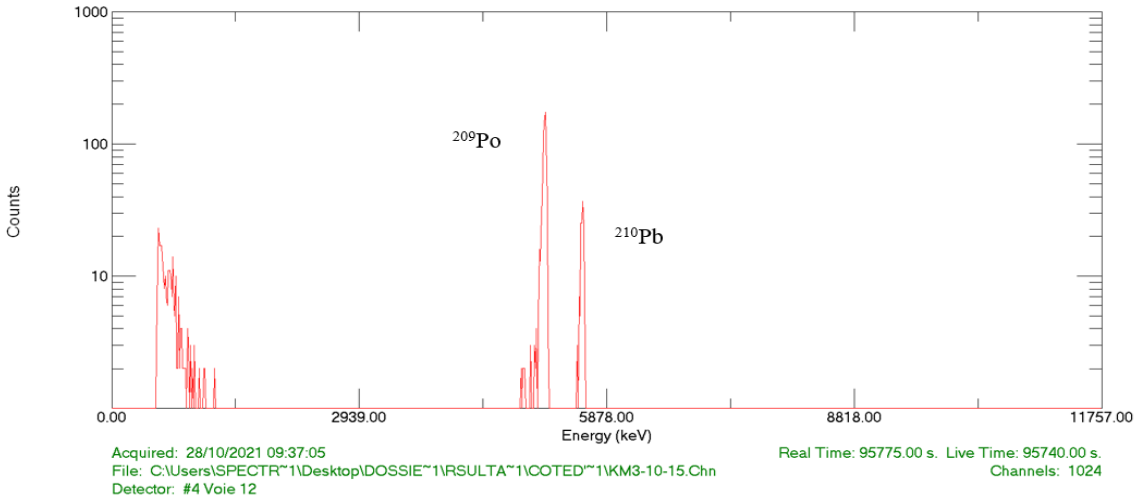


Figure 4. Alpha emissionspectra of tracer ^{209}Po and ^{210}Pb in the KM3sediment

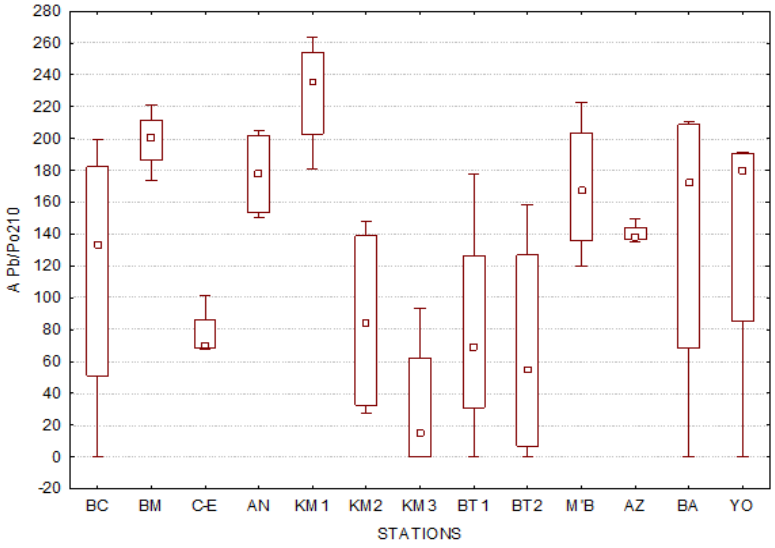
In Ivory Coast, very few studies have been carried out on ^{210}Po and ^{210}Pb in sediments.

The ^{210}Pb activitiesobtained in the different bays varyfrom 30.91±3.43 Bq/kg to 228.57±12.21 Bq/kg.

Our resultsclearly show that the Ebrié lagoonissubject to contamination by radionuclides^{210}Po and ^{210}Pb from the decaychain of Uranium 238. The contamination of the sediments of the bays of the Ebrié lagoonobserved in ourstudywouldresultfrom the combination of naturalfactors and anthropogenicfactorssuch as agricultural, petroleum, mining, cement and householdwaste.According to Miralles [**13**], Lead isbrought by atmosphericdeposits and by runoff in the marine environment.

3.2. Spatial variation of ^{210}Pb contamination of the sediments of the bays of Abidjan

Figure 5describes the spatial variation of ^{210}Pb contamination in the sediments of the bays of Abidjan. The Kruskal Wallis test carried out shows thatthereis a significantdifference ($p < 0.05$) in the variation of ^{210}Pb in the sediments of the bays of Abidjan.



KM1: Koumassi 1 Bay; **BM:** Marcory Bay; **AN:** Anna Bay; **MB:** M'BadonBay; **AZ:** Azito Bay; **BA:** Banco Bay; **YOP:** Yopougon Bay; **BC:** Cocody Bay; **KM2**: Koumassi 2 Bay; **B1**: Biétry 1 Bay; **CH:** Chenal Est Bay; **B2:**Biétry 2 Bay; **KM3:**Koumassi 3 Bay

Figure 5. Spatial variation in ^{210}Pb contamination of sedimentsfromdifferent bays

According to the Man Withney test ($p < 0.05$), the median value of ^{210}Pb ishigher in the sediments of the bay of Km 1 compared to that of the sediments of the bay of Km 3. The lowestactivityisobtained at Koumassi Bay 3 with an average value of 30.91±3.43 Bq/kg. As for the bay of Koumassi 1, itrecorded the highestactivity (228.57±12.21 Bq/kg).Theseresults show on the one hand that the bays of Koumassi 1 and Marcory which record a high activity in ^{210}Pb wouldreceive effluents from industries such as NORME and TENORM located in the southern zone of Abidjan [**8, 10**]. On the other hand, Koumassi 3 located in the same area islesscontaminated in ^{210}Pb;thiscouldbeexplained by the factthatthis last bay whichreceivesindustrial effluents and domesticwaste [**10**] isconstantlysubject to dredging and backfillingactivities. Indeed, studiescarried out by Kouassi [**2**] revealedthat the variation in activitiesdepending on the bay wouldprobablybelinked to flooding, industrial pollution and significanturbanwastedischarges.

3.3. Seasonalcomparison of the level of ^{210}Pb contamination in the sediments of the bays of Abidjan

The Kruskal Wallis test carried out indicatesthat the variations in ^{210}Pb contamination of the sediments of the bays of Abidjan are not significantfrom one season to another ($p > 0.05$) (**figure 6**).

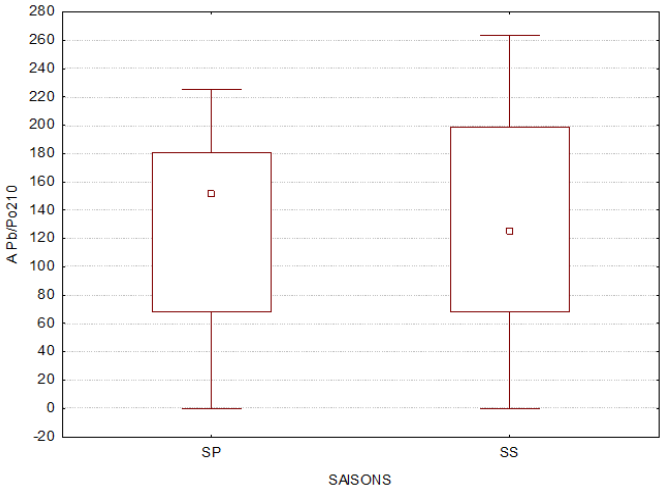


Figure 6. Seasonalcomparison of the level of ^{210}Pb contamination in bay sediments

The ^{210}Pb contamination of the sediments of the bays of Abidjan is not significantfrom one season to another. This indicatesthat the climaticseasons have no influence on the variation in ^{210}Pb contamination of the sediments of the bays of the Abidjan district. In addition, the weatherduringthesetwoyearswas favorable, preventing the transport of lead by runoff in the marine environment.

In view of all theseresults, itshouldbenotedthat the environmentalquality of the sediments of the lagoon bays of Abidjan couldfurtherbedegraded. Indeed, the significant and incessant input of industrial and domesticwasteinto the Ebrié lagoon continues to increase over the years due to the development of industrialactivities and the increase in the population [**10**]. But also, the use of chemical inputs from phosphate rocks.

The significant^{210}Pb activitiesdetected in the sediments of the various bays of the Ebrié lagooncould lead to the bioaccumulation of thisradiotoxicelement in aquaticorganismsconsumed by the Ivorian population and alsoconstitute a riskwhenswimming. Indeed, studies have shown the exposure of populations to lead linked to water ingestion [**14**].

4. Conclusion

This researchworkis a contribution to the evaluation of the level of contamination of the lagoon system of Abidjan (Côte d'Ivoire) in radioelements (^{210}Pb) from 2015 to 2016. For thispurpose, the radioelement^{210}Pb waschemicallyanalyzed in order to to highlight

itsactivitycontained in the sediments of the lagoon system. According to the resultsobtained, all the samplesanalyzedcontain, amongotherthings, significant^{210}Pb activities.This allowed us to make an assessment of the 210Pb contamination of the sediments of the Ebrié lagoon. The highest value of activitywasfound in the sedimentsfrom the bay of Koumassi 1 (228.57±12.21 Bq/kg) close to the industrial zone and the lowest in the sedimentsfrom the bay of Koumassi 3 (30.91±3.43 Bq/kg). However, no seasonal variation in 210Pb contamination of the sediments of the bays of Abidjan wasobserved.

Wewish to extendthisstudy to all matrices of the aquaticenvironment.

References

1 Deconinck JN, Bernat M, Chassefière B. Study of isotopes of U, Th and ^{210}Pb Radioisotopes in the sediments of the Canet pond (Pyrénées-Orientales).*Oceanologica Acta*1983; 6(2): 131-138.

2 Kouassi AM. Hydrochemistry and water quality of two tropical lagoons on the Ivory Coast (Ebrié, Grand-Lahou).Doctoral thesis, University of Cocody (Ivory Coast)2005;242p.

3 Yao KM, Metongo BS, Trokourey A, Boka Y. Assessment of sediments contamination by heavymetals in a tropical lagoonUrban Area (Ebriélagoon, Côte d'Ivoire). *European Journal of Scientific Research*2009; 34(2): 280-289.

4 Gouin CA, Aka N, Adiaffi B, Bamba BS, Soro N. Seasonal pollution of lagoonsediments by heavymetals (Cu, Pb and Zn) in humid tropical zones: case of the Mondoukoulagoon (South-East of Ivory Coast).*International Journal of Biological and Chemical Sciences*2016, 10(2): 835-845.

5 Guiral D, Ferhi A. Ionic and isotopiccharacterization of a tropical hydrological system: the Ebrié lagoon (Ivory Coast).*Oceanologica Acta*1989; 12(1): 47-55.

6Scheren PAGM, Kroeze C, Janssen FJJG, Hordijk L, Ptasinski KJ. Integrated water pollution assessment of the EbriéLagoon, IvoryCoast, West Africa. *Journal of Marine Systems*2004; 44: 1- 17.

7 Varlet F. The regime of the Ebrié lagoon (Ivory Coast). Paris, Works Document Orstom1978;pp1-15.

8 Soro G, Metongo BS, Soro N. Heavy metals (Cu, Cr, Mn and Zn) in the surface sediments of a tropical Africanlagoon: case of the Ebrielagoon (Ivory Coast).*International Journal of Biological and Chemical Sciences*2009; 6: 1408-1427.

9Poubady RB.The Ebrié lagoon system in Ivory Coast. Operation, hydrodynamics and salinity. Doctoral thesis in Engineering, University of Abidjan (Ivory Coast), National Polytechnic Institute of Toulouse (France)1979; 247p.

10 Kouamé KD, Yapo OB, Méité L. Contamination of the Sediments of a tropical urbanlagoon by metallic trace elements (As, Cd, Cr, Pb, Zn): Case of the lagoon bays of the city of Abidjan (Ivory Coast).*International journal of pure and appliedbioscience*2016; 4(6): 204-217.

11 Tastet JP. Quaternarysedimentary and structural environments of the coast of the Gulf of Guinea (Ivory Coast, Togo, Benin). State doctoratethesis, Bordeaux1 University (France)1979;181p.

12 Bea GT, Dangui D, Ouffoué KS, Ngohang FE, Abdelmourhit L, Yapo OB et *al.*Study of the transfer of Polonium 210 and total Lead fromsoiltreatedwith herbicide to foodcrops. *RAMReS Structural and Material Sciences*2022; 6(2): 137-156.

13Miralles J, Radakovitch O, Aloisi JC.^{210}Pb sedimentation rates from the NorthwesternMediterraneanmargin. *Marine Geology*2005; 216:155-167.

14 Béa GT, Ouffoué KS, Yapo OB, Ouattara L. Assessment and Health Risks of Glyphosate Residues and Traces MetalsElements in GroundwaterArround Abidjan Region, Côte d'Ivoire. *International Research Journal of Pure and Applied Chemistry*2023; 24(5): 122-138.