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Ecotoxicological risk of subsurface sediments, linked to inorganic pollutants, at the mouth of the Comoe River in Grand-Bassam

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Abstract

The diversion of water from the Comoé River to the Vridi canal has led to the closure of its mouth at Grand-Bassam. This situation has led to the sitting up of the bottom of water bodies, water pollution and deaths of fish. Studies in this environment have shown metal pollution but have not indicated the level of risk to the sediments and biota. The objective of this job is to highlight the intensity of the ecotoxicological risk at the outlet of River Comoe. It required the analysis of 23 samples of subsurface sediments. These sediments underwent total mineralisation before being analysed at the lCP-MS. Mūller's geoaccumulation index (Igeo) and the M-ERM-Q were used to determine the ecotoxicological quantity of sediments. The average concentrations of metals are 64.55 ug/g (Cr), 24.77 ug/g (Ni), 24 ug/g (Cu), 66.66 ug/g (Zn), 14.12 ug/g (As), 0.25 ug/g (Cd) and 13.88 ug/g (Pb). The level of pollution is in the unpolluted range (class 0) to the highly polluted range (class 5). Arsenic has the highest pollution intensity while lead has the lowest pollution intensity. The likely risk of sediments toxicity is between 9% to 21%. The majority of sediments (19/23; 82.61%) have a toxicity probability of 21%.

Keywords: Mouth; Ecotoxicological Risk; River Comoe; Grand Bassam

1. Introduction

Metallic trace elements that pollute the environment usually come from the increasing anthropogenic activities (urbanisation and industrial activities) resulting in pressure on highly populated areas. They have the ability to accumulate living organism and cannot be degraded by decomposing bacterias [1 ; 2]. Several disasters related to metal pollution have made many countries to be conscious of the preservation of their environment [3]. The dumping of toxic waste in the city of Abidjan and its surrounding is a good of this,it has caused deaths and many diseases.The water bodies of the coastal area of lvory Coast is not an exception of this situation, they receive run off from agricultural land and domestic non channelled sewage network. These hydro systems are invaded by floating plants which associated with waste waters lead to eutrophication and fish death at the at the level of coastal aquatic ecosystems [4]. The water mouth of River Comoe has been closed, since 1997. This closure promotes the diversion of water into the Vridi Canal. The developemént of floating vegetals and the confinement of this environment. In 2018, the ivorian authorities have lunched the project to reopen this water mouth under the international call for tender N°T01/PABC/2018. The scientific works carried out in the water mouth on the metallic trace elements revealed the pollution of sediments whose intensity varies between no pollution and moderately polluted [4 ; 5]. However these studies did not make it possible to know

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the risk of sediments toxicity. It is therefore necessary to assess this risk in order to prevent the effects on the settlements of this localiry on its environment.

2. Material and methods

2.1. Sampling of Sediments

The water mouth of the Comoe River is in the eastern end of the Ebrie Lagoon in Grand Bassam. It's situated between 5°12' and 5°14' north latitude and 3°42 and 3°44 of the western longitude [6]. The lithological facies consists of coarse sand, medium sand, fine to very fine sand vases and mixed facies [7]. Slopes are low with notched areas of depression [8]. The sampling of the sediments was carried out by means of a van veen skip, the study collected 23 sediments samples (Figure 1). The sediments are kept in coolers at 4° to be transported to the laboratory.

2.2. Total mineralisation of Sediments

The fine fraction of the sediments (< 63um) recovered after sieving the total sediment is dried up in an oven at 50°C. It was homogenised by grinding with the help of a mortar and an agate pestle. A mass of 30 mg of fine sediment is added to a triacid mixture consisting of hydrochloric acid (750 µL of HCl at 30.9%) of nitric acid (250 µL of HNO_3 at 65.5%) and hydrofluoric acid (2 ml of HF at 65%). All maintained together for two hours at 110°C on a hot plate. After cooling, a new heating is carried out at 100°C for 12 hours to evaporate the contents of the vials. The vials are cooled again and are washed with Milli-Q water. Heating is carried out at 100°C for 12 hours to evaporate the contents of the bottles. After cooling the digestion residue is taking up with 250 µL of HNO_3 at 65.5% and 5 mL Milli-Q water. The temperature of this solution is maintained at 80°C for 10 minutes. The solution is kept at rest to allow it to cool and condense. A sample of 3.5 mL of supernatant is diluted with 6.5 mL Milli-Q water. The determinatio of the metallic elements is done by an inductively coupled plasma mass spectrometry (ICP MS) [1].

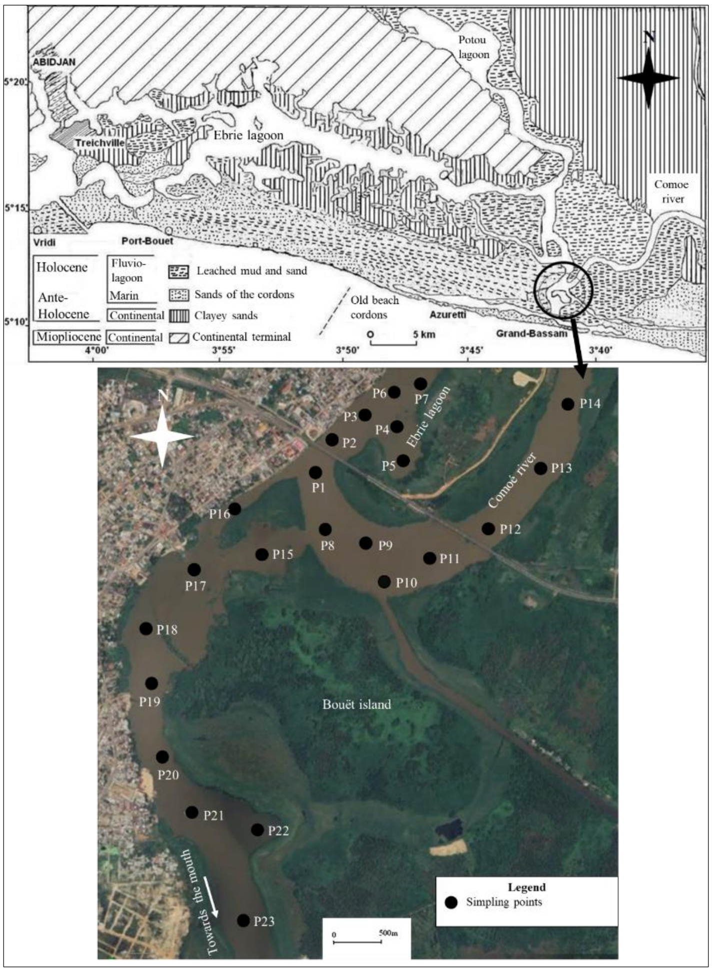

Figure 1 Location of Sediment Sampling Points

2.3. Geoaccumulation index

The geoaccumulation Index (Igeo) is used to determine the intensity of metallic pollution. This index has seven groups that determine the degree of pollution. It includes different levels of pollution from the natural contents, synonyms of no pollution untill to highly polluted sediments (Table 1). The geoaccumulation Index is determined according to Muller"s formular [9] :

$$Igeo = \log_2 (C_n / 1.5 B_n)$$

C_n : sediments concentration for the element

B_n : Geochemical base contents (Geochemical Background Noise) for elements n 1.5 : Constant that associate natural variation in the concentration of an element in a medium and low anthropogenic pressures. The contents of the metallic trace elements in the continental crust are taken as a geochemical background [10], in this study because they are of world reference.

Table 1 Muller's population Class [9]

Class	Geoaccumulation Index	Pollution intensity
0	Igeo = < 0	No pollution
1	0 < Igeo < 1	From not polluted to moderately polluted.
2	1 < Igeo < 2	Moderately polluted.
3	2 < Igeo < 3	From moderately polluted to highly polluted.
4	3 < Igeo < 4	Highly polluted
5	4 < Igeo < 5	From highly polluted to extremely polluted
6	5 < Igeo	Extremely polluted....

2.4. Ecotoxicological risk identified

The intensity of the risk is calculated using the mean-ERM-quotient. It is calculated according to the formular [11 ; 12] :

$$m\text{-}ERM\text{-}Q = \sum_{i=1} (Ci/ERMi)/n$$

With :

C : Contaminant Concentration

ERM : EMR Contamination Value

n : number of elements taken into account in the sum

The values of Effect-Range-Median (EMR) are [13] : Cu (270 µg/g), Ni (51.6 µg/g), Zn (410 µg/g), As (70 µg/g), Cr (370 µg/g), Cd (9.6 µg/g) and Pb (218 µg/g).

Five classes of probability toxicity defined as follows [14] :

- m-EMR-Q<0.1:9% probability of toxicity ;
- 0.11<m - EMR-Q<0.5: 21% probability of toxicity ;
- 0.51 < m- EMR-Q< 1.5: 49% probability of toxicity ;
- 1.5< m-EMR-Q< 5: 76% probability of toxicity ;
- m-EMR-Q > 5 : > at 90% probability of toxicity

3. Results

3.1. Quantitative variation of metals

The results of the determination of trace elements in sediments are presented in Table 2. The minimum concentration of chromium (22.6 µg/g), Nickel (11.04 µg/g), Copper (7.15 µg/g), Zinc (32.64 µg/g), As (2.18 µg/g) and lead (7.8 µg/g) were recorded in the sample P10 located near Bouët Island on the east side of the confluence zone. Maximum chromium concentration (105.6 µg/g), Nickel (47.55 µg/g) and Zinc (97.67 µg/g) were obtained at the station P3. This station is located in the Ebrie Lagoon close to homes. The highest content of Copper and arsenic is observed respectively at the station P6 and P20. P6 is located in the Ebrie Lagoon not far from the station P3. Station P20 is located on the south of Bouët Island towards the water mouth of River Comoe. Station P9 records the maximum level of lead. This station, located in the area where the Ebrie Lagoon and River Comoe meet also records the maximum cadmium content. The minimum grade of cadmium is obtained in the river Comoe at station P13. The coefficient of variation of metals concentrations ranfrom 25.2 to 101.6%.

Table 2 Characteristic value of metals

	Cr	**Ni**	**Cu**	**Zn**	**As**	**Cd**	**Pb**
Minimum	22.60	11.04	7.15	32.64	2.18	0.02	7.80
Maximum	105.60	47.55	108.58	97.67	49.19	0.79	21.69
Average	64.55	24.77	24.00	66.66	14.12	0.25	13.88
TI	53.6-75.6	20.3-29.2	14.8-33.2	59.4-73.9	7.9-20.3	0.2-0.3	122.2-15.5
Median	56.6	24.0	16.4	68.3	8.0	0.1	14.3
Variance	647.0	106.5	448.0	281.3	205.9	0.0	14.5
CV	39.4	41.7	88.2	25.2	101.6	84.7	27.4

TI (-95 ; +95%) : Trust Intervals, CV : Coefficient of Variation

3.2. Sediments pollution level

The Muller, chromium, Nickel, Copper and Zinc levels meet in the classes 0 to 1 (Figure 2) The pollution intensity of these metals ranges from no pollution (class 0) to no pollution to moderately polluted (class 1). Arsenic geoaccumulation Index values varies from-0.46 (class 0) to 4.04 (class 5). This is equivalent to an intensity of pollution ranging from no pollution to heavily extremely polluted. Lead has Index values below 0. They all belong to the class 0. This metal does not pollute the sediments.

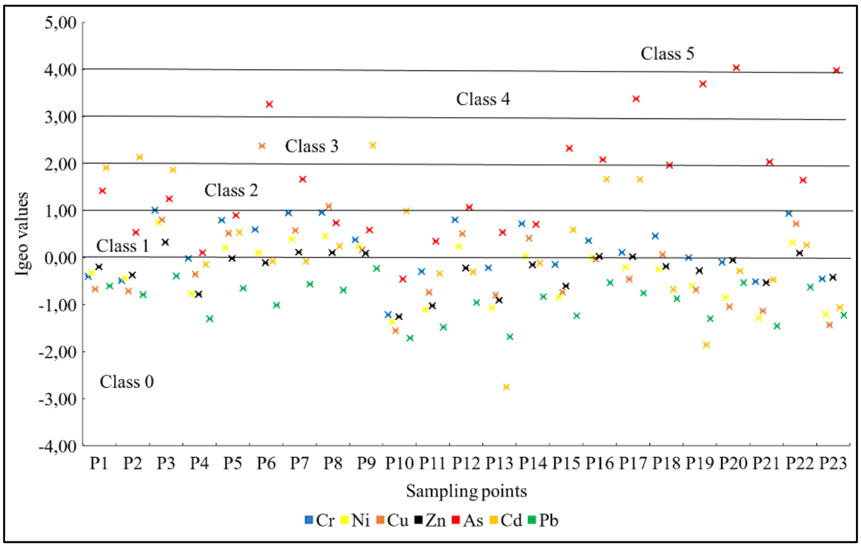

Figure 2 Igeo metal value in the Sediments at the water mouth of River Comoe

3.3. Sediments Toxicity

The values of the m-ERM-Q oscillates from 0.07 to 0.27. The likely risk of toxicity is between 9% and 21%. Statistics data shows that 17.3% of stations (P10, P11, P13 and P21) indicates 9% of toxic probability, while 82.61% shows 21% toxic risk (Figure 3). The stations that have lower toxic risk are found in the eastern zone meeting point between the river and the lagoon (P10 and P11) in the River Comoe ((P13) and towards the water mouth of River Comoe (P21).

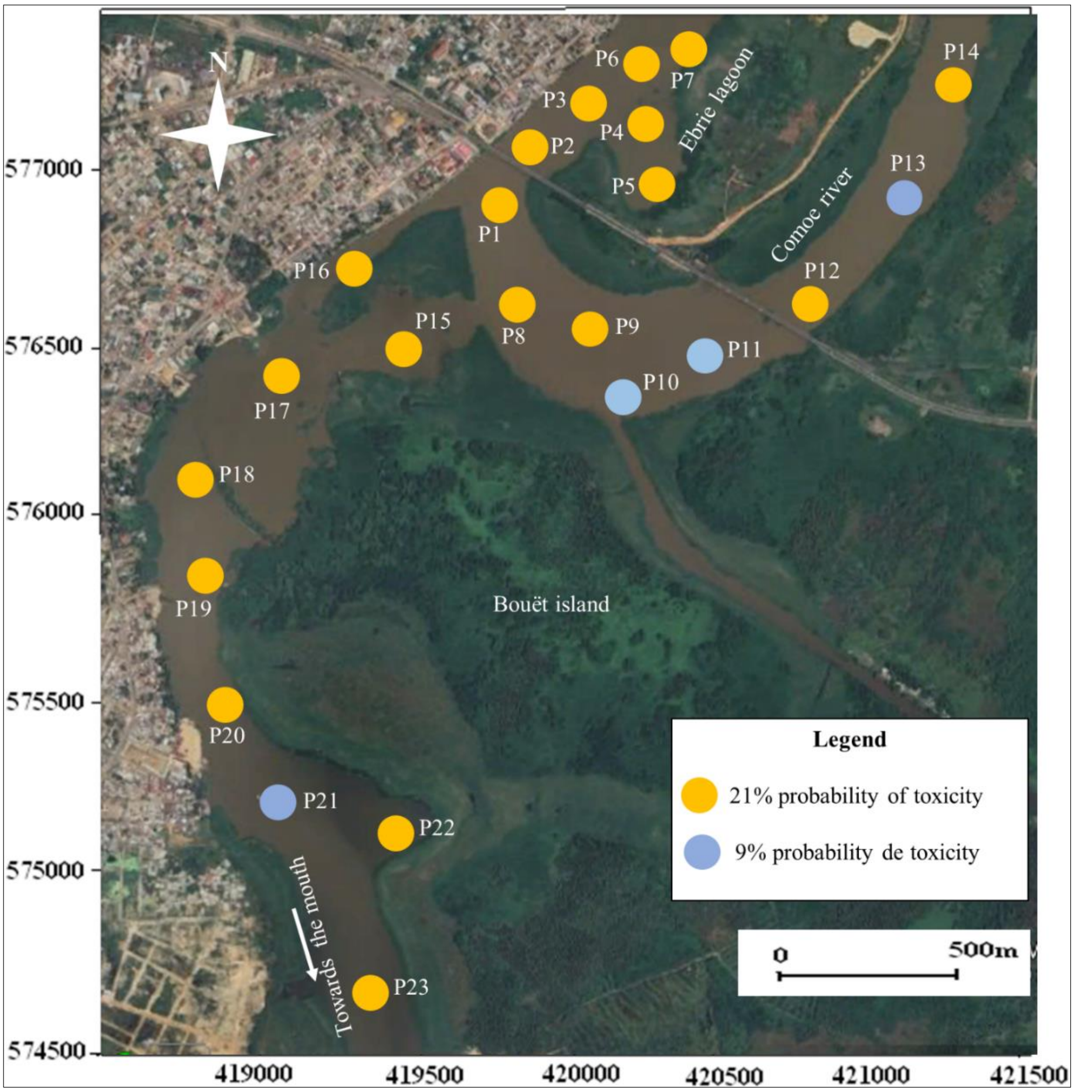

Figure 3 Ecotoxicological Quality of Sediments at the water mouth of River Comoe

4. Discussion

4.1. Variation of metal concentrations

The high levels of metals were recorded in the sediments taken near the homes (P3, P6, P9 and P20). On the other hand lower contents of metal are found in the stations far from homes (P10 and P13), precisely besides the eastern shore (vegetated environment). The high concentration found near the inhabited areas indicates a supply of metals from the water body through urban activities such as discharge of waste water and sewage. They can also come from agricultural treatment by plant protection products like dye and pigments (As,Cd,Cu,Pb,Zn), wood preserving products (As), agricultural input (Zn, As, Cu), tyre wears (Zn) and roofs ((Zn) are sources of anthropogenic releases of metals into the environment [15]. The adsorption of these metals depend on the hydrodynamics and the nature of the sediments. Station sediments P3, P6, P9 and P20 are made up of very fine mud and sand. At the station P10 and P13, we have respectivily fine sand and muds. Metals have high affinity for fine sediments particles [16]. They are abundant in confined environments with very large specific surfaces [17]. In the lagoons of the atlantic ocean, the size of the sediments increases with the intensification of hydrodynamics while the amount of organic matter in the sediments decreases [18]. These three parameters, which are article size, amount of organic matters and hydrodynamics have a significant impact on the distribution of metals in the sediments [19 ; 20 ;21 ;22]. The coefficients of variation are in the sets between we 25.2 and 101.6%. They are very high (> 15%). This trend reflect a very strong variation in the content of metals , in the stations related to their different sources. The high value of the coefficients of variation would indicate a very significant difference between the various sampling points. In the other hand a low value of this coefficients would show a distribution of the value of these parameters within the different stations [23 ; 24].

4.2. Comparison of Results with Other Studies

The average contents obtained by this présent study are 64.55 µg/g for Cr, 24.77 µg/g for Ni, 24.00 µg/g for Cu, 66.66 µg/g for Zn and 13.88 µg/g for Pb. The study carried out more than ten years ago respectively indicates contents of 65.43 µg/g, 56.7 µg/g, 14.77 µg/g, 49.68 µg/g and 54.88 µg/g for metals [5]. The average levels of chromium, Nickel and lead in the present study are lower than those in 2013. However the average level of copper and zinc in this study are higher than the level recorded by the 2013 work. This difference in concentration of metals would be due to the method of treatment of the Sediments used and the number of samples analysed. Indeed, in this study the metals were assayed by ICP-MS. In the other study the data came from the treatment of three seasons of 10 sediment samples. The assaying of metals was done by atomic absorption spectrometry. Arsenic in the present study has the highest geoaccumulation index (Igeo=4.04). On the other hand, in the study carried out in 2010, copper has the most important index with an Igeo value equal to 4.4 [4]. This difference in the most polluting metal could be attributed to the geochemical backgrounds used. Indexed the reference contents of this study are significantly higher than the contents of the geochemical backgrounds used by these authors. This study used the concentration of metals in the continental crust as a geochemical background. The 2010 study used the metal concentration of a sample taken from the Ebrie lagoon in an area protected from the influence of human activities.

5. Conclusion

The results of this study shows a very high variability in metal contents. This variation in metal concentration depends on their sources, nature of sediments and the hydrodynamics. Zinc has the highest average contents 66.66 µg/g. The pollution level changes from class 0 to class 5. Pollution intensity for chromium, nickel and zinc vary from no pollution to moderately polluted. Arsenic has a pollution intensity that ranges from no pollution to highly to extremely polluted. Cadmium, pollution goes from no pollution to moderately polluted. Lead does not pollute sediments. The likely risk of sediments toxicity is between 9% and 21%. The majority of sediments (82.61%) present a toxic risk of 21%. The sediments treatment method has a safe impact on the metal concentration level. Also the geochemical background influences the level of metal pollution of the sediments.

Compliance with ethical standards

Disclosure of conflict of interest

The authors declare that there are no conflicts of interest.

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