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Factors Influencing the Partitioning of Metal Residues (Lead) in Nokoué Lake, Benin

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ABSTRACT

The impacts on housing and living species (fish, shrimp) related to the disposal of untreated sewage by municipalities and discharges of solid waste was studied by assessing the whole Organic Matter (OM) of the sediments, Chemical Oxygen Demand (COD), Suspended Materials (SM), nitrogen pollution indicators (nitrate-NO_3^-, nitrite-NO_2^-, ammonium-NH_4^-), phosphated (ortho-phosphate ions- PO_4^{3-}), sulphide (sulphate-SO_4^{2-}, sulphite SO_3^{2-}, sulphides S^{2-}) of water and total Pb contents of water and sediments of Lake Nokoué. The organic matter content of sediments (19600 to 17164 mg / kg) and COD (130 to 1880 mg/L) of water are very high and indicate an increase in organic pollution of the lake compared to in previous years (Youssao, 2011, Mama et al., 2011). The strong variations in pH are dependent on the contributions of marine origin (basic to neutral) and the mineralization of the organic matter (pH < 7) in the areas of human settlement resulting in a greater or less mobility of the residues of metals in making sulphur available in its reduced form (sulphide and sulphite). The assessment of pollution indicators in the central part of the lake shows that it is heterogeneous in terms of source and impact of pollution. The sediment Pb concentration (Pbsed) / concentration of Pb in water (Pbw) ratio, represented by Pbsed/Pbw ratio shows that lead is 200 to nearly 1000 tiSM more concentrated in sediments than in the water showing a predominance of the organic form of Pb in the ecosystem of Nokoué lake. Indeed, organic lead residues are massively released into this ecosystem by oil traffickers who use motorized canoes to transport their products from Nigeria.

1. Introduction

Rapid population growth in the cities of Cotonou, Abomey-Calavi and lake villages is followed by heavy pollution of lake ecosystems (Daouda, 2010) in the southern part of Benin. This situation is exacerbated by mismanagement of septic tank emptying waste and the unhygienic behavior of a large section of the poor population living in the surrounding area, near or on natural water bodies FIFI (2010). Surface waters become sites for the disposal of solid and liquid wastes and even excreta that are discharged directly through the stilt latrines built on the lake. However, Nokoué Lake is one of the most important wetland ecosystems of southern Benin and the West African sub-region from a socio-economic point of view (Lalèyé et al., 1995). The Beninese population draws a good part of its protein requirements (fish and others) and these resources are also a source of foreign currency because exported to European countries. In some places, the proliferation of aquatic vegetation hostile to aquatic life is an evidence showing the destruction of this environment. The lakeside villages are also established transforming the lake into a real dump. Now, despite the important services it offers to humans and because of its limited capacity, the aquatic environment cannot ensure the self-purification of all these anthropogenic toxic releases. This is becoming more difficult in urban areas, especially in African capitals, which have not yet sufficiently integrated a fully functioning waste management system. The purpose of this study is to understand the reaction mechanisms of metals in anthropized natural environments. An assessment of indicators of organic and inorganic pollution of the environment in relation to metals generally allows a better understanding of these phenomena of chemical transformation of metallic pollutants and their mechanism of migration in food chains. The mastery of these mechanisms contributes to the establishment of effective models for managing the regeneration capacity of surface water quality.

2. Material and methods

2.1 Presentation of the study area

Lake Nokoué is located in the southern part of Benin between parallels 6°20 ' and 6°30' North and meridians 2°20 'and 2°35' East Nokoué Lake in the lower valley of the Ouémé River and the Sô river. It stretches from East to West about 12 km long and from North to South, 7 km wide parallel to the Atlantic coast from which it is separated by a coastline. It is connected to the Atlantic Ocean by the Cotonou Channel. The shores of Lake Nokoué are marshy and its depth does not exceed two (02) meters in some places (Figure 1). This ecosystem is marked by a very abundant human presence in and around the area, which throws away

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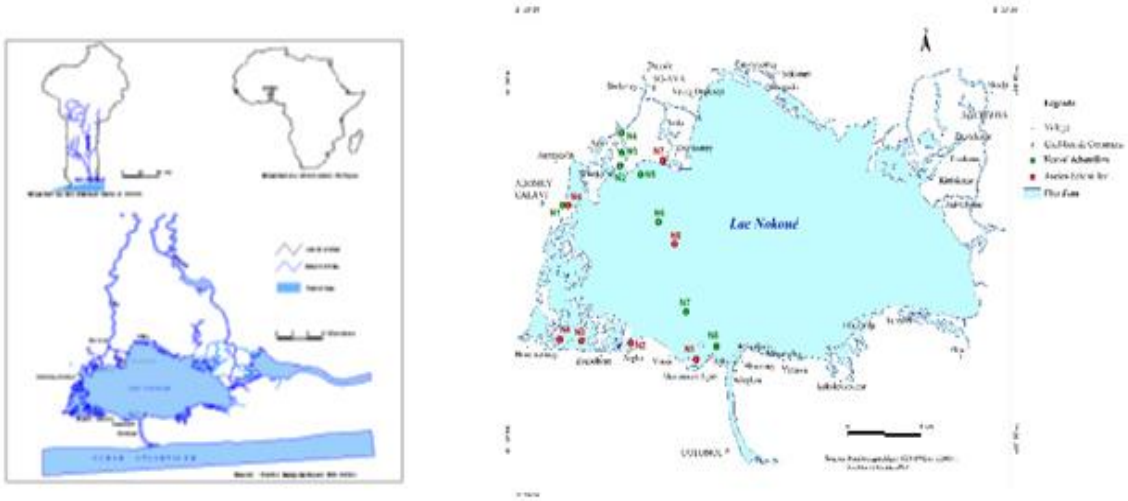

Figure 1. Location map of sampling sites on The Lake Nokoué.

all the wastes and carries out dangerous activities such as the trafficking of petroleum products from the oil-producing country of Nigeria located in the East of Benin.

2.2 Selection of sampling sites

A previous study was carried out in the area indicating a high level of pollution in the surrounding areas at garbage dumps and discharges in the peripheral areas of the effluents transported via the gutters and collectors. To deepen the paradox of a higher contamination in the sediment lead core area, the present study focused a little more on the central zone where four sites were identified in more than four others in the peripheries which were already followed during from the previous study.

2.3 Sampling and conditioning technique for water samples

The taking of a water sample is a delicate operation to which great care must be taken; it conditions the analytical results and the interpretation that will be given (J. Rodier, 1978). For this, the containers used for sampling are a function of the physicochemical characteristics of the element to be analyzed. As part of our study, we used glass and plastic bottles, previously washed and dried in an oven at 105 °C. Water was taken with a bottle plunged about 10 cm below the surface. The bottle is filled flush to avoid trapping air bubbles. All samples of water, sediment, fish are kept in a cooler. Cold accumulators are used to keep them cool in the cooler. Once brought back to the laboratory, the water samples are refrigerated at 4 °C while the sediment samples are placed in the freezer.

2.4 Measurement of physical parameters

These are temperature, pH, conductivity, total dissolved solids (TDS) and total salinity. The pH was measured in the field with a PCS Testr 35 multimeter by immersing the probe in the water taken from a 50 mL beaker by immersing the probe about 10 cm from the surface of the water, and reading digital display of pH and temperature, as well as conductivity, TDS, and salinity successively. These parameters were measured using the PCS testr multi parameter mark 35. . The multiparameter's probe has been immersed in the water about 10 cm below the surface and the reading is done on the screen of the device. The soil pH determination method consists in weighing 20 g of fine sediment screened to 2 mm, add 50 mL of demineralized water and shake for 15 minutes. Leave the suspension at rest for 30-60 minutes, immerse the pH-meter probe in the supernatant water and read to the nearest 0.1; the pH meter is calibrated beforehand. This protocol is that of ISO 1842: 1992.

2.5 Determination of organic and inorganic pollution indicators

The indicators of organic pollution measured are the total organic soil material (OM), the Chemical Oxygen Demand (COD) and the Suspended Material (SM). The OM of the soils was determined by loss on ignition (Rodier, 1978) by carrying a determined quantity of sediment in the oven at 105 °C, weighing after 24 hours and then at 550 °C and weighing again. The difference in mass allows the determination of total organic matter (OM). This parameter was measured by the gravimetric method using a filter with a diameter of less than 45 µm. The Determination of the Chemical Oxygen Demand (COD) by potassium dichromate in an acid and a hot medium.

Indicators of inorganic nitrogen pollution were determined by:

- the ammonium molybdate method for phosphate ions. The principle is based on the fact that in acidic medium and in the presence of ammonium molybdate, the phosphates give a phosphomolybdic complex which, reduced by ascorbic acid, develops a blue colour susceptible to a colorimetric dosage.
- the Nessler (alkaline potassium iodo-mercurate) reactive method for ammonium ions with formation of dimercuriammonium iodide which can be assayed spectrophotometrically at the wavelength of 400 to 425 nm.
- the sodium salicylate colorimetric method for nitrate ions by the use of sodium salicylate in the presence of nitrates which gives sodium paranitrosalicylate colored in yellow and which is capable of a colorimetric assay at the wavelength of 420 nm.
- the Zambelli reagent method and the sulphanilic acid in hydrochloric acid medium for nitrite ions. The complex formed with the NO_2^- ions is colored yellow and is capable of a colorimetric assay at the wavelength of 435 nm.

Sulphur and orthophosphate pollution indicators were determined by kit-based colorimetry, except sulphate ions, which were determined gravimetrically using barium chloride. The lead residues were determined by the colorimetric method exposed by Youssao et al. (2018b).

3. Results and discussion

3.1 Evolution of the physical parameters

The conductivity is 7.94 at the Middle Lake site1 (Mil1) at 392 mS/cm at the mouth of the river with an average of 105.27 mS/cm. These values are well above those of Dongui et al. (2017) in fresh water (48.2 to 98.6µS/cm) in the Aghien lagoon and Bhange et al. (2018) whose values are in the range of 149 to 348 µS/cm; but close to the results of Dimon et al.

Table 1. Physico-chemical characterization of the environment.

Sites	pH	Temperature (°C)	Cond (mS/cm)	TDS (ppm)	Salt (ppm)	O_2 (ppm)
Cal	7.7	28.6	8.22	5820	4690	8.0
Gan_m	6.6	28.1	9.65	685	486	5.0
Gan_c	6.4	28.3	292.00	208	145	1.5
Sô	6.4	28.4	392.00	277	194	3.8
Mil1	7.7	30.0	7.94	5530	4480	9.0
Mil2	8.0	29.5	10.20	8	6	7.5
Mil3	8.4	28.7	16.90	>LD	>LD	12.0
Jes	8.0	29.0	>LD	>LD	>LD	8.0
Min	6.4	28.1	7.94	8	6	1.5
Max	8.4	30.0	392.00	5820	4690	12.0
Moy	7.4	28.8	105.27	2088	1667	6.9

Caption

Parameter	Symbol	pH	Cond	TDS	Salt	O_2
Parameters	Name	pH	Conductivity	Total Dissolved Solid	Salinity	Dissolved Oxygen

Site name	Calavi	Ganvié marché	Ganvié centre	Sô	Milieu de lac1	Milieu de lac2	Milieu de lac3	Jéssouko
Symbol	Cal	Gan_M	Gan_C	Sô	Mil1	Mil2	Mil3	Jes

(2014) by Guézin (11.7 mS/cm) in the Lake Ahémé. While the TDS and salinity ranged respectively from 8 to Mil2 at 5820 mg/L at the landing site of Calavi gasoline and from 6 to 4690 mg/L at the same sites. All values of conductivity and TDS are high, as well as marine inputs, this saline intrusion but also TDS, in natural waters and springs, as well as in natural sources. Dimon et al. (2014) were recorded very late from TDS up to 11820 mg/L at Guézin.

The average annual salinity established by Issola et al. (2008) in Fresco lagoon surface waters is in the order of 15.69 mg/L with minimum and maximum values of 12.48 mg/L and 18.05 mg/L. These values are also lower than those obtained during this study. But a value far superior to the measuring range of the device was observed at the JESUKO (Jes) site in this study.

The variations in the pH of the Nokoué Lake water as a function of the sampling sites are presented in Figure1. On the pH results obtained at the sampled sites are between 6.4 and 8.4. It appears that during our study period, the water is relatively acidic at the level of Ganvié and sô (Gan_M, Gan_C and Sô) and basic to the rest under the influence of marine intrusions. The research works of Lamizana-Diallo et al. (2006) revealed, for a river in Burkina Faso, a pH between 6.7 and 8.7 which are within the tolerable range (5 to 9) for most plant and animal species and particularly fishes. Similarly, Dongui et al. (2017) found in the Aghien lagoon a pH generally close to neutral pH (pH between 6.94 and 7.85). Bhange et al. (2018) recorded the pH of the variant water in the range of 7.1 to 7.6 which is within the acceptable limit for the natural environment. Minimum and maximum averages of 7.42 and 7.60 have respectively been obtained by Issola et al. (2008) which is similar to the previous range of values.

Temperatures range from 28.1 °C to 30 °C with an average of 28.8 °C. It is reported that the temperature increases towards the middle of the lake and gradually decreases as it goes close to The Cotonou channel. This is due to the marine waters which are relatively cool, more and more sunny since the sampling has started in the morning on the Cotonou channel.

On a strong value of dissolved oxygen level at Mil3 (12 mg/L) and low values at Ganvié center (1.5 mg/L) and Sô (3.8 mg/L) with a overall average of (6.9 mg/L) low. These values are consistent with the pH values (acidic waters). These relatively low values are consistent with the low pH values (acidic waters) due to the mineralization of organic matter at these sites occupied by lake populations because of oxygen consumption by the biodegradation of organic matter. These values are relativly low as those of Dongui et al. (2017) who found values between 3.5 and 7.9 mg/L in the Aghien lagoon. Dimon et al. (2014) reported lower dissolved oxygen values in Lake Ahémé (0.71 mg/L) in some places.

3.2 Indicators of organic pollution

We note a high content of suspended matter at Jessuko (252 ppm) which is a site marked by the presence of latrines on stilts. In contrary, the SM are very weak at the two sites studied in Ganvié. Issola et al. (2008) recorded the SM values in the Fresco lagoon with an annual average of 5.16 mg/L with an average rate ranging from 4.66 mg/L to 5.50 mg/L; these values are well below that of this study. Both Ganvié sites show high values in OM. The rate of OM decreases towards the middle of the lake and then gradually increases towards the Cotonou channel whereas the high value of COD is registered at Jessuko level in the stilt latrine area.

3.3 Indicators of inorganic pollution

The indicators of nitrogen, phosphate and sulphur pollution in water have been presented in the table 2 below.

Inorganic nitrogen concentrations varied from 1 to 4.67 mg/L for ammonium ions, 0 to 0.21 mg/L for nitrite ions and 0.87 to 3.87 mg/L for nitrate ions. The highest ammonium rates are recorded at Ganvié and Sô and decrease gradually while moving towards the channel of Cotonou. These nitrite contents are more remarkable at the two sites of Ganvié, that of Sô and at Calavi. These results confirm those found by Mama et al. (2011) in the same ecosystem that reported the highest nutrient rates from the Cotonou and Calavi sanitation systems (respectively 360kg / d and 840 kg / d - N) and lacustrine populations in Ganvié (150 kg/day and 700 kg / day-N).Ortho phosphate ion concentrations between 0.08 and 0.65 mg/L. According to Mama et al. (2011), large quantities of phosphorus are drained from the northern part by the Ouémé river to Totchè in the dry season. Nitrate concentrations' averages are below the baseline in aquatic areas. The average values of ammonium, nitrite and nitrate are respectively 2.71 mg/L, 0.072 mg/L and 1.71 mg/L while those of sulphide, sulphite and sulphate are 0.03 mg/L respectively. L, 0.8 mg/L and 0.31 mg/L. Bhange et al. (2018) obtained sulphate concentrations ranging from 0 to 10 mg/L which are within the allowable limits and covering the range of concentrations obtained in this study. These results are similar to that of Issola et al. (2008). In fact, the average annual concentration of ammoniacal nitrogen in surface waters of the Fresco lagoon is 0.06 mg/L and the concentrations vary from 0.04 mg/L to 0.12 mg/L. As for the

Table 2. Concentrations (in mg/L) of inorganic nitrogen, phosphorus and sulphur in water.

Sites	NH_4^+	NO_2^-	NO_3^-	PO_4^{3-}	S^{2-}	SO_3^{2-}	SO_4^{2-}
Cal	2.65	0.043	1.01	0.41	0.02	0	0.04
Gan_M	4.67	0.138	1.87	0.23	0.02	0.6	0
Gan_C	4.43	0.15	1.28	0.2	0.02	0.6	0
Sô	4.62	0.21	1.62	0.29	0.02	1.2	0
Mil1	1.78	0.003	0.87	0.34	0.02	0.7	0.11
Mil2	1.41	0	1.28	0.08	0.04	2	0.78
Mil3	1.13	0	1.88	0.65	0.02	0.7	0.81
Jes	1	0.028	3.87	0.17	0.04	0.7	0.76
Min	1	0	0.87	0.08	0.02	0	0
Max	4.67	0.21	3.87	0.65	0.04	2	0.81
Moy	2.71	0.072	1.71	0.30	0.03	0.80	0.31

Legend

Nom	Calavi	Ganvié marché	Ganvié centre	Sô	Milieu de lac1	Milieu de lac2	Milieu de lac3	Jéssouko
Symbole	Cal	Gan_M	Gan_C	Sô	Mil1	Mil2	Mil3	Jes

nitrous nitrogen in the surface waters of the Fresco lagoon, the annual average is 0.31 µmol / L and that of the nitrate nitrogen in the waters is 21.31 mg/L much higher than that obtained during this study. Ortho phosphate ions have an average concentration of 0.30 mg/L. Corriveau (2009) in a follow-up of river pollution by the agricultural surplus showed the transport of nutrients mainly in the form of N03- and NH_4^+ for nitrogen, and of ortho phosphate for phosphorus. The latter has thus demonstrated a significant reducing activity in the sediments, leading to the consumption of NO_3^- and to high concentrations of NH_4^+ and NO_2^-. Lamizana-Diallo et al. (2006) reported at different stations, phosphorus concentrations ranged from 16.5 mg/L to 116.5 mg/L, except for one station that has a value of 3 mg/L which is close to our values. Similarly, Bentekhici et al. (2018) showed that dam water was highly polluted and had a dry residue of 1,940 mg · L^{-1}, dissolved oxygen of 66.5%, NH4 of 2 mg · L^{-1}, nitrite of 0.22 mg · L^{-1} and phosphorus 0.51 mg · L^{-1}. All these values obtained by the latter are close to those obtained during the present study. These comparative analyzes of nitrogen, phosphate and sulfur pollutants highlight the predominance of the reduced nitrogen form (ammonium), followed by sulfur (reduced form) and phosphate (table).

3.4 Variations of chemical indicators of organic pollution

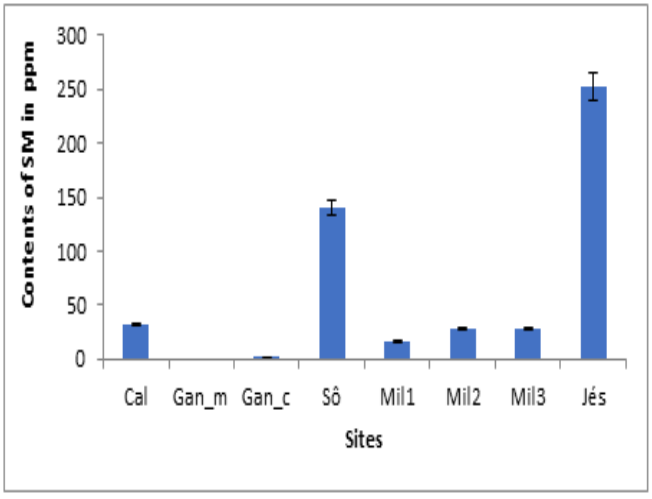

Figure 2. Suspended matter content.

Suspended matter (SM) levels show the highest values at Jesuko (252 mg/L) and at the mouth of the Sô River (140 mg/L). The evolution of the concentrations in the middle of the lake (Midl1, Midl2 and Midl3) shows a pollution coming from the northern part especially carried by the Sô River.

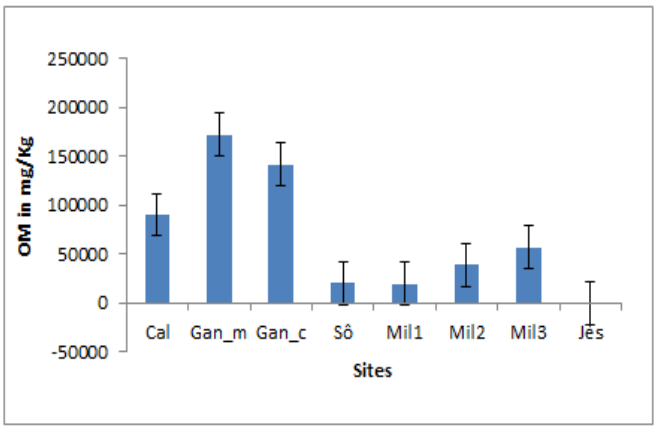

Figure 3. Organic matter.

The OM concentrations of the water are increasing in evolution at the middle of the lake sites with a similar appearance to that of SM with a relatively higher value at Mil3 (56.8 g / L); these values are well above those of Issola et al. (2008), the maximum and minimum levels of SS are 25.06 mg/L and 47.69 mg/L, respectively. This result confirms inputs from the Sô River (Mama et al., 2011). In contrast, the Ganvié sites (171.6 g / L at the Gan_M site) outweighed all others in terms of organic pollutant loads followed by Calavi. This shows the impact of lake discharges characterized by a high proportion of dissolved organic matter. The Jesuko site, characterized by a toilet on stilts, shows higher SS rates and lower MW rates indicating the self-purifying nature of the lake. The acidification is due to the mineralization of organic matter at the sites occupied by houses or receiving pollutant inputs from them. This phenomenon takes place deeper than at the surface, as evidenced by the average pH variations between 6.6 and 7.5 for the waters of the lake bottom and between 6.9 and 7.8 found by Mama et al. (2011) for surface water collected on the lake. The case of the Calavi site, which has very high values of TDS and salinity while the conductivity is low, shows the impact of the hydrocarbons that have been spilled there for decades.

Under favorable hydraulic conditions, particles suspended with contaminants can be deposited on the lake floor, and thus act as an important reservoir. Changes in sediment chemistry may result in remobilization of these contaminants. Subsequently, exposure to a different chemical environment could result in the desorption and transformation of contaminants into toxic or more biochemical available forms (Zoumis et al., 2001). For the comparison of the different forms of pollution (nitrogen and sulfur),

conversions in elementary concentrations (table) should be carried out in order to deepen the analysis.

3.5 Origins of inorganic forms of pollution and influences on the Pb partition in the Lake Nokoué

Areas under strong anthropogenic influence such as Ganvié market and Ganvie center and Calavi have very high ammonium rates. In addition nitrite and nitrate ions have lower concentrations than ammonium ions. This is consistent with the strongest of OM and more particularly at the site Ganvié_centre (1.5 mg/L). These results are similar to those found by Mama et al. (2011) who found that in the dry season, Sô has the highest rate of organic load (53% BOD). This strong predominance of ammonia nitrogen at the Gan Marché, Gan Center and Sô sites explains a lower pH 7. The nitrogen element emanates from the degradation of the organic matter resulting in a release of organic acids and nitrogen ions. These results match the high levels of organic matter at the sites of Calavi, Ganvie center and Ganvié market. This is in perfect agreement with the results of Dongui et al. (2017) on seasonal variation analysis gave high values for ammonium, phosphate, nitrite, COD, BOD5 and conductivity.

All in all, nitrogen would come from the mineralization of organic matter while sulfur. In contrast to nitrogen, sulfur has higher levels in the middle of the lake with a peak at the Mil2 site and low concentrations in high anthropogenic media such as Calavi and Ganvié (center and market). Overall, inorganic sulfur concentrations are ten tiSM lower than inorganic nitrogen concentrations. But sulphides have higher concentrations than oxidized forms such as sulphite and sulphate ions which have similar values and the same evolutionary tendency.

It can be seen that the high levels of ammonium concentrations are recorded at Ganvié and Sô and gradually decrease while moving towards the Cotonou Channel and located at the edge of the lake. In contrast to nitrogen pollution, sulfur is an increasing trend going from Calavi to Ganvié and then from the middle of the lake to Jesuko, the closest site to Channel of Cotonou and located on the edge of the lake.

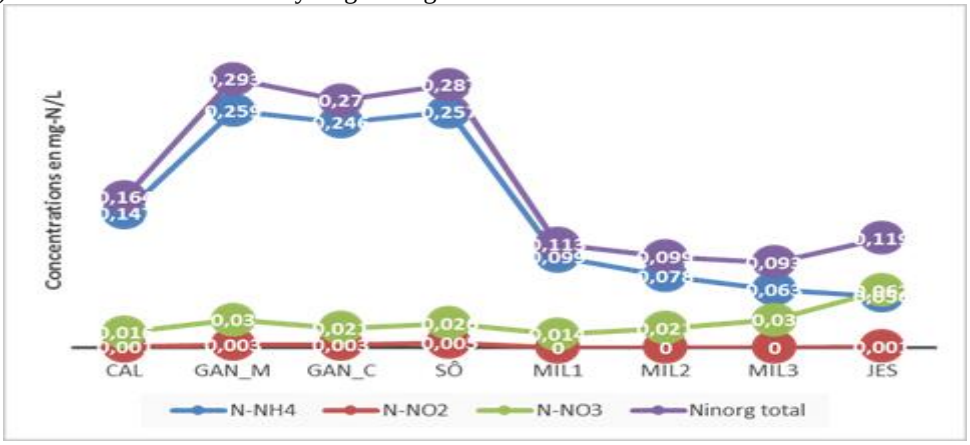

Figure 4. Evolution of nutrients (nitrogen forms and sulphur).

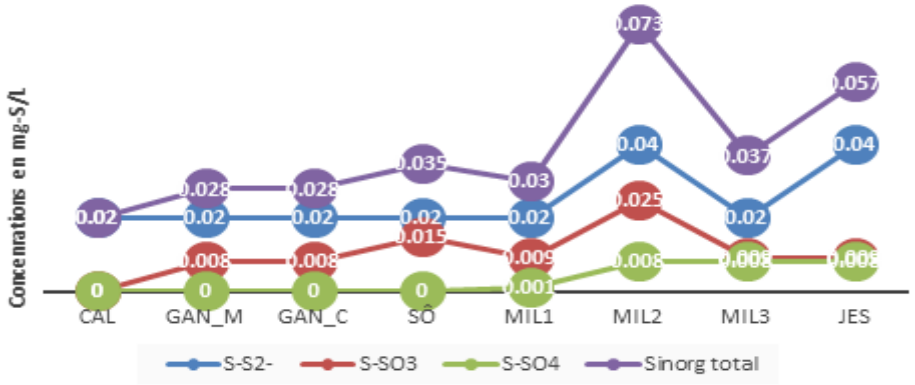

Figure 5. Variations in sulphur pollution indicators.

3.6 Metal toxicity indicator: P sediment / Pb water ratio

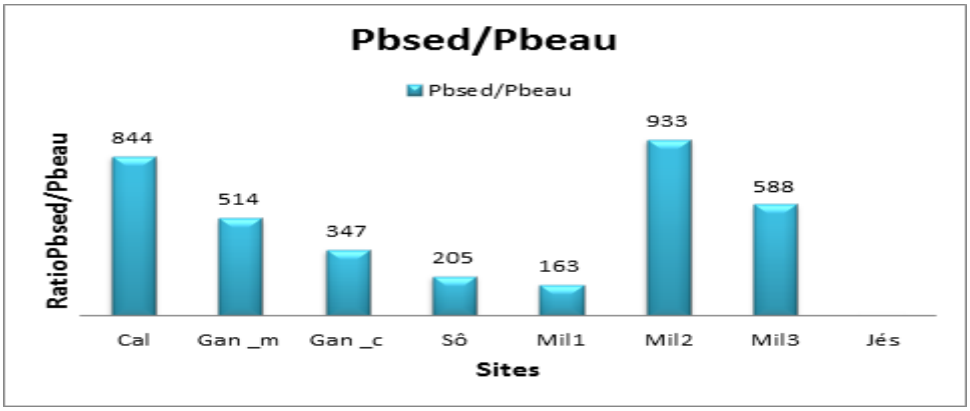

Figure 6. Evolution of the ratio Pbsed/Pw.

This figure shows the ratio Pb- sediment and Pb- water levels of lead in the waters and sediments collected on the Lake Nokoué. The sediment / water Pb ratios at Calavi (844 tiSM that of water) and Ganvié and at Mil2 are the highest recorded in this study. It shows a mineralization factor related to the acidification of the environment. In addition, since the Calavi site has been a landing place for species transported from Nigeria for several decades, this high value observed at the Mil2 site shows a similar phenomenon. Indeed, this site was chosen as a reference site because far from urban and lacustrine pollution. However, the transit of products is via this site which would be affected by accidental or intensional spills during sporadic prosecutions organized by the police. This result is consistent with those obtained previously (Youssao et al., 2011b) in sediments with the highest concentrations compared to all sites in the Channel and Lake. According to our previous studies, averages obtained from the gill, muscle and liver concentrations of different fish species show higher values in channel fish than those in Nokoué Lake and the Atlantic Ocean.On the other hand, when the residue analysis refers to the muscles only the fish in the lake are slightly more contaminated than those in the channel (Youssao et al., 2011b, Youssao et al., 2018). These results are in agreement with the high Pbsed / Pbeau toxicity ratios at sites known for gasoline traffic such as the Calavi Pier.

The temperature of a surface water is closely related to changes in ambient temperature and the season. Measurements were carried out in October during the long dry season in the north (October - March) and the short rainy season in the south (March - November) with a peak in October. The pH values of the water are within tolerable limits (6.5-8.5) favorable to the development of aquatic species. These values are comparable to those of Lamizana-Diallo et al. (2006). The pH sediments are also acidic at Calavi and Ganvié, which would make the metals more soluble. Conductivity is higher than Lamizana-Diallo et al. (2006) obtained for freshwater. Thus, as shown by the results obtained for organic matter in sediments, the abundance of organic matter in these media in organic matter (19,600 mg / kg to 171,643 mg / kg) is justified and above all, it is necessary to focus on the sites of Calavi and Ganvié. The rates of suspended solids are high at Sô (140 mg/L) and Jésuko (252 mg/L), values well above the quality standard of 35 mg/L in Bénin. This rise in the rate of suspended matter in Sô is due to the influx of the river Sô by the contributions in suspended matter on the one hand, and to the mobility of the water to this precise point, waste dumped in the river, water at the level of Jesuko on the other hand; then, the COD values obtained on all sites that are well above the 125 mg/L quality standard confirm the high pollution of this lacustrine area. Thus, one can say that the lake is confronted with big problems of organic pollution in Ganvié, Sô, especially in the middle of the Lake and in Jesuko where masses of "*acadjas*" systems are established and also the pollution by the garbage, it arises therefore already eutrophication problem at the Lake. Phosphate concentrations are within the acceptable limit of 0.5 mg/L (Gaujous, 1995); except the Mil3 site which reached a threshold of 0.65 mg/L; in fact, phosphorus can play a limiting role in the primary productivity of a water. Not enough phosphate and the medium is not very productive (oligotrophic), too much phosphate and it is eutrophication; the excess of phosphates can result from industrial and domestic discharges (synthetic detergents); for phosphate concentrations it can be said that all sites sampled meet the phosphate concentration standard of 0.5 mg/L except the Mil3 site which is 0.65 mg/L, a sign of phosphate pollution. The relatively high values of the inorganic pollution indicators are mainly due to the mineralization of organic matter, especially excreta, in the same way as the chemical fertilizers that create a threat to the aquatic ecosystem of the Lake Nokoué, which is depleted in dissolved oxygen necessary to aquatic life by the process of biodegradation and the proliferation of plant biomass including *Eichhornia Crassipes*. These results are similar to those of (Youssao et al., 2017).

In sum, sulfur pollution, even if it has the same origin as that of nitrogen, could be linked to metallic elements because sulphides, which are the most abundant forms, have a very high affinity with them. However, the predominance of the reduced form indicates the organic origin of this element in the environment which is anoxic as well as the nitrogen whose ammoniacal form is predominant in sites with high organic pollution. Nevertheless, the acidic pH of the water and sediments of these area would be the origin of the high concentrations of ammonium ions observed at Ganvié and Sô unlike other inorganic forms. In fact, the destruction of organic matter (food remains, fish excrement, plant waste) by aerobic-type bacteria releases ammonium ions and carbon dioxide into the medium. Ammonium is in fact not toxic for fish, it is assimilable by plants, but its presence in the environment is a risk for ichthyenne fauna because at a high pH the H^+ ions bind to OH^- ions by releasing NH_3 (ammonia) which is very toxic; ammonia causes the fish to stick to the gills, leading to respiratory failure and death by asphyxiation. In the same way, nitrites are extremely toxic, but the nitrite rates obtained at the various sites of our study is in conformity with the quality standard of surface water, nevertheless the nitrate ions can degenerate into nitrites because there is not enough oxygen in these medias by the action of anaerobic of nitrifying bacteria.

4. Conclusion

At the end of this study, the results obtained reveal a strong pollution of the Lake in general and in particular of the sites of Calavi, Ganvié and Jesuko. The partition or toxicity index is an important indicator that reflects the high potential of the residues to accumulate more in the muscles than in the gills and other organs of the fish. Calavi and the middle of Lake sites1 and 2 are characteristic of oil pollution and exhibit a higher risk of toxicity with respect to the higher values of the Pbeau / PbSed toxicological index. Pollutant inputs come from a variety of sources, mainly of anthropogenic and lacustrine origin: domestic activities, commercial activities, industrial activities and urban runoff (wastewater). The high organic pollution may result in a risk of fish asphyxiation due to the lack of dissolved oxygen caused by the high demand for COD for the oxidation of the large amount of organic matter. The possible consequence of eutrophication is the reduction of gas exchanges with the atmosphere. Ecosan technology is a credible alternative for composting excreta, urine and household waste that can limit solid discharges to Lake Nokoué. These substrates will be accessible to market gardeners if the public authorities encourage the construction of these latrines; they will thus be able to contribute to the sustainable management of sandy soils with a low retention capacity, provided that the public authorities invest in improving access to lakeside populations for sustainable sanitation and also those living in peri-urban areas. This will have a major impact on ecotourism in lake villages.

The influence of pollution of organic origin, especially in hydrocarbon, increases the toxicity of lead residues and

makes them more bioavailable to aquatic organisms such as fish and shrimps. The partition of metal residues between the sediments and the water column is strongly influenced by the organic matter and the products of its mineralization, the most important of which is sulfur. The toxicity index defined by the sediment Pb ratio on Pb water of the respective concentrations in water and sediments of Pb residues is an indicator that should be taken into account for both preventive and corrective measures for the depollution of ecosystems. aquatic.

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