Journal Homepage: -www.journalijar.com

INTERNATIONAL JOURNAL OF ADVANCED RESEARCH (IJAR)

ISSN NO. 2320-5407

DOI:10.21474/IJAR01/xxx
DOI URL: http://dx.doi.org/10.21474/IJAR01/xxx

RESEARCH ARTICLE

Physicochemical quality of water and sediments of Lake Hlan in southern Benin

Key words: -
physicochemical quality, water, sediments, Lake Hlan

Abstract

Lake Hlan is experiencing environmental problems that threaten its existence. This lake is located in the south of Benin and is shared by two communes namely Zogbodomey and Toffo. The lake is a subject of different anthropogenic pressures linked to demographic expansion. This present study aims to evaluate the physicochemical quality of the water and sediments of this lake. To achieve this objective, field and laboratory work was carried out. To understand the impact of pressure on the water quality of the lake in the municipality of Toffo, the targeted for water and sediment sampling. The methodological approach took three phases: Documentary research having made it possible to better understand the contours of the subject, data collection through a survey, sampling of water and sediments, laboratory analyzes and interpretation of data collected. The survery resultats indicate that 35% of the population practices agriculture and market gardening, 36,67% practice the transformation of pal nuts into red oil, 23,33% practice fishing 5% practice breeding. As for the results of physicochemical analyzes, we note that water is moderately charged and polluted by ortho phosphates and ammonium, which is justified by activities by the activities carried out around the lake and the input of waste through runoff. Lead and cadmium levels are respectively (21,769 to 39,607 mg/kg) and (1,769 to 3,003 mg/kg). These results are higher than standards for aquatic life and indicate pollution of the lake and constitutes a threat to aquatic species and to humans.The presence of trace metal elements which are beyond standards are due to anthropogenic activities, particularly agriculture, through intensive use of fertilizers and pesticides.

Corresponding Author:-D.Y. Nicodème ; dossouyovonicodeme7@gmail.com
Address: -Institut National de l'Eau (INE),Laboratoire d'Hydrologie Appliquée (LHA),Université d'Abomey Calavi (UAC).

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Introduction: -

Water is essential to all forms of life; it is necessary for health, agriculture, industry, tourism, recreation, navigation, etc. (Dovonou et al., 2012). The increase in industrial activities, urban development, and the industrialization of agricultural practices are impacting the environment, particularly water quality, through urban runoff and wastewater, chemicals, and fertilizers discharged into lakes, lagoons, rivers, etc. These discharges generate physical, chemical, and microbiological pollution of water quality and sediments. These various forms of pollution are due to anthropogenicactivities. Lake Hlan, located in southern Benin between the municipalities of Zogbodomey and Toffo, is subject to the impact of riparian populations, as are other watercourses in the country. The various anthropogenic activities carried out around this water body lead to waste of all kinds (domestic wastewater, uncontrolled waste, agriculturalresidues, etc.) being discharged in its vicinity. Indeed, these discharges increase the organic matter load in surface waters, and their contamination can affect the food chain (Kougblenou et al., 2018). Lake Hlan exhibits a complex, fragile ecosystem governed by precise physicochemical laws. This pollution detrimentally disrupts the lake 's ecosystems (Hounkpe et al., 2017). Therefore, investigating the water and sediment quality of the lake is crucial to ensure the sustainability of ecosystem services that benefit local populations.

I. Materials and Methods :

The field survey, Study Area, Sample Collection and Static treatment

The field survey

After the phase ofdata acquisition, we have the phase of the field survey which is a phase during which the information necessary to achieve the objectives of the study was collected. The surveys were conducted by administering questionnaires to the inhabitants of Kpomè, close to the lake and who use the lake for their various activities on September 12, 2023. To succeed in the survey, we relied on the populations closest to the lake and who are able to carry out a direct or indirect activity on the lake. For Lake Hlan in Toffo, it is the Azonmè village which is located around, so it is this village which was our target. The population size of the village of Azonmè, located around Lake Hlan is 2706 (RGPH4., 2013). Not being able to interview the entire population, we used the formula of Rea et al (1997) to find our sample size.**n= (tp² x P(1-P) x N) /(tp² x P(1-P) + (N-1) x y²)**(Rea LM et al., 1997), with n the sample size; N=100 the estimated population size; tp = 1.96 the sampling confidence interval; P = 0.5 the expected proportion of 50% of a population response and y = 0.0804 which is the margin of sampling error. Thus we have : n= ((1.96) ² x 0.5(1-0.5) x 100) / ((1.96) ² x 0.5(1-0.5) + (100-1) x (0.0804) ²) ; n = 60.

In conclusion, we have 60 people to interview.

> **Comment [H1]:** ame the formula instead of saying the following formula The formula of Rea et al (1997)

> **Comment [H2]:** Show how the 20 households are obtained using the Rea et al formula

Study Area

Lake Hlan is a small body of water in central Benin with a surface area of 0.18 to 0.3 km2 (Lalèyè et al., 1997). Oriented from northwest to southeast, Lake Hlan is a small body of water about 6 to 10 m wide and 30 km long located in the Zou and Atlantique departments, in the communes of Zogbodomey and Toffo in Benin between 6°46' and 7°8' north latitude and 2°5' and 2°7' east longitude (Montchowui et al., 2005). Kpomè is the area in which this lake is located and its surface area increases considerably during the flood, during which time it is connected to the Ouémé River (510 km). It crosses two forests, one of which, sacred, of about 2 ha, is located upstream and fully protected by the population and the other, downstream, constitutes the Lokoli swamp forest of an area of about 500 ha. At Kpomè, the lake is located in a flood zone covered with floating grassy vegetation (Montchowui et al., 2005).

Figure 1 shows the geographical location of Lake Hlan.

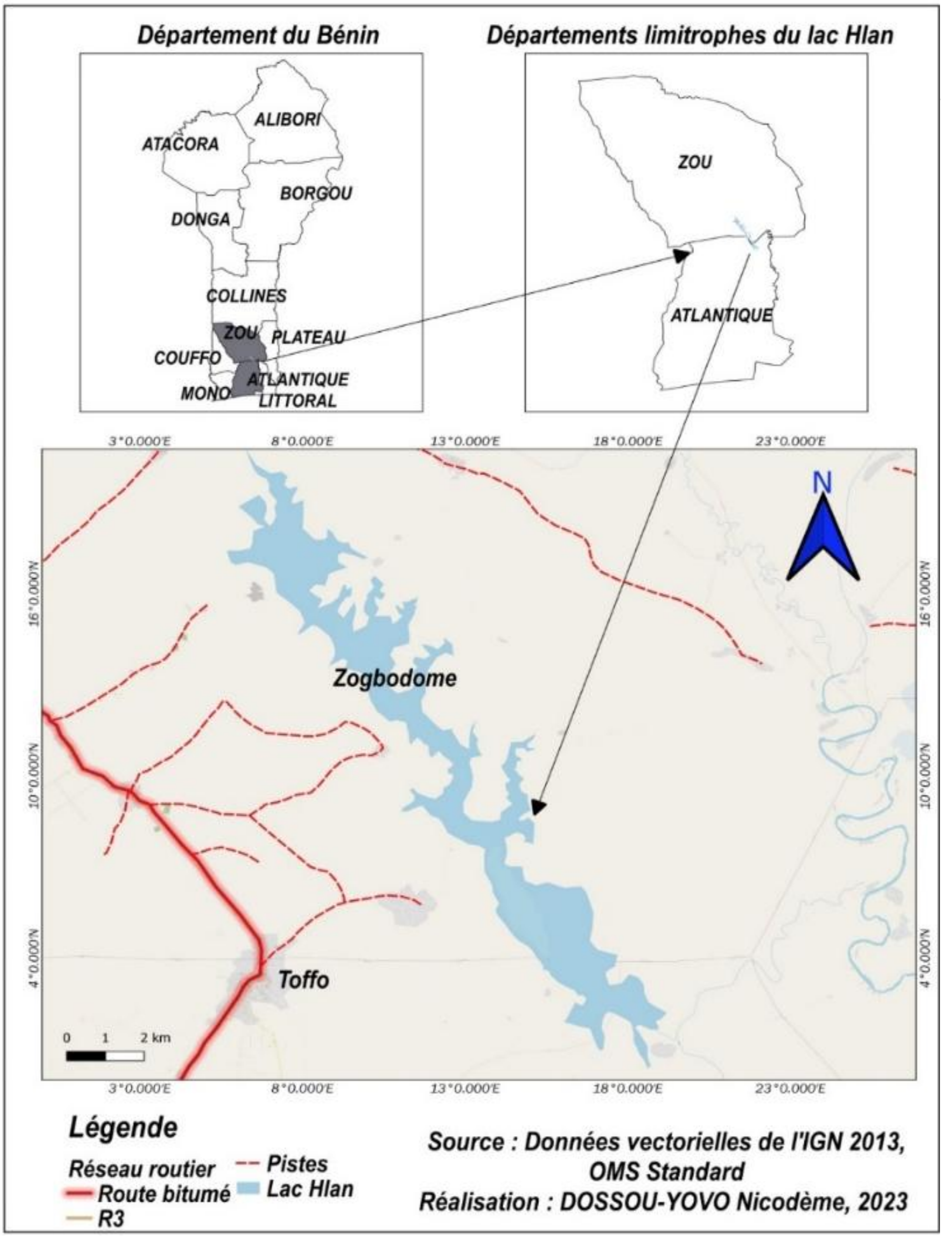

Figure 1 :Map of the presentation of the study area

Sample Collection After this phase we have the field work phase whichwere carried out on 09/20/2023. They consisted of taking pictures to map the sources of pollution and collecting water and sediment samples. Sampling sites for water and sediment were selected based on station accessibility, the presence or absence of urban areas, the existence of agricultural activities or a pollution gradient, the diversity of the biotope and the presence or absence of border vegetation. A total of ten samples (five for water and five for sediment) were selected from Lake Hlan. Water samples were collected in 1.5 liter polyethylene bottles after rinsing with the water to be sampled so as not to leave any air bubbles. Sediments were collected using a sediment grab. Samples are taken from the first centimeters (0-5cm) of the sediment layer in accessible locations. Sediment samples are collected directly into plastic bags branded NF 229 04/05 120A. All samples are stored in a cooler with ice packs before being transported to the laboratory. A chosen point gives the water sample at the same time as the sediment.

Figure 2 shows the distribution of sample collection points across the lake

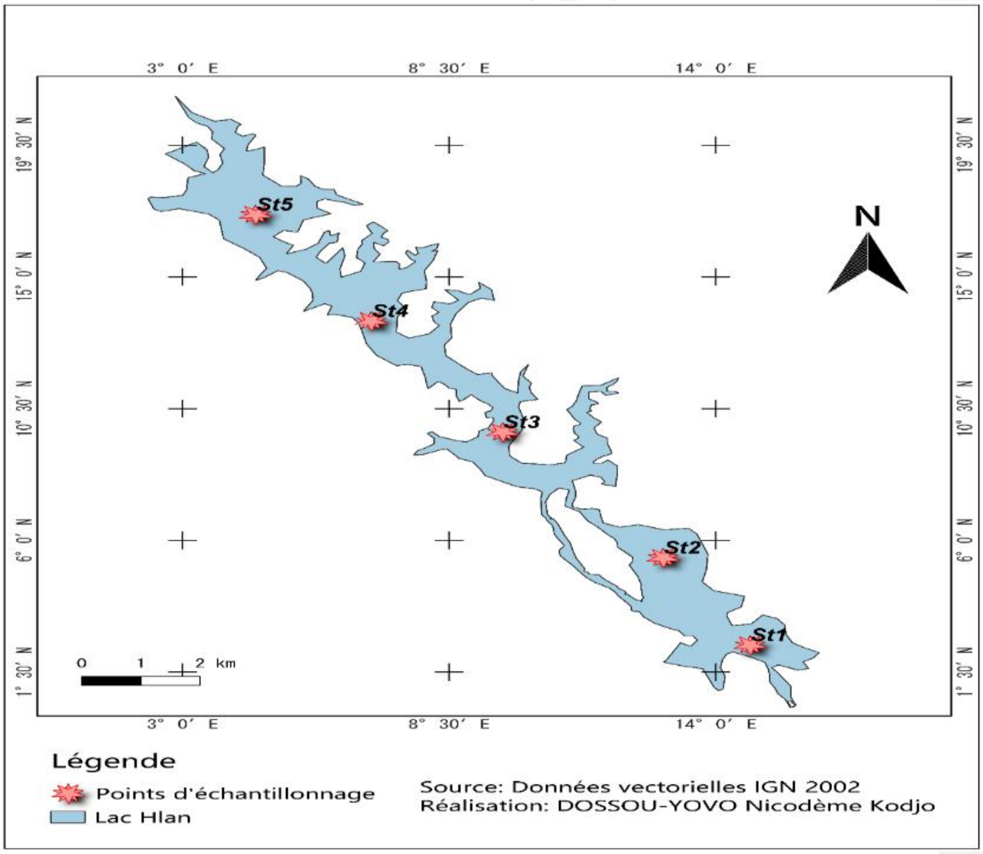

Figure 2 : - Map of water sample collection points.

Static treatment

Regarding the analysis of in-situ physicochemical parameters, we measured thePotential of hydrogen (pH), temperature, conductivity, resistivity, total dissolved solids (TDS) and salinity are measured with a multi-parameter AQUAREAD AP-700. For each measurement, the probe is first rinsed with distilled water and then with the sample. The various parameters are read and recorded in situ using the probe which has been immersed in the water sample taken. The sample analysis phase was carried out at the Applied Hydrology Laboratory (LHA). During this phase, we carried out the physicochemical analysis of the water samples, where nitrates, nitrites, ammonium, orthophosphate and total phosphorus were measured using the methodscolorimetric analyses andspectrophotometric. For the sediments we analyzed two heavy metals namely lead and cadmium using theMetalyser HM3000.

Comment [H3]: Specify the methodology used for these physicochemical analyses

Results and Discussion :

The results and discussion of our various works are presented in three parts : the different activities carried out around the lake, the results of the physicochemical analyses and the heavy metals measured in the sediments.

3-1 The different activities practiced around the lake .

Among the activities practiced around Lake Hlan, we note agriculture where we have the cultivation ofcorn, cassava, bananas, oil palms. The population living around Lake Hlan uses the lake's water for their crops during the dry season. After agriculture, we have livestock farming, which is an activity practiced in the vicinity of the lake and its products are likely to run off into the lake. The majority of animals (sheep and especially cattle) are brought to Lake Hlan to use the waters of Lake Hlan as drinking water. The population raises poultry, cattle, sheep, goats and pigs. After livestock farming, we have fishing, which remains the main activity of the populations living around the lake, although it is less practiced because theLake Hlan is the only body of water with an area of 1.65 km2 on the eastern boundary in the Kpomè districtThey use canoes and traps to go fishing. Finally, we have processing, which is an activity.based on the use of palm nuts. This is an activity during which we witness the extraction of red oil and separation of palm nuts. This is an activity carried out not far from the lake.
The diagram in Figure 3 shows the proportion of different uses of the lake.

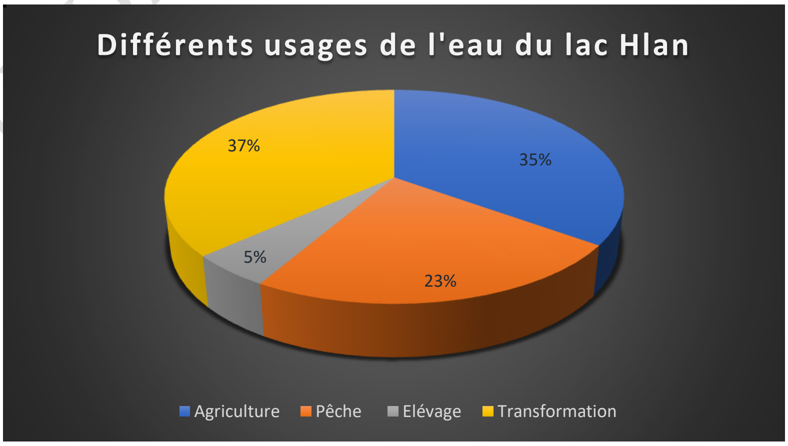

Figure 3 : Different types of uses of lake water.

Indeed, agriculture, processing, and livestock farming are activities that complement primary activities. They are developed by the riverside populations around Lake Hlan.
Agriculture and processing are the main activities of the residents of Lake Hlan. Fishing also remains one of the main activities of the residents, butIt is much less practiced among the residents of Lake Hlan, because this lake constitutes the only body of water offering an area of 1.65 km2 on the eastern boundary in the district of Kpomè. It is essentially based on the traditional technique which is the trap. This fishing technique poses a great threat to aquatic resources because the trap used does not meet the standard. Regarding processing, the discharge of waste from processing palm nuts into red oil can cause water pollution by organic matter. Livestock farming will generate fecal matter, organic waste that will run off into the lake, which is especially observed during flood periods, and this constitutes a source of pollution. Agriculture generates nutrients including nitrates, ammonium and phosphorus after the use of chemical fertilizers. Pesticides and fertilizers used for production during market gardening are risks of pollution for the lake. In addition, this is accentuated by the leaching of the soil thanks to flooding and the slope which promotes the runoff of water towards the lake. All this is a threat to water quality. Due to the lack of sufficient drinking water sources, all animals are brought to the lake to use the lake water as drinking water. All this contributes to the increase in organic matter from fecal matter in the lake water because these animals defecate while drinking the lake water. It should also be noted that some local residents also use the lake water as drinking water.

3-2 The physicochemical parameters of the lake water.

The results of the physicochemical analyses, namely hydrogen potential, TDS, conductivity, dissolved oxygen, turbidity, nitrate, nitrite, ammonium, orthophosphate and total phosphorus, are recorded in Table I.

Sites	T(°C)	Ph	TDS (mg/L)	Turbidity (NTU)	NH4 (mg/L)	Nitrite (mg/L)	Nitrate (mg/L)	Ortho-P (mg/L)	PT (mg/L)
St-1	27.47	6.51	44.00	28.00	0.346	0.154	0.00	0.213	0.069
St-2	27.42	6.60	39.00	32.00	0.352	0.143	0.00	0.205	0.067
St-3	27.49	6.58	43.00	28.00	0.391	0.141	0.065	0.213	0.069
St-4	27.41	6.68	31.00	23.00	0.275	0.121	0.732	0.098	0.032
St-5	27.40	6.66	33	25	0.354	0.172	0	0.201	0.066

3-2-1Potential of Hydrogen (pH)

The different pH values obtained at Lake Hlan vary very little and are between 6.51 and 6.68 with an average of 6.61. The highest value is obtained at station no. 4 and the lowest is obtained at station no. 1. The different values are located in the range of 6.5 to 8.5 which are the limits recommended by the NEQ for surface waters. Figure 4 shows the variation of pH at the different stations.

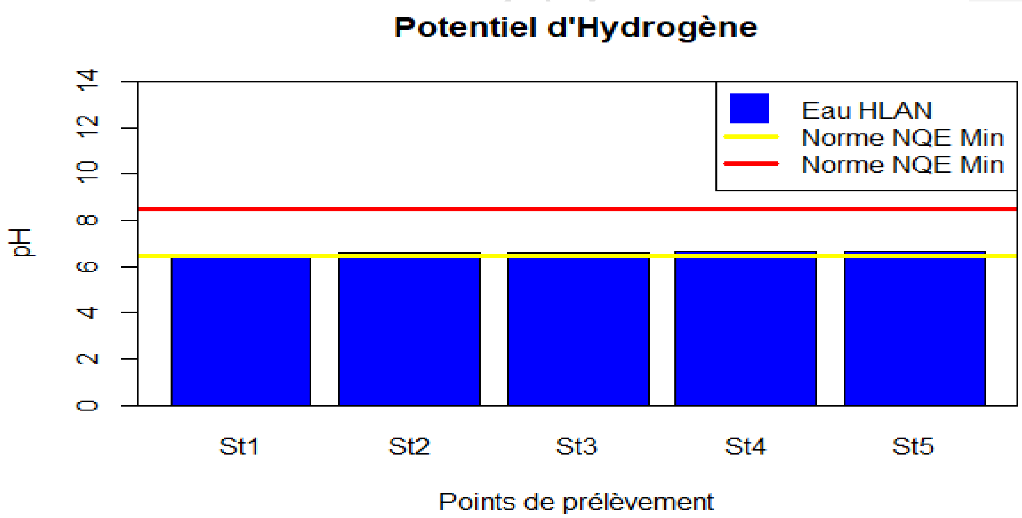

Figure 4: Variation in pH at the different targeted stations on Lake Hlan.

The values thus found are compatible with the results (6.05-7.80, in June) of Dovonou et al (2011) who managed to demonstrate that Lake Nokoué is eutrophic, it is also the same as the results (6.5 to 8.2) of Lalèyè et al, (2003) and Alhou et al, (2009) on the Niger River. But these values are almost lower than the results (8.66 and 10.51) of Dimon et al (2014) on Lake Ahémé, and those of Metinhoue for his bachelor's thesis on Lake Toho in Kpinnou in the commune of Athiémé in November 2018, this difference is explained by the water supply in the long rainy season which causes dilution. The values obtained for the pH are therefore acceptable. According to Blinda (2007), pH values between 5 and 9 allow normal development of flora and fauna.

3-2-2 The temperature. The temperature recorded at the different stations varies from 27.40 to 27.49°C with an average of 27.44°C. The lowest value is obtained at station No. 5 and the highest value is obtained at station No. 3. We note that the temperature values of these waters are not in the range [20; 25] which represents the standardized value for this parameter (NQE, 2015). Figure 5 shows the positioning map of the sites with the temperature data in the middle contour plus data.

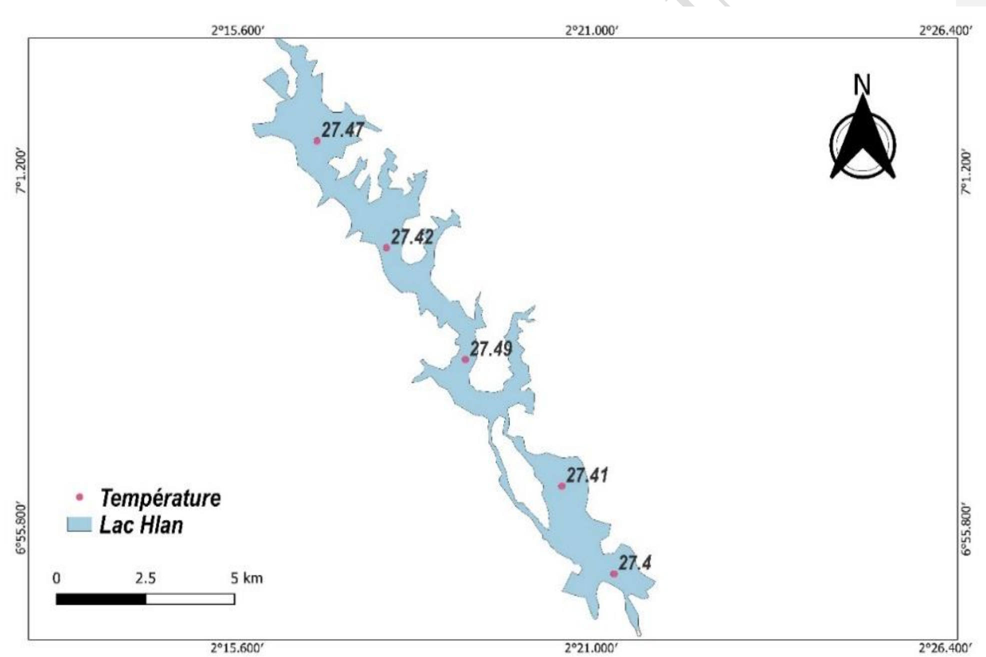

Figure 5 : Site positioning map with temperature data in the middle contour plus data.

These variations could be explained by both the times of water sampling and the period during which fieldwork was carried out. The temperature values obtained are consistent with those found by Bassirou in 2003 in the Niger River (21.6 to 26.4°C). They are also compatible with the work of Dimon et al (2014) on Lake Ahémé (27 to 30.0°C), but lower than the values found in 2003 by Soclo in the ponds and rivers of the W reserve and its hunting zones (30.1°C to 32.1°C) during the dry season.

3-2-3 Electrical conductivity (EC)

The conductivity recorded at the different stations shows a variation between 61µS/cm and 88µS/cm ; giving an average of 75.6µS/cm. The smallest value haseteobtained at station n°4 and the highest value at station no. 1. None of these values are found within the range accepted for surface water by the NQE, i.e. [750 ; 1300] µS/cm. Figure 6 shows the variation in conductivity at the different stations.

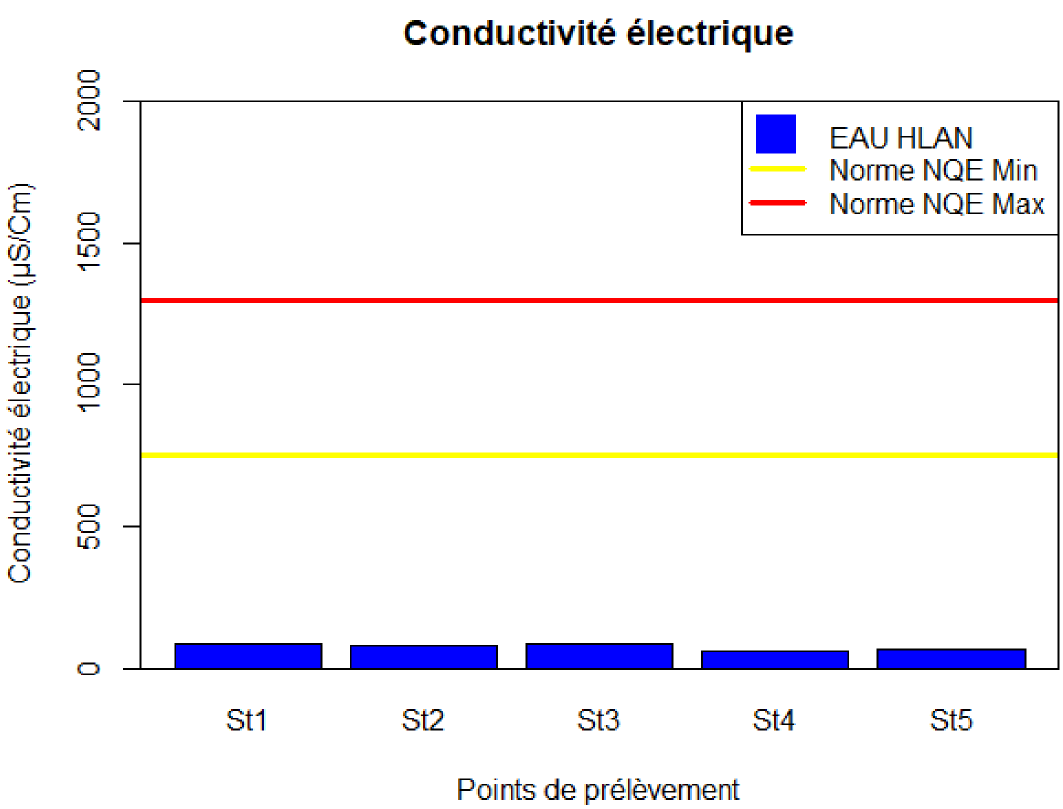

Figure 6: Variation in conductivity at the different stations targeted on the lake.

3-2-4 TDS (total dissolved solids)

The TDS values obtained at the various stations are between 31 mg/L and 44 mg/L; the lowest value is obtained at station no. 4 and the highest value at station no. 1. The average is 38 mg/L andnone of these values are found within the range accepted for surface water by the NQE, i.e. [500; 1200] mg/L. The graph in Figure 7 shows the evolution of the quantity of total dissolved solids at the different stations.

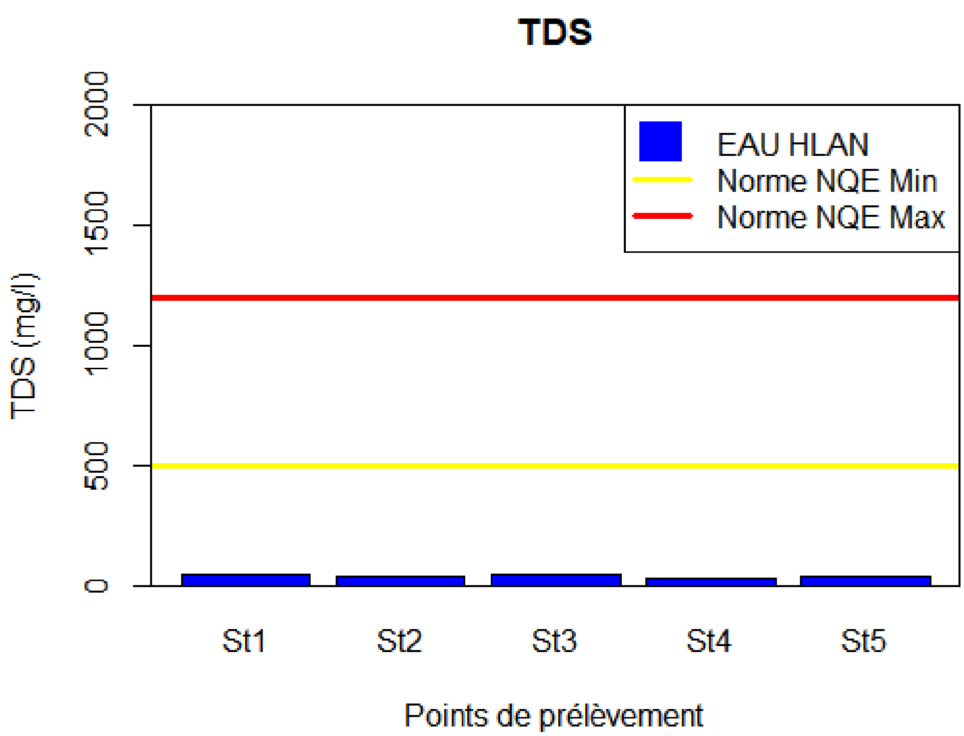

Figure 7 : Variation of TDS at the different targeted stations on Lake Hlan.

3-2-5Turbidity

At Lake Hlan, turbidity ranges from 23 to 32 NTU. The lowest value is obtained at station No. 4 and the highest value is obtained at station No. 2. The average is 27.2 NTU.None of these values are found within the range accepted for surface water by the NQE, i.e. [5; 20] NTU

Figure 8 shows the variation in turbidity at the different stations targeted on the lake.

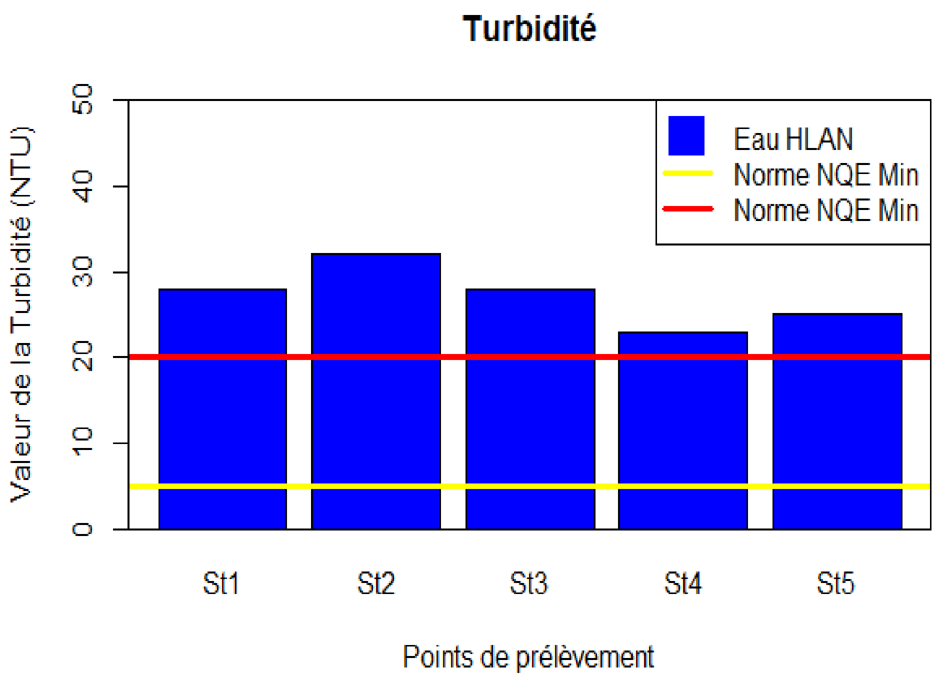

Figure 8: Variation in turbidity at the different stations targeted on Lake Hlan.

All these values found are higher than the NEQ standard (5-20 NTU), so we can say that the lake waters are turbid. These results obtained are similar to those of Zandagba et al (2016) on Lake Nokoué. Indeed, the high turbidity values are explained by the input of runoff water and the marketing of fishery products around the lake.

3-2-6-Dissolved oxygen

At Lake Hlan, the amount of dissolved oxygen is between 0.97 and 1.22 mg/L with an average of 1.09 mg/L. The lowest value is obtained at station No. 1 and the highest value is obtained at station No. 2. All values are below 5 mg/L, which does not comply with WHO recommendations. This means that the amounts of dissolved oxygen obtained are not in accordance with WHO recommendations.

Figure 9 shows the variation of oxygen at the different stations targeted on the lake.

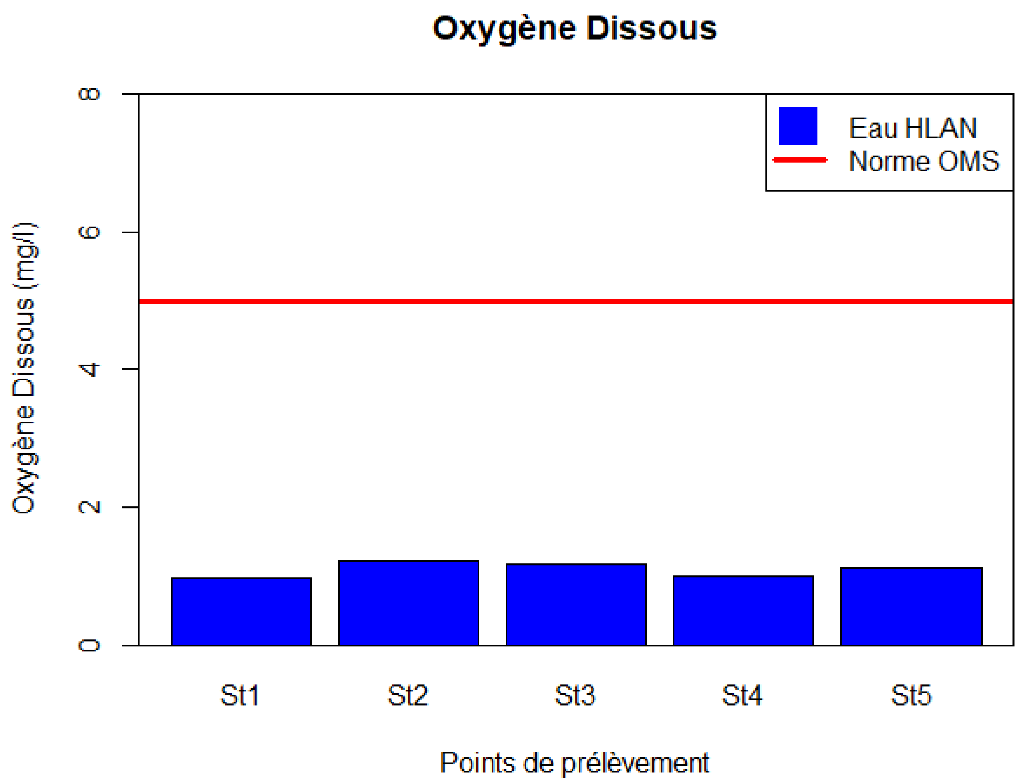

Figure 9 : Variation in dissolved oxygen at the different stations targeted on the lake

3-2-7- Ammonium

The values obtained for ammonium at the different stations are between 0.275 mg/L and 0.391 mg/L with an average of 0.344 mg/L. The lowest value is obtained at station no. 4 and the highest value at station no. 3. We note that all these values found are within the range accepted for surface water by the NQE, i.e. [0.1; 0.5] mg/L. The graph in Figure 10 shows the variation of ammonium at the different targeted stations.

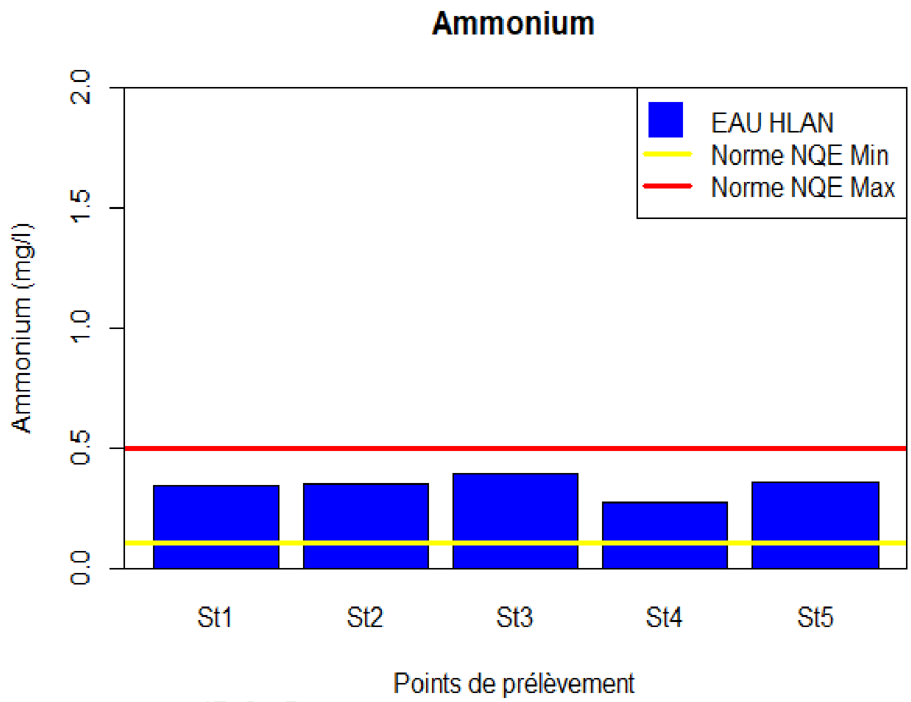

Figure1: Variation of ammonium at the different targeted stations on Lake Hlan.

The values are lower than the results (0.59-1.91mg/L) of Metinhoue (2019) on Lake Toho in Kpinnou in the commune of Athiémé, this superiority is explained by the higher dilution observed in the long rainy season in July and also by the very high market gardening and rice cultivation with the use of chemical fertilizers in the area, these values are extremely lower than the values found by Dovonou et al (2011) in June on Lake Nokoué where all the values are higher than 8, this is explained by the very high anthropogenic pressure on the lake with the excessive use of chemical fertilizers, and the discharge of wastewater into the lake, Lake Nokoué would be more exposed to anthropogenic pressure than Lake Hlan.

3-2-8- Nitrite

Nitrites are produced by the transformation or oxidation of nitrate under the action of microorganisms. The nitrite concentrations obtained at the different stations vary slightly from 0.121 to 0.172 mg/L with an average of 0.146 mg/L. The lowest value is obtained at station No. 4 and the highest value at station No.

5.We note that these values are below the maximum permitted value which is 3mg/L (Lisec, 2004). The graph in Figure 11 shows the variation of thenitrite concentration at the different stations.

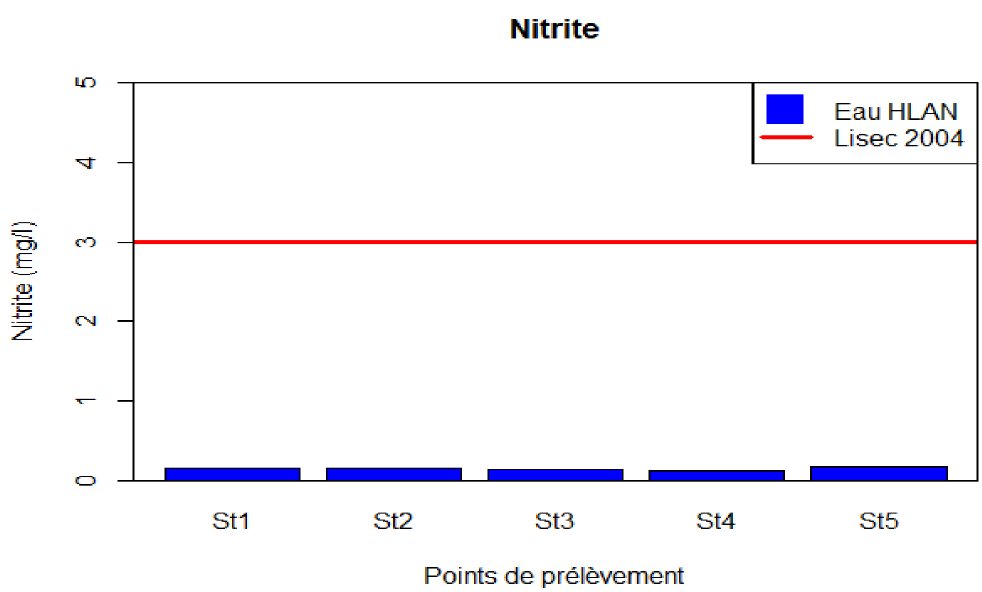

Figure 11 : Variation of nitrites at the different targeted stations on Lake Hlan.

These values are not without danger for fish because water containing nitrites can be considered suspect or even toxic, for fish even at low doses according to Vissin et al, these values are explained by a high activity of microorganisms, and are higher than the results of S. Buhungu et al (2018) in the Kinyankonge River, a tributary of Lake Tanganyika in the city of Bujumbura in Burundi where all the values are below 0.1 which is explained by the existence of treatment plants which make the different waters less loaded before discharging them. These values are slightly lower than the results of Dovonou et al (June, 2011) on Lake Nokoué, which would be linked to a dilution in the middle of the rainy season on Lake Hlan while Lake Nokoué was studied at the beginning of the rainy seasons, the same causes explain the inferiority of these values to most of the values (0-3 mg/L) of Dimon et al (July, 2014) on Lake Ahémé.

3-2-9- Nitrates

The nitrate concentration measured at the sampling stations varies between 0 and 0.73 mg/L. The lowest values (0 mg/L) are obtained at stations 1, 2 and 5. The highest values are obtained at stations 3 (0.065 mg/L) and 4 (0.731 mg/L). The highest value obtained at station 4 is explained by the presence of oil palms and the practices of human activities including the cultivation of corn, cassava and the various discharges of pollutants caused by those who frequent the pier for their various activities. The average concentration is 0.159 mg/L. We note that these values are below the maximum permitted value which is 3 mg/L (Lisec, 2004). The graph in Figure 12 shows the variation in nitrate concentration at the level of the various targeted stations.

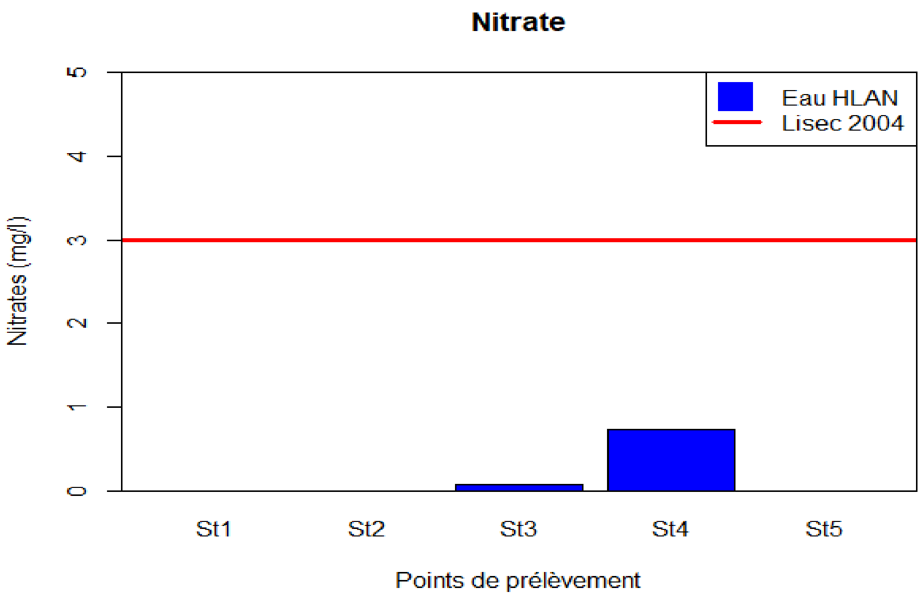

Figure 12 : Variation of nitrites at the different targeted stations on Lake Hlan.

The presence of nitrates in watercourses is due either to the leaching of agricultural soils or to the oxidative reactions of ammoniacal nitrogen and nitrites (Khalaf et al., 2007). The nitrate concentrations obtained at the different stations vary from 0 to 0.731 mg/L with an average of 0.159 mg/L. These nitrate values are significantly below the value accepted by Lisec (2004). This could be explained by the period of sampling. In fact, the water was collected during the short rainy season. Therefore, not all of the water has yet flowed into the watershed. In addition, we have an absence of the nitrification phenomenon. Nitrification consists of the transformation of ammonium ($NH4+$) into nitrites ($NO2-$).

3-2.10- Ortho-phosphate

The values obtained after dosing ortho-phosphate vary from 0.098 to 0.213 mg/L with an average of 0.146 mg/L.Stations No. 1 and No. 3 gave the same values, which is 0.213 mg/L, while station No. 4 gave the lowest value, which is 0.098 mg/L. All these values are within the range allowed for surface water by the

NQE, i.e. [0.2; 0.5] except for the value of station No. 4 which is below the range. The graph in Figure 13 shows the variation in the amount of ortho-phosphorus in the lake at the different targeted stations.

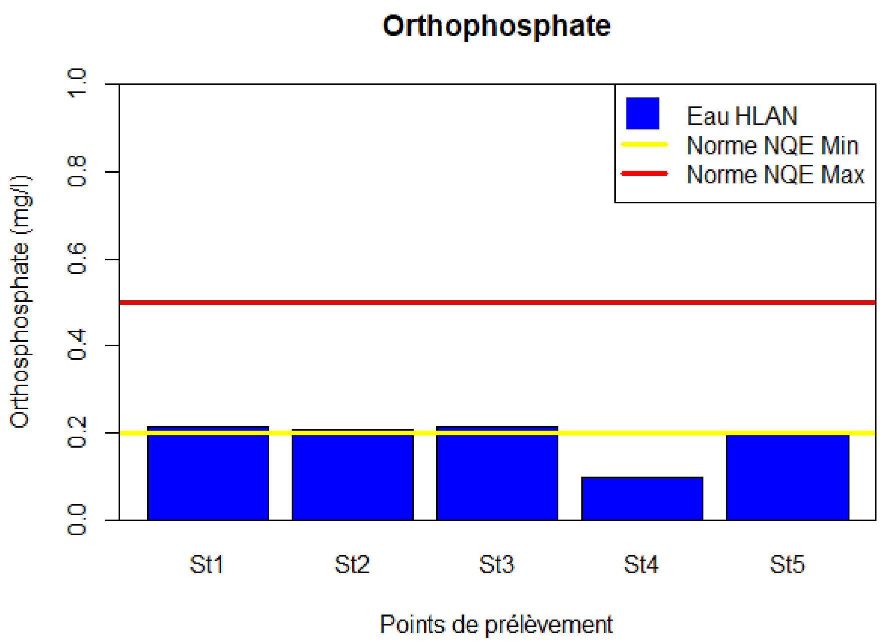

Figure 13 : Variation of orthophosphate at the different stations targeted on the lake

3.2.11- Total phosphorus

It is an indicator of the phosphorus content in the aqueous medium. The different values obtained vary between 0.032 and 0.069 mg/L with an average of 0.061 mg/L.Stations No. 1 and No. 3 gaves the same values which is 0.069 mg/L while station No. 4 gives the lowest value which is 0.032 mg/L.All these values are lower than the maximum value permitted by the Beninese standard (waste water), i.e. 2 mg/L.The various values are below the limit, so the water is not polluted by phosphorus. These low concentrations observed despite the domestic uses observed on the lake are linked to the rainy season. In fact, we have a dilution of phosphorus by rainwater.

Figure 14 shows the evolution of the phosphorus content of the environment at each station.

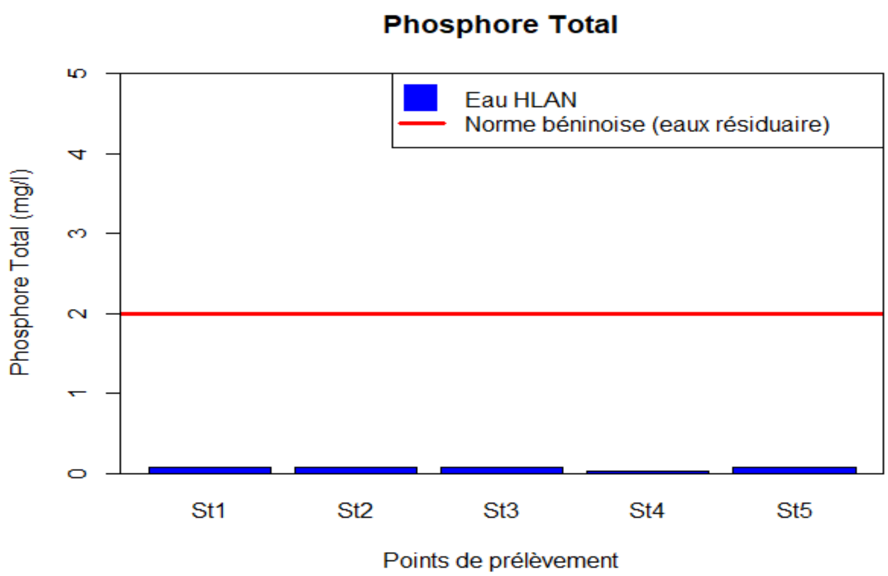

Figure2: Variation of total phosphorus at the different stations targeted on the lake

Total phosphorus is an important parameter in the fertilization of water bodies. It plays a major role in planktonic growth (Mama et al, 2011). This nutrient is a relevant indicator for assessing the trophic level of waters (Dimon et al, 2014). Phosphates could have a natural (calcium phosphate) and/or anthropogenic (fertilizers, detergents) origin, the values obtained in the present study are below the recommended limit, this parameter correlates with ortho-phosphate for which we recorded values also below the limit, therefore it is concluded that the lake water is not polluted by phosphorus, this confirms the absence of development of aquatic plants at the lake level in the area considered. Total phosphorus and ortho-phosphorus evolve in the same direction, the same observation was made by S. Buhungu et al (2018) in the Kinyankonge River, a tributary of Lake Tanganyika in the city of Bujumbura in Burundi, the values obtained for total phosphorus are extremely lower than the results (3.06-8.91 mg/L) of Dimon et al (July, 2014) on Lake Ahémé, this inferiority would be due to the high anthropogenic pressures at the time when the work is carried out in the same periods. The values of ortho-phosphate being lower than the standards are compatible with the work of Chouti et al in 2011 (0-0.08 mg/L) on the Porto-Novo lagoon. Note that the different values are lower than the results of Dovonou et al (June, 2011) where all the values are above 0.5, this difference can be explained by the fact that the work is carried out at the beginning of the rainy seasons on Lake Nokoué while ours is in the middle of the rainy season, there is therefore an advanced dilution effect on Lake Hlan which is not the case on Lake Nokoué.

3-3- Heavy metals measured in sediments

To assess the quality of sediments and their impact on the life of aquatic species in Lake Hlan, we used trace elements such as lead and cadmium. The results of the measurement of these trace elements are shown in Table II.

Sites	Measures	
	Lead (Pb in mg/kg)	Cadmium (Cd in mg/kg)
St1	33,0429	3,0033
St2	22,7243	2,7357
St3	22,5372	2,4202
St4	39,6073	2,9543
St5	21,7686	1,7692

Two heavy metals were measured in the sediments: lead and cadmium. Analyses of trace metal elements showed that these are present at all sites in quantities exceeding the required standards and therefore represent a danger to aquatic species and also to humans. In this study, the high values of ETM are due to the use of fertilizers and pesticides due to the fact that the lake is located in a rural area dominated by agricultural activities.

3-3.1- Lead

Lead values ranged from 21.77 to 39.61 mg/kg with an average of 27.94 mg/kg. The highest value was obtained at station 4 while the lowest value was found at station 5. Lead levels are significantly higher than the Contamination Prevention Criteria for Aquatic Organisms (CPC_O), which is 0.19, the standard set. Lead concentrations therefore pose a risk to humans and organisms in the Lake. The graph in Figure 15 shows the different variations in lead concentration in Lake Hlan at the different targeted stations.

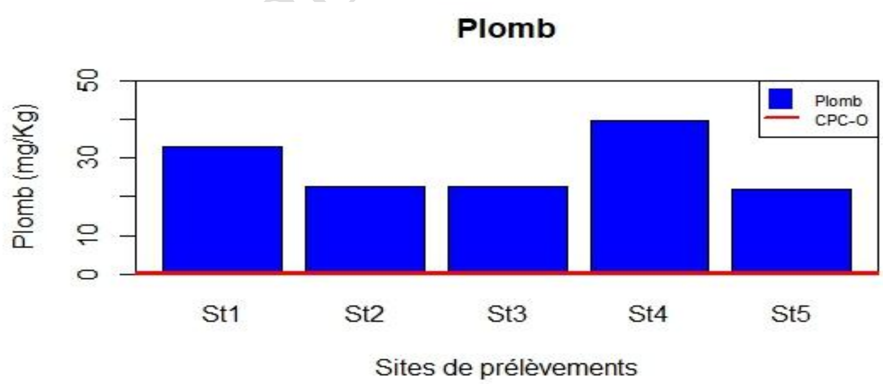

Figure 15 : Variations in lead concentration in Lake Hlan at the different targeted stations.

These levels of lead are all higher than the threshold recommended by the WHO (0.01 mg/L) and all of this constitutes a risk for humans and organisms present in the lake. These levels could be due to vehicle exhaust fumes (Abdallaoui, 1990). The highest value (39.607 mg/kg) obtained at station No. 4 is explained by household solid waste, pollutants resulting from the various activities carried out at the pier. The contamination of the system studied by lead seems to come from the lead used in fishermen's nets (Matias Miguel Salvarredy Aranguren, 2008), without neglecting the contribution of wastewater discharge and solid waste, agricultural activities. The values obtained for the concentration of lead at the different stations are higher than the results of Dimon et al on Lake Ahémé in July 2012 where the highest value is 26.25 mg/kg. They are also higher than the results of Chouti et al (2010) on the Porto-Novo lagoon during the four seasons of the year where all the values are less than or equal to 7 mg/kg. They are extremely higher than the results found by Agonkpahou E (Pb : 0.043 mg/Kg and 0.040 respectively in the Okpara River in Northern Benin and in Lake Nokoué in Southern Benin). The values obtained are lower than the results (4µg/g–337) by Halima Ben Bouih et al (2005) on Lake Fouarat (Morocco), which is explained by the lake's high exposure to industrial effects and exhaust gases due to its geographical location.

3-3.2- Cadmium

Cadmium values ranged from 1.77 to 3.00 mg/kg with an average of 2.58 mg/kg. The highest value was obtained at station 1 while the lowest value was found at station 5. Cadmium levels are significantly higher than the Contamination Prevention Criteria for Aquatic Organisms (CPC_O), which is 0.13, the set standard. Cadmium concentrations therefore pose a very high risk to humans and to the organisms present in the lake.The graph in Figure 16 shows the different variations in cadmium concentration in Lake Hlan at the different targeted stations.

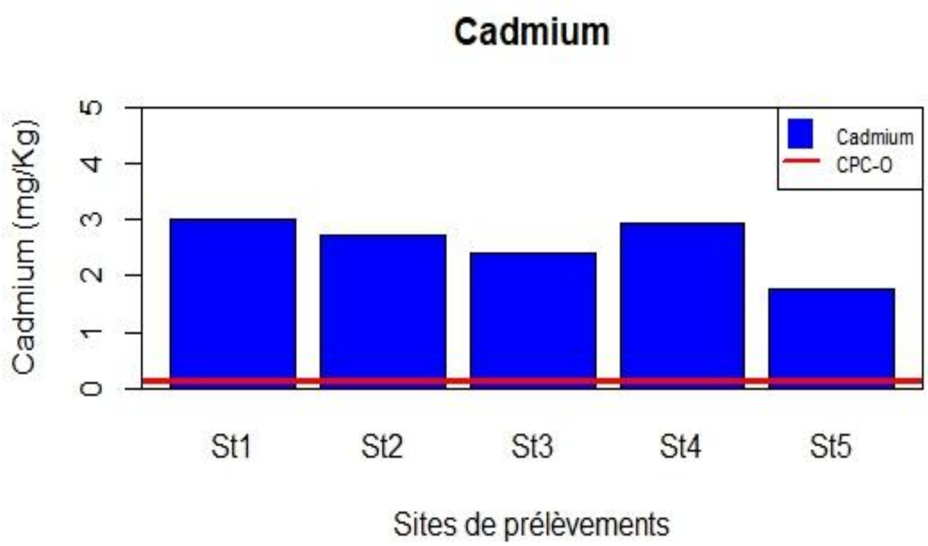

Figure 16 : Variations in cadmium concentration in Lake Hlan at the different targeted stations.

All the values obtained are greater than the limit value because all these values are above the CPC_O.The highest value (3.003 mg/kg) obtained at station No. 1 is explained by the contribution of the discharge of wastewater and runoff water, pollutants generated by the various activities, including fishing, processing and agriculture carried out at the pier. Cadmium is a trace element that is very toxic by cumulative effect; it acts even at low concentrations.Cadmium concentrations therefore pose a very high risk to humans and also to the organisms present in the lake.The values obtained for the concentration of cadmium at the different stations are all higher than the results of D. Saint Laurent et al (2010) on the southern portion of Lake Saint-Pierre (Quebec, Canada) where the average content is 0.38 mg/kg.

Conclusions:

The quality of surface water depends on the nature of the lithosphere crossed and the different activities that are practiced near these waters. At the end of this present study aimed at evaluating the consequences of the different uses of the water of Lake Hlan, we led us to inventory the different activities that take place near the lake, evaluate certain physicochemical parameters of the water and measure the trace elements in the sediments. It appears that fishing constitutes the direct use of the lake; processing, livestock, agriculture and market gardening are activities practiced near the lake. The various analyses show that the water is moderately loaded and polluted by ortho phosphates and ammonium, which is justified by the activities carried out around the lake and the input of waste by runoff. The measurement of trace metal elements in the sediments showed a high amount of lead and cadmium, which leads to the assertion that the lake is polluted by trace metal elements and all this constitutes a threat to aquatic species and to humans.

II. -

Conflict of interest

The authors declare that they have no conflict of interest in the publication of this article.

Data availability statement

Data cannot be made publicly available; readers should contact the corresponding author for details.

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Comment [H4]: