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Physicochemical Qualities of the Waters of Lake Toho in the Department of Mono, South-west of Benin

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Abstract: In order to assess the pollution status of the waters of Lake Toho, a study was carried out by collecting and analyzing water samples using a spectrophotometer. The results revealed that, on the physicochemical level, the waters of the lake are weakly mineralized and the salinity is almost zero during the sampling period. The measured values for parameters such as temperature, pH, TDS, conductivity, and turbidity comply with the standard. Nitrites, nitrates, phosphate and ammonium are in high concentration and above the standard for surface waters. These levels constitute a high risk for the aquatic organisms present in the lake. There is also a high organic matter load accompanied by high levels of total phosphorus and total nitrogen. Lake Toho is also threatened by faecal contamination revealed by indicators such as E. coli, thermotolerant coliforms, faecal enterococci. In short, Lake Toho is subject to physicochemical and bacteriological pollution linked to a strong increase in anthropogenic activities. It is urgent to set up a management and control system for actions around the lake.

Keywords: Pollution, organic matter, physicochemical parameters, Lake Toho

1. Introduction

Water is a crucial resource necessary to all living beings but rare in terms of quality. This resource is unevenly distributed throughout the world. It is necessary for health and of great importance for domestic, agricultural and industrial activities. The wetlands in Benin, ecosystems with important resources, are concentrated in the South. According to [1], the South of Benin is home to more than 50% of the Beninese population (with densities rarely less than 150 inhabitants per km²) on 10% of the national territory. This situation justifies that the surrounding ecosystems undergo an anthropic pressure that does not guarantee the sustainability of resources composing them. In some ecosystems, chemicals can be the cause of certain animal and/or plant species disappearance and, consequently, lead to the trophic chain (low biodiversity...) dysfunction [2]. Among these chemical pollutants, phosphorus and nitrogen, nutritive elements, are responsible of the eutrophic phenomenon. The resulting algal growth depletes the water of oxygen and leads to fish and other aquatic life the death [3].

In lakes, massive nutrient inputs from multiple anthropogenic activities very often cause eutrophication, characterized by the proliferation of water hyacinth [4-5].

A lake is a body of water surrounded by land, usually freshwater: it is a standing body of water and does not drain into a river. Lake Toho, the object of our study, is an environment of biological productivity and possibilities for fisheries production.

In Benin, Lake Toho is one of the most productive water bodies where annual fish catches reached 603.60 metric tons [6-7]. Tossavi reported about 20 species there [8]. It is worth noticing that artisanal fishing and fish farming in pens or ponds, pig farming, aulacodiculture, trade, crops (sometimes using fertilizers) and handicrafts are activities carried out by the inhabitants on this lake.

With an area of 9.6 km^2 at low water and 15 km^2 at rising water, Lake Toho is located in southwestern Benin and is on average 7 km long, 2.5 km wide in the south and about 500 m wide in the north [9]. Lake Toho is subject to hydrological dynamics characterized by freshwater inflows from the Mono River (also from the Diko and Akpatohoun creeks) and the Sazoe River during the high water season [10]. The Kpakohadji channel acts as an outlet and tributary.

Indeed, Lake Toho is impacted by anthropogenic activities and improper waste management. The survey conducted by [11] shows that the natural pastures of hippos, i.e., the vegetation located in the immediate vicinity of their habitat in the wetlands of Mono and Couffo, have been considerably reduced in favor of farmlands, plantations and market gardening activities. These activities are of significant economic interest and are expanding with population growth. The decline in fishery resources was perceived by 91.47% of the surveys against 6.20% and 2.33% of the surveys that perceived its increase or stability respectively [12]. The indicators through which fishermen perceive this decline in fishery resources are: the disappearance of some fish species, the decrease of the taken fish size [12].

2. Materials and Methods

2.1. Study area

The study was conducted in the communes of Athiémé, Lokossa and Houéyogbé which are communes surrounding Lake Toho. Located between the Agamè plateau and the northwestern part of the Bopa plateau, Lake Toho extends on average during low water from 6°35' to 6°40' north latitude and from 1°45' to 1°50' east longitude. It is part of the Mono basin [9]. The latter covers an area of 374 km² and is located in the Western complex of wetlands in southern Benin (Ramsar Site 1017).

2.2. Climatic characteristics

Lake Toho has a sub-equatorial climate characterized by two rainy seasons and two dry seasons alternating as follows [13]: a large rainy season from mid-March to mid-July, a small dry season from mid-July to mid-August, a small rainy season from mid-August to mid-November and a large dry season from mid-November to mid-March.

2.3. Collection of water samples

The choice of the sampling points was made in order to get precise information on the global factors of the pollution of the lake, and according to the zones of domestic discharges, runoff and other contributions. Thus nine sampling points were defined. The sampling campaigns took place according to the four seasons of the year.

Plastic bottles of 1.5 L were used for water sampling, they were washed beforehand, then rinsed thrice with simple water and distilled water. While sampling, the bottle is carefully rinsed with the water to be sampled at each site. Water sampling is done at each site at about 5 cm from the surface of the lake and the water samples were transported to the laboratory at 4°C in a cooler and kept in a refrigerator under the same temperature.

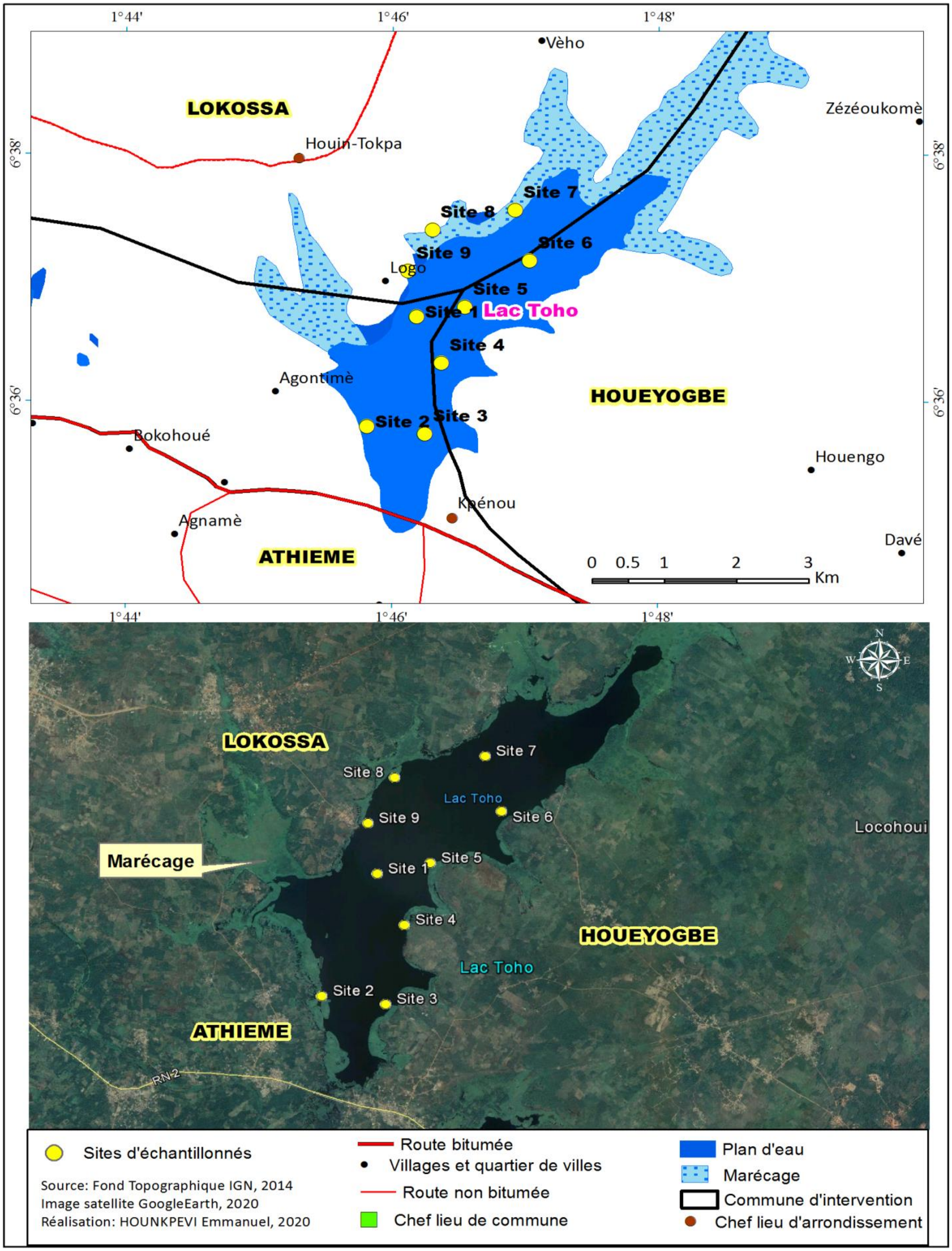

Figure 1: Spatial distribution of the different sampling sites

2.4. Physico-chemical analyses

Parameters such as temperature, turbidity, pH, conductivity, salinity, dissolved oxygen, TDS were measured *in-situ* with a VWR CO310 conductivity meter and a VWR DO210 oximeter. The chemical oxygen demand (COD) was quantitatively measured by the hot oxidation method using potassium dichromate following the standard. Biological oxygen demand (BOD5) was evaluated by incubating lake water samples at 20°C for a period of five days. The different contents of nitrite, nitrate, orthophosphate, total nitrogen, and total phosphorus and ammonium ions were determined by the VWR 1600 PC UV/Visible spectrophotometer method.

3. Results

- **Temperature and hydrogen potential (pH)**

Table 1: Spatial and temporal variation of pH and water temperature of Lake Toho

Sites	Temperature				pH			
	GSS	**FGSP**	**PSS**	**PSP**	**GSS**	**FGSP**	**PSS**	**PSP**
S1	32.8	27	26.9	27.8	9.0	7.2	7.7	6.4
S2	32.7	27	27.2	27.9	9.1	7.2	7.8	6.6
S3	32	27.6	27.6	28.2	8.9	7.2	8.51	6.8
S4	33.36	27.3	27.6	28.1	8.9	7.3	8.03	6.6
S5	32.32	27.2	27.1	28.3	8.1	7.4	7.82	6.4
S6	32.6	27.1	26.8	27.6	8.3	7.2	8.17	6.6
S7	32.9	27.1	26.9	27.7	8.8	7.6	8.3	6.6
S8	33.1	27.4	26.6	27.4	8.7	7.4	8.23	6.6
S9	32.6	27.1	26.6	27.4	8.8	7.2	8.09	6.6
Average	32.71	27.2	27.03	27.82	8.7	7.3	8.07	6.58

PSP = short rainy season **PSS** = short dry season

GSS = long dry season **FGSP** = the end of the long rainy season

The water temperature of Lake Toho (Table 1) varies from 27°C to 28.3°C during the rainy season and from 26.6°C to 33.36°C during the dry season. The highest values are observed during the dry season. Moreover, there is little variation in temperature during the same season along the lake.

Spatial and temporal variation in the pH of the lake water (Table 1) reveals values ranging from 6.4 to 7.6 during the rainy season and from 7.7 to 9.1 during the dry season. The highest value is observed at sites 2 (Kponou) and 3 (Kpinnou) in the dry season and at sites 3 and 7 in the rainy season. The averages obtained during the seasons are respectively 8.39 in the dry season and 6.94 in the rainy season. The average obtained in the dry season is in agreement with that obtained by [13] on the same lake. It shows that the lake waters are basic during the dry season. [14] obtains an average (7.94) higher than that obtained during the short rainy season.

- **Dissolved Oxygen (O_2)**

Dissolved oxygen levels recorded ranged from 0.67 to 3.2 mg/L in dry seasons and from 3.5 to 8.63 mg/L in rainy seasons. The average level obtained in dry seasons (2.39 mg/L for the long dry season and 2.27 mg/L for the short dry season) is lower than the one obtained in rainy seasons (4.98 mg/L for the end of the long rainy season and 7.04 mg/L for the short rainy season). The highest value of dissolved oxygen is obtained during the short rainy season at site 2 (8.63 mg/L) while the lowest value is observed during the short dry season at site 3 (Kpinnou).

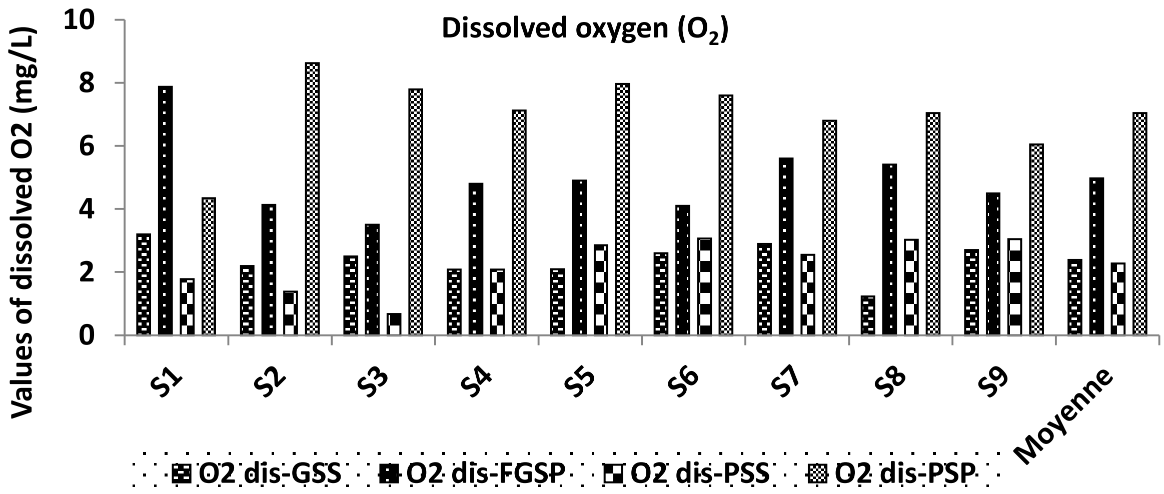

Figure 2: Spatial and temporal variation of the quantity of dissolved oxygen in the waters of Lake Toho

Suspended particles

- **TDS, Electrical Conductivity (EC) and Turbidity**

Table 2: Spatial and temporal variation of TDS, electrical conductivity and turbidity of the lake Toho

	TDS (mg/L)				EC (µS/Cm)				Turbidité (NTU)			
Sites	**GSS**	**FGSP**	**PSS**	**PSP**	**GSS**	**FGSP**	**PSS**	**PSP**	**GSS**	**FGSP**	**PSS**	**PSP**
S1	219.5	147.5	140	190.6	391.8	235.5	220	293.2	30.6	9.47	51.8	9.85
S2	216.2	174	144	185.7	332.7	264.9	214	285.5	32.9	7.72	49.9	9.66
S3	218.2	179.5	142	183.5	380	276.4	211	282.2	29.3	7.09	42.4	9.01
S4	216.7	178.5	143	184.9	385	260.7	212	284.3	36.8	6.53	49.2	9.94
S5	219.8	219.9	146	187.8	388.2	272.3	215	288.9	24.5	7.27	26.2	8.38
S6	219.9	219.8	144	186	388	216.2	215	286.1	29.4	7.26	39.4	8.48
S7	216.7	216.7	144	187	383.6	213.6	212	288.2	26.9	6.8	40.5	9.32
S8	218.8	218.8	144	185.4	388.8	236.4	215	285.4	25.0	6.62	29.9	9.48
S9	217.09	217	145	183.1	382.6	233.7	215	281.4	30.5	6.29	33.8	9.39
Moyenne	218.10	196.86	143.56	186	380.08	245.52	214.33	286.13	29.5	7.23	40.34	9.28

The analysis in Table 2 reveals that the TDS values obtained during the long dry season are high compared to those obtained during the rainy season. But during the rainy season, the averages obtained are higher than those obtained during the short dry season. This suggests that inorganic salts and organic matter inputs are coming from human activities around the lake through runoff. Sites 5 (Goudôhoué) and 6 (Hogbonou), 7 (Aïdjèdo), 8 (Sangannou) and 9 (Logbo) have the highest concentrations and remain almost constant between the long dry season and the long rainy season. There is also little variation in TDS content during the same period besides the main rainy season.

Analysis of Table 2 shows that water conductivity is higher in the long dry season than in the rainy season. Like the TDS contents, the conductivity values obtained during the rainy season including the averages are higher than those of the short dry season.

Turbidity is the more or less cloudy appearance of water. The study conducted at these different sites shows from Table 2 that the turbidity of the water varies from 6.29 to 9.94 NTU during the rainy season and from 24.5 to 51.8 during the dry season. The highest values were observed during the dry season, particularly at Kponou.

- **Suspended solids (MES)**

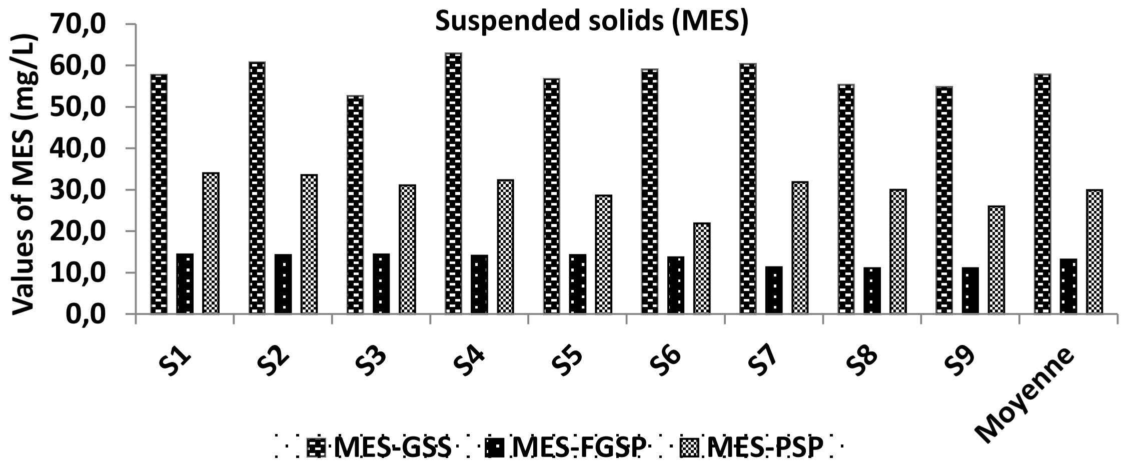

Figure 3: Spatial and temporal variation of TSS values in Lake Toho waters

The MES content recorded (Figure 3) in the waters of the lake is higher in the dry season than in the rainy season. It varies from 52.6 to 62.9 mg/L. Let's note that outside the rainy season, all the MES contents obtained are above 25 mg/L during the dry season.

The highest values of turbidity and MES are observed at the same site: Hounkpotannou.

- **Salinity**

The salinity of the water is almost zero at all points of the lake. It is constantly 0.2% during the dry season and 0.1% during the rainy season. The average obtained is lower than that found by [13] in the waters of the said lake.

Oxidizable organic matter

- **Chemical oxygen demand (COD) and biological oxygen demand (BOD_5)**

COD values vary from 64.75 mg/L O_2 to 146.91 mg/L O_2 during the rainy season and then from 107.12 to 193.6 mg/L O_2 during the dry season with an average of 104.86 mg/L O_2 and 142.99 mg/L O_2 respectively above 20 mg/L O_2.

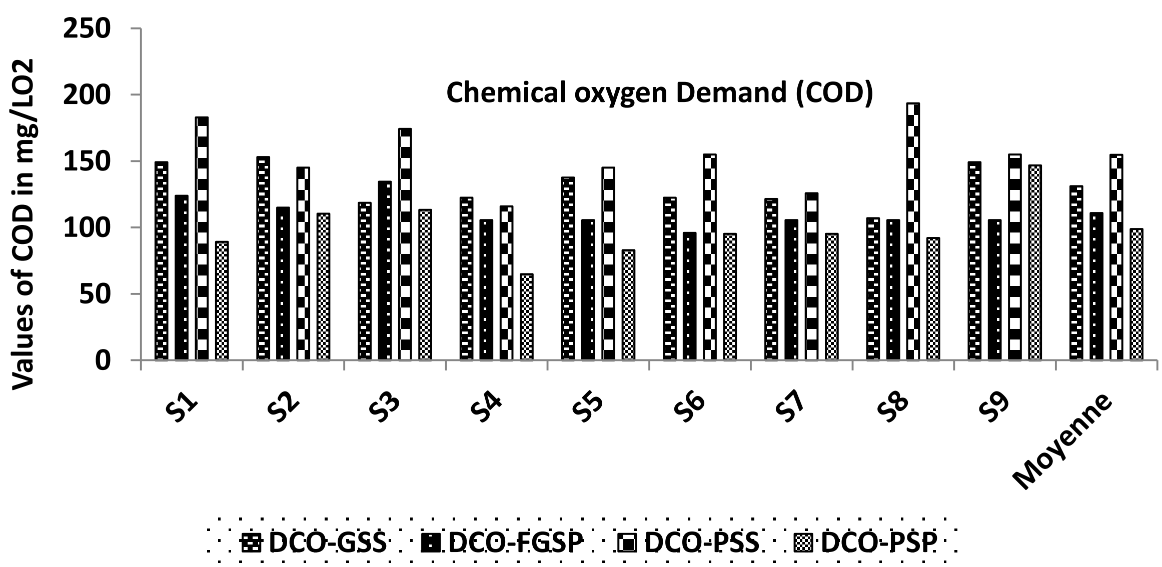

Figure 4: Spatial and temporal variation of COD values of Lake Toho waters

BOD values vary from 1 to 27 mg/L O_2 during the rainy season and then from 37 to 80 27 mg/L O_2 during the dry season. Spatial variation in BOD values reveals that the levels recorded during the dry season are higher than those during the rainy season. The highest value is observed at site 2 during the long dry season and the lowest value is observed at sites 4 and 5 at the end of the long rainy season.

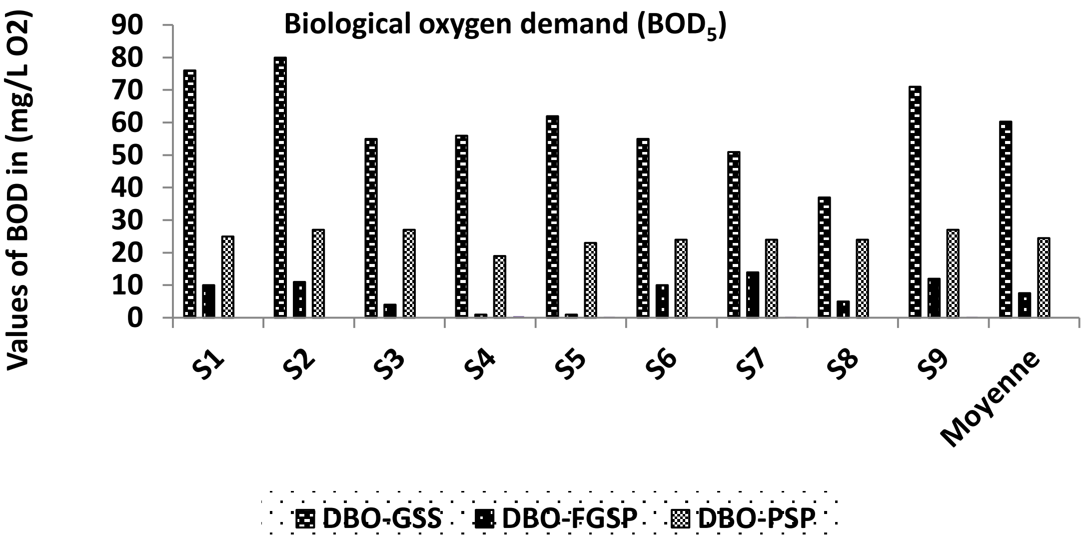

Figure 5: Spatial and temporal variation of BOD values in Lake Toho waters

Organic and nutrient loads

- **Phosphate ions**

Phosphate ion levels vary from 0.08 to 0.43 mg/L during the dry season then from 0.06 to 2.48 mg/L. The highest values and the highest average (2.05 mg/L) are obtained during the short rainy season. The lowest values are obtained at the end of the long rainy season with an average of 0.18 mg/L. The dilution effect would influence the values obtained at the end of the long rainy season.

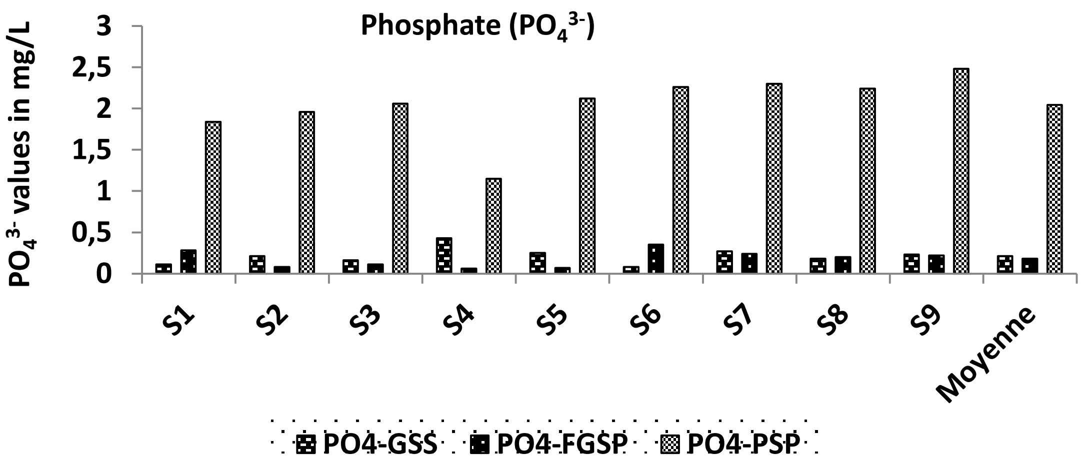

Figure 6: Spatial and temporal variation in phosphate ion levels in Lake Toho

- **Total phosphorus**

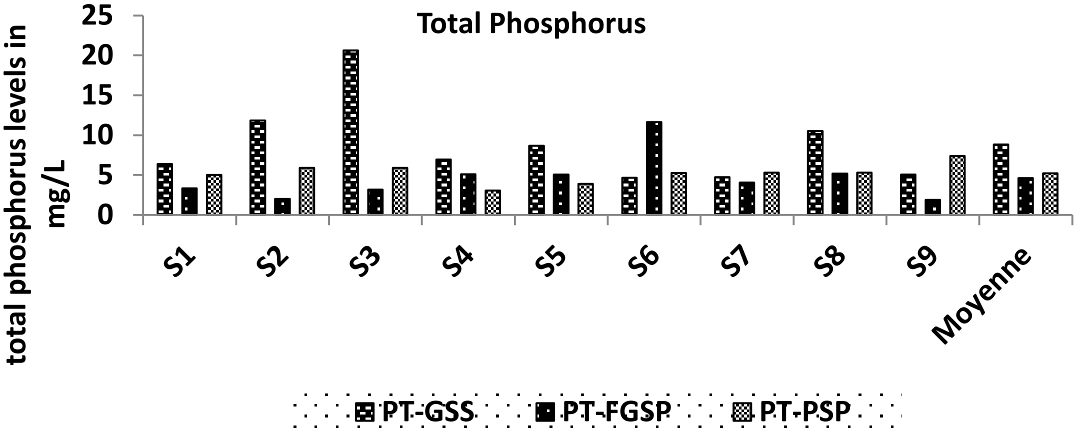

Figure 7: Spatial and temporal variation of total phosphorus contents in Lake Toho waters

The spatio-temporal variation of total phosphorus levels (Figure 7) reveals values ranging from 4.65 to 20.6 mg/L during the dry season and then from 1.9 to 11.63 mg/L. The average obtained in the dry season (8.82 mg/L) exceeds those obtained during the long and short rainy seasons.

- **Total nitrogen NTK**

The analysis of Figure 8 shows that NTK is more concentrated in the water in the dry season than in the rainy season. The levels obtained vary from 1.2 to 7.2 mg/L in the rainy season and from 3.15 to 22.54 mg/L in the dry season. The highest value (22.54 mg/L) is observed at Kpinnou (site 3) during the short dry season while the lowest value (1.2 mg/L) is at Hôgbonou (site 6) during the long rainy season.

Total nitrogen NTK and total phosphorus follow a very marked evolution during the long dry season, the long rainy season and the short rainy season with almost equal levels.

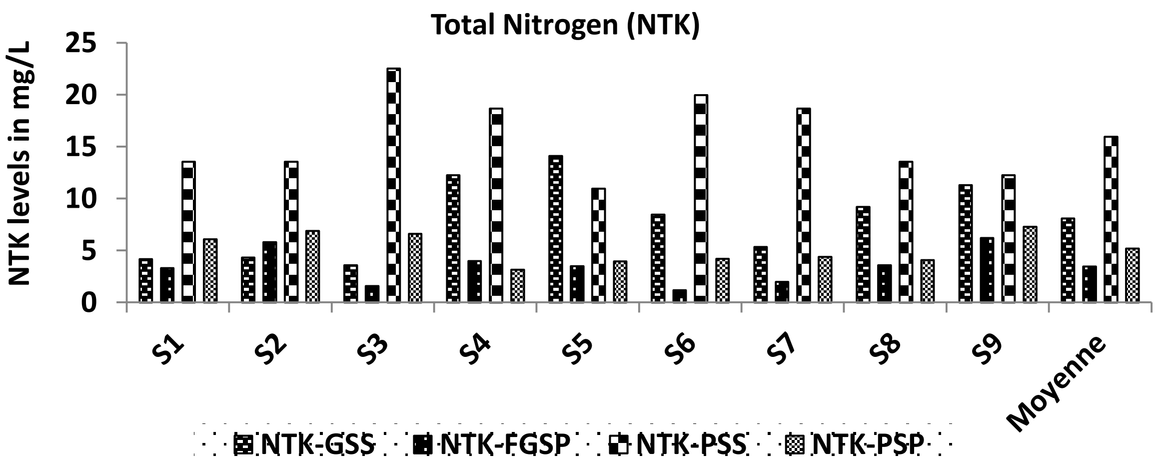

Figure 8: Spatial and temporal variation of total nitrogen levels in Lake Toho waters.

- **Nitrite ions**

Analysis of Figure 9 reveals that nitrite ion levels range from 0.103 to 0.136 mg/L during the dry season and from 0.001 to 0.086 mg/L during the rainy season. The highest values are obtained during the long dry season while the lowest values during the short rainy season.

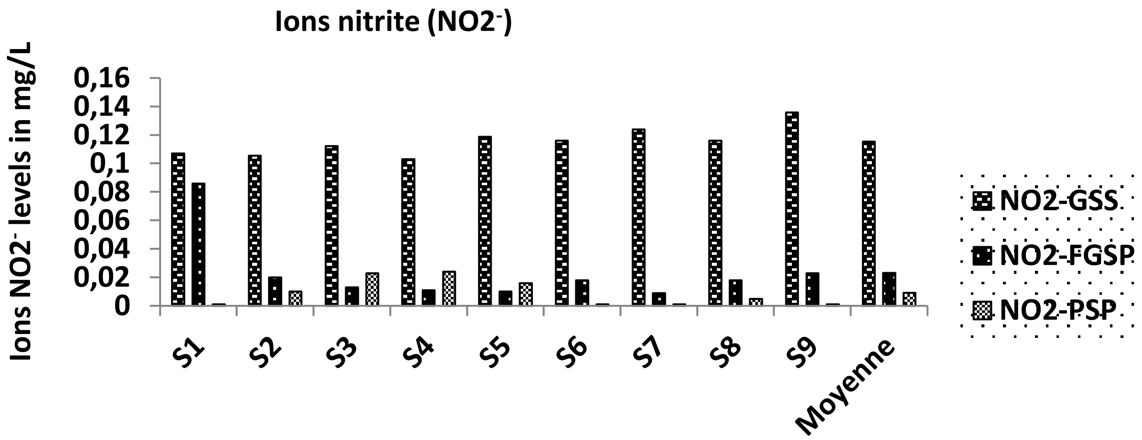

Figure 9: Spatial and temporal variation of nitrite ion levels in Lake Toho waters.

- **Nitrate ions (NO_3^-)**

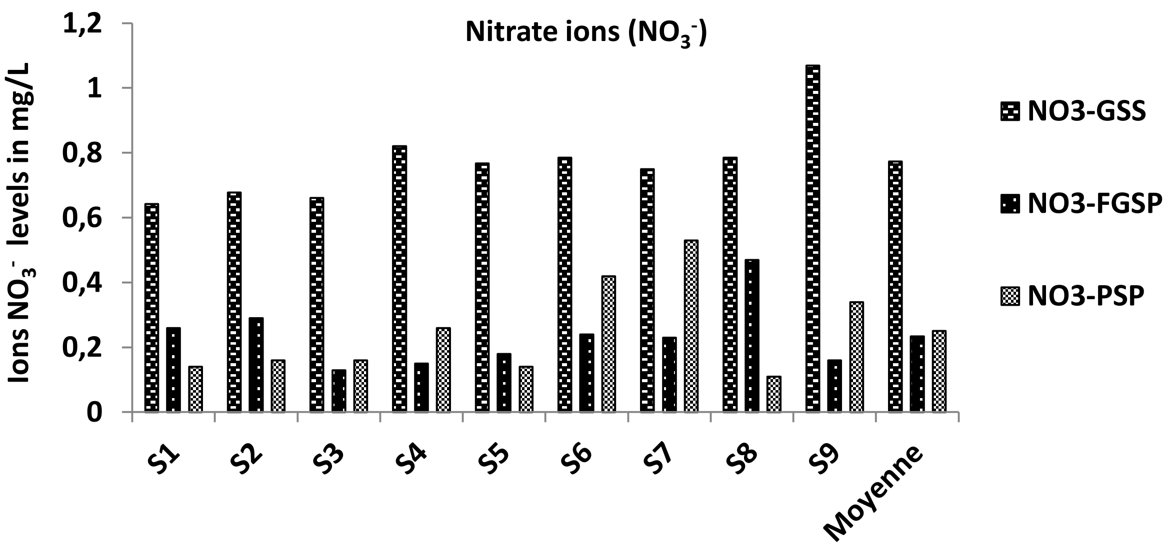

Figure 10: Spatial and temporal variation of nitrate ion levels in Lake Toho waters.

Figure 10 shows the seasonal variation of nitrate ion concentrations. The analysis shows that nitrate ions are more concentrated in the dry season than in the rainy season. Levels vary from 0.64 to 1.07 mg/L in the dry season and from 0.11 to 0.53 mg/L in the rainy season. The highest value is observed at Logbo during the long dry season and the lowest value at Sangannou during the short dry season.

- **Ammonium ions (NH_4^+)**

Analysis of Figure 11 indicates that ammonium ion levels are higher in the rainy season (end of the long rainy season and short rainy season) than in the dry season. The highest value is observed at site 4 during the long rainy season while the lowest value is observed at site 7 during the long dry season.

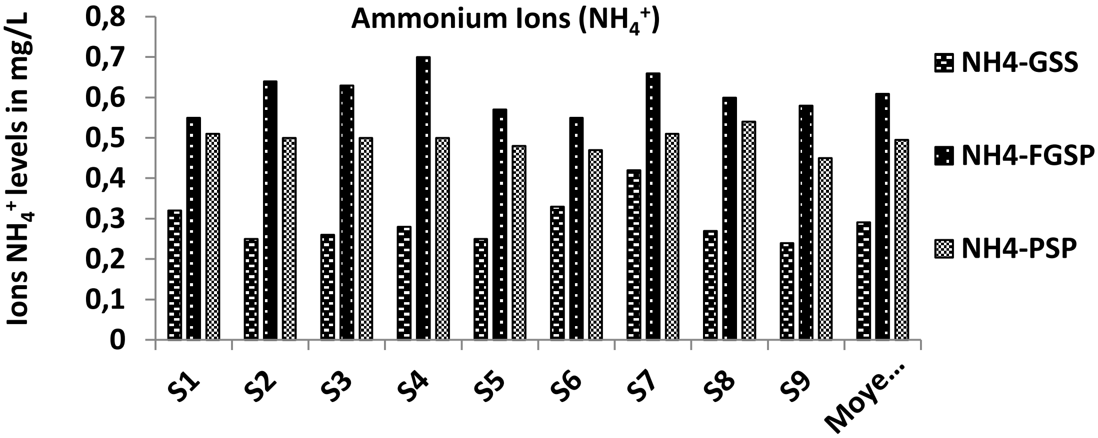

Figure 11: Spatial and temporal variation of ammonium ion levels in Lake Toho waters.

4. Discussions

The results of the physicochemical analyses of the water samples taken at the various selected stations of Lake Toho reveal that the highest average value of the temperature recorded on this water body is 32.7 °C during the long dry season. This temperature increase can be explained by the effect of global warming on Lake Toho since no warm residual water discharge source was recorded. According to [15] on the issue of climate change in Benin, the temperature rose by 0.9°C after 2010 in Benin. This recovered value is slightly higher than the one obtained (32.33°C) by [14] and in agreement with the one obtained by [13] (32.1±0.8°C) in this same water body. All temperature values recorded in dry and rainy seasons respect the tolerable limit by the French standard (6.5°C; 35°C) and do not disturb the growth of aquatic species. For good growth of aquatic species, a temperature margin of 24°C to 35°C is required [16].

The pH values measured on water samples in dry and rainy seasons indicate that the waters of Lake Toho are basic in dry seasons (short and long dry seasons) and neutral in rainy seasons. Most of the values obtained during the long dry season tend towards the maximum value allowed (pH=9) for surface waters where aquatic life can develop [13-17]. The averages obtained for all the sampling campaigns respect the Wold Health Organisation (WHO) recommendation (6; 9). They also respect the standards accepted by the Canadian Council of Ministers of the Environment Quality Guidelines [18] for surface water and aquatic life (6.5; 9.0).

For the mineralization of the lake water, the average values of parameters such as TDS (218.1 mg/L), salinity (0.2 ppt), conductivity (380.08 µS/cm) are below the limit set by French and WHO standards. The TDS gives information on the total salt content of the water. The results revealed that, from a physicochemical point of view, the waters of the lake are weakly mineralized and the salinity is almost null during the periods of sampling (0.2 mg/L in dry season and 0.1 mg/L in rainy season). The respective values of these different parameters related to the mineralization of Lake Toho water then fall from the main dry season to the main rainy season (0.1 ppt for salinity; 196.86 mg/L for TDS; 245.52 µS/cm for electrical conductivity). This fact can be explained by the massive input of fresh water caused by the rains. Other freshwater inflows can be recorded from the Diko, the Kpakohadji channel, which act as an outlet and tributary, and also freshwater inflows from the Akpatohoun and Sazoe rivers during the high water season [10]. For MES, the averages obtained during the short rainy season (29.91 mg/L) and the long dry season (57.8 mg/L) are much higher than those obtained by [13] in the waters of that lake. According to the latter in 2008, these localities are areas where anthropic activities are very intense, namely: fishing, agriculture, fish trade etc. The practice of these different activities generates other things like, solid particles of medium and coarse size that are discharged into the water body and contribute to its pollution. Comparing the results of the latter with those obtained during the present work, we deduce that the anthropic activities have increased enormously at all points of the lake.

Dissolved oxygen is the most fundamental parameter of water quality [19]. In addition to the level obtained at site 1 during the main rainy season (7.88 mg/L), all levels in that season and the main and short dry seasons are below the tolerable limit (6.5 mg/L) set by the Canadian Surface Water Quality Guidelines for the Protection of Aquatic Life [19-20-21-22]. These sites present risks for the life of aerobic aquatic beings because for average values of the oxygen rate lower than the admitted limit, the aerobic aquatic life becomes difficult. These low values indicate organic pollution in these localities [13]. The high anthropization and decomposition of aquatic plants would influence the dissolved oxygen values. However, the values obtained during the short rainy season and the average meet the Canadian standard cited. In March 2008, Kple obtained in the different stations of Lake Toho, an average of 6±3.5 mg/L of dissolved oxygen in stations such as Hogbonou (site 6), Douimè (8.6 mg/L), shoreline between Logbo (site 9) and Kpinnou (site 3) (9.2 mg/L) and shoreline between Hogbonou and Douimè (8.5 mg/L). We therefore deduce an increase in the level of organic pollution. For this work, the low dissolved oxygen levels obtained during the dry season are in agreement with those obtained by [23] in the waters of Lake Nokoué. These low values found in the months of February and August correspond to the decomposition period of macrophytes [23]. [3] found low dissolved oxygen values in the high water period followed by the rainy period in the lagoon of Porto-Novo. In the present work, dissolved oxygen is the first factor influencing aquatic organisms, especially fish living in Lake Toho and would intervene in the phenomenon of fish death especially at Kpinnou (site 3) in May 2018 and August 2021. According to the values obtained, Kpinnou represents a site at risk particularly for the rearing of fish during the long dry season, the long rainy season and the short dry season.

As indicated by dissolved oxygen, most of the BOD and COD values recorded during the dry seasons (long dry season for BOD and long dry season and short dry season for COD) are higher than those recorded during the rainy seasons. The different COD values obtained at all sites during all the sampling campaigns, largely superior to the limit allowed by the French standard (40 mg/L O2) show that Lake Toho is very rich in chemically oxidizable particles. It thus emerges the contribution of chemical particles (non-biodegradable organic matters) by runoff water, resulting from the use of herbicides, insecticides at the time of the treatment of the fields of cultures and the realization of the gardening in the immediate surroundings and on the catchment areas of the lake. For BOD, the high values observed in dry season are probably related to the decomposition of macrophytes in the lake. According to [14] (Lake Toho), and [23] (Lake Nokoué), the high BOD levels would be explained by the introduction followed by the decomposition of tree branches, acadjas used for fishing and water hyacinth (biodegradable organic matter). The introduction of these toxic particles participates in the neutralization of aquatic species in the lake. Based on the assessment grid of the [24], the waters of Lake Toho are of poor quality because the contents of BOD (77.78%) and COD obtained during all the campaigns are respectively higher than 10 mg/L O2 and 30 mg/L O2. This organic matter contamination is accompanied by a high nutrient content (total phosphorus; total nitrogen, orthophosphate, ammonium, nitrite and nitrate). The different levels recorded for total phosphorus, total nitrogen, nitrite and nitrate in dry seasons are higher than those in rainy seasons. We thus deduce that the evolution of these parameters follows in a very marked way, the concentration effect related to evapotranspiration (high concentration in dry season) and the dilution effect during high water [23]. This confirms the low values obtained in dissolved oxygen and a high chemical oxygen demand, especially during the dry seasons. The introduction of organic matter and nutrients would contribute to the depletion of the aquatic environment in terms of dissolved oxygen available for the life and activity of aquatic living beings. According to the Canadian Council of Ministers of the Environment [18], high concentrations of nutrients in surface waters can promote the growth of plants that are harmful to aquatic life. The Province of Manitoba recommends that nitrogen (organic and total inorganic) be limited to prevent undesirable growth of rooted, attached and floating aquatic plants, fungi, etc., which would render the water unfit for routine use. Nitrites are the first phase of the oxidation of ammonia in the absence of oxygen and are known to be acutely toxic even at low concentrations. Water containing nitrites can be considered as suspicious or even toxic for fish even at low doses according to [25]. In surface waters, the concentration of nitrite must be less than or equal to 0.006 mg/L according to the French standard. In this case, all average values obtained are above the French standard. According to the United States Environmental Protection Agency [26] and the Ministry of the Sustainable Development, the Environment, Faun and Parks [27], the limit levels of nitrite admitted for the protection of Aquatic

Life according to Chronic and Acute effects are respectively 0.02 mg/L and 0.06 mg/L. Most of the nitrite levels collected at all sites as well as the averages obtained for the three seasons (short rainy season, the end of the long rainy season and long dry season) largely exceed the French standard (0.006 mg/L). Besides, most of the nitrite levels collected at all sites and the averages obtained during the major dry and rainy seasons do not meet the criterion for the protection of Aquatic Life under chronic effects. All the levels recorded during the long dry season also do not meet the accepted standard for the protection of Aquatic Life under acute effects. This also confirms the non-availability of oxygen during these two seasons. Only the levels and average obtained during the short rainy season meet the standard set for the protection of Aquatic Life under chronic and acute effects. [28]concluded from their study that small fish (including larvae) are unlikely to be more sensitive to nitrite than large fish of the same species. For some species, there is even evidence that small fish are more tolerant than medium and large fish. The concentration at which no species dies in 10 days is 0.06 mg/L [29]. The average nitrite ion level measured in water samples (0.009 mg/L) during the short rainy season is lower than that found by [14] in Lake Toho (0.17 mg/L). In Lake Toho, nitrites are therefore another factor involved in the disruption of the aquatic ecosystem and would be involved in the massive death of fish in this lake, as constituting poisons even at low doses. The nitrate levels obtained are higher than those of nitrite. It thus appears in reality an availability of dissolved oxygen but which is from time to time used by the nitrites to be transformed into nitrate. The concentrations obtained during each season and at all sites are above the French standard (0.01 mg/L) for the eutrophication parameter. All nitrate concentrations obtained with their averages during the three seasons are under the allowed limit (3 mg/L) by the Canadian standard in its updated document entitled [30]. The different average ammonium ion concentrations obtained during the major dry season (0.29 mg/L), at the end of the major rainy season (0.61 mg/L), and during the minor rainy season (0.5 mg/L) are higher than that obtained [13] (0.09 mg/L) in the same lake and those obtained [31] in the Alibori River (0.044 mg/L in the dry season; 0.36 mg/L in the rainy season and 0.023 mg/L at the end of the rainy season). The values obtained are above the WHO standard (0.2 mg/L) for natural waters. Above this concentration, the water and aquatic organisms have reached a level of contamination [32]. These average values are also beyond the quality standards accepted for surface water (0.1 mg/L) according to Nisbet and Vernaux cited [33]. From these different analyses, it appears that ammonium ions pollute the lake Toho. Orthophosphate also allows us to assess the trophic level of the aquatic ecosystem because it is the form of phosphorus assimilated by plants. The high concentrations are obtained during the small rainy season, hence a contribution by the runoff water which constitutes thus a source of pollution of the lake. The average orthophosphate contents of the lake waters are higher than the 39 µg/L and 50 µg/L contents recorded respectively in Lake Geneva [34] and in Lake Ichkeul [35] in comparison with which [3] established a comparison with the orthophosphate contents obtained in the lagoon of Porto-Novo. Total phosphorus is an important parameter in the fertilization of water bodies, it plays a great role in planktonic growth. This nutrient is a relevant indicator for the evaluation of waters trophic level [36-23]. All levels obtained during the sampling campaigns are well above 100 µgP/L. The lake is then hypereutrophic according to the Organization for Economic Cooperation and Development [37]. According to the Canadian standard set by the Ministry of the Sustainable Development, the Environment, Faun and Parks [27], the total phosphorus content should not exceed 0.03 mgP/L in order to limit the excessive growth of algae and aquatic plants in surface waters. High levels are achieved in dry seasons. For total nitrogen, the average levels obtained greatly exceed the one obtained by [14] in the waters of the same lake (0.8 mg/L). Similarly, the average levels obtained in dry seasons exceed those obtained by [38] during the low water period. Both total nitrogen and phosphorus levels are high in dry seasons. Overall, water soluble nutrients are very sensitive to dilution effects due to freshwater inputs and prolonged evapotranspiration in the dry season. Some of the high values obtained in the rainy season show that runoff is a major endogenous source of nutrient input.

5. Conclusion

Lake Toho is an environment of high biological potential and growth of the aquatic ecosystem. From the analyses carried out on various seasons, it appears a strong nitrogen and phosphorus pollution due to the anthropic activities around the lake. It also appears that the phenomena of evapotranspiration and dilution influence the results because apart from phosphate and ammonium ions, the other chemical parameters measured have high levels in the dry season. This, in addition to the nutrients in the water column, contaminates the aquatic environment and depletes it of oxygen; this creates a difficulty of life, especially for fish, and leads to their massive deaths. It is worth noticing that Kpinnou constitutes a site at risk of fish farming because of its low oxygen content which would contribute to the massive death of fish in May 2018.

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