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RESEARCH ARTICLE

ORGANIC POLLUTION INDEX IN THE EVALUATION OF THE QUALITY OF LAKE DOHOU, A SOURCE OF DRINKING WATER SUPPLY IN THE CITY OF DUEKOUE (WEST CÔTE D'IVOIRE)

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Abstract

The abiotic typology of the different sampling stations based on physico-chemical parameters and the assessment of the nutrient load and the relative contributions of the different nutrient sources to this surface water were analysed. Five physical and chemical parameters (temperature, dissolved oxygen, transparency, pH and conductivity) were measured in situ at each sampling campaign in Lake Dohou over a period of one year, once a month at seven (7) selected stations. Water samples were taken for subsequent determination of dissolved solids, biological oxygen demand for 5 days and nutrient salts (nitrite, nitrate, phosphate, ammonium).Thephysico-chemical characterisation revealed weakly mineralised water with average conductivities varying from 12.38 ±16.33 µS.cm-1 to 39.63 ±45.28 µS.cm-1 with high temperatures in the dry season. A hierarchical ascending classification (HAC) was used to group the stations into 3 groups. Group I (stations 6), due to its exposure to domestic discharges and leaching from agricultural land, is heavily loaded with organic matter and nutrients. The values of the pollution index express a high organic pollution at all the sampling stations. The water of Lake Dohou is highly loaded with organic matter and receives a very high amount of pollutant from the environment.

Introduction:-

Continental aquatic ecosystems include different types of water bodies existing in their natural state (rivers, lakes, swamps, etc.) but also those created by man (reservoirs, rice fields, irrigation channels, etc.). These ecosystems are home to a large number of aquatic species, or species dependent on these environments, both animal and plant, which play an essential role in their functioning (Edia, 2008). Unfortunately, these ecosystems are exposed to many threats due mainly to anthropic pressure (Lévêque and paugy, 1999 ; Adjagodo et al., 2016) and climate change.

Indeed, many African countries have experienced tremendous population growth in recent years, accompanied by a sudden acceleration in urbanization and land use for industrial and agricultural purposes. All this has led to a huge increase in the discharge of a wide range of pollutants into receiving water bodies and has had undesirable effects on the various components of the aquatic environment and on fisheries (Saad et al., 1990). Organic residues mineralize in receiving water bodies and the resulting nutrients stimulate plant production, resulting in eutrophication according

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to Dejouxet al., 1981. Excessive production of organic matter leads to an accumulation of "sludge", and the mineralization process consumes all the dissolved oxygen present in the water column, which causes fish kills. This is why it is said that organic pollutants are oxygen demanding wastes (Saad et al., 1990).

Lake Dohou, used in Duékoué by the Société de Distribution d'Eau de Côte d'Ivoire (SODECI) as the main source of drinking water for the urban population and surrounding villages, is not immune to the problems listed. Formerly remote from the city, it is currently generating multiple and complex disturbances that have a direct or indirect, long or short term influence on the quality of the environment and public health (Ahoussiet al., 2008). To better apprehend the current quality of this lake and to minimize the risks of pollution and human exposure of this one, the evaluation of the quality of this water body thus proves necessary and imperative.

This study therefore proposes to evaluate the nutrient load and the relative contributions of the various sources of nutrients to this surface water for the implementation of pollution control measures aimed at preventing or slowing down its eutrophication. The main objective is tomake a typology of the different sampling stations and to calculate the organic pollution index (IPO).

Materials And Methods:-

Study area

Located in the west of Côte d'Ivoire, 470 km from Abidjan, between latitudes 6°45'0773 and 6°45'3591 N and longitudes 7°21'06.25 and 7°21'4931 W, the town of Duekoué is the capital of the Guémon region. It is bordered to the north by the departments of Kouibly and Bangolo, to the south by the sub-prefecture of Buyo, to the east by the town of Guéssabo and to the west by the department of Guiglo. With an area of about 1 km2, Lake Dohou is an artificial water reservoir created to supply the population of the town of Duekoué with drinking water. The banks of the lake are occupied by several anthropogenic activities which are among others agriculture, chicken farms, artisanal gravel quarries, auto mechanical garages and receives waste drained by runoff as well as wastewater from these anthropogenic activities in the vicinity of the city (Kouaméet al., 2019). Lake Dohou belongs to the Sassandra River basin. The climatic regime prevailing in our study area is a sub-equatorial mountainous type climate characterized by annual rainfall that varies between 100 mm and 400 mm. This climate is marked by a rainy season, which extends from April to October and a dry season, which covers the period from November to March (Koli&Brou, 1996). The average annual temperature oscillates around 25° C (Brou, 2005).

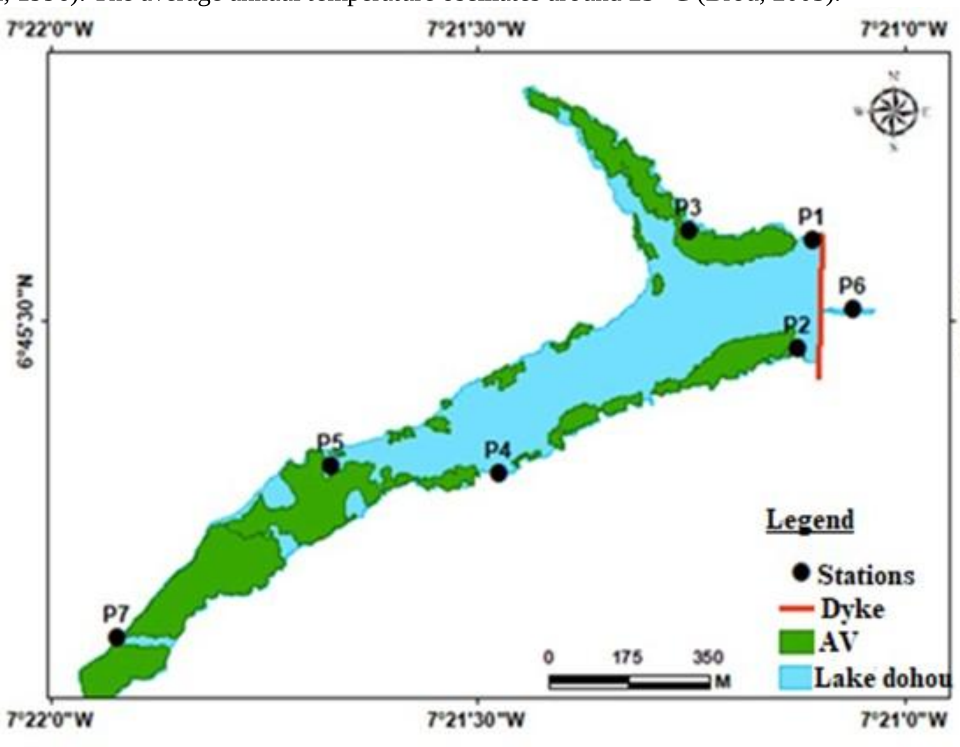


Figure 1:- Map of the study area showing the sampling stations (P1 to P7) selected on Lake Dohou in Duekoué (Côte d'Ivoire).

Sampling technique
The sampling stations were selected considering accessibility, permanence in water at any timof the year and anthropogenic activities. The frequency of sampling was monthly forone year from November 2017 to October 2018. For this purpose, seven stations were selected (Figure1).Thephysico-chemical parameters of the water (temperature, pH, conductivity, dissolved oxygen, TDS and transparency) were measured in situ between 6 a.m. and 7 a.m. at each site using the HANNA-HI9820 multi-parameter. For water temperature, pH, conductivity and dissolved oxygen, the previously calibrated measuring device was first switched on, the probes were then immersed in the water and the selection of the desired parameter function gave the value on the display. The Secchi disk was immersed in water until it disappeared completely. It is then slowly raised and the depth at which it reappears corresponds to the transparency. For the determination of nutrient salts, water samples were taken using a VAN DORN type hydrological bottle and kept in amber bottles and glasses to avoid photo degradation of the BOD5 parameter sensitive to solar radiation. These samples were kept cool in a cooler at a temperature of ± 4º C and then transported to the laboratory. In the laboratory, the determination of nutrients (nitrates, nitrites, ammonium and orthophosphates) was estimated according to standard norms (respectively AFNOR ISO 7890-3, ISO 6777.T 90015, T900-23) after filtrationof the samples on Whatman filter paper with a porosity of 0.45 um. The spectrophotometer (SHMADZU UV / visible 1700 pharma) was used for these analyses. The BOD5 measurement was carried out according to the WARBURG respirometer principle, in which the biomass respiration is directly measured by Oxytop.

Data analysis
An ascending hierarchical clustering (ACH) was performed to group the sampling stations according to their environmental similarity. Variations in physical and chemical parameters between groups were evaluated using the Kruskal-Wallis and Mann-Withney tests. The normality of the data was checked by the Shapiro test ($P < 0.05$ at each group) before performing the comparison test. Analyses were performed using the open source software R 4.0 and PAST 3.4.

The organic pollution index (IPO) was calculated from ammonium, nitrite, phosphate and biological oxygen demand (BOD5) data according to Leclercq and Maquet (1987). The principle is to divide the values of the polluting elements into 05 classes, to determine from its own measurements the number of the class corresponding to each parameter, then to calculate the value of the indicator for each parameter and to calculate the average of the classes. This average makes it possible to determine the level of organic pollution (Table 1).

Table I:- Grid of organic pollution index classes (**Leclercq, 2001**).

Classes	**BOD5 (mg/l)**	**NH4+ (mg/l)**	**NO2-(µg/l)**	**PO43- (µg/l)**	**Class average**	**Organic pollution**
5	< 2	< 0,1	≤ 5	≤ 15	4,6 - 5,0	None
4	2,1 - 5	0,1 - 0,9	6 - 10	16 - 75	4,0 - 4,5	Low
3	5,1 - 10	1 - 2,4	11 - 50	76 - 250	3,0 - 3,9	Moderate
2	10,1 - 15	2,5 - 6	51 - 150	251 - 900	2,0 - 2,9	Strong
1	> 15	> 6	> 150	> 900	1,0 - 1,9	Very strong

Results:-
Abiotic typology of the stations
The ascending hierarchical classification (ACH) allowed to group the stations into three groups according to their abiotic similarity. The physico-chemical parameters do not show significant variation (Kruskal-Wallis test ; $p > 0.05$) between the different groups except for conductivity, transparency and BOD5 (Kruskal-Wallis test ; $p < 0.05$). Group I consists of the samples from station P6, which are characterized by water with relatively higher BOD5 (76-921 mg/l), Ammonium (0.042-0.849 mg/l) and Nitrate (0.8-16.4 mg/l) contents and lower transparency (0.17- 0,57 m) than those observed in group II and groupIII. Concerning group II, it consists of the samples of stations P4, P5 and P7. This group differs from the others by a higher conductivity water (11,73 - 330 µs/cm). Group III is made up of samples from stations P1, P2 and P3. These stations are characterized by a well oxygenated water with a relatively high pH and a clearer transparency.

Organic pollution from Lake Dohou stations

After the calculation of the organic pollution index IPO using the annual average values of the pollution indicator parameters (NO_2 -, BOD5, NH_4 $^+$ and PO4 3-), the water quality class is determined for the 84 samples related to the seven sampling stations over the period from November 2017 to October 2018. Thus, the values of OPI varied from 2.25 to 2.5 expressing a strong organic pollution index at all the surveyed stations (Table II).

Table II:- Result of the calculation of the organic pollution index of Lake Dohou waters studied from November 2017 to October 2018.

	NO_2- (µg/l)	Class	NH_4^+ (mg/l)	Class	$PO_4$3- (µg/l)	Class	BOD5 (mg/L)	Class	Class average	Organic pollution level
P1	22 ± 14,68	3	0,20±0,2	4	438,33±686,72	2	124,58±89,6	1	2,5	strong
P2	19 ± 11,54	3	0,2± 0,10	4	419,17±456,82	2	135,33±86,6	1	2,5	strong
P3	21,25±15,56	3	0,18±0,1	4	260± 158,52	2	130 ± 87,74	1	2,5	strong
P4	22,66±17,56	3	0,23±0,3	4	248,33±253,80	2	177,25 ± 94,46	1	2,5	strong
P5	28,41±34,84	3	0,16±0,8	4	268,33±232,80	2	206,58 ± 104,77	1	2,5	strong
P6	34,25±44,33	3	0,35±0,4	4	208,83±603,32	1	464,58 ± 336,92	1	2,25	strong
P7	96,41±213	2	0,41±0,44	4	440± 326,27	2	178,5 ± 137,08	1	2,25	strong

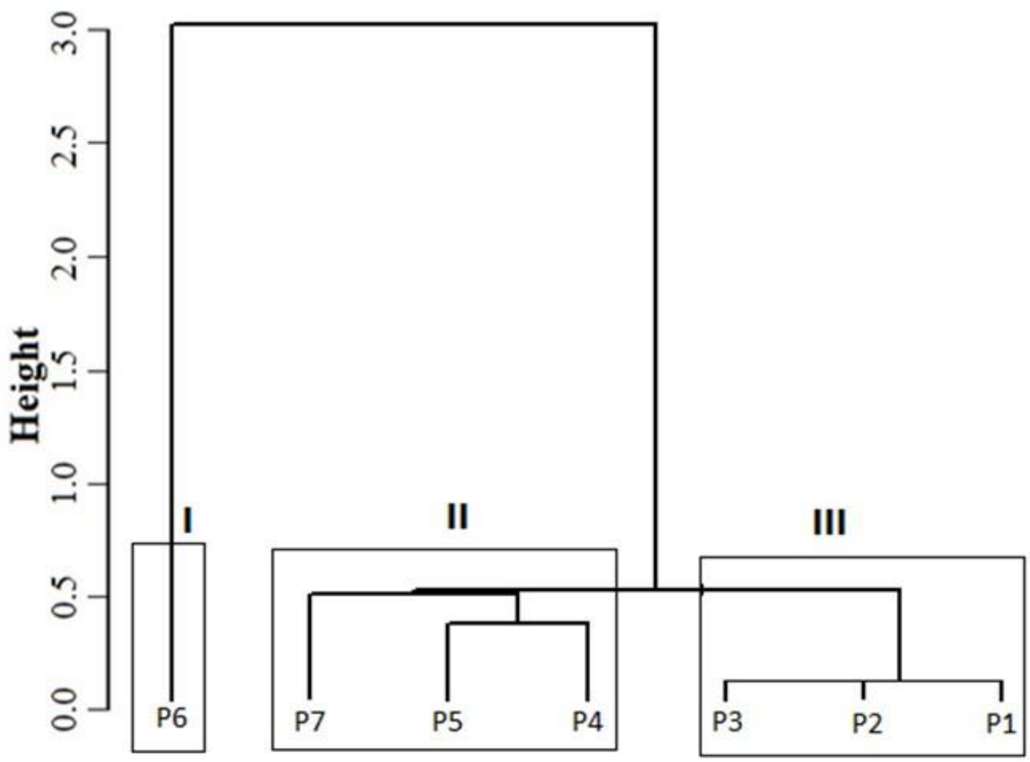
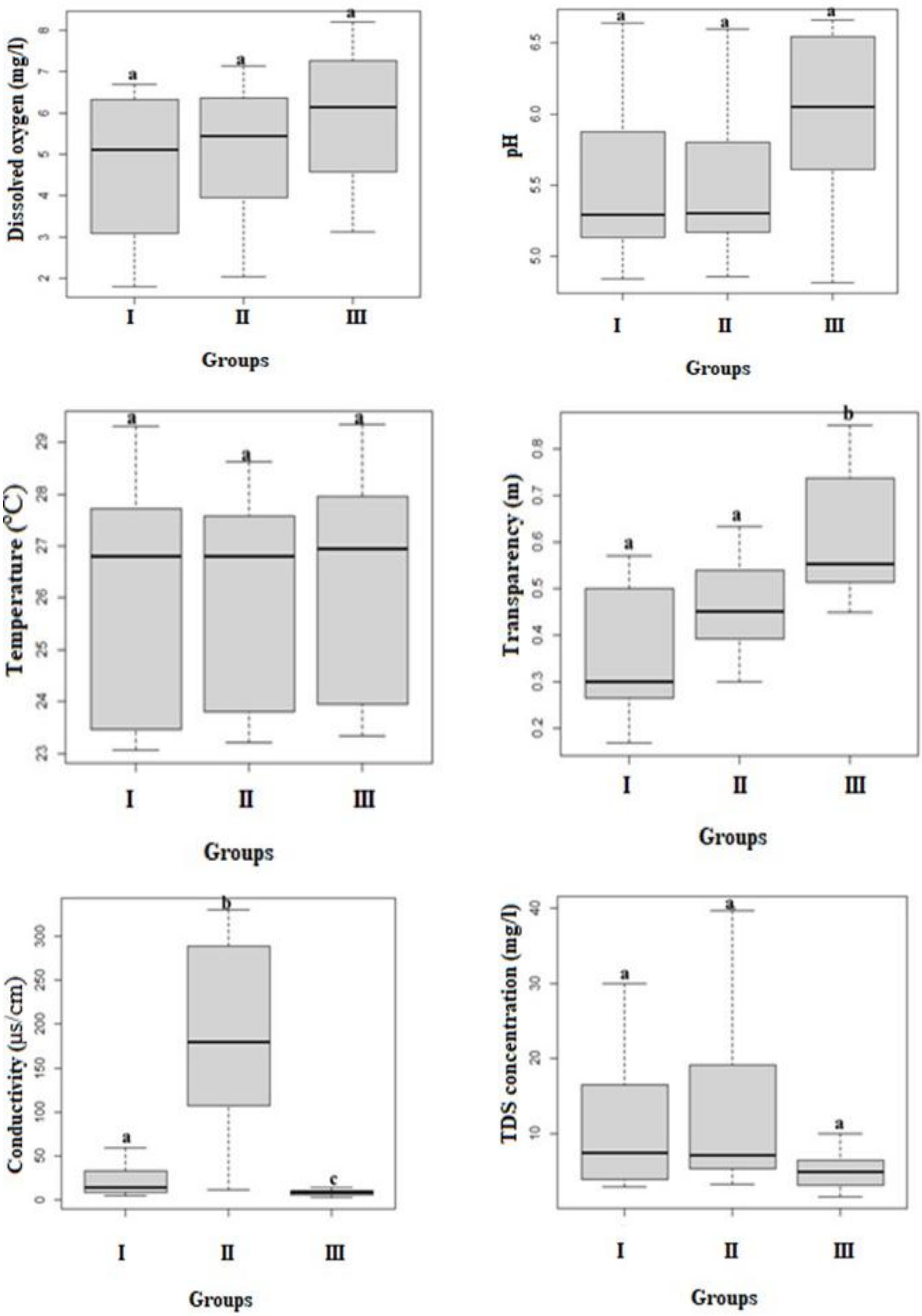


Figure 2:- Hierarchical classification of sampling stations defined on theLakeDohou from the values of the physical and chemical parameters: I, II and III = group.


Dissolved oxygen (mg/l)
2 3 4 5 6 7 8
a a a
I II III
Groups
pH
5.0 5.5 6.0 6.5
a a a
I II III
Groups
Temperature (°C)
23 24 25 26 27 28 29
a a a
I II III
Groups
Transparency (m)
0.2 0.3 0.4 0.5 0.6 0.7 0.8
a a b
I II III
Groups
Conductivity (µs/cm)
0 50 100 150 200 250 300
a b c
I II III
Groups
TDS concentration (mg/l)
10 20 30 40
a a a
I II III
Groups

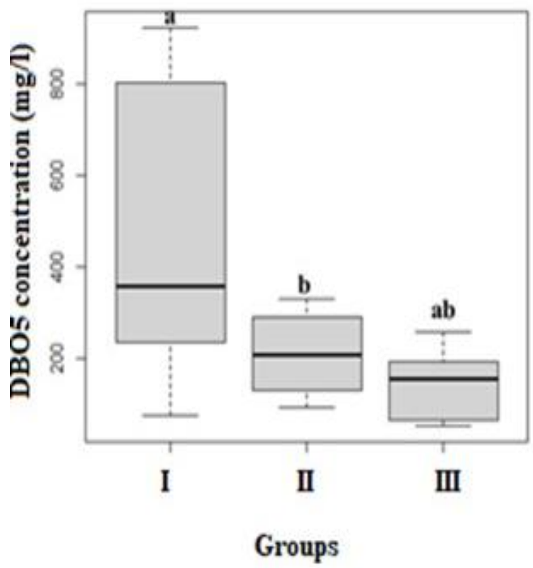


Figure 3:- Box-plots showing the differences in physico-chemical parameters between groups (I-III). Different letters on the box plots indicate significant differences between them (Mann-Withney test, $P < 0.05$).

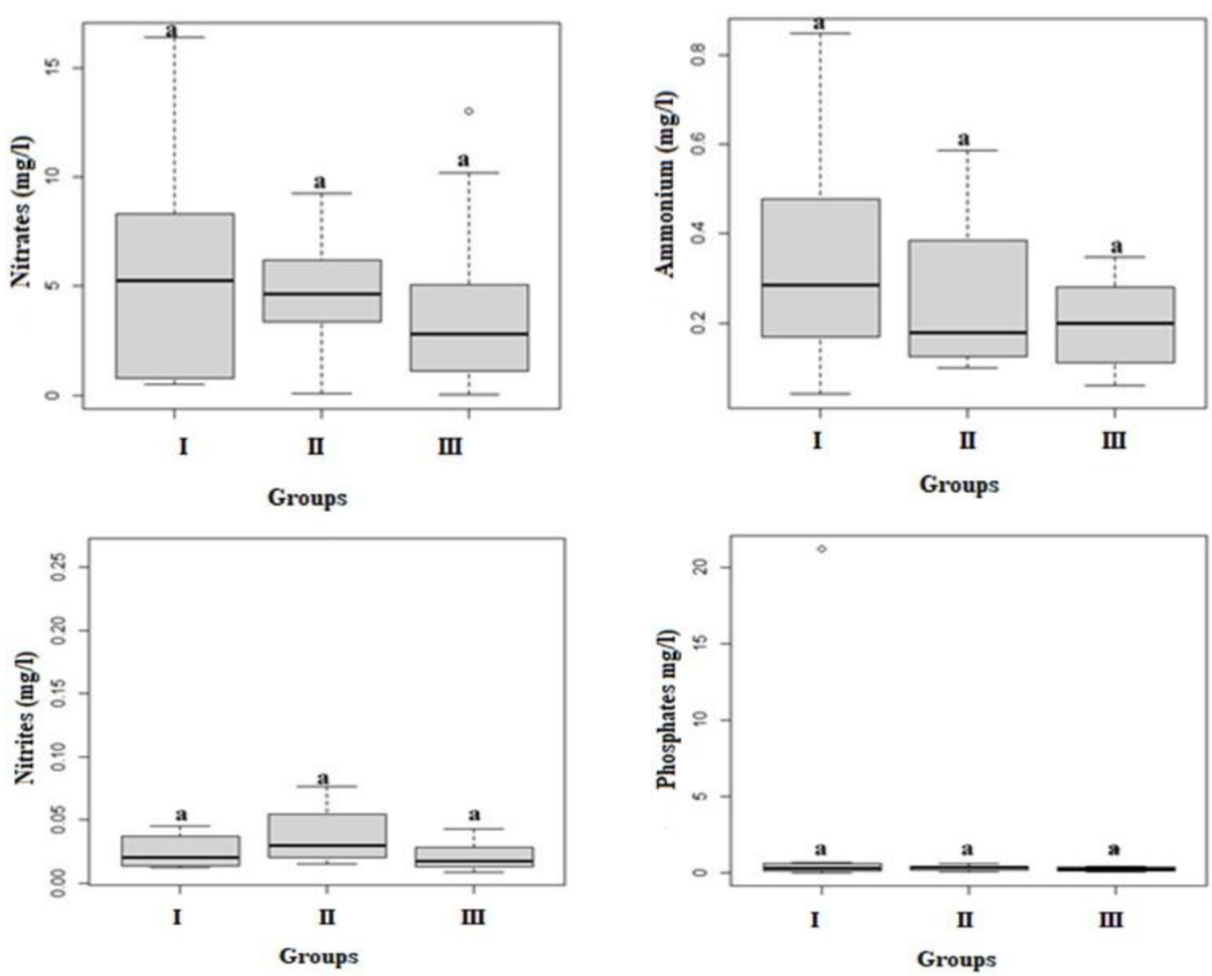


Figure 4:-Box-plots showing differences in nutrient concentrations between groups (I-III). Different letters on the boxes indicate significant differences between them (Mann-Withney test, $P < 0.05$).

Discussion:-
The abiotic differentiation from the hierarchical classification allowed to group the stations into three (03) groups. Group I was characterized by a water loaded in organic matter and nutrients with low values of transparency, conductivity and TDS. Indeed, this station is the outlet of the wastewater treatment plant and is under the influence of several anthropic activities (market gardening, rice cultivation, rubber field...). Land leaching after fertilizer application and domestic sewage would increase nutrients such as nitrate and phosphate in the water, which promotes the growth of aquatic plants and ultimately leads to increased plant decomposition and greater back and forth movement in the diurnal dissolved oxygen level (Lodh, 2014, Jen, 2002). Moreover, parameters like conductivity and TDS are closely related to the nature and concentration of dissolved substances in the medium. Thus, a low conductivity for a stream is also synonymous with low mineralization of salts present in the medium. (Ben Moussa et al., 2012). Group II is therefore found with more mineralized waters with significantly higher conductivity values than those obtained in the other two groups. The state of pollution of the waters of Lake Dohou, calculated from the organic pollution index IPO, shows that the seven (07) stations present a strong organic pollution (IPO between 2.25 and 2.5) during our study campaigns from November 2017 to October 2018). The degradation of the quality of the waters of this lake is due to human actions (agricultural activities, domestic waste and wastewater discharges) combined with climatic factors. Adamou et al, 2015 indicates that climate change and anthropogenic activities remain the fundamental causes of all the transformations that have affected the state of the resources. During the leaching of agricultural lands highly loaded with fertilizers, and discharges of domestic effluents, there is transfer of important mineral and organic load into the lake (Taybiet al., 2016; Vital et al., 2018).

Conclusion:-
The monitoring of the organic pollution index (OPI) during this study shows that the water of Lake Dohou in Duekoué town is highly loaded with organic matter and receives a very high amount of pollutants from the environment. It is therefore necessary to take monitoring measures to reduce and control nutrient inputs to avoid possible eutrophication.

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