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Physico-chemical quality of the Okpara River waters in northeastern Bénin

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Abstract

Water is a natural element essential to life. Man makes it polluted, which poses a real threat to human beings. This study aims to evaluate the physico-chemical quality of Okpara River waters in the commune of Parakou and Tchaourou in the Northern part of Republic of Bénin. Ten (10) sampling sites were selected and fourteen (14) physico-chemical parameters were studied: Water temperature, hydrogen potential, electrical conductivity, dissolved oxygen, turbidity, total dissolved solids, nitrates, nitrites, phosphate, calcium, magnesium, chemical oxygen demand, iron and chloride. Only four (04) of these parameters were found not to be within World Health Organization (WHO) and Bénin's permissible limits for drinking water. This is firstly the temperature 27.29 °C ± 1.11 exceeding the standards required by WHO (25 °C) and Bénin (25 °C). Then the turbidity 61.50 NTU ± 49.26 exceeds the standards of WHO (<5 NTU) and Bénin (5 NTU). The dissolved oxygen 3.84 mg/L ± 1.630 is also below the WHO standard (5≤ O2 ≤8) and the standard required by Bénin (≥ 5 mg/L). Finally, the iron 2.06 mg/L ± 0.70 also exceeds the standards required by WHO (0.2 mg/L) and Bénin (0.3 mg/L). The results obtained by the different physico-chemical parameters were affected by the study's season or the condition of analysis. Given these results, the Okpara River waters, which mainly is the economic sustenance for a good part of the population of Parakou, are qualified as polluted through its physicochemical constituents evaluated, which are very low by the recommended standards.

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Introduction

Water is an indispensable element for life and for the real and sustainable socio-economic development of a country (Belghiti *et al.*, 2013). It is therefore necessary to have a better knowledge of existing water resources, especially information concerning their physico-chemical quality and the necessary measures to develop, manage and protect these waters.

The rational exploitation and conservation of aquatic ecosystems have become major ecological and economic issues and are today at the center of sustainable development policies, both national and international (Chouti *et al.*, 2017). Surface waters, especially the fresh water resources of the planet face increasing threats (GWP, 2009). Today, access to potable water is in the heart of most public health problems in developing countries.

The potential sources of water contamination are socio-economic activities related to agriculture, industry, artisanal fisheries and tourism (Zerrouqi *et al.*, 2013). In West Africa, water is a factor of great utility for agricultural production, energy production, field of industry, domestic uses and other activities of daily life.

Only 3% of households dispose of their household wastewater properly. Wastewater is dumped directly into the streets, yards and gutters; which causes the stagnation of puddles between houses (Eau et Assainissement pour l'Afrique, 2012). Bénin, as the developing countries suffered a population explosion, resulting in anarchic land occupation (Alassane, 2004) as well as several human activities that constantly and frequently drain production and consumption flows, which result in the release of polluting substances into the environment and especially into the surface waters.

These polluting substances are present in the form of mineral elements that destroy water quality and threaten aquatic life (Mama *et al.*, 2011) and their concentration determines the quality of these waters and whether they are suitable for a particular purpose or not (Koudenoukpo *et al.*, 2017). Our objective is to study the water quality of the Okpara River by performing physico-chemical analyzes to determine the potability of the different sampling sites.

Materials and methods

Location of the Okpara River

The Okpara River located between 8° 13 ' and 10° 03' North Latitude and between 2° 31 'and 3° 25' East Longitude covers the departments of Collines and Borgou and is one of the two main tributaries of the Ouémé River in Bénin. Within these departments, various communes are drained by the waters of the Okpara River. These are Bembèrèkè, N'Dali, Nikki, Pèrèrè and Parakou located at the north of the basin and Tchaourou, Ouèssè and Savè located at the south of the basin. In Parakou, the river supplies water to the Okpara dam, built on the river. The Okpara basin goes across the communities of Parakou and Tchaourou and covers an area of 9,461 Km2 or 8.24% of the surface of Bénin and supplies approximately 1,131,791 inhabitants (INSAE, 2013), about 11.3% of the Beninese population and eight communes out of seventy-seven (10.39%). This basin is disadvantaged by its particular hydrogeology, the pollution of all kinds that it undergoes, which increases the difficulty of access to drinking water (Dossou-Yovo *et al.*, 2017). Thus it is important to know the quality of the river's waters, in particular its physicochemical qualities, in order to regulate their pollution if possible, considering their uses for the water supply of these communities (Fig. 1).

Presentation of sampling sites

To assess the quality of the waters of the Okpara River, we have selected 10 sampling sites. Some sites are more exploited by the population through agricultural activities, grazing animals, garbage market, laundry and beverage (Fig. 2).

Samples

The samples were taken in sterilized plastic bottles, 1.5 liter of water at each sampling site, during October 18, 2018, and are refilled immediately after the sampling.

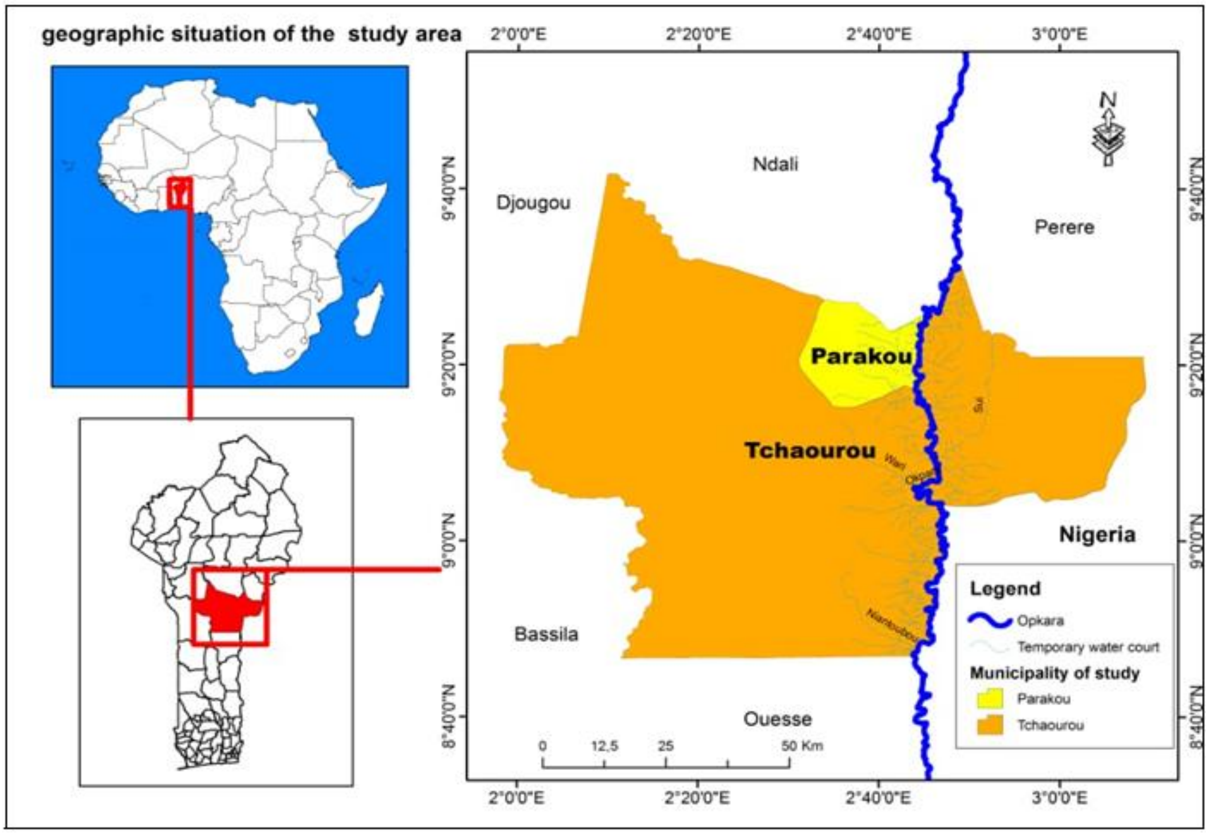

Fig. 1. Map of the study area.

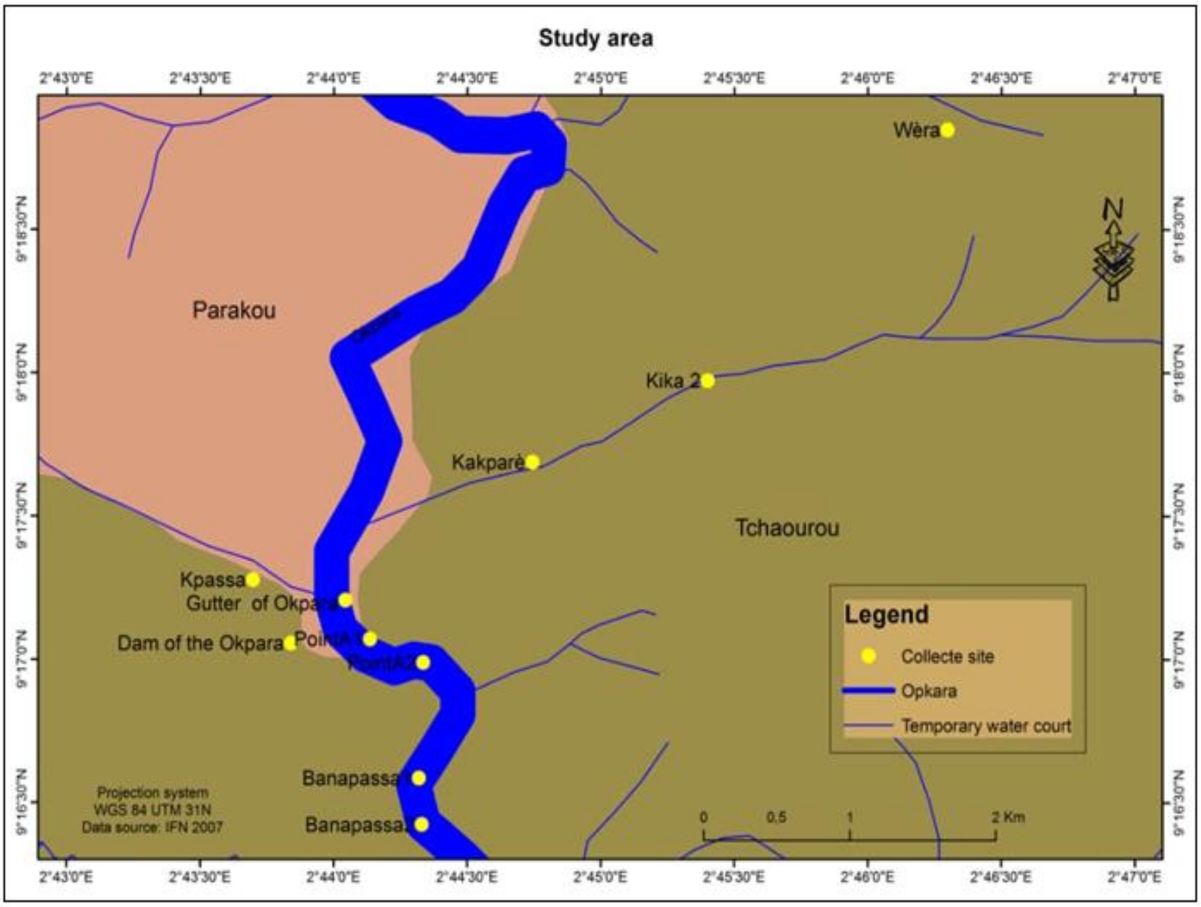

Fig. 2. Map of sampling sites.

Samples were stored under refrigerated conditions (4°C) and taken to the laboratory for the various series of analysis and analyzed within 24 hours.

Physico-chemical analysis

During the execution of work, we followed the modus operandi adopted by Rodier *et al.* (2009) and the recommendations of the World Health Organization and Benin. The temperature is recorded directly at the sampling sites using a pH meter. The pH is determined using a pH meter, which allows the measurement of a potential difference existing between a glass electrode and a reference electrode immersed in the same solution.

The electrical conductivity expressed in micro-siemens per centimeter (µs/cm) is measured using a conductivity meter.

Total dissolved solids expressed in milligrams per liter (mg/L) are measured using a conductivity meter. Dissolved oxygen expressed in milligrams per liter (mg/L) measured with an oximeter. The turbidity, which is the reduction of the transparency of the liquid due to the presence of undissolved material, is determined using a turbidimeter.

Nitrate, nitrite, phosphate, calcium, magnesium, chemical oxygen demand, iron, and chloride are expressed in milligrams per liter (mg/L) and measured with a spectrophotometer DR 6000.

The histograms were made from the Excel spreadsheet to show the comparative variation of each of the evaluated parameters. Then, the correlation circle recognized with the software R version 3.5.0 to establish the correlations between the variables with the parameters assessed by analyses in the tables.

Results

In order to have an overview of the physicochemical quality of water intended for human consumption in the Okpara River in Bénin, we performed global statistical analyses for the ten (10) water samples collected. By selecting various parameters, the program determined the averages. In essence, we compared our results with the standard norm by WHO and Bénin.

Table 1 presents the variation of the chemical concentration in the water samples.

Table 1. Variations of Physico-Chemical Parameter Values of water samples.

Parameters	Obtained values				Norms of Bénin (2001)	Norms of OMS (2011)
	Units	Minimum	Maximum	Means $\pm\sigma$		
Temperature	^{0}C	25,5	29	27,29±1,11	25	25
Hydrogen potential	Unité pH	6,6	7,8	7,19±0,36	6,5-8,5	6.5- 8.5
Conductivity	µS/cm	32,9	53,2	38,05±6,68	2000	< 1500
TDS	mg/l	13,3	25	17,45 ±3,48	2000	< 600
Dissolved Oygen	mg/l	1,8	5,43	3,84 ±1,630	≥ 5	5≤ O_2 ≤8
Turbidity	FTU	27	199	61,50±49,26	5,0	< 1
Nitrate	mg/l	0	2,1	0,87±0,73	45	<50
Nitrite	mg/l	0	1	0,2 ±0,42	3,2	< 0.1
Phosphate	mg/l	0	0,149	0,03±0,04	5	≤ 0,5
calcium	mg/l	0	1,24	0,41±0,35	100	200
magnesium	mg/l	1,74	2,48	2,21±0,27	50	150
COD	mg/l	2,66	17,2	7,48±4,92	26,02	30
Iron	mg/l	1,43	3,24	2,06±0,70	0,3	PVG
Chloride	mg/l	2,1	9,1	4,04±1,98	250	≤ 250

NGV = No Guide Value

Table 2. Hydro-chemical groups according to the studied physicochemical parameters.

Parameters	Temp	pH	EC	TDS	O_2	Turb	NO_2^-	NO_3^-	PO_4^{3-}	Ca^{2+}	Mg^{2+}	COD	Fe	Cl^-
Groups	1	2	1	1	2	3	2	2	2	2	2	2	2	2

Temperature

The values of this parameter are ranging from 25.5 °C (Kika 2) to 29 °C (Banapassa 2).

The instructions recommended by the WHO and Benin standard norms was that the optimum temperature of drinking water was 25 °C for both the cases. We found that the temperature of all samples taken exceeds 25 °C. Therefore, a temperature exceeding 25 °C promotes the growth and development of microorganism's 27.29 °C ± 1.11. Fig. 3 shows the spatial variation of the temperature.

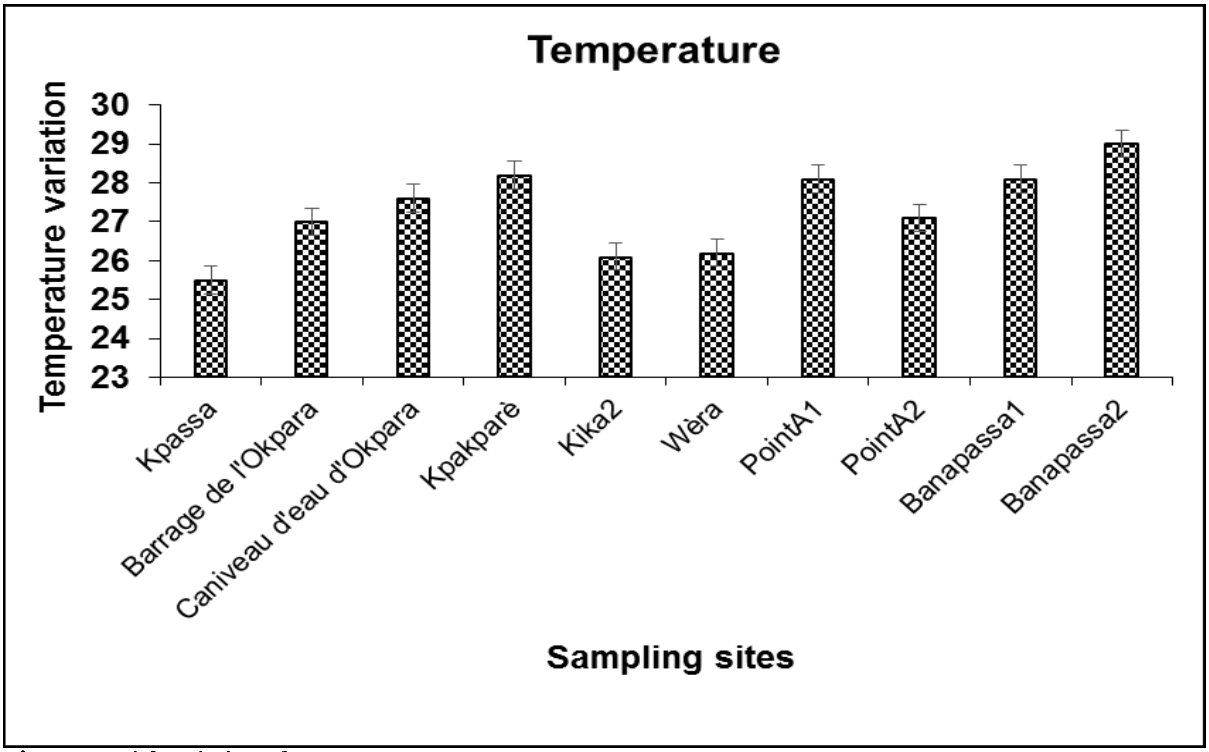

Fig. 3. Spatial variation of temperature.

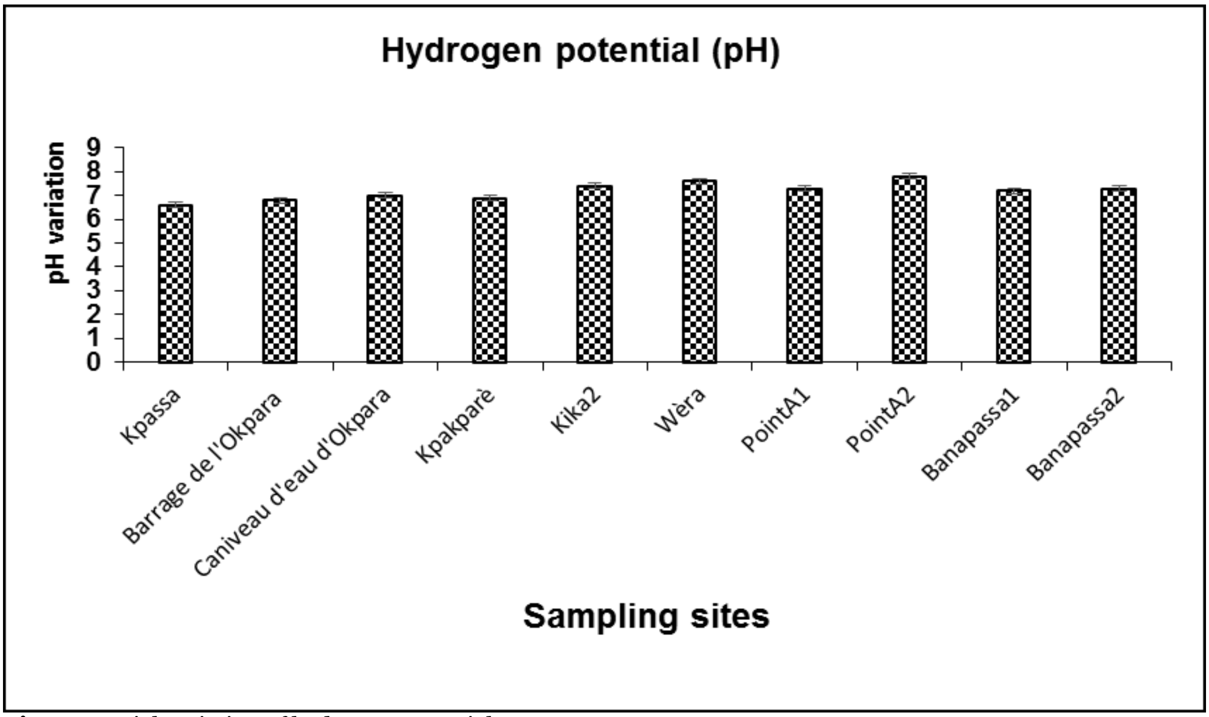

Fig. 4. Spatial variation of hydrogen potential.

pH

The values for this parameter range from 6.6 (Kpassa) to 7.8 (Point A 2). The pH of the waters of the Okpara River is relatively neutral 7.19 ± 0.36 which effectively matches adequately with the standards of WHO (6.5 to 8.5) and Bénin (6.5 to 8.5) for drinking water. Hense, the water quality of the Okpara River is acceptable. Fig. 4 shows the spatial variation of the hydrogen potential.

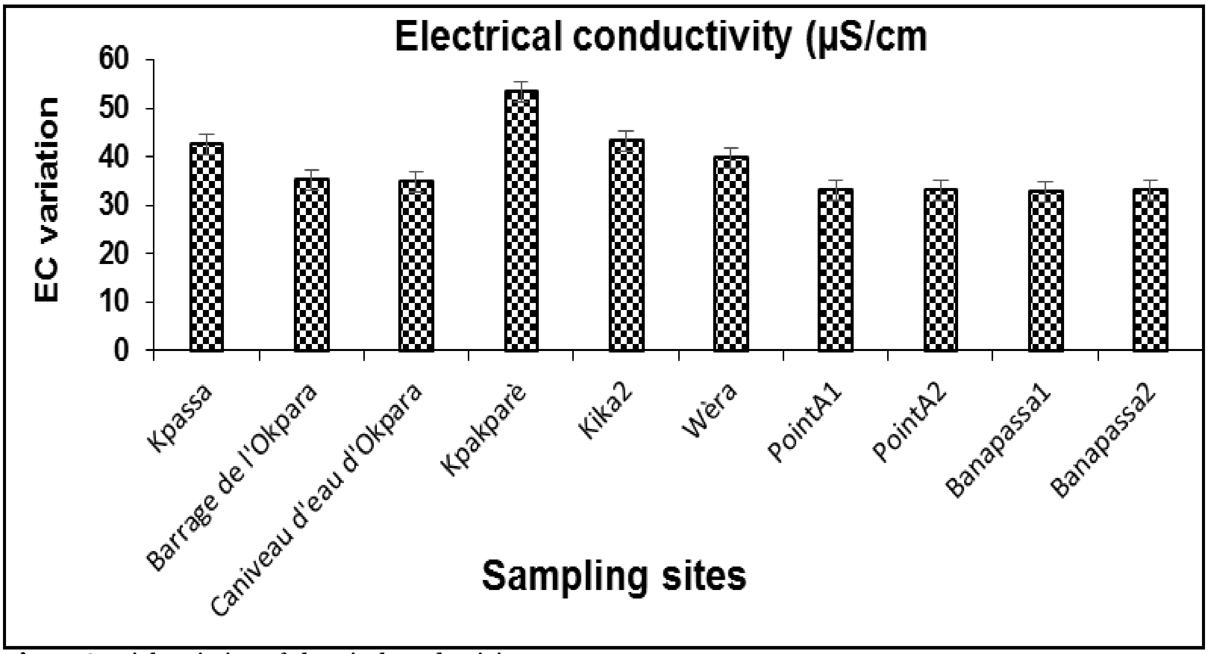

Fig. 5. Spatial variation of electrical conductivity.

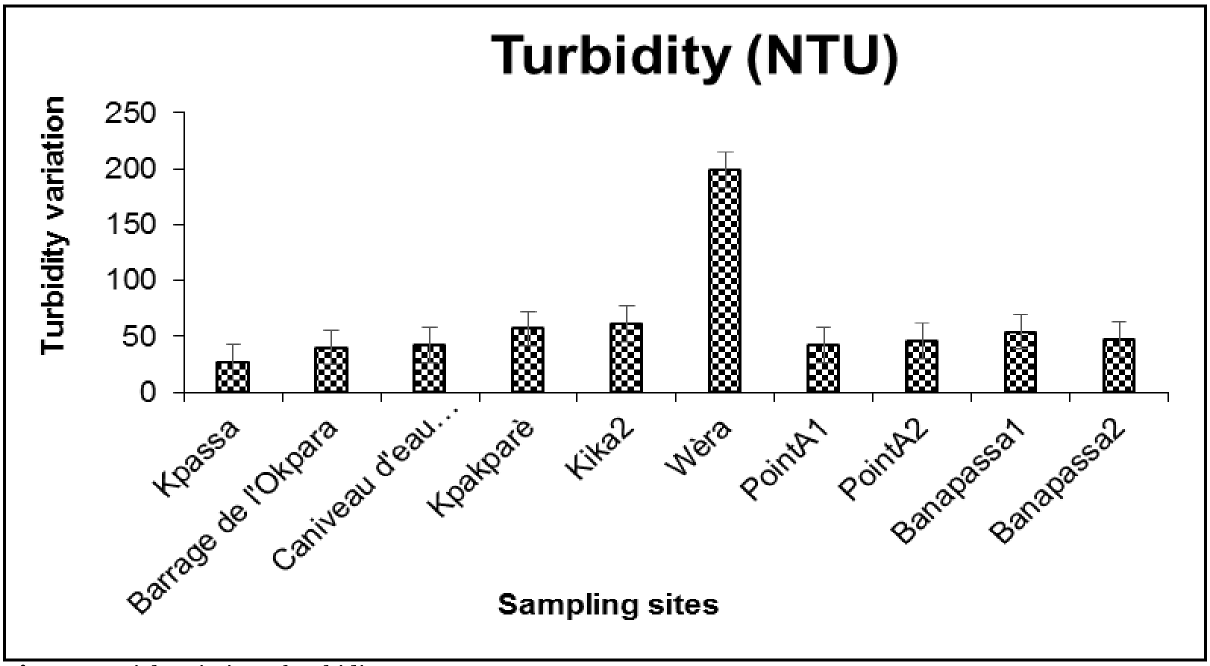

Fig. 6. Spatial variation of turbidity.

Electrical conductivity

The values of this parameter range from 32.9 µs/cm (Point A1) to 53.2 µs/cm (Kpakparè) for sampling sites. The electrical conductivity is the transmission of electrical power, which is due to the concentration of ions. Referring to the WHO (<1500 µs/cm) and Bénin (2000 µs/cm) standards, we found that these values are much less than the average. Therefore the waters of the Okpara River do not pose a risk and are acceptable, and very low in electrical conductivity 38.05 µs/cm ± 6.68. Fig. 5 shows the spatial variation of the electrical conductivity.

Turbidity

The turbidity of water is characterized by its content of suspended materials. The values of this parameter vary from 27 NTU (Kpassa) to 199 NTU (Wèra). Standards are referred for WHO (<1 NTU) and Bénin (5 NTU). We found that the values obtained for the Okpara River waters are much higher than WHO and Bénin standards for drinking water. The water is not limpid, therefore is not acceptable because of its turbidity 61,50 NTU ± 49,26. Fig. 6 shows the spatial variation of the turbidity.

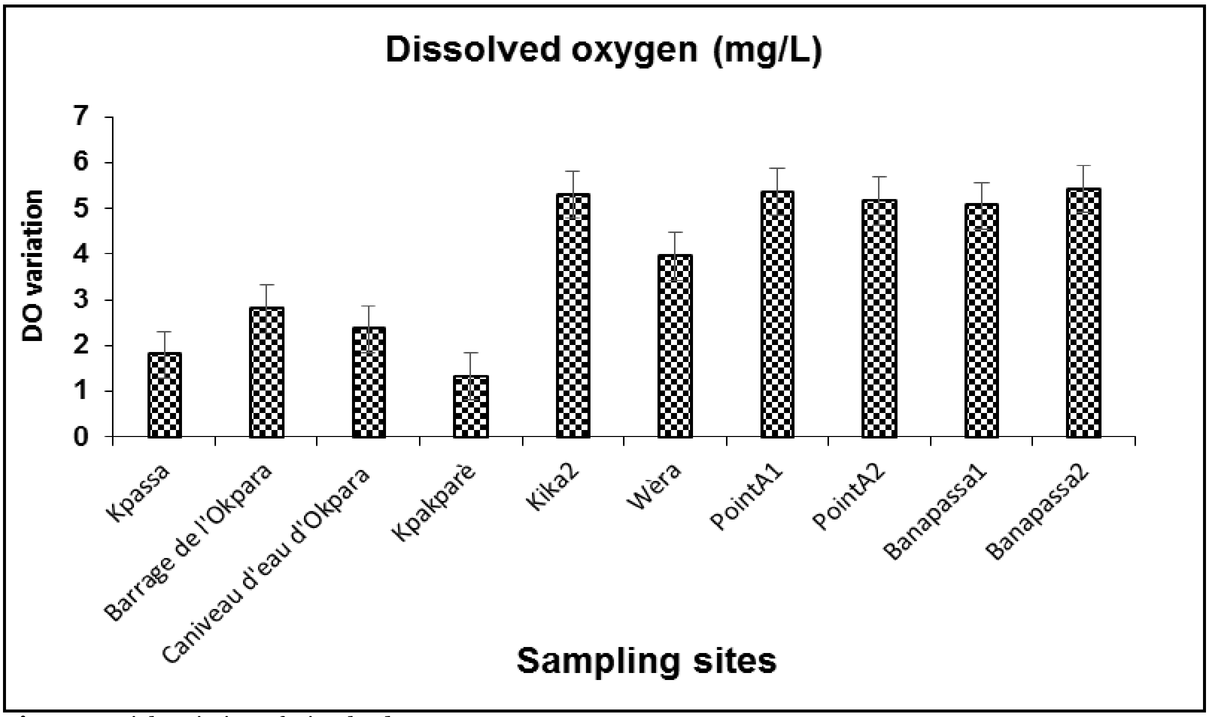

Fig. 7. Spatial variation of Dissolved Oxygen.

Dissolved oxygen

Dissolved oxygen is one of the most sensitive parameters to pollution. The values of this parameter range from 1.8 mg/L (Kpakparè) to 5.43 mg/L (Kika 2). Dissolved oxygen levels are defined by WHO standards (5 ≤ O2 ≤ 8) and Bénin (≥ 5 mg/L) for drinking water. We found that all the values of the sampling sites are below the standards defined by Bénin and WHO. Therefore, the waters of the Okpara River are not acceptable because of their dissolved oxygen content 3.84 mg/L ± 1.630. Fig. 7 shows the spatial variation of the dissolved oxygen.

Total dissolved solids

Total dissolved solids are useful parameters. The values of this parameter range from 13.3 mg/L (Okpara Dam) to 25 mg/L (Kpakparè). Based on WHO (<600 mg/L) and Bénin (2000 mg/L) standards for drinking water, we found that these values are lower than required standards. Therefore Okpara River waters are not a risk, therefore are acceptable and are very poorly represented as total dissolved solids 17.45 mg/L ± 3.48. Fig. 8 shows the spatial variation of the total dissolved solids.

Nitrates

The values of this parameter range from 0 mg/L (Kpakparè, Kika 2, and Wèra) to 2.1 mg/L (Banapassa 1). Nitrates show normal rate for Okpara River waters 0.87 mg/L ± 0.73. These values were found to be within those defined by WHO (<50 mg/L) and Bénin (45 mg/L). So the waters of the Okpara River are acceptable for drinking water and this low nitrate level can be explained by the study season that leads to leaching. The spatial variation of the nitrate is shown in Fig. 9.

Nitrites

Nitrites are considered to be intermediate ions between nitrates and ammoniacal nitrogen. Nitrate values ranged from 0 mg/L (for all sampling sites) to 1 mg/L for the sites A1 and A2. Nitrites are in low concentration in the waters of the Okpara River 0.2 mg/L ± 0.42; not exceeding Bénin standards (3.2 mg/L) but contrary to WHO standards (<0.1 mg/L). Hense, the water quality of the Okpara River is also acceptable in nitrite. Fig. 10 shows the spatial variation of the nitrites.

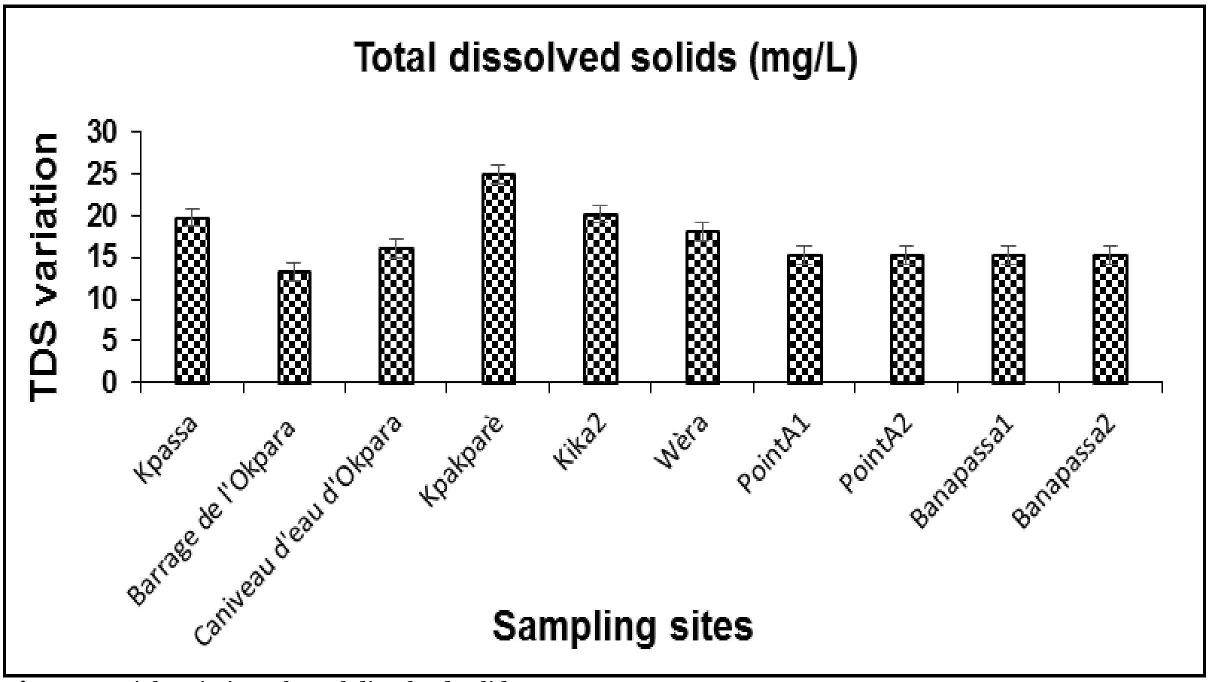

Fig. 8. Spatial variation of Total dissolved solids.

Phosphates

The values of this parameter range from 0 mg/L (Point A1) to 0.149 mg/L (Kpassa). Phosphates are in the waters of the Okpara River in a relatively small amount 0.03 mg/L ± 0.04; which correspond to the standards required by WHO (≤0.5 mg/L) and Bénin (5 mg/L). So, this content is considered normal and acceptable in phosphate. Fig. 11 shows the spatial variation of the phosphate.

Calcium

The calcium values ranged from 0 mg/L (Okpara Dam) to 1.24 mg/L (Wèra). According to the standards defined by WHO (200 mg/L) and Bénin (100 mg/L) for drinking water, the values obtained are very low. This is considered as normal for health, therefore the water is acceptable for the calcium 0.41 mg/L ± 0.35. Fig. 12 shows the spatial variation of the calcium.

Magnesium

The values of this parameter range from 1.74 mg/L (Kpakparè) to 2.48 mg/L (Okpara dam and Okpara gutter waters). Based on the instructions of the WHO (150 mg/L) and Bénin (50 mg/L), the values obtained are very low. Therefore this water can be recommended as drinking water. This water is acceptable for the magnesium 2.21 mg/L ± 0.27. Fig. 13 shows the spatial variation of the magnesium.

Chemical oxygen demand

The values for this parameter range from 2.66 mg/L (Okpara dam) to 17.2 mg/L (Kika 2). The chemical oxygen demand of the waters of the Okpara River (7.48 mg/L ± 4.92) does not exceed the standards of the WHO (30 mg/L) and Bénin (26.2 mg/L) for a drinking water. Therefore this water poses no risk according to the chemical oxygen demand and is acceptable. Fig. 14 shows the spatial variation of the chemical oxygen demand.

Iron

The values of this parameter range from 1.43 mg/L (Point A1) to 3.24 mg/L (Kpakparè). These values are higher than Bénin standards (0.3 mg/L), of which WHO has no guide value, for drinking water. So this Okpara River water presents a health risk and therefore is not acceptable 2.06 mg/L ± 0.70. Fig. 15 shows the spatial variation of iron.

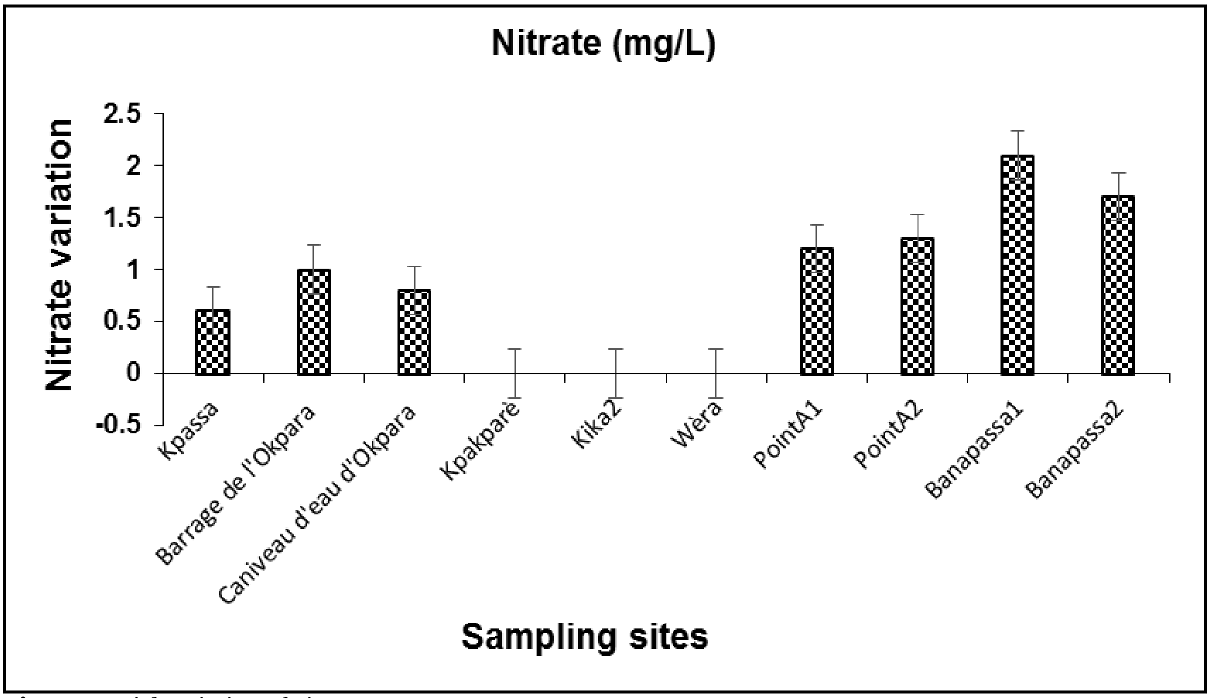

Fig. 9. Spatial variation of nitrate.

Chlorides

The chloride content of the waters studied range from 2.1 mg/L (Okpara dam) to 9.1 mg/L (Wèra). This content is much less than WHO (≤250 mg/L) and Bénin (250 mg/L) standards for a drinking water. Hense, this water does not present a risk to the health of the population and therefore is acceptable (4.04 mg/L ± 1.98). Fig. 16 shows the spatial variation of the chlorides.

Some techniques are used to classify the physico-chemical parameters of water into distinct hydro-chemical groups (Belkhiri *et al.*, 2011). Table 2 below shows the groups according to the studied parameters.

The Phenon line was chosen for a binding distance of 75 which allowed the different groups to be distinguished according to their hydrochemical variables.

Group 1, includes: Temp, EC and TDS that operate in the control of significantly way the concentration for different soluble chemical elements. Only the temperature operates more in this group for the different soluble chemical elements.

Group 2 is divided into two subgroups of which we have:

Subgroup 1 consists of: Mg^{2+}, Fe, NO_3^-, Ca^{2+}, NO_2^- and PO_4^{3-} which originate mainly from wastewater and agricultural activities. In this subgroup, only iron operates much more in these wastewater and agricultural activities.

Subgroup 2 consists of: COD, pH, O_2 and Cl^- are caused by carbonate formations, different processes of natural erosion and industrial activity. In this subgroup, only dissolved oxygen operates more in carbonate formations and different processes of natural erosion.

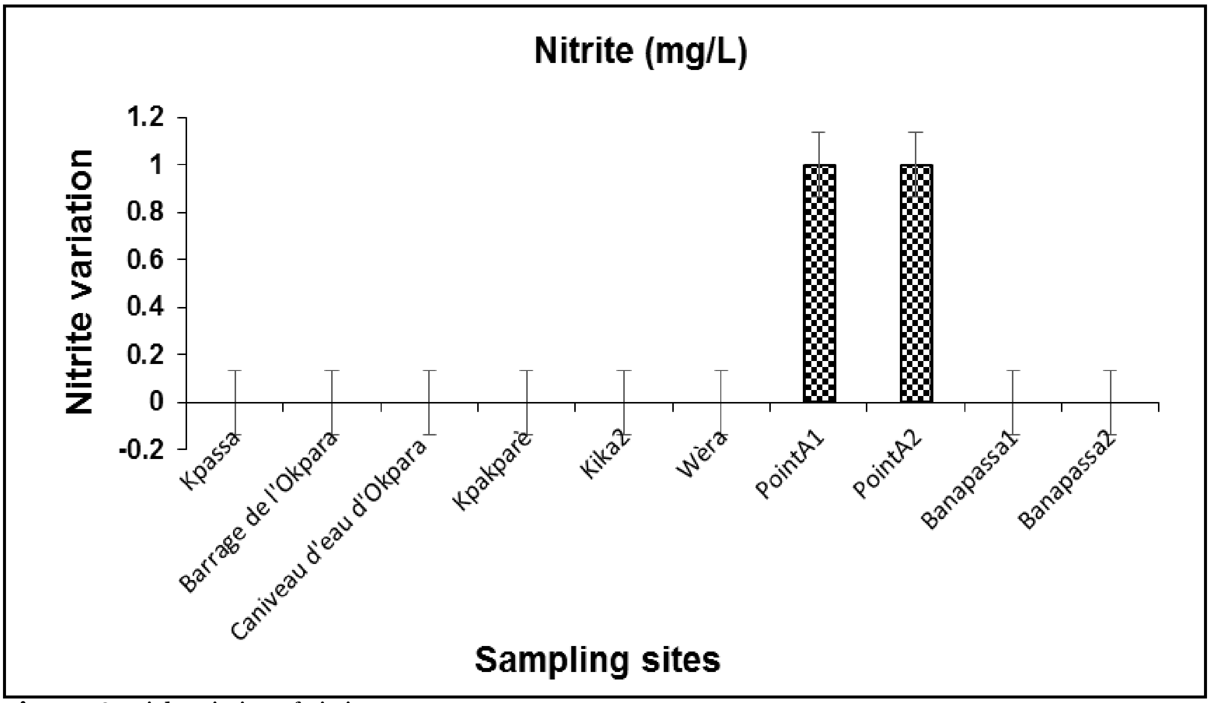

Fig. 10. Spatial variation of nitrite.

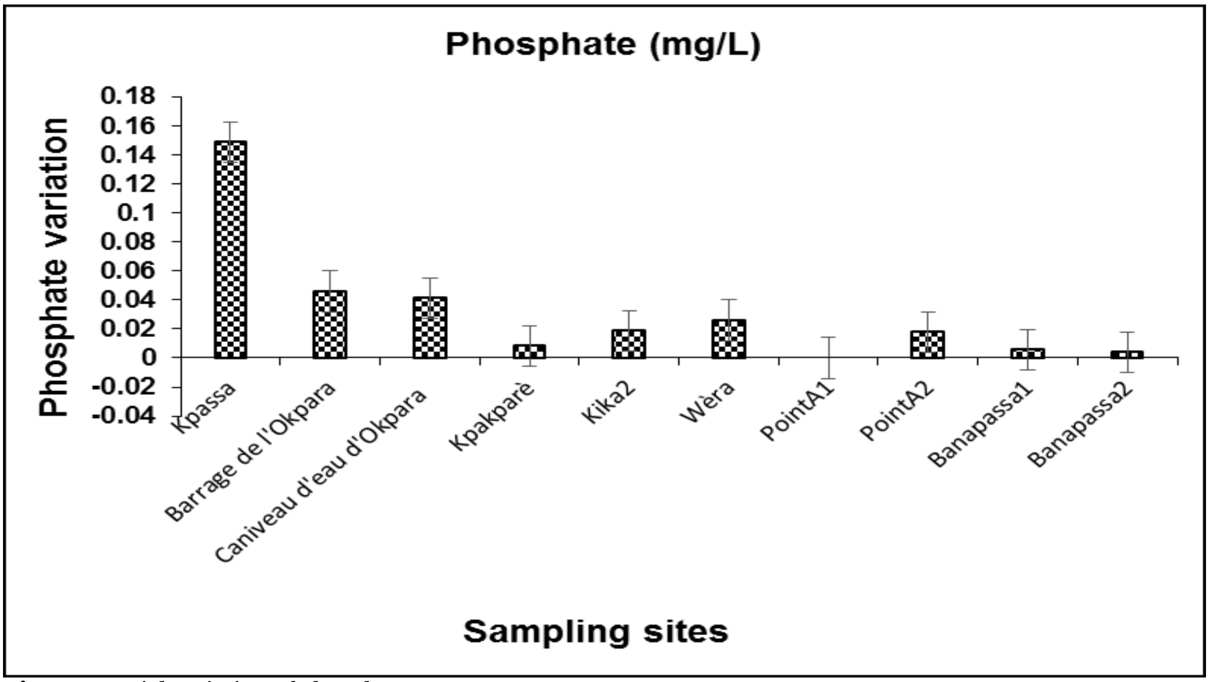

Fig. 11. Spatial variation of phosphate.

Finally, group 3 which consists of Turbidity (Turb) which is due to the presence in the water of mineral or organic suspended particles, living or detritic.

Thus, the more water is loaded with phytoplankton biomass or sedimentary particles, the more turbid it is. Fig. 17 shows the dendrogram of the grouping of physic-chemical variables.

Discussion

Anthropogenic activities can enter aquatic ecosystems and become part of suspended solids, which presents a huge danger for aquatic organisms (Noumon *et al.*, 2015).

The temperature increase compared to the norms of WHO (2011) and Bénin (2001), can be explained by the samples taken during the rainy season because during these periods, the temperatures are lower.

The results obtained for the temperature are close to those obtained by (Koudenoukpo *et al.*, 2017) in a study on the physico-chemical characterization of the Sô River in Southern Bénin. At elevated temperatures, the development of microorganisms is favored and problems of taste, color and odor may increase (WHO 2011). It influences, in fact, the biological reactions that occur in the water (Makhoukh *et al.*, 2011, Akil *et al.*, 2014).

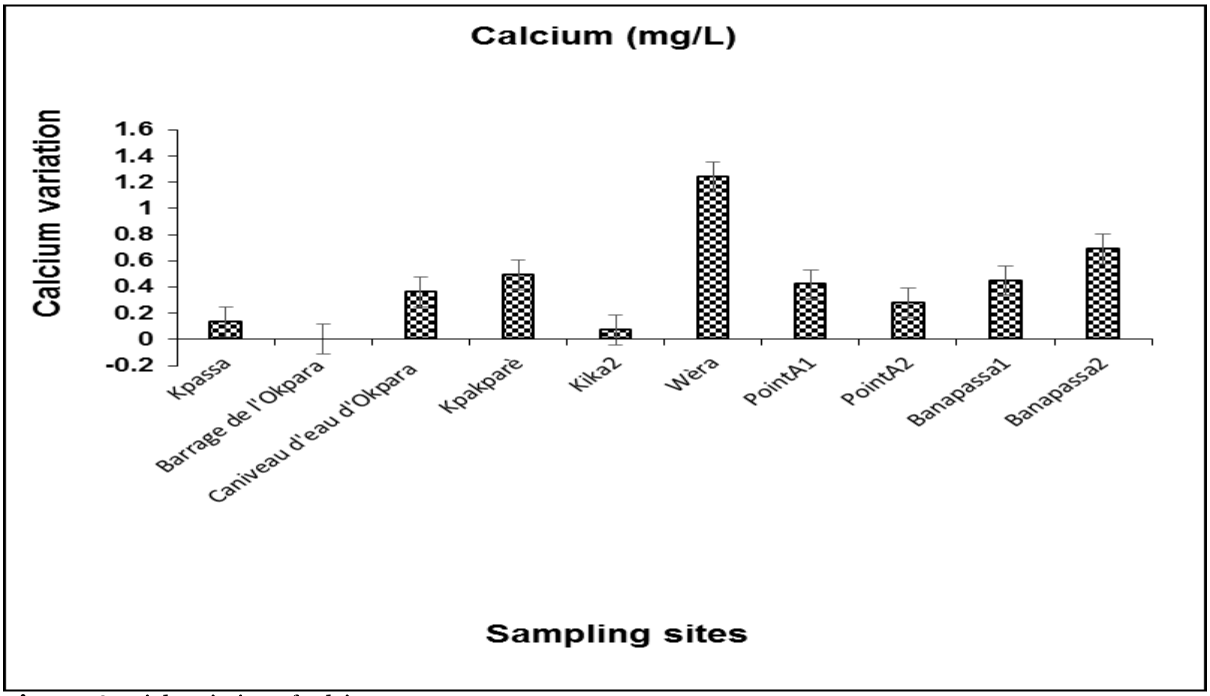

Fig. 12. Spatial variation of calcium.

The pH has a minimum and a maximum of 6.6 to 7.8, which is in accordance with the standards of WHO (2011) and Bénin (2001) is 7.19 ± 0.36 for the ten sampling sites. This could be explained by the presence of bicarbonates which have a buffer capacity in the water. These results are similar to those recorded by Wanélus (2016) for six (6) samples in the physico-chemical characterization of water intended for human consumption in the Metropolitan Region of Port-au-Prince in Haiti.

The electrical conductivity with a minimum and a maximum of 32.8 μS/cm at 53.2 μS/cm responds to the standards of the WHO (2011) and Bénin (2001) is 38.05 μS/cm ± 6, 68; which clearly shows that the waters of the Okpara River are weakly ionized. The results obtained are very weak compared to the values obtained by (Chouti *et al.,* 2017), in their study on the physico-chemical characteristics of the Togbin coastal lagoon in Grand-Popo. The rising waters, coinciding with our sampling period, are the cause of these low values, because the waters of the Okpara River are diluted by the contribution of rainwater.

The total dissolved solids of the Okpara River show a minimum of 13.3 mg/L and a maximum of 25 mg/L responds to the standards of WHO (2011) and Bénin (2001) i.e. 17.45 mg/L ± 3 48.

These values are relatively very low considering the ionic constituents contained in the water. The dissolved oxygen has a minimum (1.8 mg/L) and a maximum (5.43 mg/L) and does not correspond to the standards of WHO (2011) and Bénin (2001) which is 3.84 mg/L ± 1,630 in the different sampling sites.

The dissolved oxygen measures the concentration of oxygen in the water (Rodier, 2009). It participates in the majority of chemical and biological processes in the aquatic environment.

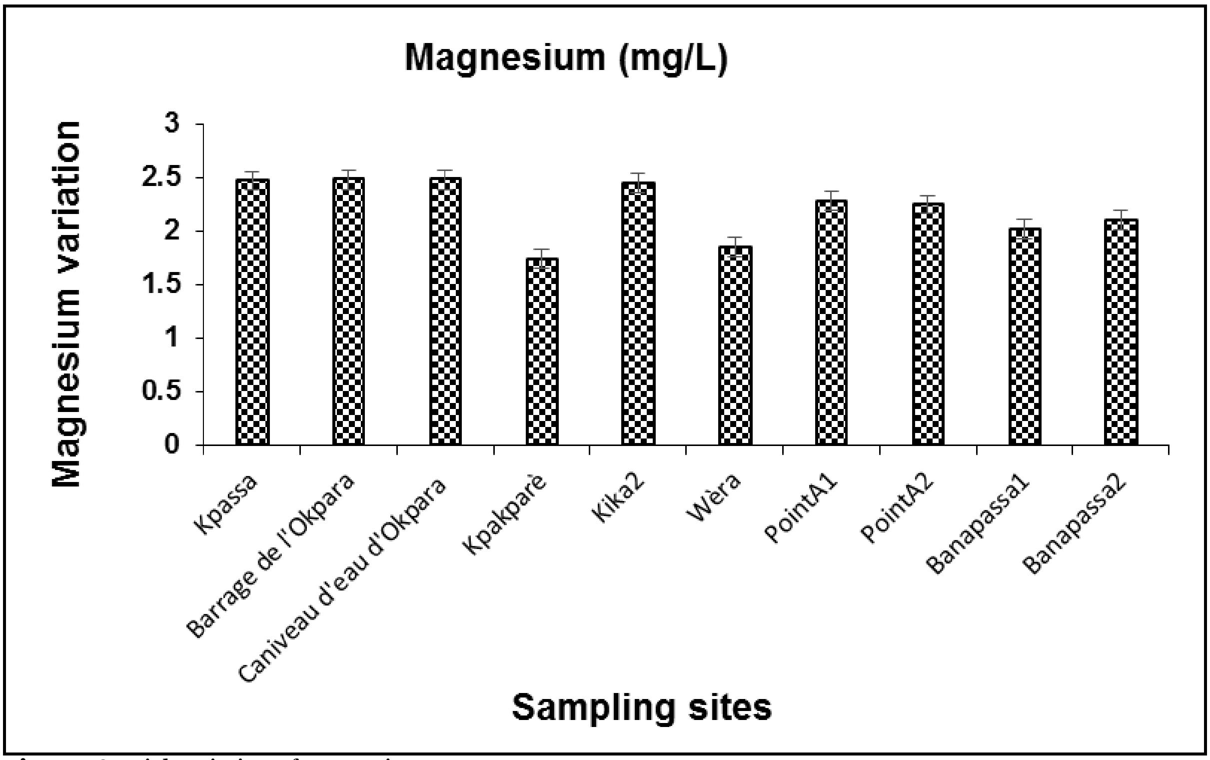

Fig. 13. Spatial variation of magnesium.

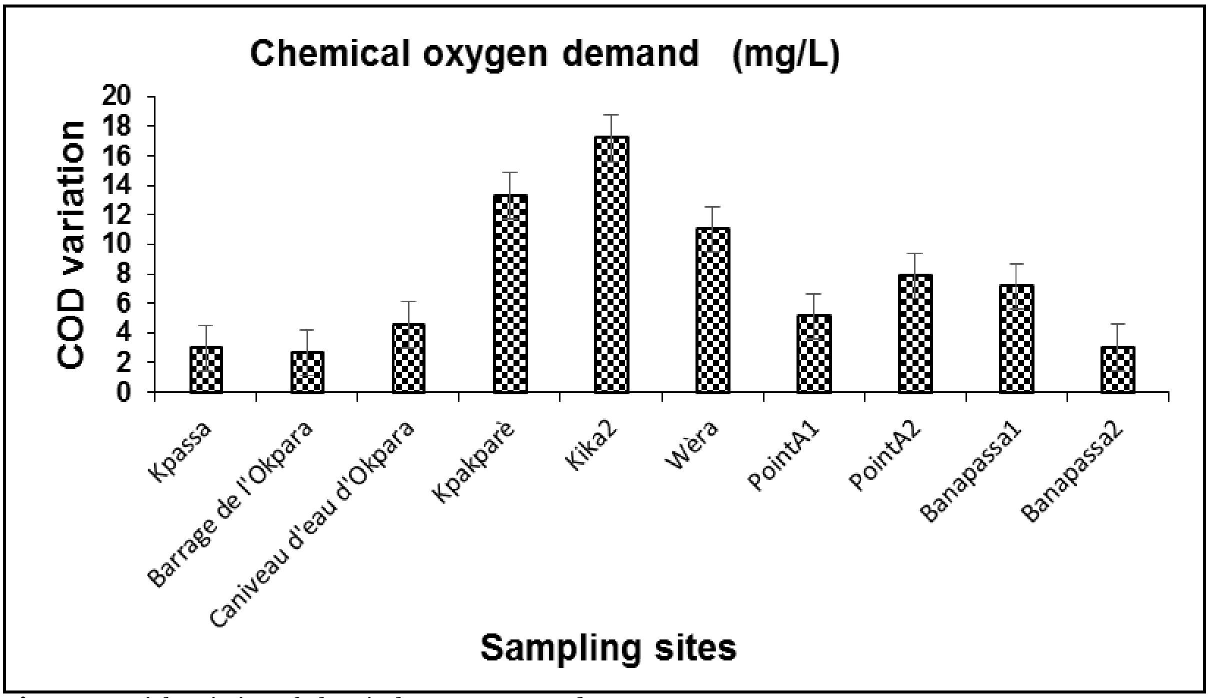

Fig. 14. Spatial variation of Chemical Oxygen Demand.

Turbidity reflecting the water quality for a minimum of 27 NTU and a maximum of 199 NTU exceeds the standards recommended by WHO (2011) and Bénin (2001) which is 61.50 NTU ± 49.26 in our sampling sites. Hence the waters of the Okpara River do not show clarity and are cloudy.

On the other hand, at the nitrate level, the minimum and the maximum vary from 0 mg/L to 2.1 mg/L, which are poorly represented, which is 0.87 mg/L ± 0.73 corresponding to WHO standards (2011) and Bénin (2001). Usually derived from the decomposition of organic matter, nitrates are also synthetically produced by fertilizers (Chapman & Kimstach, 1996) and are one of the factors in the degradation of water quality. With regard to nitrites, with a minimum and a maximum of 0 mg/L to 1 mg/L are very poorly represented in the waters of the Okpara River, i.e. 0.2 mg/L ± 0.42. This average corresponds to Bénin standards (2001) for drinking water and does not correspond to the standards described by WHO (2011). Nitrites are considered as intermediate ions between nitrates and ammoniacal nitrogen, which explains the small quantities encountered in the aquatic environment.

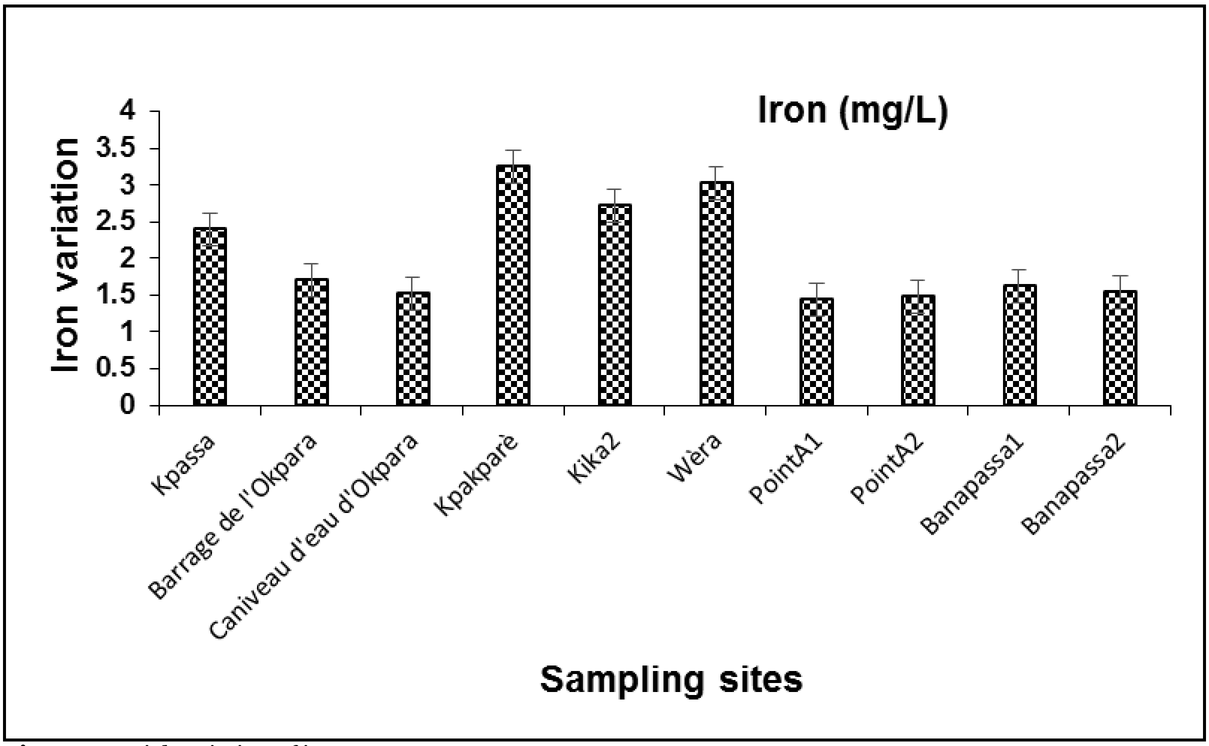

Fig. 15. Spatial variation of iron.

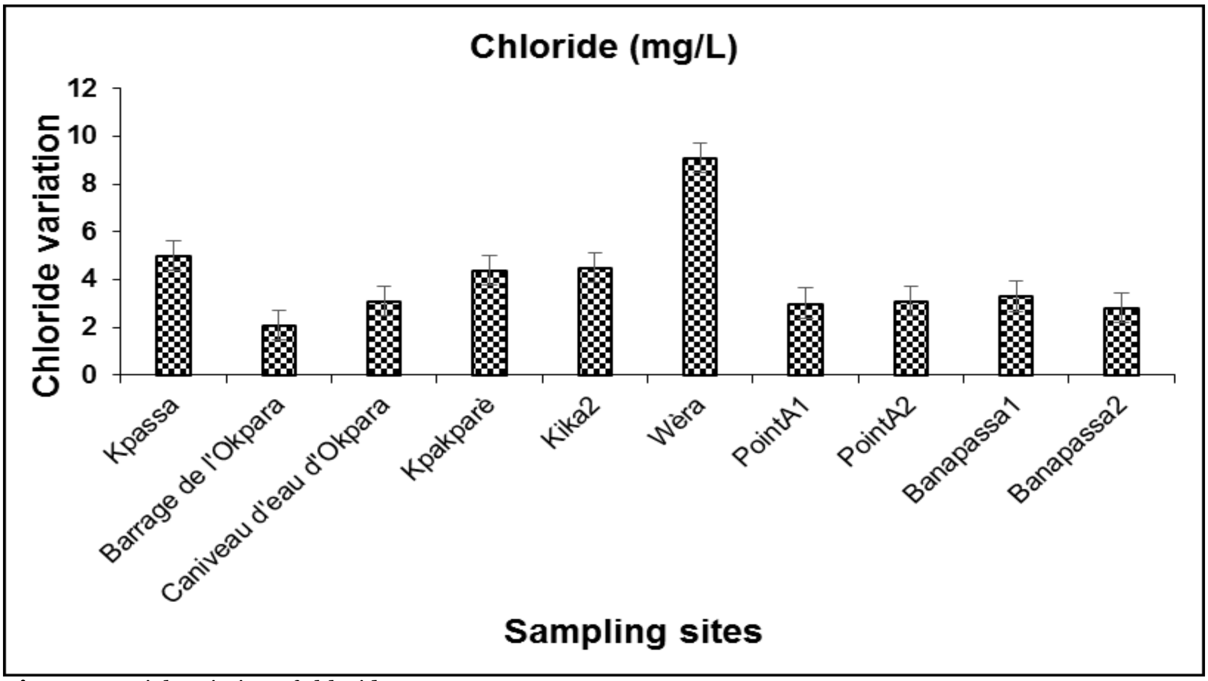

Fig. 16. Spatial variation of chlorides.

This low content is considered normal because nitrites are formed when the conditions are reducing (Ramade, 2000).

Phosphate is poorly represented with a variation of 0 mg/L to 0.149 mg/L, ie 0.03 mg/L ± 0.04 corresponding to the standards required by WHO (2011) and Bénin (2001). Phosphate can degrade and give assimilable compounds by plants and photosynthetic organisms and thus intervenes decisively in the eutrophication phenomena of rivers. So phosphates are involved in the composition of many detergents.

In addition, the calcium and the magnesium are respectively between 0.41 mg/L ± 0.35 and 2.21 mg/L ± 0.27, which is relatively low compared to the standards required by WHO (2011) and Bénin (2001). They conclude that these waters are weakly ionized in calcium and magnesium, which is important for the survival of some plants and fish in water. These results are similar to those obtained by (Ghazali & Zaid, 2013), in their study on the waters of the Salama-Jerri spring in Morocco.

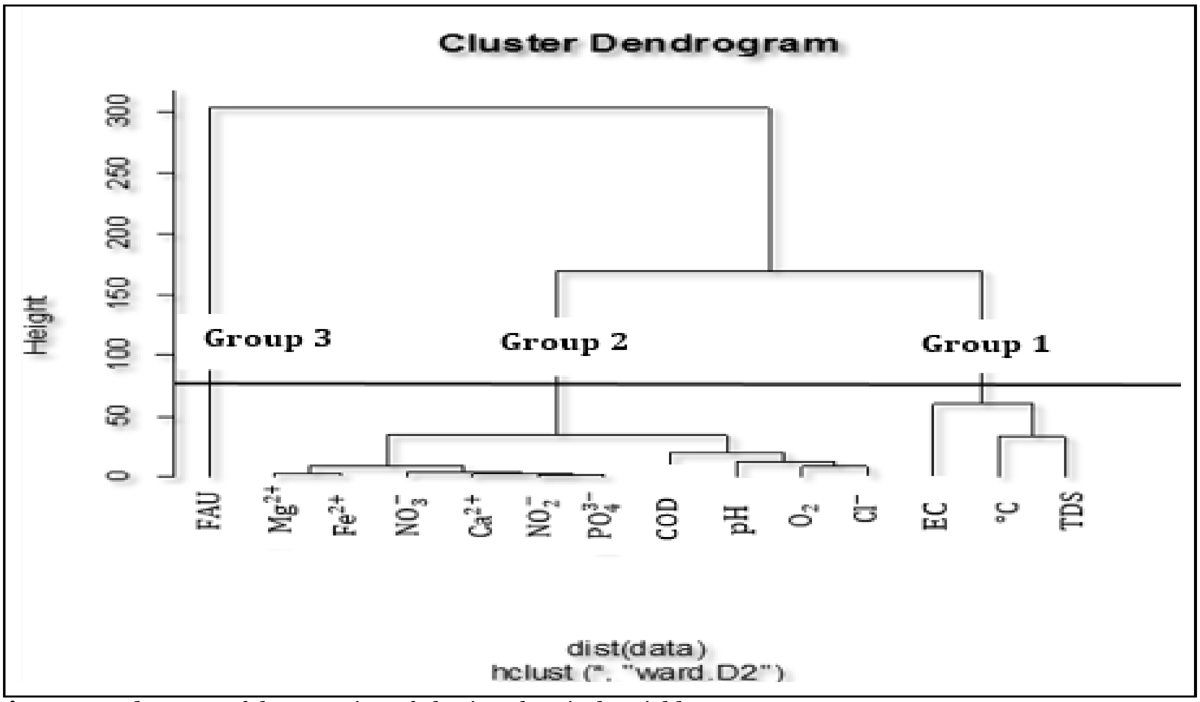

Fig. 17. Dendrogram of the grouping of physico-chemical variables.

The chemical oxygen demand remains on average low, i.e. 7.48 mg/L ± 4.92, which corresponds to the WHO and Bénin standards for a drinking water. These results are very weak compared to those obtained by (Mouni *et al.*, 2009) in their study on the waters of Wadi Soumman in Algeria.

Iron remains in high proportion along the Okpara River, i.e. 2.06 mg/L ± 0.70; significantly above the drinking water standards of Bénin (2001), of which WHO does not have a guide value. These observed values are due to the nature of the soils of the commune, which are ferralitic and have a high iron content.

Finally, chlorides are poorly represented in the waters of the Okpara River, i.e. 4.04 mg/L ± 1.98 compared to the standards of the WHO (2011) and Bénin (2001). We can attribute these low values to the water dilution, but we note that these values are very low compared to those obtained on the waters of Oued Moulouya in Morocco (Makhoukh *et al.*, 2011) even in the rainy season. So the waters of the Okpara River have a low concentration of chlorine.

The waters of the Okpara River have physico-chemical levels that are 71.43% in the standards required for drinking water on the 14 parameters evaluated, i.e. 10/14. Only temperature, dissolved oxygen, turbidity and iron are the exception and do not correspond to the drinking water standards of Bénin and even those of WHO. So we note that the rainy season affects certain parameters such as temperature and ions. During these periods, the temperatures are lower and the precipitation is high, which explains the low temperatures recorded and the low conductivity of the water which is caused by the high dilution of water, these waters becoming less ionized. The ascending hierarchical classification of the variables groups the parameters in different groups: group 1 (temperature), group 2 (subgroup 1: dissolved oxygen and subgroup 2: iron), and group 3: turbidity. By combining the parameters of the groups with the other parameters we can say that the waters of the Okpara River can be of poor quality and will evolve towards a much higher level of pollution.

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