Organic pollution of Ouémé River in Benin Republic

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Abstract:
The objective of this study is to assess the level of pollution of the Ouémé River. Nine physicochemical parameters were measured in nine different stations between March and October 2016, during periods of flood recession and flooding. Methods used were those recommended by the French Association of Normalization (AFNOR).Data were subjected to a univariate descriptive statistical analysis and Principal Component Analysis (PCA). The Leclercq Organic pollution index was used to assess the level of organic pollution. The values of measured parameters indicate a trend to organic pollution on all stations.

Keywords: Water quality, pollution, spatial-temporal variation, Delta of Ouémé.

Introduction

A river is a system comprising both the main course and the tributaries, carrying the one-way flow of a significant load of matter in dissolved and particulate phases from both natural and anthropogenic sources (Shrestha and Kazama, 2006). Rivers play a major role in assimilation or transporting municipal and industrial wastewater and runoff from agricultural land. Municipal and industrial wastewater discharge constitutes a constant polluting source, whereas surface runoff is a seasonal phenomenon, largely affected by climate within the basin (Singh *et al.,* 2004). Polluting elements can also alter the uses of water (Burton and Pitt, 2001). Therefore, the effective, long-term management of rivers requires a fundamental understanding of hydro-morphological, chemical and biological characteristics. The study of water quality in the Delta Ouémé River is necessary since many human activities taking place within its watershed causing anthropogenic stress to environment. Intensive farming, fishing, sand extraction, domestic effluent discharges, construction of roads and dams are among the main disruptions affecting water quality and stream morphology of this River. This result in eutrophication and changes in stand dynamics (Aguilar-Ibarra, 2004, Chikou, 2006). A diagnosis of the current pollution situation and a rigorous follow-up of its evolution are of great importance for the conservation of this ecosystem. In the present study, data obtained are subject to index evaluation and statistical techniques to extract information about the similarities or dissimilarities between sampling sites, and to identify water quality variables responsible for spatial and temporal variations in river water quality.

1. Materials and methods

1.1. Study area

Ouémé River is the largest River of Benin Republic. It is located between 6° 30° and 10° north latitude and 0° 52 'and 3° 05' east longitude. Its main course is about 510 km long. It takes it source in the Tanéka Mountains in the Department of Atacora and receives two main tributaries, Okpara (200 km) and Zou (150 km) (Lalèyè *et al.,* 2004). It crosses several agro-ecological zones and feeds downstream, the lagoon system ''Lake Nokoué-lagoon of Porto-Novo'' through a Delta zone. The lower Delta of Ouémé, part of our study is located between latitude 6° 33'N and 8° 15 'and the meridians 1° 50' and 2° 00 'E (Figure 1). (Zinsou *et al.,* 2016). The lower Delta of Ouémé begins after municipality of Adjohoun in the department of Ouémé and ends at the south facade where the river flows into the lagoon complex ''Nokoué-Porto-Novo'' (Lalèyè *et al.,* 2004). The study area are influenced by the subequatorial climate type, characterized by two rainy seasons and two dry seasons. On the other hand, its hydrological regime depends on the Sudanian climate (north-Benin) with a low water period usually lasts seven months (November to June) and a flood period (July to October) (Lalèyè, 1995). The plant formations along the area are characterized by swamps inhabited by floating plants dominated by water hyacinth (*Eichornia crassipes*), water lily (*Nimphea lotus*), water lettuce (*Pistia stratiotes*) and lemna

(*Lemna pairciostata*). There are also undeveloped marshy forests, dominated by the raphia palm (*Raphia hookeri*) and the oil palm (*Elaeis guineensis*). The part of the valley covered by the water is very productive in fish (Zinsou *et al.,* 2016).

1.2. Sample collection

Nine stations (S_1 to S_9) were selected along Ouémé River because they are accessible and reflect the actual characteristics of the water (Akpadanou (S_1); Affame (S_2) ; Atchonsa (S_3) ; Bonou (S_4) ; Houedja (S_5) ; Akassa (S_6) ; Vodounhoué (S_7) ; Ahlan (S_8) ; Dolivi (S_9). Agricultural and domestic activities identified in the study area were recorded. Water samples were taken during the dry period (March 2016) and during the wet season (October 2016). This last period shows intense rainfall and a violent flood. Water samples were collected in 1 L polyethylene bottles previously rinsed with the water of the station. Water samples were taken at least 2 m from the banks. Samples collected were stored at 4°C in a cooler, and transported to the laboratory immediately for analysis. For each sample, water temperature, electrical conductivity, pH, and total dissolved salts (TDS) were measured *in situ* using a multiparameter WTW 340i. Ammonium ions and nitrites (NO^-_2) were assessed by spectrophotometry methods at the Laboratory for the Quality Control of Water and Food of the National Direction of Public Health (DNSP). The analytical methods used were those recommended by the AFNOR standards (1997) and by Rodier (2009). Chemical oxygen demand (COD) was measured according to AFNOR standard T90-101 (1988) by colorimetric methods. 5-day biochemical oxygen demand (BOD_5) was measured by the OxiTop respirometric method in a BOD meter at 20 °C for five days according to the AFNOR standard T90-103 (1975). The data quality was checked by careful standardization, procedural blank measurements, spiked and duplicate samples.

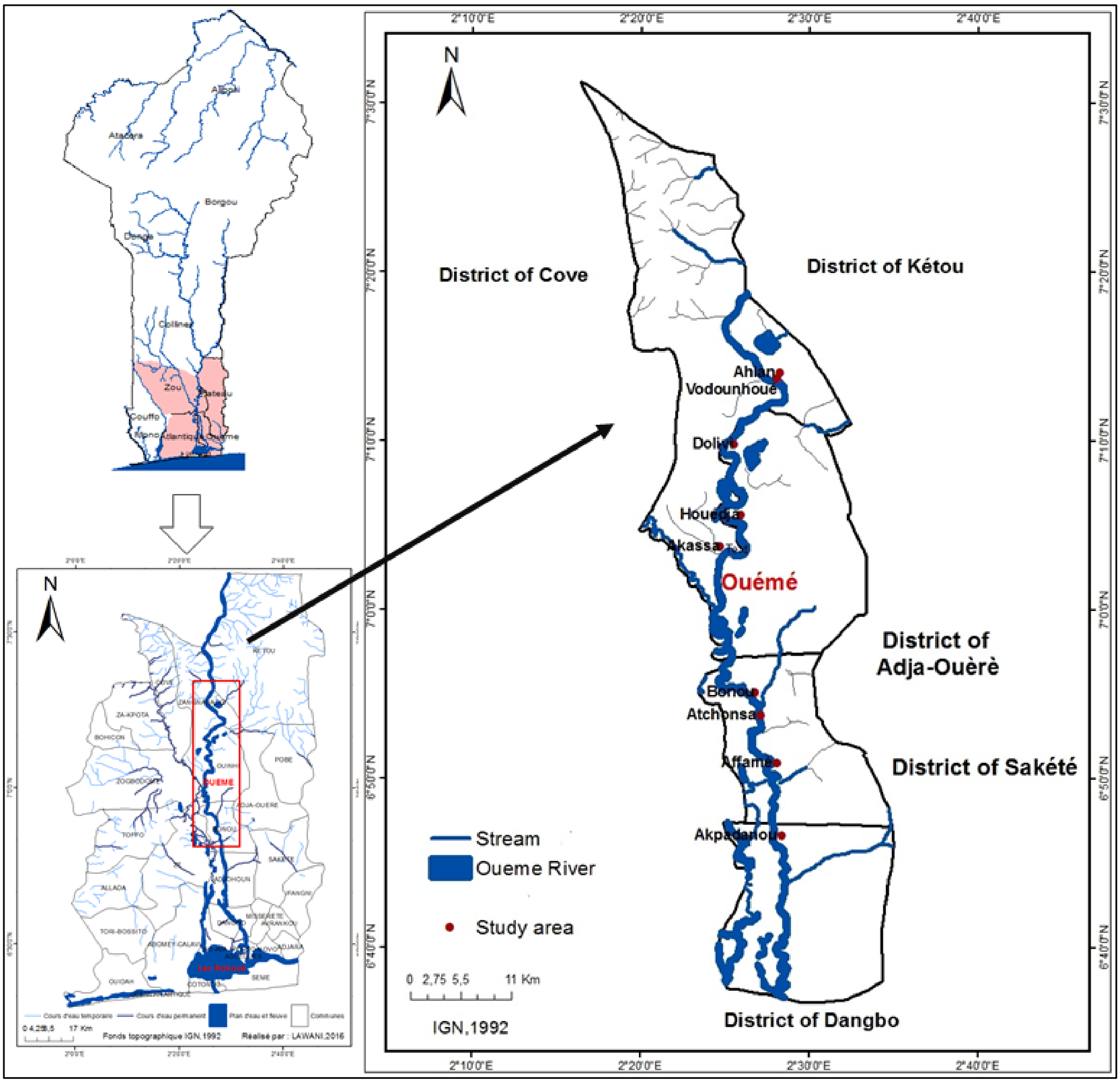

Figure 1: Map of study site and sampling area

1.3. Data processing method

Measured parameters were subjected to univariate descriptive statistical analysis (mean, standard deviation, minimum and maximum) and multivariate statistical methods. In order to establish a relationship between the various physicochemical parameters and to better evaluate the effect of anthropogenic activities on the quality of surface water, a principal component analysis (PCA) was applied to all parameters. This method is widely used to interpret hydrochemical data (El Blidi *et al.,* 2006, El Morhit *et al.,* 2008). The PCA was performed in the Minitab 9.0 software on a data matrix consisting of 9 stations per campaign. The assessment of organic pollution was made using the Organic Pollution Index (OPI) (Leclercq and Vandevenne, 1987) (Table 1).The OPI depends on contents of water in ions ammonium, nitrite and total phosphorus and the BDO5. OPI definite 5 classes of contents for each of these parameters. The IPO is the average of the numbers of the classes of every parameter. The values of the IPO allow to distribute the organic pollutions of water in 5 levels.

Table 1: Class Limits of the Organic Pollution Index (Leclercq, 2001)

Classes	BDO_5 (mgO_2/l)	NH_4 (mg/l)	NO^-_2 (µg/l)	PO^{3-}_4 (µg/l)
5	<2	< 0.1	< 5	< 15
4	2-5	0.1 – 0.9	6-10	16 - 75
3	5.1-10	1 – 2.4	11-50	76 - 250
2	10.1-15	2.5 - 6	51 - 150	251 - 900
1	>15	> 6	> 150	> 900

Table 2: Level of organic pollution of waters according to the Organic Pollution indication

OPI	Level of organic pollution
5.0 à 4.6	Very weak organic pollution (hopeless)
4.5 to 4.0	Weak organic pollution.
3.9 to 3.0	Organic pollution curbed
2.9 to 2.0	Strong organic pollution.
1.9 to 1.0	Very strong organic pollution.

The classification of the organic parameters is made according to five classes of quality corresponding to the generally admitted colors (Adnour, 2001). Measured parameters were evaluated according to the Water Quality Assessment System for Streams (SEQ - Water, France 2003) (Table 2). WHO (WHO, 2004) standards for drinking-water quality have also been taken into account.

Table 3: Limit of classes of physico-chemical parameters of the quality of Surface water (SEQ-Eau, MEDD and Agency of Water 2003, France).

Parameter	Very Good	Good Medium	Medium	Poor	Very Poor
PO_4^{2-} (mg/L)	0-0.1	0.1-0.5	0.5-1	1-2	>2
NO_3^- (mg/L)	0-2	2-10	10-25	25-50	>50
NH4	0-0.1	0.1-0.5	0.5-2	2-5	>5

2. RESULTS

2.1. Physical parameters

The temperature of the Ouémé River recorded ranged from 28.3°C (station S_1) to 29.57°C (S_5 stations) during wet periods. During dry periods, the temperature was between 28.5°C (station S_8) and 35.13°C (station S_5). Temperatures were higher during low water periods (dry season). PH values varied around 4.99 and 6.38 during periods of high level of water. These pH were significantly higher in the low-water period (6.17 and 7.04) with an average value of 6.61. Values of conductivity showed significant variations; they fluctuated between 110µs /cm in station S_9 and 183.33 µs / cm in stations S_3 and S_4 during dry periods and between 80 and 93.33µs / cm during wet periods. The figure 2 showed mean values of 41.7 mg /L in high waters for total dissolved solids. They had a higher average value in low water period (80.7mg /L) (Figure 2). The salinity was zero percent (0 ‰) on all sampled stations during both seasons.

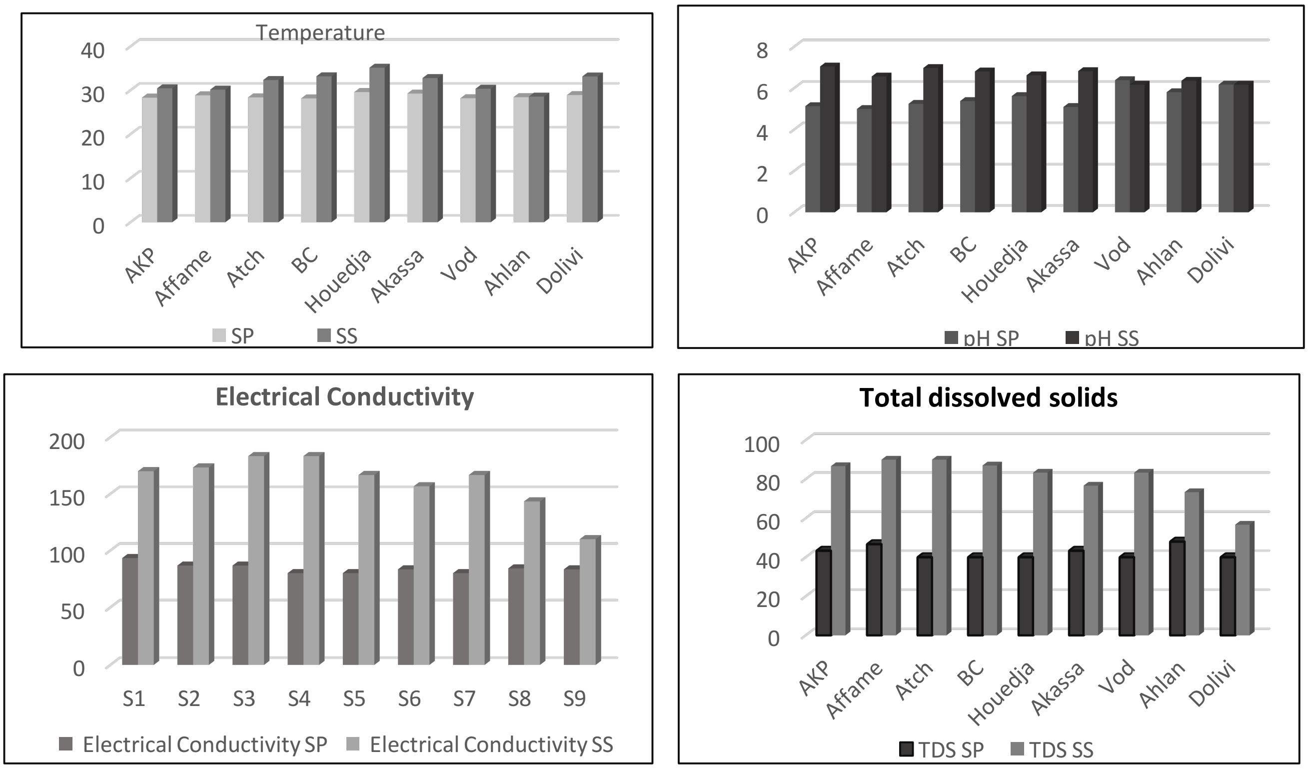

Figure 2: Physical water quality parameters

2.2. Evaluation of biomass

Values of organic pollution expressed in BOD_5 showed insignificant variations between the different sampling campaigns. BOD_5 values ranged from 5.33mg /L to 54 mg /L with an average of 17.41mg /L in the dry season and between 13.67mg /L and 31mg /L in the rainy season (Table 4). COD values showed a significant variation throughout the study period. They ranged from 11.83 mg /L to 110.11 mg /L with an average of 41.56 mg /L in the dry season, while in the rainy season COD values fluctuated between 29.95 and 110.53 mg /L. The concentration of ammonium showed a spatiotemporal variation. Values ranged from 0.06 to 0.26mg /L during high water period (October). In the dry season, values fluctuated between 0.08 and 0.22 mg /L with an average of 0.16 mg /L. Nitrite concentrations was low in both high and low water.

Table 4: Mean values calculated for each physico-chemical variable measured between March and October 2016

Localities	Nitrite(mg/l)	Ammonium(mg/l)	COD(mg/l)	BDO_5 (mg/L)	PO^{3-}_4 (mg/l)
Akpadanou (S_1)	0.00200	0.11	73.47	22.50	4.96
Affame (S_2)	0.01533	0.14	64.97	19.67	3.76
Atchonsa (S_3)	0.00300	0.12	88.11	36.83	5.30
Bonou (S_4)	0.00333	0.09	46.35	20.83	6.06
Houedja (S_5)	0.00317	0.16	69.80	24.67	4.42
Akassa (S_6)	0.00583	0.11	26.35	11.50	4.46
Vodounhoué (S_7)	0.03033	0.19	42.01	18.50	5.72
Ahlan (S_8)	0.00379	0.23	55.75	18.32	8.02
Dolivi (S_9)	0.01550	0.22	6.03	18.16	4.47

2.3. Spatial similarity and site grouping

Principal component analysis was performed to compare the compositional pattern between analyzed water samples and identify the factors influencing each one. The analysis of the results showed that most of information are explained by the first two factorial axes. These two axes described the correlations between variables related to spatial structures, and explained 75.7% of the total information with 47.2% for axis 1 and 28.5% for axis 2 respectively.

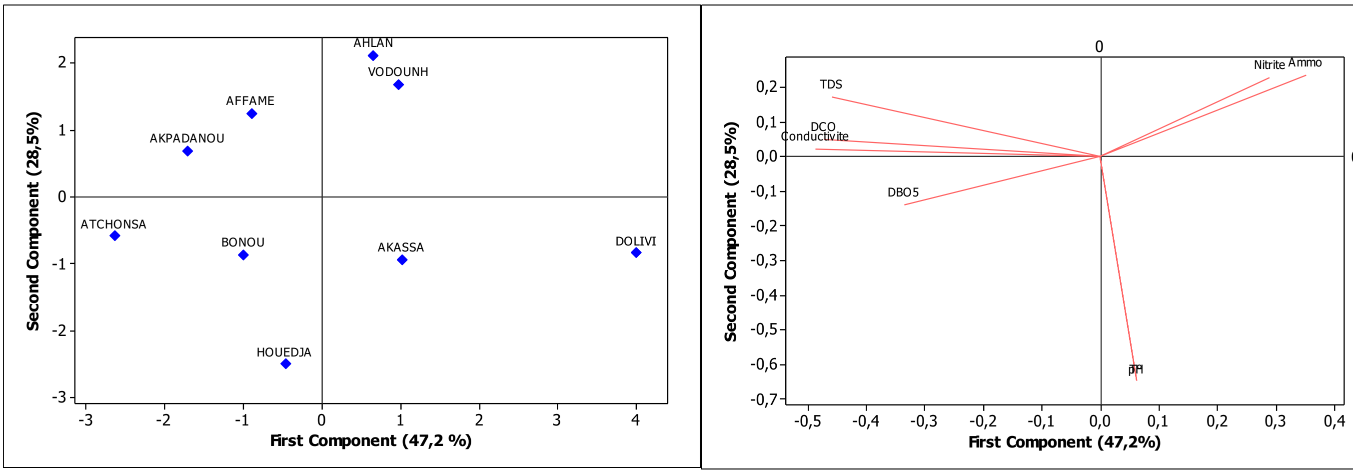

Figure 3: Principal components including all the areas studied

Analysis of correlation of the physico-chemical parameters and their contributions to the axes showed that axis 1 expressed towards its positive pole by ammonium. Conductivity, TDS, COD and BOD_5 are correlated to axis 1 negatively. So stations that record high ammonium values had low values of conductivity, TDS, COD and BOD_5. Axis 2 is defined by the pH and the temperature towards its negative pole. The projection of the different sampling points in the factorial axes showed that Dolivi locality opposes to the localities of Atchonsa and Akpadanou on axis 1 while the locality of Houédja opposes to Affamè, Vodounhoué and Ahlan localities in axis 2. Therefore, it appears that Dolivi locality recorded high ammonium values but low pH values and low water temperature. The locality of Houedja had low ammonium values but records a high pH and temperature. The values of conductivity, TDS, COD and BOD_5 were low in Atchonsa and Akpadanou localities. The localities of Affamè, Ahlan and Vodounhoué showed a non-significant variations of these parameters.

Table 5: Correlation coefficients between the variables and the main axes

Variable	F1	F2
T°	0.062	-0.647
pH	0.062	-0.647
Conductivity	-0.488	0.024
TDS	-0.459	0.173
Nitrite	0.289	0.231
Ammonium	0.352	0.236
COD	-0.473	0.052
BDO_5	-0.335	-0.139

2.4. Assessment of organic pollution

Values of Organic Pollution Index (OPI) and corresponding quality levels are given in Table 6 and figure 3. Overall, these values ranged between 2.25 and 3.75 (strong and moderate organic pollution), 77.77 % of the studied stations had a strong level of organic pollution and 33 % hade a moderate level of organic pollution.

Table 6: Organic Pollution Index (OPI) of stations

Localities	NO^-_2 (µg/l)	NH_4 (mg/l)	BDO_5 (mg/L)	PO^{3-}_4 (µg/l)	OPI	Level of Organic Pollution
S_1	2.00	0.11	22.50	4960	2.75	Strong Organic Pollution
S_2	15.33	0.14	19.67	3760	2.25	Strong Organic Pollution
S_3	3.00	0.12	36.83	5300	2.75	Strong Organic Pollution
S_4	3.33	0.09	20.83	6006	3	Moderate Organic Pollution
S_5	3.17	0.16	24.67	4420	2.75	Strong Organic Pollution
S_6	5.83	0.11	11.50	4460	3.75	Moderate Organic Pollution
S_7	3.033	0.19	18.50	5720	2.75	Strong Organic Pollution
S_8	3.79	0.22	18.32	8020	2.75	Strong Organic Pollution
S_9	15.50	0.22	18.16	4470	2.25	Strong Organic Pollution

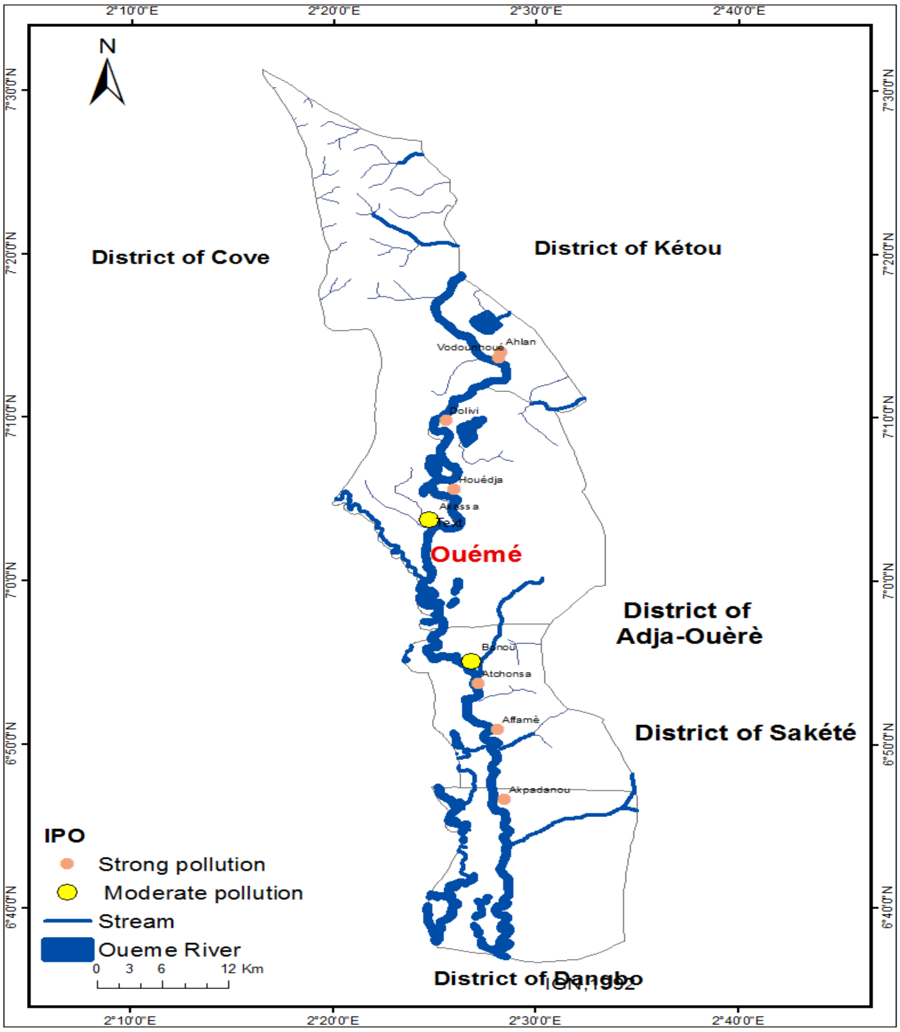

Figure 3: Organic pollution indication (IPO) map of Ouémé River in Benin Republic

DISCUSSION

Analytical results presented in this study indicated that Ouémé River had a good quality of water in terms of its ability to present biological potentialities and for various uses in relation to the standards of the water course assessment system of water (SQE-Water, 2003). The different temperatures recorded were in line of the range tolerated by hot aquatic water (25 to 30° C) species with a slight variation from one station to another. PH is acid at all stations, both during rainy and dry periods. These low pH values may be due to the presence of organic matter in the Ouémé River. Most of the pH values found in this study were outside of the thresholds (6.5 <pH <9.5) of the World Health Organization (WHO). However, according to Arrigon (1976) and Merceron (1999), these found values were in the tolerable limits for most aquatic species (5.0 <pH <9.0). These trends are corroborated by the studies of Chikou (2006) and Zinsou *et al.,* 2016 in the same River. Similarly, low pH values were found by Keumean *et al.,* 2013 on the Comoé River in Ivory Coast during the flood period. The recorded conductivity values showed low mineralization of the water of Ouémé River. All the samples had a conductivity below the threshold of the WHO standard which is less than 400 µs/ cm

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for surface water. The temporal distribution of the electrical conductivity of the studied water samples showed a decrease during the rainy period (Figure 2). This decrease might be due to the dilution of water by raining during this season. Indeed, parameters such as conductivity and TDS were closely related to the nature and concentration of substances dissolved in water. Similar results were found by Akognongbé *et al.,* (2014) at stations in the Ouémé basin at the outlet of Bétérou where the waters sampled upstream of the basin were weakly mineralized. Dianou *et al.,* 2011 also found in its study a weak mineralization of the water of the Niger River in Niamey.
The spatiotemporal profiles of BOD_5 showed the presence of a large organic charge. The temporal evolution of BOD_5 was characterized by higher values during the rainy season. Dilution caused by rainwater remains the decisive factor in this finding. In all stations, the concentration of BOD_5 was relatively high compared to that detected in other sites such as the Ganges River in India where it fluctuates between 2.7 mg /L and5.95 mg /L in the Babughat station and between 0.75 mg /L and 2.8 mg / L in the Gangasar station (Sarkar *et al.,* 2007). The COD showed the presence of a large mineral charge with oscillating mean values. The nitrite concentration was generally low at all stations. These results are similar with those found (nitrite concentration between 0.004 and 0.13 mg /L) by Zinsou *et al.,* (2016) in Ouémé River, and by Uzoukwu *et al.,* (2004) in Ubu River in the Niger Delta in Nigeria. In 2005, Yehouenou-Pazou found also values of nitrite concentration below 0.5 mg /L and only traces in certain stations of Ouémé River. However, these lower values of nitrite could affect the fish health and quality because water containing nitrites can be considered suspicious or even toxic to fish at low quantity. Most of the measured parameters met the standards. Only the COD and BOD_5 parameters indicated moderate organic pollution in all stations studied. In addition, the typological structure revealed by the principal component analysis makes it possible to distinguish a group characterized by an organic pollution (Atchonsa, Akpadanou), a second group characterized by nitrogen pollution and a third group characterized by acid pH and low temperature.

Conclusion

Analyzes carried out showed that Ouémé River are affected strong organic pollution in the majority of stations. This pollution was mainly caused by excess ammonium and high values of biological oxygen demand. The main physical parameters of quality showed values that are relatively compatible with aquatic life. This study highlighted the primordial influence of seasonal variations and anthropogenic activities on the water quality of the Ouémé River in the Upper Delta. These data will be supplemented by taking into account more exhaustive parameters (toxic heavy metals and eutrophication parameters) in future studies.

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