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Assessment of the physico-chemical and biological quality of the Okpara dam in Benin

Ayodélé Shola David Darius Adje*[1], Koudjodé Simon Abahi[1], Hervé Akodogbo[2], Pierre Midogbo Gnohossou[1], Modeste Fadéby Gouissi[1], Zoulkanérou Orou Piami[1], Christelle Madina Tchaou[1], Jeff Okoya[1]

[1]*University of Parakou (UP), Faculty of Agronomy (FA), Laboratory of Ecology, Health and Animal Productions (LESPA), Parakou, Benin*

[2]*University of Abomey-Calavi (UAC), Laboratory of Hygiene, Sanitation, Toxicology and Environmental Health, Interfaculty Center of Training and Research in Environment for the Sustainable Development, Cotonou, Benin*

[3]*University of Abomey-Calavi (UAC), Polytechnic School of Abomey-Calavi (EPAC), Research Laboratory in Applied Biology (LARBA), Cotonou, Benin*

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Abstract

The purpose of this work is to study the macroinvertebrate community and the physico-chemical quality of Okpara dam water, in order to assess the impact of anthropogenic activities. Water sampling and macroinvertebrate sampling were conducted at eight stations along the dam. The organic load in the river and the organization of the macroinvertebrate community have been assessed through the calculation of the Leclercq Organic Pollution Index (IPO) and Shannon diversity indices, Piélou and Simpson equitability. The results revealed a strong organic pollution in the dam of Okpara with strong values of physicochemical parameters. The analysis of the macroinvertebrate community revealed the weak presence of Ephemeroptera, Trichoptera, Plecoptera and the dominance of Diptera and especially of the family Chironomidae. Structurally, the Shannon, Piélou and Simpson Fairness indices indicated a poorly diversified and largely unbalanced stand. These results show that the dam's waters are threatened by domestic effluents and agricultural activities, resulting in the disappearance of several pollo-sensitive taxa. It is therefore imperative to set up a chemical monitoring system that complies with all the standards of protection of the Okpara water reservoir.

***Corresponding Author:** Ayodélé Shola David Darius ADJE ✉ adjedarius@gmail.com

Introduction

Freshwater ecosystems are natural compartments necessary for the continuity of life (Simpi B *et al.*, 2011). Water and wetlands have long shaped the lives of human beings (Tshimbamba, 2005). And as Kamto (1996) states, "water is, with the air, one of the abiotic elements of the biosphere without which all life is impossible". Water is life! Unfortunately, the human activities that develop along the rivers modify the living conditions of aquatic species, whether animal or plant. In the face of this degradation of the water quality, the modification of the morphology of the river and the dynamics of the stands (Aguilar Ibarra A, 2004, Chikou, 2006), it is important to limit the pollution of our water courses since it is paradoxical to understand that water called "source of life" becomes a cause of mortality.

In addition, the design of effective and reliable diagnostic means is necessary for the characterization of the status, aquatic ecosystems, detection of disturbances, prevention, monitoring and opposition to undesirable transformations (US EPA, 1997). For some decades now, the assessment of surface water quality has been based on the measurement of physico-chemical parameters as well as on the presence or absence of bioindicating organisms such as macroinvertebrates. Biological monitoring and physicochemical monitoring of watercourses are complementary methods (Moisan *et al.*, 2013).

Various studies in Benin have focused on macroinvertebrates (Abahi *et al.*, 2018, Adandedjan 2012, Adandedjan *et al.*, 2018) and the bacteriological quality of raw water from reservoirs (Hounsou *et al.*, 2010). However, none of these previous studies highlights the joint use of physicochemical and biological methods to assess the water quality of dams in Benin. The purpose of the study is to evaluate the water quality of the Okpara dam using physicochemical parameters and benthic macroinvertebrates.

Material and methods

Field of study and sampling stations

The Okpara Dam is on the road from Parakou to the Nigerian border (Fig. 1). It is erected on the river of the same name, which represents one of the two main tributaries of the Ouémé River in Benin. It consists of an earth dam and three spillways. The length of the dike is about 480m with an earth part of 365m and a maximum height of 10m. The width of the ridge varies between 10 and 16m and its area is 2070 km². The Okpara River crosses five communes of the Borgou department namely Tchaourou, N'Dali, Pèrèrè, Nikki and Parakou (PNE, 2008).

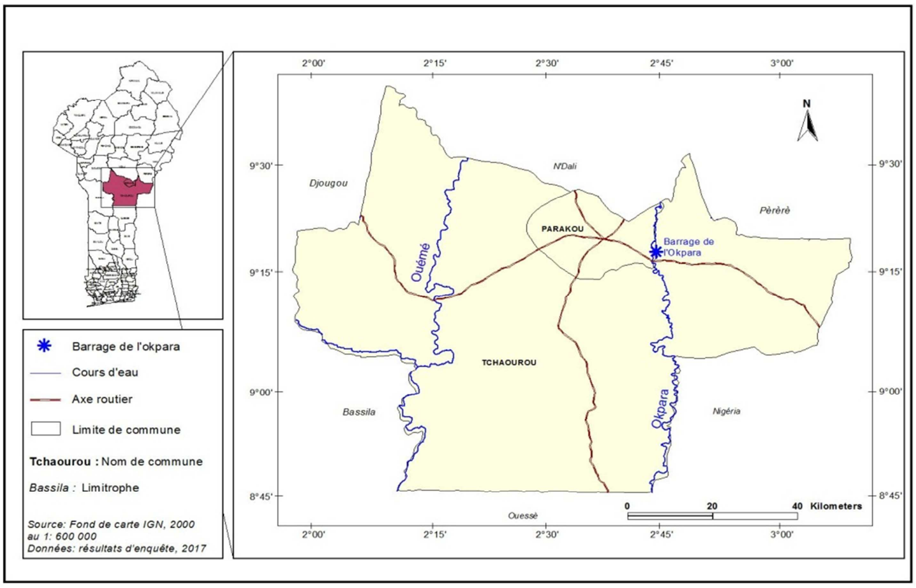

Fig. 1. Map of the communes of Parakou and Tchaourou showing the location of the Okpara dam.

Its catchment consists of a crystalline peneplain with hard rock hills, and the main types of soils encountered are mainly tropical ferruginous soils, ferralitic soils, sandy clay or sandy loam soils, and granitic-gneissic soils. promote the growth of telose trees Afzelia africana, Khaya senegalensis, Pterocarpus erinaceus. The climate is Sudanese with alternating rainy season (May-October) and dry season (November-April). The average annual rainfall is 1,200mm with temperatures ranging from 18°C (December-January) to 38°C (March-April). More than 2,988 inhabitants, mainly Batumbu, Boo, Dendi, Nago and Fulani enjoy the dam and its watershed. Each actor develops his / her activity / interest with its logic, its strategy in order to optimize for its sole benefit the services of water and associated natural resources. For the study, eight (08) sampling stations spread over the entire dam were installed.

Sampling of water samples and physico-chemical analyzes

Physico-chemical parameters such as temperature, conductivity, TDS (Dissolved Solids), pH and dissolved oxygen were measured in situ between 6 and 9 o'clock at all stations. For these measurements the following devices have been used: a portable pH meter (HANNA HI 98107) has for measurement of the pH, the electronic oxygen meter of mark (INOLAB oxi level 2) for the measurement of the temperature (Temp in °C) and dissolved oxygen (Dissolved oxygen in mg / l) and the meter-meter (Pioneer 30 Radiometer Analytical) for measuring conductivity and TDS.

To further investigate in the laboratory, water samples were taken 15 to 30cm below the surface of the water using 500ml plastic bottles. These bottles were stored in an ice-cold box and transported to the Parakou water analysis laboratory. The measured chemical parameters are nitrates, nitrites, ammonium, and phosphate. Table 1 show the devices and methods used for the different analyzes.

Harvesting of benthic organisms

The macroinvertebrates were sampled using a 100m mesh Surber mesh net. The Surber was placed on the bottom of the bed, the opening of the net facing the current and scratches on a few centimeters by hand the substrate, which has the effect of dragging the organisms in the net (AFNOR, 2004). Twelve samples with a unit area of 1/20 m2 were made per station according to the protocol of the IBGN standard (Archaimbault, 2004). The collected organisms are fixed to formaldehyde 5% in labeled jars and are transported to the laboratory.

Table 1. Chemical parameters achieved and reference of the analytical method used.

Parameters	Standard	Appliances used	Methods used
COD expressed in mg O2/l	AFNOR (T90-101).	photometer PalinTest model DR 7500	Dichromate oxidation potassium
BOD_5 expressed in mg O2/l	NF EN 1899 - 1998	BOD-meter	OxiTop method
Nitrites expressed in mg O2/l	NF T 90-012		N-1 method naphthylethylenediamine
Nitrates expressed in mg O2/l	NF T 90-012	spectrophotometer	Sodium salicylate method
Phosphates expressed in mg O2/l	S22-24/25	QW324A	Dosage after oxidation persulfate
Ammonium expressed in mg O2/l	NF T 90-015		Method in blue indophenol

Identification of macroinvertebrates

In the laboratory, the macroinvertebrates sampled were rinsed, sorted and identified under a binocular magnifying glass brand Olympus SZ40. Macroinvertebrates were separated and grouped by taxon from class to family according to the IBGN standard (Archambault, 2010). The taxonomic determination was made with the keys: Aquatic entomology (McCafferty, 1981); Freshwater Invertebrates (Tachet *et al.*, 2000) and Guide for the Identification of Quebec's Principal Freshwater Benthic Macroinvertebrates (Moisan, 2010). After the taxonomic determination, the organisms were enumerated and put back in pillboxes containing 70% alcohol in the laboratory and the faunistic list was established.

Statistical analyzes

Stand study

The organization and distribution of the macroinvertebrate community was measured by the calculation of the richness, abundance, Shannon diversity index (H '), Piélou's equitability index (E) and Simpson's index (D) (Koumba *et al.*, 2017).

Determination of the organic pollution index

The organic pollution index, based on measurements of BOD5, ammoniums, nitrites and phosphates, was used to evaluate the pollution between the different stations (Leclercq, 2001). The grades are divided into (05) five classes of the organic pollution index (Table 2). Following the determination of the class of each pollutant, an average is then made to characterize the pollution (Table 3).

Table 2. Classes of the Organic Pollution Index (OPI) (Leclercq, 2001).

Classes	DBO5 (mg/l)	Ammonium (mg/l)	Nitrites (µg/l)	Phosphates (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 3. Average class and characterization of organic pollution (Leclercq, 2001).

Average classes	Characterization of organic pollution
5,0 – 4,6	Null
4,5 – 4,0	Low
3,9 – 3,0	Moderate
2,9 – 2,0	Strong
1,9 – 1,0	Very strong

Results

Analysis of physicochemical parameters

Table 4 presents the values of the various parameters analyzed by station and according to the season. In fact, the average values of the water temperatures of the Okpara dam obtained vary between 24.16°C and 31.94°C during the dry season while those of the rainy season vary between 23°C and 30°C. Thus, temperatures are higher in the dry season than in the rainy season. The pH values of the Okpara water during the dry season vary between 7.2 and 9.21 with an average value of 7.86, and those of the rainy season vary between 6 and 8.4 with an average of 7.31 . The overall average of the conductivity of the water is 169 µs/cm. The lowest value 76 µs/cm was recorded during the recession at stations 5, 6 and 8 and the highest 186µs/cm during the flood at station 4. The TDS values describe a similar evolution as those of the conductivity.

In addition, the average content of dissolved oxygen is 4.21mg/l. The low value (2.1mg/l) was recorded during low water and the high value (6.3 mg/l) during the flood. The low values of BOD5 and COD (14 and 51mg/l) were recorded during low water and high values (59 and 102mg/l) during the flood. Nitrate levels ranged from 2.08 to 6.41mg/l and those of phosphates ranged from 4.2 to 7.63mg/l. As for nitrites and ammonium, their contents are very low and close to 0mg/l.

Organic Pollution Index (IPO)

The values of the Organic Pollution Index (IPO) and the corresponding quality levels are shown in Table 5. The values of the Organic Pollution Index range from 1.75 (very high organic pollution) to 2.75 (strong organic pollution). Considering the average of the seasons, it appears that all the stations are strongly polluted with low values of the IPO which do not exceed 2.75.

Populations of Benthic Macroinvertebrates

A total of 718 individuals of aquatic macroinvertebrates grouped into 14 families, 11 orders and three classes were recorded in the Okpara dam. Insects with six (06) orders and eight (08) families accounted for 58.91% of total wealth (Fig. 2). Molluscs followed with 32.17% of total wealth, consisting of two orders and three families. Worms (three orders and three families) make up the marginal group with 8.91% of total wealth.

Table 4. Physicochemical characteristics of the waters of the Okpara dam.

Parameters	season	1	2	3	4	5	6	7	8	Average	Min.	Max.
Temp.	Dry	27,33	24,16	31,94	28,05	29,22	28,16	26,44	28	27,91	24,16	31,94
	Rainy	26,3	23	30	28	29,2	28,1	26,2	28	27,35	23	30
Cond	Dry	80	82	102	152	76	76	78	76	90,25	76	152
	Rainy	92	82	126	186	80	90	104	86	105,75	80	186
TDS	Dry	40	40	51	76	38	38	39	38	45	38	76
	Rainy	46	41	63	93	40	45	52	43	52,87	40	93
DBO5	Dry	18	21	49	16	23	19	20	14	22,5	14	49
	Rainy	26	22	59	19	42	31	27	20	30,75	19	59
DCO	Dry	69	74	93	51	79	72	87	68	74,12	51	93
	Rainy	78	85	102	58	86	95	94	86	85,5	58	102
Nitrites	Dry	0,099	0,009	0,002	0,066	0,016	0,023	0,012	0,022	0,03	0,002	0,099
	Rainy	0,03	0,002	0,01	0	0,04	0,001	0,002	0	0,01	0	0,04
Nitrates	Dry	5,28	4,4	3,96	2,08	4,66	4,1	6,41	5,12	4,50	2,08	6,41
	Rainy	3,9	3,8	3,66	3	4,2	3,5	5,2	3,9	3,89	3	5,2
Ammonium	Dry	0,36	1,63	0,41	1,27	1,31	0,92	1,02	0,74	0,95	0,36	1,63
	Rainy	0,3	1,5	0	1,12	1,04	0,2	1	0,1	0,65	0	1,5
pH	Dry	7,16	7,21	8,2	8,62	7,02	8,09	9,21	7,4	7,86	7,02	9,21
	Rainy	6	7,2	7,5	8	6,9	7,2	8,4	7,3	7,31	6	8,4
Oxy Diss	Dry	4,7	3,7	2,1	5,2	3,6	4,1	3,8	4,6	3,97	2,1	5,2
	Rainy	5,2	4	3,9	6,3	4,1	4	4,2	4	4,46	3,9	6,3
Phosphates	Dry	6,24	5,35	5,2	5,65	4,2	7,04	7,63	5,82	5,89	4,2	7,63
	Rainy	6,1	4,3	4,5	5,1	4,3	5,4	7	5,2	5,23	4,3	7

Table 5. Organic Pollution Index (OPI) of stations.

Stations	OPI Dry season	OPI Rainy season	OPI Average	Interpretation of the degree of pollution
Station 1	2	2,25	2,13	Strong organic pollution
Station 2	2,25	2,50	2,34	Strong organic pollution
Station 3	2,75	2,75	2,75	Strong organic pollution
Station 4	1,75	2,5	2,13	Strong organic pollution
Station 5	2	2	2	Strong organic pollution
Station 6	2,25	2,75	2,5	Strong organic pollution
Station 7	2	2,5	2,25	Strong organic pollution
Station 8	2,5	2,75	2,63	Strong organic pollution

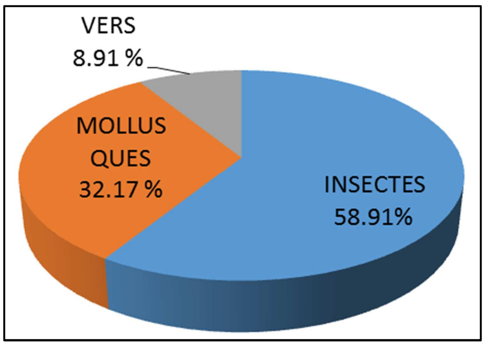

Fig. 2. Relative abundance of the different class of benthic macroinvertebrates recorded.

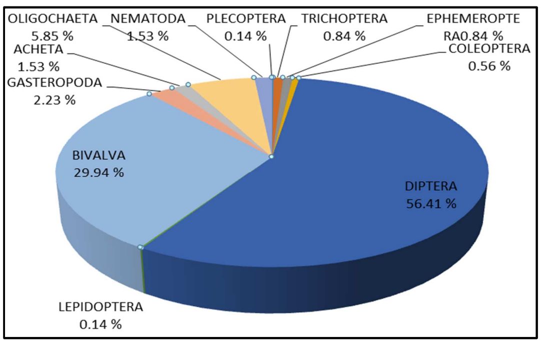

Fig. 3. Relative abundance of the different orders of macroinvertebrates recorded.

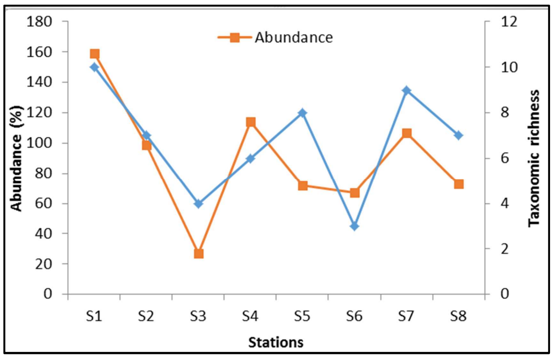

Fig. 4. Structural analysis of the macroinvertebrate stand.

As for the orders (Fig.3), it was the Diptera made up of 56.41% of the total workforce that were the most abundant. Next come Bivalves and Oligochaetes with respectively 29.94% and 5.85% of the total number of individuals harvested. Regarding families (Table 6), Chironomidae were the richest family with 334 individuals or 46.52% of the total wealth. The families of Sphaeriidae, Ceratopogonidae and Lumbriculidae followed with respectively 29.94%, 9.89% and 5.85% of the total wealth. The other ten families of this fauna have less than 2% relative abundance.

Table 6. List of benthic macroinvertebrate taxa harvested from the Okpara dam.

Classes	Orders	Famillies	S1	S2	S3	S4	S5	S6	S7	S8	relative abundance
	Plecopteres	Perlodidae	0	0	0	0	0	0	1	0	0,14
	Trichopteres	Rhyacophilidae	1	0	0	0	3	0	2	0	0,84
	Ephemeropteres	Caenidae	0	0	0	0	0	0	1	0	0,14
Insects		Baetidae	2	0	0	0	3	0	0	0	0,70
	Coleopteres	Elmidae	0	1	0	0	0	0	2	1	0,56
	Dipteres	Ceratopogonidae	18	10	6	9	5	3	9	11	9,89
		Chironomidae	69	60	15	37	10	55	58	30	46,52
	Lepidopteres	Pyralidae	0	0	0	0	0	0	0	1	0,14
Molluscs	Bivalves	Sphaeriidae	34	16	3	54	44	9	29	26	29,94
	Gasteropodes	Hydrobiidae	2	3	0	0	4	0	2	3	1,95
		Viviparidae	2	0	0	0	0	0	0	0	0,28
Vers	Achetes	Glossiphoniidae	3	0	0	6	1	0	0	1	1,53
	Oligochetes	Lumbriculidae	21	6	3	7	2	0	3	0	5,85
	Nemathelminthes	Nématodes	7	3		1	0		0		1,53

Variation in richness and taxonomic abundance

Maximum taxonomic abundance was found at Station 1 (159 individuals) and minimum taxonomic abundance was observed at Station 3 (27 individuals). Station 1 recorded the highest taxonomic richness (10 families) while the lowest taxonomic richness was recorded at Station 6 (03 families).

Structural analysis of the stand of macroinvertebrates

Variations in the Shannon diversity index (H '), Piélou (E) and Simpson equitability are shown in Table 7. The Shannon index ranged from 0.57 bit at station 6 and 1.61 bits at station 1. While Piélou's Equitability showed values that oscillated between 0.51 at station 6 and 0.82 bits at station 3. As for Simpson's index, it varied from 0.30 at station 6 and from 0.73 at station 1.

Table 7. Variation in Simpson's, Shannon's and Piélou's Fairness Indices.

Stations	Shannon Index	Piélou Index	Simpson Index
S1	1.61	0.70	0.73
S2	1.25	0.64	0.59
S3	1.14	0.82	0.61
S4	1.28	0.71	0.65
S5	1.34	0.64	0.59
S6	0.57	0.51	0.30
S7	1.30	0.59	0.62
S8	1.32	0.68	0.67

Discussion

The study of the physicochemical characteristics of the waters of the Okpara dam reveals that the physico-chemical characteristics considered vary in space and time. The temperature of the surface water is used to evaluate its quality. It influences biological processes in aquatic systems (Kadlec, Reddy 2001) and regulates the growth of zooplankton populations (Hong *et al*., 2003). The high temperatures recorded are due to the direct exposure of the water reservoir to solar rays which according to Groga (2012) could increase the rates of chemical and biochemical reactions. These observed temperature values are close to the values recorded for the waters of the warm tropical regions (Konan *et al*., 2017; Villanueva, 2004). They are consistent with those obtained by Lalèyè *et al*. (2003) on the Ouémé delta and by (Abahi *et al*., 2018) on the upper part of the Ouémé river.

The TDS values are proportional to those of the conductivity. The strong TDS values explain the strong anthropic pressure (Mompoint, 2004). The variation of the conductivity (76- 186 µs/cm) and especially the peak observed at the station 4 indicates a strong mineralization and confirms the presence of anions and cations. The maximum measurements recorded during the study are due to the concentration of the ions present in the dam water as a result of the reduction in the volume of the dam (recession). These values thus corroborate those of Chikou (2006) who obtained high values of conductivity during the recession period. This same situation was observed by Aguilar (2004) in the Garonne river basin. This phenomenon has been reported by some authors such as Kambole (2003); Atibu *et al*. (2013); Tshibanda *et al*. (2014) who state that high electrical conductivity also indicates the degree of mineralization of water. PH is a measure of the acidic or basic nature of water. The aquatic life is influenced by the pH which must be between 5 and 9.

The average pH of the dam water (7,86) is within the tolerance range of the fish species. For most aquatic species, the optimal pH range for reproduction is between 6 and 7.2. These values do not differ from those of Chikou (2013) which obtained an average pH of 7.7. Moreover, just like Zinsou (2013), there is a slight variation in pH during the rainy season following the rains that dilute the water.

The COD/BOD5 ratio is often used as a water biodegradability index YAHIATENE (2010). It gives a first estimate of the biodegradability of the organic matter of the effluents. Our analyzes show that, of the 8 stations, only station 4 has a COD/BOD ratio of less than 3. All the others are above the norm which confirms the hypotheses of Mompoint (2004), stating that when the COD/BOD ratio is less than 3, this means that the effluent is easily biodegradable. Of our analyzes carried out during the dry season, only station 3 has a COD/BOD5 ratio less than 3. These high values are, for the most part, due to the leaching of the organic matter accumulated during the dry season (Buhungu *et al.* 2018). As a result, the waters of the Okpara Dam are heavily loaded with organic matter that is not easily degradable. On the other hand, during the rainy season, all eight stations have a ratio less than 3.

Other studies such as those of Gnagne *et al.* (2015) have shown a positive correlation between these two parameters, thus asserting that these two parameters are strongly linked. The average COD and BOD5 concentrations found in this study are for the most part above the river discharge standards set at 80 mg O2/L and 25 mg O2/L (Bli-Effert C. and Perraud). R, 2001). The water reservoir of Okpara does not allow the development of aquatic organisms.

Dissolved oxygen is an important parameter in the assessment of water quality (BUHUNGU 2018). We observed a spatio-temporal variation of dissolved oxygen. During the dry season the minimum value observed is 2.1mg/l. Such water does not allow adaptation of very diverse aquatic species, and only species that withstand high organic pollution resist. This is explained firstly by the fact that the valves of the National Water Company of Benin (SONEB) are closed, thus preventing the current water flow and also it is explained by the fact that the domestic wastes (solid and liquids) are heavily loaded with organic matter that oxidizes by consuming oxygen. This confirms the results of Davonou (2008), which states that the various discharges associated mainly with the contributions of the Cotonou Channel and the Ouémé River contribute to the decrease of its oxygen content. During the rainy season the water was highly oxygenated by runoff as observed in South African river ecosystems by Dallas and Day (2004).

Phosphates are derived from the decomposition of organic matter or agricultural leaching (Khalaf *et al.*, 2007, Saadali *et al.*, 2015) and pose threats to the receiving environment. They come from domestic activities around the dam and their presence promotes the rapid growth of organisms such as algae and lentils. But these macrophytes consume a large amount of oxygen and prevent the penetration of light into the water. The average value of phosphate on the dam is 5.82mg/l (dry season) and 5.2mg/l (rainy season). This finding comforts the observations of Niyungeko (2017) who also reported high phosphate values in the Kinyankonge River. As for other stations, phosphates come from domestic wastewater. Under these conditions, the water then becomes unlivable for other aquatic organisms (fish, shrimp, crabs, MIB) which justifies the low rate of fish production on Okpara, a tributary of upper Ouémé. Nitrites that enter the nitrogen cycle between nitrates and ammonium are very unstable and have very little presence in water. The average nitrite values obtained are low 0.03mg/l (dry season) and 0.01mg / l (rainy season) and are in compliance with Jippeaux (2002) and Zinsou *et al.* (2016) who also found approximate values for nitrite content in groundwater in Niamey and in the Ouémé delta in Benin respectively. it should already be noted that for values close to 0.015mg/l of nitrite, some fish die by hypoxia (Gray *et al.*, 2002). However, Hakmi, (2006) states that any water containing nitrite is considered suspect and should attract the attention of conservators and managers because for values of 0.13mg/l, fish mortality was observed by Zinsou *et al*. (2016) on the Ouémé. Nitrates come from the oxidation of ammoniums to nitrites and then nitrates. The nitrous ion is unstable. It is transformed into nitrates which are the final state of ammonium oxidation (BUHUNGU 2018). Their presence in rivers is due either to the leaching of agricultural soils or to the oxidative reactions of ammoniacal nitrogen and nitrites (Khalaf 2003, Saad *et al*., 2004, Khalaf *et al*. Some studies have shown that when in a river the concentration of ammonium ions is between 0.1-3 mg/l NH4 +, the water is polluted (Belhaouari *et al*., 2017).

The results of the physicochemical analyzes show that the ammoniums have varied from 0.36-1.63mg /l NH4 +. Nitrates are therefore good indicators of organic contamination. The presence of ammoniacal nitrogen in water usually reflects a process of incomplete degradation of organic matter. It results from the first stage of the degradation of the nitrogenous organic matter by bacteria. Ammonium is weakly present in the dam water at a rate of 0.95 (dry season) to 0.65mg/l (rainy season). But it changes rather quickly to ammonia, which is harmful to fish when it enters their gills (Davonou 2008). In all the sampled stations, the ammonium contents are higher than those of the nitrites which results from a process of incomplete degradation of the organic matter.

The low values (1.75-2.75) of the organic pollution index indicate the high organic load on the dam water. These low values of the IPO obtained confirm the high levels of physico-chemical parameters found in this dam. In fact, the leaching of agricultural land and the discharge of domestic effluents generate a strong discharge of organic matter in the waters of the dam and are responsible for the strong organic pollution of the dam water. Similar results were reported respectively by (Zinsou *et al*., 2016) in the Ouémé river delta in Benin and by (Buhungu *et al*., 2018) on the Kinyankonge River in Burundi. The inventoried macroinvertebrate community belongs to the Insect Class (58.91%) of total wealth followed by molluscs (32.17%) and worms (8.91%).

The Order of Diptera is best represented and constitutes 56.41% of the total population followed by Bivalves (29.94%) and Oligochaetes (5.85%). The dominance of Insects and Diptera was also observed in the upper part of the Ouémé River in Benin where insects predominated in the benthic community of this part of the river (Abahi *et al*., 2018), and other similar results were recorded in the Boura hydro-agricultural dam in the Volta Basin in Burkina Faso (Sanogo *et al*., 2014).

In addition, indicator taxa of good water quality (Ephemeroptera Plecoptera and Trichoptera) are very rare in this dam and make only 1.82% of the total wealth. These organisms are known to live in well-oxygenated waters with little pollution at a relatively cool temperature (Touzin and Roy, 2008). In contrast, other taxa known to live in poorly oxygenated waters with a good amount of pollutant at a higher temperature were encountered in this dam. These are Chironomidae (46.52%), Ceratopogonidae (9.89%), Sphaeriidae (29.94%) and Lumbriculidae (5.85%), which are very present in this dam. These taxa are characteristic of aquatic environments disturbed by anthropogenic activities (Tachet *et al*., 2000). Thus, the low presence of Ephemeroptera, Trichoptera, Plecoptera and the dominance of Diptera and especially the families of Chironomidae observed reveals an accumulation of nutrients in the environment, consequences of intense anthropogenic activities (Nuamah *et al*., 2018, Adandedjan, 2012).

The degree of organization of the macroinvertebrate community of the Banco River has been evaluated through the diversity indices of Shannon (H), the equitability (E) of Pielou) and Simpson. The low values of the index of diversity and equitability (Dajoz, 2000) and Simpson (Simpson, 1949) reflect poorly diverse communities with a low degree of organization. Thus, the aquatic macroinvertebrate community of the Okpara dam appears to be very unbalanced with the small values of the diversity and equitability indices observed. Disturbance of the dam by domestic sewage and agricultural effluents disrupts the macroinvertebrate community by promoting the proliferation of pollo-tolerant macroinvertebrates (Chironomidae, Ceratopogonidae, Sphaeriidae and Lumbriculidae) to the detriment of pollen-sensitive macroinvertebrates. Similar results have been recorded on the upper Ouémé River (Abahi *et al.*, 2018), on Toho Lake (Adandedjan *et al.*, 2018) and in Nima Creek in Ghana (Nuamah *et al.*, 2018).

Conclusion and recommendations

This study is a contribution to the assessment of the water quality of the Okpara dam. The results of the analysis of water samples, and macroinvertebrates carried out show that certain physico-chemical parameters of the dam's water, have values that exceed the discharge standards, that the dam waters undergo a strong organic pollution and the macroinvertebrates community is poorly diversified and largely unbalanced. The results reflect the deterioration of the water quality in the dam, as a result of increased inputs of organic matter from agricultural leaching and discharges of domestic effluents. Future investigations should therefore be directed towards a more in-depth study to measure the impacts of this pollution on the biodiversity of this ecosystem and on the external biodiversity that uses the waters of this dam.

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