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Résumé de l'article

Face aux innombrables conséquences de la pollution des cours d'eau par les activités anthropiques, il est nécessaire d'évaluer leur qualité pour une gestion durable. La présente étude vise à évaluer la qualité de l'eau de la partie supérieure du fleuve Ouémé au Bénin à l'aide d'indices biotiques. Au moyen d'un filet Surber, les macroinvertébrés ont été échantillonnés dans quatre stations réparties sur le profil longitudinal de la partie supérieure du fleuve Ouémé. Après la collecte, les macroinvertébrés ont été triés, identifiés et comptés sous une loupe. Au total, 13 ordres et 24 familles de macroinvertébrés ont été capturés dans cette étude. La famille des Chironomidae était la plus abondante. Les résultats de l'indice EPT (éphéméroptères, plécoptères, trichoptères), de l'indice EPT/Chironomidae, de l'indice Hilsenhoff et de l'Indice biologique global normalisé (IBGN) ont révélé que les eaux de la partie supérieure du fleuve Ouémé sont d'une très mauvaise qualité. Les intenses activités humaines dans cette partie du fleuve Ouémé ont entrainé une pollution organique grave, qui a pour conséquence une prolifération des macroinvertébrés polluo-résistants au détriment des polluo-sensibles. Partant de ce fait, des mesures de protection et de récupération doivent être prises afin de préserver et d'améliorer l'état écologique des eaux de la partie supérieure du fleuve Ouémé.

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ASSESSMENT OF THE WATER QUALITY OF THE UPPER REACHES OF THE OUÉMÉ RIVER IN BENIN USING BENTHIC MACROINVERTEBRATE-BASED BIOTIC INDICES

Évaluation de la qualité de l'eau de la partie supérieure du fleuve Ouémé au Bénin par l'utilisation des indices biotiques à base de macroinvertébrés benthiques

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ABSTRACT

To cope with the numerous consequences of stream pollution caused by anthropogenic activities, it is necessary to evaluate the water quality for sustainable management. The present study aims to evaluate the water quality of the upper reaches of the Ouémé River in Benin using biotic indices based on benthic macroinvertebrates. Macroinvertebrates were sampled using a Surber net in four stations distributed over the longitudinal profile of the upper reaches of the Ouémé River. After sample collection, the macroinvertebrates were separated, identified and counted under a stereo-microscope. A total of 13 macroinvertebrate orders and 24 macroinvertebrate families were collected in this study. The Chironomidae was the most abundant family. The results of the Ephemeroptera, Plecoptera, Trichoptera (EPT) Index, the EPT/Chironomidae Index, the Hilsenhoff Index and the Standardized Global Biological Index (IBGN) revealed that the Upper Ouémé River has very poor water quality. The intense pressures from human activities in this part of the river have led to serious organic pollution, which has resulted in the proliferation of macroinvertebrates resistant to pollution to the detriment of those sensitive to pollution. On the basis of this result, protection and recovery measures must be taken to preserve and improve the ecological status of the waters of the upper reaches of the Ouémé River.

***Key words*: macroinvertebrates, biotic indices, water quality, pollution, Ouémé River.**

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RÉSUMÉ

Face aux innombrables conséquences de la pollution des cours d'eau par les activités anthropiques, il est nécessaire d'évaluer leur qualité pour une gestion durable. La présente étude vise à évaluer la qualité de l'eau de la partie supérieure du fleuve Ouémé au Bénin à l'aide d'indices biotiques. Au moyen d'un filet Surber, les macroinvertébrés ont été échantillonnés dans quatre stations réparties sur le profil longitudinal de la partie supérieure du fleuve Ouémé. Après la collecte, les macroinvertébrés ont été triés, identifiés et comptés sous une loupe. Au total, 13 ordres et 24 familles de macroinvertébrés ont été capturés dans cette étude. La famille des Chironomidae était la plus abondante. Les résultats de l'indice EPT (éphéméroptères, plécoptères, trichoptères), de l'indice EPT/Chironomidae, de l'indice Hilsenhoff et de l'Indice biologique global normalisé (IBGN) ont révélé que les eaux de la partie supérieure du fleuve Ouémé sont d'une très mauvaise qualité. Les intenses activités humaines dans cette partie du fleuve Ouémé ont entrainé une pollution organique grave, qui a pour conséquence une prolifération des macroinvertébrés polluo-résistants au détriment des polluo-sensibles. Partant de ce fait, des mesures de protection et de récupération doivent être prises afin de préserver et d'améliorer l'état écologique des eaux de la partie supérieure du fleuve Ouémé.

Mots-clés* : *macroinvertébrés, indices biotiques, qualité de l'eau, pollution, fleuve Ouémé.

1. INTRODUCTION

In developing countries, such as Benin, the demographic explosion, industrialization and agricultural intensification are creating new problems in waste management (solid, liquid) and in the use of pesticides. These untreated wastes are discharged into streams (CHOUTI *et al*., 2010) and more than 99% of used pesticides are spreading through ecosystems to pollute water, soil and air (RICHARDS *et al*., 2015; AGBOHESSI *et al*., 2015). Thus, the environmental disturbances are due to agricultural, domestic and industrial effluents, which deteriorate the populations, cause intoxications and induce biocenotic disturbances, or even the extinction of certain species (AGBOHESSI *et al*., 2015). Nowadays, it is recognized that surface water quality assessment systems should include biological criteria (FISHAR and WILLIAMS, 2008). In fact, the macroinvertebrates are known as good indicators of aquatic ecosystems health because of their sedentary lifestyles, their varied life cycles, their great diversity and their variable tolerance to pollution and to the degradation of habitat (MOISAN *et al*., 2013). They are the most used group as bioindicators in the assessment of the ecological status of aquatic environments (BENETTI and GARRIDO, 2010).

In Benin, the most recent works on the use of benthic macroinvertebrates to assess stream water quality are those of AGBLONON HOUELOME *et al*. (2016) in the middle course of the Alibori River and ZINSOU *et al*. (2016) in the delta of the Ouémé River. The work of CHIKOU *et al*. (2018) evaluated the degree of disturbance of the Alibori River during the rainy season. All of those studies assessing water quality used the Self-Organizing Map (SOM) analysis method, which orders study stations based on environmental variables and taxa association. No studies have been conducted yet to assess the water quality in the upper reaches of the Ouémé River. The Ouémé River is the largest river in Benin and its upper reaches drain a large amount of agricultural, domestic and industrial wastes from the upstream river to its lower part (LALEYE *et al*., 2004; HOUSSOU *et al*., 2017). The upper part of the Ouémé River is affected by the domestic wastewater (washing powder, washing machines and dishes), the agricultural wastewater loaded with pesticides and fertilizers, and by industrial wastewater (HOUSSOU *et al*., 2017). These factors make the water resources of this part of the Ouémé River vulnerable to pollution. Anthropogenic activities are therefore the main cause of the degradation of aquatic ecosystems and have a direct impact on the diversity and structure of macroinvertebrates (AZRINA *et al*., 2006; CAMARA *et al*., 2014; CHIKOU *et al*., 2018). Thus, it is very necessary, even essential, to evaluate the water quality of the upper Ouémé River. The study aims to assess the level of disturbance of the Ouémé River by studying the macroinvertebrate community.

2. MATERIAL AND METHODS

2.1 Study area and sampling stations

The Ouémé River is located between latitudes 6°30' and 10° North and longitudes 0°52' and 3°05' East. With a length of 510 km, the Ouémé River originates from the mountains of Tanéka and receives two main tributaries, Okpara (362 km) and Zou (250 km). The Ouémé River, subdivided into two major parts: Upper Ouémé and Lower Ouémé, runs through several agro-ecological zones and feeds downstream the lagoon system Lake Nokoué - Porto-Novo through a delta area (LALEYE *et al*., 2004). The upper reaches of the Ouémé River, to which our study relates, is bounded by the hydrometric station of the Savè bridge to the south, to the northwest by the Pendjari Basin and the Atacora Chain and in the northeast by the Niger Basin. The upper reaches of the Ouémé River are exposed to the dry Sudanian zone, between 9° and 12° North, where rainfall varies from 900 to 1 100 $mm \cdot a^{-1}$ and the Sudano-Guinean zone, between 8° and 9° North, where rainfall varies from 1 000 to 1 200 $mm \cdot a^{-1}$ (BOKO, 1992). The Upper Ouémé River is affected by three types of pollution sources: domestic (wastewater, laundry, dishes, washing of motorcycles), agricultural (pesticides and fertilizers) and industrial (wastewater from the sugar mill).

The sampling stations were prospected from upstream to downstream on the upper reaches of the Ouémé River (Figure 1). The four sampling stations were selected according to water sustainability, altitude, accessibility in any season, depth (less than 1 m), speed of water current (fairly low), according to the protocol of the IBGN norm (AFNOR, 2004).

2.2 Sampling of macroinvertebrates

The macroinvertebrates were sampled in low water using a Surber net (catching area: 0.05 m^2; net mesh size: 100 µm). The Surber was positioned firmly on the stream bottom facing upstream and a few centimeters of the substrate was scratched. At each sampling station, 12 samples were taken in different habitats (8 in dominant habitats and 4 in marginal habitats), according to the protocol of the IBGN norm (AFNOR, 2004). All collected samples were placed in labeled plastic bottles containing 10% of formaldehyde solution and were transported to the laboratory.

2.3 Identification of macroinvertebrates

Once in the laboratory, the macroinvertebrates from each sampling station were sorted out, carefully rinsed with cleaned water and 70% alcohol preserved. The identification of macroinvertebrates was done under binocular loupe and using appropriate identification guides (MARY, 2017; TACHET *et al.*, 2000; MCCAFFERTY, 1981; MOISAN, 2010). During this operation, the macroinvertebrates were counted, separated according to their morphological appearance and grouped by class, order, and family (ARCHAIMBAULT and DUMONT, 2010).

2.4 Calculated indices

2.4.1 Ephemeroptera, Plecoptera and Trichoptera (EPT) Index

The Ephemeroptera, Plecoptera and Trichoptera (EPT) Index displays the taxa richness within the insect groups which are considered to be sensitive to pollution and therefore should increase with increasing water quality (TOUZIN and ROY, 2008). The EPT Index is equal to the total number of families represented within these three orders in the sample.

2.4.2 EPT/Chironomidae Index

The EPT/Chironomidae index is calculated by dividing the sum of the total number of individuals classified as Ephemeroptera, Plecoptera and Trichoptera by the total number of individuals classified as Chironomidae (GRANDJEAN *et al.*, 2003).

2.4.3 Family Biotic Index (Hilsenhoff Index)

The Family Biotic Index (FBI) was used to assess water quality of various stations. It is based on categorizing macroinvertebrates depending on their response to organic pollution. Family Biotic Index (HILSENHOFF, 1988) was calculated as follow:

$$\text{FBI} = \frac{\sum_i^F n_i t_i}{N} \quad (1)$$

where F is the family number, n_i is the number of individuals in the i^{th} family, t_i is the tolerance value of the i^{th} family, and N is the sum of individuals. The tolerance values of macroinvertebrate families were from HILSENHOFF (1988). The interpretation of the FBI values is described in Table 1.

2.4.4 Standardized Global Biological Index (IBGN)

The calculation of the Standardized Global Biological Index value was as follows:

- Identification of the taxonomic variety class. The taxonomic variety class is the value of the class corresponding to the total number of taxa identified per station (Table 2).
- Identification of the Faunistic Indicator Group (FIG). It is determined by selecting the taxa with the highest degree of sensitivity to pollution in the station sample and following the indications given in the list of indicator taxa (Table 3).
- Calculation of the IBGN value. The IBGN value is calculated using the following formula (AFNOR, 2004):

$$\text{IGBN value} = \text{FIG} + \text{variety class} - 1, \text{ with IBGN} \leq 20 \quad (2)$$

The water quality assessment is performed from table 4 based on the IBGN value.

2.5 Statistical analysis

The Kruskal-Wallis test was used at 5% level of significance to globally compare the biotic index calculated between stations. R software version 3.4.2 was used (R CORE TEAM, 2018).

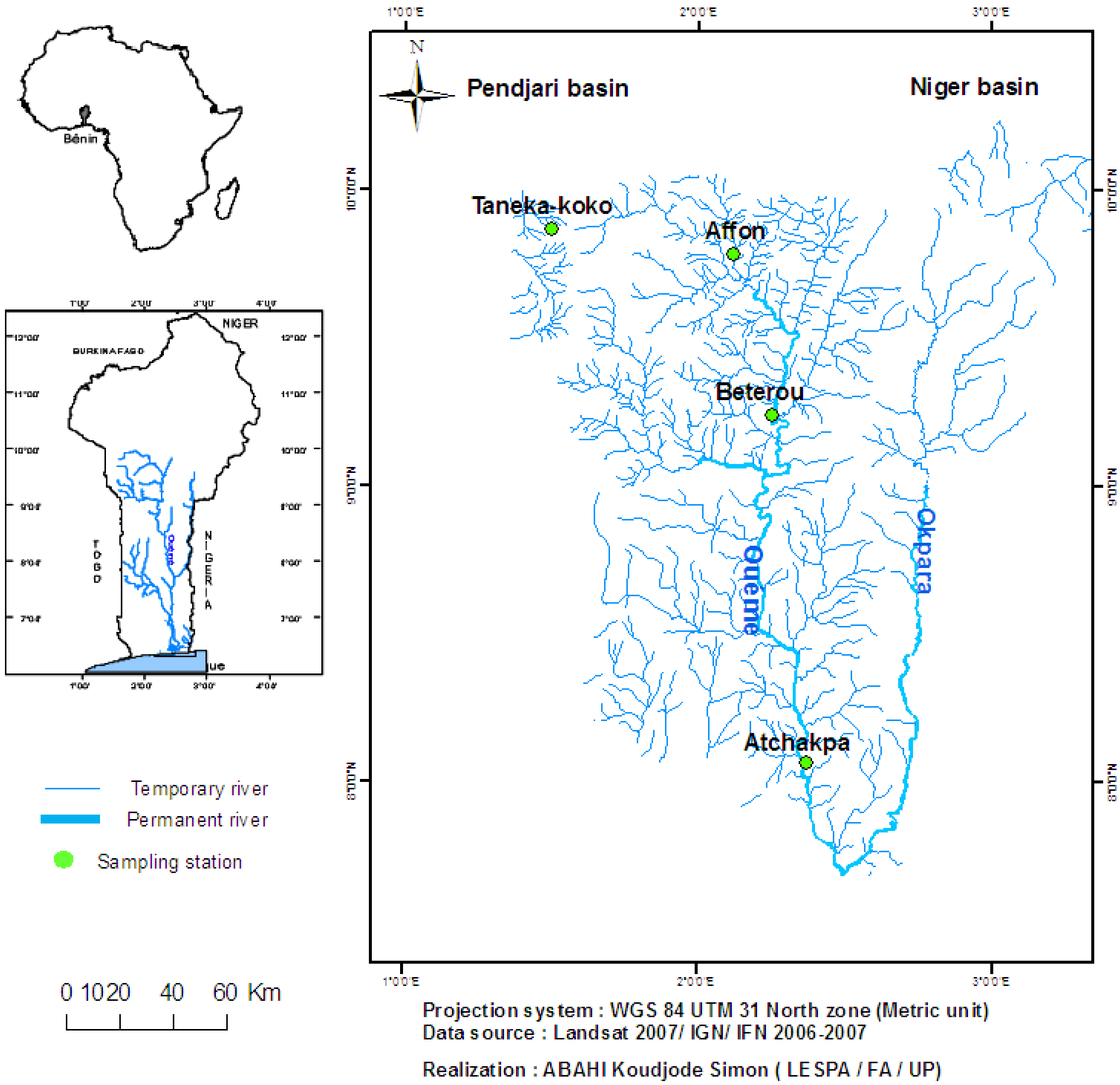

Figure 1. Map of the upper reaches of the Ouémé River showing the sampling stations.
Carte de la partie supérieure du fleuve Ouémé montrant les stations d'échantillonnage.

Table 1. Hilsenhoff Index interpretation scale (HILSENHOFF, 1988).
Tableau 1. Échelle d'interprétation de l'indice Hilsenhoff (HILSENHOFF, 1988).

Family Biotic Index	Water quality	Degree of organic pollution
0.00 to 3.75	Excellent	Organic pollution unlikely
3.76 to 4.25	Very good	Possible slight organic pollution
4.26 to 5.00	Good	Some organic pollution probable
5.01 to 5.75	Fair	Fairly substantial pollution likely
5.76 to 6.50	Fairly poor	Substantial pollution likely
6.51 to 7.25	Poor	Very substantial pollution likely
7.26 to 10.00	Very poor	Severe organic pollution likely

Table 2. Variety classes (ARCHAIMBAULT and DUMONT, 2010).
Tableau 2. Classes de variétés (ARCHAIMBAULT et DUMONT, 2010).

Number of taxa	Variety class
>50	14
45 to 49	13
41 to 44	12
37 to 40	11
33 to 36	10
29 to 32	9
25 to 28	8
21 to 24	7
17 to 20	6
13 to 16	5
10 to 12	4
7 to 9	3
4 to 6	2
1 to 3	1

Table 3. Faunistic indicator group (FIG) (ARCHAIMBAULT and DUMONT, 2010).
Tableau 3. Groupe faunistique indicateur (GFI) (ARCHAIMBAULT et DUMONT, 2010).

Observation scale	FIG	Taxa[a]
	9	Chloroperlidae, Perlidae, Perlodidae, Taeniopterygidae
+	8	Capniidae, Brachycentridae, Odontoceridae, Philipotamidae
	7	Leuctridae, Glossosomatidae, Beraeidae, Goeridae, Leptoplebiidae
Pollution-sensitive	6	Nemouridae, Lepidostomatidae, Sericostomatidae, Ephemeridae
	5	Hydroptilidae, Heptageniidae, Polymitarcidae, Potamanthidae
-	4	Leptoceridae, Polycentropodidae, Psychomyidae, Rhyacophilidae
	3	**Limnephilidae**, Hydropsychidae, **Ephemerellidae**, Aphelocheiridae
	2	**Baetidae**, **Caenidae**, **Elmidae**, **Gammaridae**, Mollusques
	1	**Chironomidae**, **Asellidae**, Acheta, **Oligochaeta**

[a] Taxa in bold represent at least ten individuals (three individuals for other taxa)

Table 4. Standardized Global Biological Index (IBGN) values and ecological interpretation.
Tableau 4. Valeurs de l'Indice biologique global normalisé (IBGN) et interprétation écologique.

IBGN	Color	Ecological quality
20-17	Blue	Excellent
16-13	Green	Good
12-9	Yellow	Medium
8-5	Orange	Low
4-1	Red	Very low

3. RESULTS

3.1 Macroinvertebrates composition

The study has identified 13 orders and 24 benthic macroinvertebrate families. Five classes of benthic macroinvertebrates were harvested. These are insects (7 orders and 17 families), crustaceans (1 order and 1 family), molluscs (2 orders and 3 families), worms (2 orders and 2 families) and Arachnida (1 order and 1 family). Table 5 lists the different taxa of benthic macroinvertebrates captured.

3.1.1 Class of insects

The entomofauna was composed of seven orders. These are Diptera, Ephemeroptera, Odonata, Trichoptera, Coleoptera, Heteroptera and Plecoptera (Figure 2).

3.1.1.1 Order of Diptera

The Diptera families collected during the study constitute 95.8% of the insects and 81.65% of the total abundance. They are the order with the most families and the most individuals. The families encountered are: Chironomidae (2 463 individuals), Ceratopogonidae (452 individuals), Culicidae (67 individuals) and Chaoboridae (4 individuals). Thus, Chironomidae and Ceratopogonidae are the most important families of Diptera and of all families constituting respectively 79.02% and 14.5% of the insects and 67.5% and 12.36% of the total abundance.

3.1.1.2 Order of Ephemeroptera

Consisting of three families: Caenidae (12 individuals), Baetidae (34 individuals) and Potamanthidae (9 individuals), the order of Ephemeroptera represents 1.76% of the insects and 1.5% of the total abundance. The Baetidae are the most represented in this order with 61.82% and followed by Caenidae (21.82%).

3.1.1.3 Order of Odonata

In this order two families were sampled: Calopterygidae and Libellulidae. The Libellulidae count 24 individuals against only one for Calopterygidae. Odonata represent 0.8% of the insects and 0.68% of the total abundance of macroinvertebrates collected.

3.1.1.4 Order of Trichoptera

The order of the Trichoptera composes 0.58% of the insects and 0.49% of the total abundance. Only two families of Trichoptera have been observed namely Philopotamidae with 3 individuals and Rhyacophilidae with 15 individuals.

3.1.1.5 Order of Coleoptera

Coleoptera constitute 0.61% of the insects and 0.52% of the total abundance. The Coleoptera families collected are: Curculionidae, Dytiscidae and Hydrophilidae. The Dytiscidae have 16 individuals and represent 84.21% of Coleoptera.

3.1.1.6 Order of Heteroptera

The Notonectidae is the only family of Heteroptera observed. It has 12 individuals representing 0.33% of the macroinvertebrate richness and 0.38% of the insects.

Table 5. List of macroinvertebrate organisms collected.
Tableau 5. Liste des macroinvertébrés collectés.

Class	Order	Family	Relative abundance (%)
Insects (85.23%)	Plecoptera	Perlidae	0.03
		Perlodidae	0.03
	Trichoptera	Philopotamidae	0.08
		Rhyacophilidae	0.41
	Ephemeroptera	Caenidae	0.33
		Baetidae	0.93
		Potamanthidae	0.25
	Heteroptera	Notonectidae	0.33
	Coleoptera	Curculionidae	0.03
		Dytiscidae	0.44
		Hydrophilidae	0.05
	Diptera	Ceratopogonidae	12.36
		Chaoboridae	0.11
		Chironomidae	67.35
		Culicidae	1.83
	Odonata	Calopterygidae	0.03
		Libellulidae	0.66
Crustaceans (0.16%)	Amphipoda	Gammaridae	0.16
Mollusc (1.07%)	Bivalva	Sphaeriidae	0.14
	Gasteropoda	Hydrobiidae	0.74
		Limnaeidae	0.03
Worms (13.43%)	Oligochaeta	Lumbriculidae	11.81
	Nemathelmintha	Nematoda	1.61
Arachnida (0.27%)	Hydracarians	Hydracarians	0.27
			Total abundance = 3 657

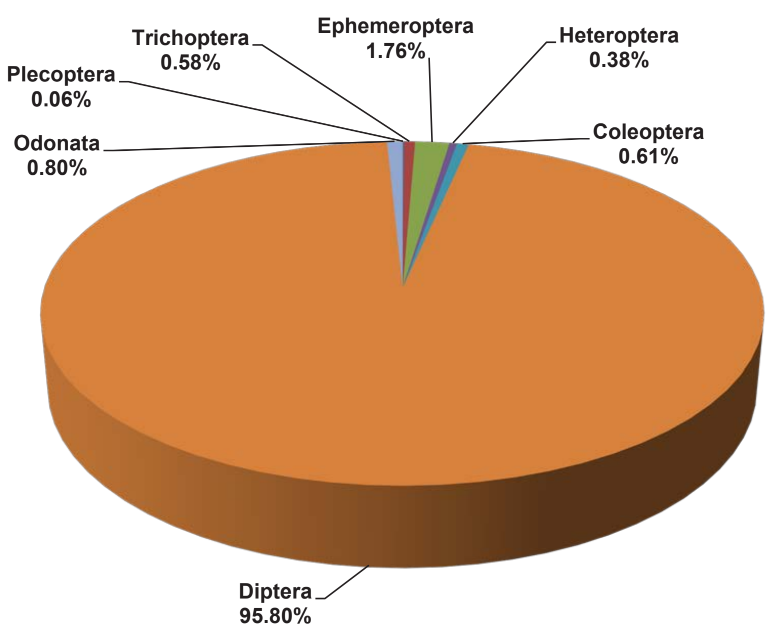

Figure 2. Relative abundance of the orders of the insect class.
Abondance relative des ordres de la classe des insectes.

3.1.1.7 Order of Plecoptera

Two families have been observed in this order: Perlidae and Perlodidae. The Perlidae were caught in Bétérou while the Perlodidae were harvested in Atchakpa. The Perlidae and Perlolidae represent 0.05% of the total abundance and 0.06% of the insects.

3.1.2 Class of crustaceans

The only crustaceans caught are Amphidopa and more specifically Gammaridae. They were sampled at Tanéka-Koko and represent 0.16% of the total abundance.

3.1.3 Class of molluscs

The malacofauna harvested is composed of two orders: Bivalva and Gasteropoda. Bivalva have one family Sphaeriidae, and represent 0.14% of the total macroinvertebrate richness. As for gastropods, they compose 0.77% of the total richness with two families: Hydrobiidae (27 individuals) and Limnaeidae (1 individual).

3.1.4 Class of worms

Worms (13.43% of sampled macroinvertebrates) is the second most represented class with 491 individuals divided into two orders, namely: Nemathelmintha and Oligochaeta. They each have one family, which are respectively: Lumbriculidae (87.98% of worms) and Nematoda (12.02% of worms). In addition, the family Lumbriculidae (11.81% of the total abundance) is the third most important of all sampled families.

3.1.5. Class of Arachnida

Harvested in Affon, Tanéka-Koko and Atchakpa, the Hydracarians constitute the only order of the Arachnida collected. Hydracarians, with 10 individuals, accounted for 0.27% of the sampled macroinvertebrates.

3.2 Variation of EPT and EPT/Chironomidae indices

Table 6 presents the values of the EPT and EPT/Chironomidae indices according to each station. It reveals that the lowest value of EPT was recorded at Affon station (0.13%), whereas the highest value of EPT was observed at Atchakpa station (8.93%). Globally, most of the study stations presented low EPT Index values. These reflect the deterioration in water quality of the upper reaches of the Ouémé River. Furthermore, the EPT/Chironomidae Index values of all stations were very close to zero. This result indicates that the waters of the various stations had poor ecological quality and reveals the level of stress undergone by aquatic ecosystems of the upper reaches of the Ouémé River. The variations observed did not show any significant difference between the different stations ($P > 0.05$).

3.3 Spatial variation of the Hilsenhoff Index

Figure 3 presents the spatial variation of the Hilsenhoff Index. The maximal value of the Hilsenhoff Index was obtained at Bétérou station (7.79) whereas the minimal value was recorded at Affon station (7.06). Besides, the Family Biotic Index (FBI) calculated for the upper reaches of the Ouémé River was 7.56. This high value of FBI indicates that this river has very poor water quality and severe organic pollution. No significant differences ($P > 0.05$) were observed for this index between the different stations.

3.4 Variation of the Standardized Global Biological Index (IBGN)

Table 7 gives the IBGN values from upstream to downstream. It indicates that the water of Affon and Bétérou stations are of very bad biological quality because their IBGN value was 4. The Tanéka-Koko station water is of bad biological quality (IBGN value = 6) while the station Atchakpa has medium biological quality (IBGN value = 9). Moreover, the average value of IBGN is 5.75. As a result, the waters of the upper reaches of the Ouémé River have poor ecological quality. No significant differences ($P > 0.05$) were observed between the different stations.

4. DISCUSSION

The objective of this study was to assess the degree of disturbance of the Ouémé River water by studying the macroinvertebrate community. Thus, 3 657 benthic macroinvertebrate individuals were inventoried during the study. The macroinvertebrate communities of the upper reaches of the Ouémé River are essentially represented by insects (85.23%) with a predominance of the Chironomidae family (67.35%). Therefore, this imbalance is explained by the scarcity of pollution-sensitive taxa which are vulnerable to disturbance and organic pollution. These results corroborate those of IMOROU TOKO *et al*. (2012) and KOUDENOUKPO *et al*. (2017) in Benin freshwaters. The diversity of the Diptera order observed and especially of the Chironomidae family, which is one of the pollution-resistant taxa, reflects the accumulation of nutrients in the river. Indeed, the overabundance of this family shows the high levels of pollution due to multiple anthropogenic activities (FU *et al*., 2016). These activities, located close to the river, have led to high quantities of organic matter discharged from different sources (wastewater, agricultural and industrial effluents) into the river. Therefore, anthropogenic activities caused a disturbance in the benthic communities, the displacement and even extinction of sensitive taxa (KOJI *et al*.,

Table 6. Variation of EPT (Ephemeroptera, Plecoptera, Trichoptera) and EPT/Chironomidae indices between stations.
Tableau 6. Variation des indices EPT (Ephemeroptera, Plecoptera, Trichoptera) et EPT/Chironomidae entre les stations.

Parameter	Station			
	Tanéka-Koko	Affon	Bétérou	Atchakpa
Total abundance	1 017	759	1 108	773
EPT abundance	21	1	4	69
Chironomidae abundance	643	304	834	682
EPT Index (%)	2.06	0.13	0.36	8.93
EPT/Chironomidae Index	0.033	0.003	0.005	0.101

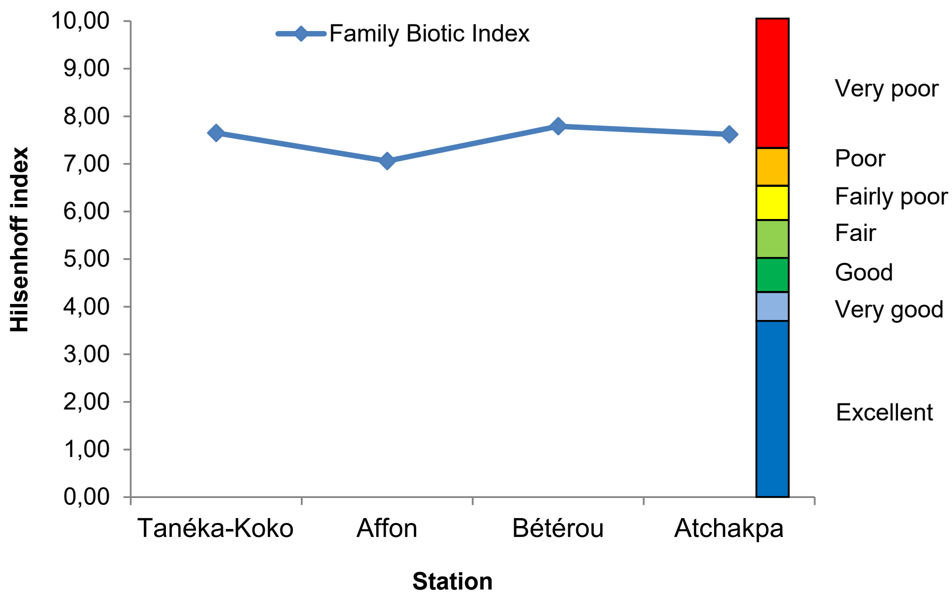

Figure 3. Spatial variation of the Hilsenhoff Index.
Variation spatiale de l'indice Hilsenhoff.

Table 7. Standardized Global Biological Index (IBGN) values and ecological quality of the stations.
Tableau 7. Valeurs de l'Indice biologique global normalisé (IBGN) et qualité écologique des stations.

Parameter	Station			
	Tanéka-Koko	Affon	Bétérou	Atchakpa
Faunistic group indicator	2	1	1	5
Variety class	5	4	4	5
IBGN	6	4	4	9
Color				
Ecological quality	Low	Very low	Very low	Medium

2017; ABBOU and FAHDE, 2017; NURHAFIZAH-AZWA and AHMAD, 2018). These results are confirmed by the low abundance of Ephemeroptera, Plecoptera and Trichoptera at stations located mainly close to crops. Similar works in other rivers indicate a decline in the diversity of pollution-sensitive orders (Ephemeroptera, Plecoptera, Trichoptera) and the best adaptation of families tolerant to pollution by anthropogenic activities (JUN *et al*., 2012; KOJI *et al*., 2017).

The taxonomic richness observed is much lower than that of the studies carried out by SAMON *et al.* (2019) in the Affon River in Benin (49 families). On the other hand, the taxonomic richness obtained is comparable to that of the Mékrou River located in the Beninese cotton basin, where 26 families of benthic macroinvertebrates have been harvested (GOUISSI *et al*., 2020). The difference in taxonomic richness observed between this study and that of SAMON *et al.* (2019) is due to the fact that the Affon River is located upstream of the Ouémé River and would be subject to less anthropogenic pressure. The low taxonomic richness observed would therefore reflect the poor quality of the upper part of the Ouémé River because a high taxonomic richness is an indicator of the good health of a watercourse (MOISAN *et al*., 2013).

Indeed, the low percentage of pollution-sensitive EPT taxa coupled with the dominance of Chironomidae globally indicates that the upper reaches of the Ouémé River is degraded (MOISAN *et al*., 2013). The low values of EPT Index (0.130-8.931) and EPT/Chironomidae Index (0.003-0.101) may reflect a poor quality of the Upper Ouémé River. However, the results obtained in this study are different from those observed in the Affon River (GOUISSI *et al*., 2019), where high values of EPT Index (1.2-23.9) and EPT/Chironomidae Index (0.00-1.5) were obtained. Thus, the low values of EPT and EPT/Chironomidae indices registered in the upper reaches of the Ouémé River are mainly due to anthropogenic activities near the river . According to FOTO *et al.* (2011), the low values of EPT and EPT/Chironomidae indices revealed the level of stress undergone by aquatic ecosystems, which provides suitable conditions for the development of Chironomidae. The Family Biotic Index (FBI) of the upper reaches of the Ouémé River was 7.56, which indicates that the water is of very poor quality and suffers from severe organic pollution. The same observations were made by NUAMAH *et al.* (2018) on Nima Creek in Ghana. The degradation of the water observed can be attributed to untreated agricultural, domestic, and industrial discharges containing organic matter and pesticides (PAN *et al*., 2013; NUAMAH *et al*., 2018). These discharges led to a proliferation of pollution-resistant families to the detriment of pollution-sensitive families. Thus, the preponderance of Chironomidae in harsh environmental conditions for other taxa (Perlodidae, Ephemerellidae) reflects a degraded environment with high values of the Hilsenhoff Index.

Moreover, the Standardized Global Biological Index values calculated at the different stations during the study fluctuate between 4 and 9. This index indicates that the water quality in the upper reaches of the Ouémé River varies between very low and medium level. These low IBGN values obtained reflect the deterioration of the waters of the upper reaches of the Ouémé River and can be attributed to poor ecological quality. ZOUGGAGHE *et al*. (2014) and BEKHOUCHE *et al*. (2017) observed similar results in Boumerzoug and Soummam rivers (Algeria) where organic wastes are constantly discharged into the rivers. On the other hand, contrary results were observed in the Belezma National Park stream in Algeria (BENZINA and BACHIR, 2018) and in the Boufekrane River in Morocco (KARROUCH *et al*., 2017). These different authors found higher values of the Standardized Global Biological Index. The poor quality of the waters reflected by the low values of the IBGN can be explained by water degradation due to anthropogenic disturbances through uncontrolled discharge of wastewater, agricultural and industrial effluents in the river (AZRINA *et al*., 2006; ARIMORO *et al*., 2015). This result has already been found by ZOUGGAGHE *et al.* (2014) during the study of the biological quality of the Soummam River watershed in North-East Algeria.

Furthermore, considering the IBGN, EPT and EPT/Chironomidae indices, the Tanéka-Koko station (upstream) is more degraded than the Atchakpa station (downstream) while the Affon and Bétérou stations (midstream) are the most degraded. However, the Hilsenhoff Index does not seem to be in agreement with the IBGN, EPT and EPT/Chironomidae indices because it indicates that the Affon station (midstream) is less polluted than the Tanéka-Koko (upstream) and Atchakpa (downstream) stations. These results show the need to pay attention to water quality and indicator organisms such as benthic macroinvertebrates in restoration and sanitation programs as they can help in the development and management of aquatic ecosystems.

5. CONCLUSION

The present study inventoried in the upper reaches of the Ouémé River 3 657 macroinvertebrate individuals divided into 13 orders and 24 benthic macroinvertebrate families. The taxonomic composition of the samples analyzed revealed that insects were the most dominant class with a predominance of the Chironomidae family. The high numbers of pollution-tolerant macroinvertebrates in the upper reaches of the Ouémé River testifies to the polluted state of the Ouémé River as all the calculated biotic indices indicated. The poor water quality of the upper reaches of the Ouémé may be attributed to anthropogenic disturbances. Anthropogenic activities affecting the upper reaches of the Ouémé River are responsible for the accumulation of organic matter in this ecosystem. This anarchic enrichment of the environment has led to serious organic pollution of the river and a decrease in the richness of pollution-sensitive macroinvertebrates to the benefit of the pollution-tolerant group. Therefore, certain protection and recovery measures must be taken in order to preserve and improve the ecological status of the waters of the upper reaches of the Ouémé River. These are the elaboration of a sustainable management program for the river, installation of an operational and efficient wastewater treatment plant by the mills, promotion of biological agriculture, education of the population on the importance of water and its quality.

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