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Seasonal Variations in the Water Chemistry and Benthic Macroinvertebrates of a North West Region (Bamenda) Cameroon

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Abstract

Freshwater resources are increasingly being subjected to organic pollution because of the escalating growth of human population which is accompanied by urbanization and the increasing demand for food (Agriculture) and habitat. Consequently, freshwater quality and aquatic ecosystem structure and function are severely affected. The Achichem stream drainage, which flows across the city of Bamenda I and III, North West Region of Cameroon is not an exception. This study, seeks to evaluate the biological and physicochemical state of the Achichem stream of Bamenda. Very little data is available on water quality and diversity of benthic macroinvertebrates of these hydrosystems. Moreover, the real impact of dumpsite Bamenda City Council (BCC) on these invertebrates remains to be determined. The specific objectives are: to determine the physicochemical parameters of the drainage system; the bio-identification of benthic macroinvertebrate communities, indicators of aquatic pollution in Mezam River; to determine the bioindicators of aquatic pollution levels in the savana highlands of the North West Region and to evaluate the relationship between physicochemical and biological community structure and water quality. A total of 06 sampling stations were selected in 3 stations of Achichem streams that flow across the center city of Bamenda I and III. In each of the stations, sampling was carried out each season (dry and rainy seasons). Analysis of abiotic variables showed that, the Achichem streams, prove to be highly polluted according to OPI and reveal higher values of heavy metals, high temperatures, with high mineralization. Regarding the biotic communities, 54 taxa of benthic macroinvertebrates distributed into 3 phyla, 3 classes, 9 orders and 36 families were identified in the two seasons. Considering the relative abundance of benthic macroinvertebrates, it is observed that the two seasons were dominated by Arthropoda. The specific species collected in dry season were Coleoptera (*Cybista* sp., *Peltodytes* sp.), Odonata (*Limnometra ciliate*, *Limnometra* sp., *Ventidius malayensis*), Ephimeroptera (*Procloeon pennulatum*), Trichoptera (*Notonecta Linnaeus*) and Diptera (*Hydropsyche* sp., *Hexatoma* sp.). The specific species collected in the season were Odonata (*Nervosa Rambus*, *Curictini* sp.), Ephimeroptera (*Procloeon pennulatum*, *Anabolia* sp.), Trichoptera (*Brachycentrus* sp., *Chimarra* sp., *Hydropsyche* sp.) and Gastropoda (*Vorticfex* sp.). On the ecological point of view, this invertebrate community is mainly constituted by predators and organisms with gills, highlighting an unpolluted medium. *Limnometra ciliata* (Heteroptera-Gerridae), a species known to be endemic in Northern zones of America, was found in the Achichem stream. The benthic fauna is less diversified and comprises essentially of Dipterans, Molluscs and Annelids, which are, in their majority, tolerant to pollution. These results show a highly polluted urban waterway within the Bamenda I and III.

Keywords

Pollution, Benthic Macroinvertebrates, Bamenda, Indicator Species, Water Quality

1. Introduction

Rivers are ecosystems with great ecological value, with a rich fauna that consists of complex community structures and a high biological value. However, their special typology makes them fragile and vulnerable to environmental changes especially, those related to anthropogenic perturbations which often imply the reversible degradation of their biota [1]. As a consequence, the biodiversity of most rivers will be reduced and their biogeochemical cycles will be altered [2]. One of the major problems affecting rivers is pollution from both domestic and industrial wastes [3]. Pollutants from both urban and agricultural activities exert considerable pressure on aquatic ecosystems which results in the deterioration of the water and habitat's quality on which the aquatic organisms depend [4]. Aquatic organisms integrate various types and degrees of environmental impacts which occur on a variety of spatial and temporal scales [5]. Anthropogenic activities such as settlement, conversion of wetlands into farm land, waste dump sites reduce this ability [4]. Among the fauna of rivers that should be highlighted are macro-invertebrates. Different groups of macroinvertebrates are excellent indicators of human actions, especially contamination. Most of them have quite narrow ecological requirements and are very useful as bioindicators in determining the characteristics of aquatic environments, as well as identify the segments of the polluted river which undergo the process of self-purification [3].

The present study was carried out in Bamenda III municipality, which has experienced a progressive deterioration in its environmental quality as a result of dumpsite Bamenda City Council (BCC) through the service of the Hygiene. When water percolates through waste, it is contaminated by a variety of toxic materials and the resulting contaminated water is called leachate which can contain high levels of pollutants amongst which are ammonia, phosphorus, heavy metals pathogens etc. [6]. The increased pollution of freshwater ecosystems has negatively affected their capacity to provide clean and reliable sources of freshwater, to maintain the natural hydrological cycle and biological food webs, and to provide food and to recycle nutrients. The main objective of this study is to investigate the impact of seasons on the water chemistry and benthic macroinvertebrates assemblage in Achichem streams. The aim was to measure the physicochemical parameters and report on the quality of the water in direct relation to the activities practised along the catchment areas in an urban environment to identify the different species of benthic macroinvertebrates present in the water and to determine the influences of the physicochemical parameters on the macroinvertebrate population present.

2. Materials and Methods

2.1. Study Area

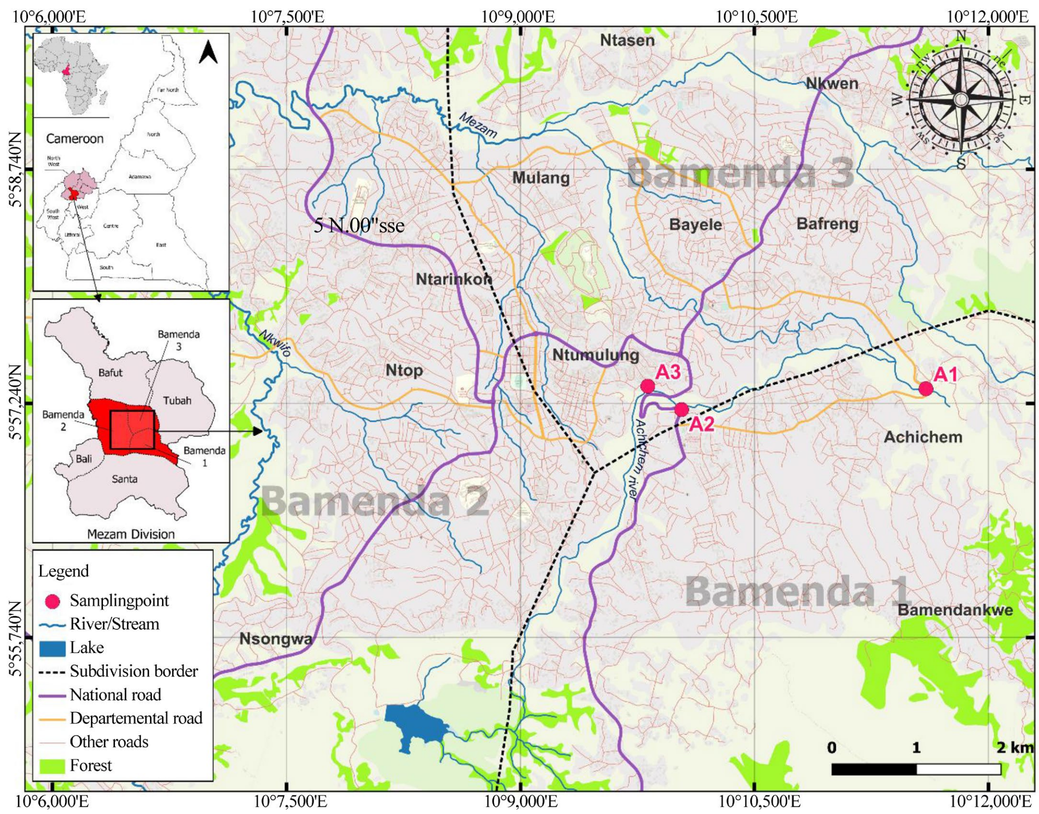

Figure 1. Map of sampling sites chosen along the Achichem stream (source: OpenStreetMap (OMS) 2023; SCR: EPSG4326-WGS84; Software: QGIS 3.28.0 Edited by Stéphane A. NOAH).

This study was conducted in Bamenda, head quarter of the Mezam division in the Northwest Region of Cameroon. With an estimated surface area of about 391 km^2, the city spans between latitude 5˚56 - 6˚00 N and longitude 10˚08 - 10˚12 E. It presents relief of interspersed plateaus with deep valleys and vegetation is the Guinea Savana type with moderate temperatures. There are two topographic units separated by a high scarp oriented NE-SW [7]. Above the cliff, stands the upper plateau which is mainly Bamenda 1 and represents 10% of the total area of the city [8]. Altitudes here vary between 1472 m and 1573 m. The minimum altitude of the lower plateau is 1201 m with the climate being the humid tropical highland type characterized by two seasons; the rainy and the dry season. The rainy season is generally longer and lasts for eight months (mid-March to mid-October) with a short, dry season of four months (mid-October to mid-march) [7] [9]. The stream which was chosen is Achichem stream which flows from Bamenda I through Bamenda III (**Figure 1**).

2.2. Description of Study Sites and Sampling Points

Station one (A1) is located at New-road just before the refuse dumpsite, below the low-cost houses Bamenda. The GPS coordinates are 05˚58'22.2 N and 010˚10'26.97 E with an elevation of 1354 m. This site is less exposed to human impact, as it is found away from households and refuse disposals. The main activity carried out along this water body is farming. It also serves as a laundry site where people carry their clothes from their homes to wash. The stream is a shallow, slow flowing one and mostly made up of stones. The vegetation around the river is of a rich diversity.

Station two (A2) is located in Mballa village. The GPS Coordinates are 05˚57'42.8 N and 010˚1110.9 E, with an elevation of 1205 m. This stream is more of a household stream; it is being surrounded by houses at both sides of the streams. Water is being carried from here to carry out house hold chores like mobbing the floor and laundry. The inhabitants of this community also use this water for farming (Irrigation). Refuse from households are being dumped into this stream.

Station three (A3) is located at two bridges, Nkwen Bamenda, with GPS coordinates as 05˚57'57.4 N and 010˚09'48.9 E, with an elevation of 1172 m. This stream separates two quarters; Ndamukong and Cowstreet. This is the closest station to the Nkwen market amongst the three study stations. It is more of a house hold stream. It has farms surrounding the stream on both sides of the stream.

2.3. Sampling

Water sampling for physico-chemical analyses and benthic macroinvertebrate was carried out from dry to rainy seasons on two by season. The water samples for laboratory analysis were taken, against the current, without bubbles, in 1000 mL polyethylene labeled bottles filled to the brim and double capped; then stored in a refrigerated enclosure and transported to the laboratory. Macroinvertebrate sampling was done following the microhabitat approach proposed by [10] and [11], which consists of a total of 20 net strokes in different microhabitats per station. Macrofauna were collected using a 30 cm × 30 cm beaker, mounted on a 150 cm long steel handle, and fitted with a conical net with a mesh size of 400 μm and 50 cm depth. The choice of microhabitats included bottom sediment types, detritus, anthropogenic wastes, aquatic plants, and the different classes of current velocity at the sampled site. At each station, 20 net strokes were done in different micro-habitats and each stroke consisted of pulling the net over a distance of approximately 50 cm in the opposite direction of the current, *i.e.* an area of about 6 m^2, in a station of about 100 m in length. Specimens were then collected with a pair of fine tweezers and a hand magnifying glass, and fixed in pillboxes containing 96˚ alcohols.

2.4. Measurement of the Physico-Chemical Parameters

In the field, parameters such as temperature (˚C), Dissolved Oxygen (%) and Electrical Conductivity (μS/cm) were measured with an electronic thermometer, a Hach HQ 30d oximeter and a Water test multiparameter respectively. In the laboratory, parameters such as Suspended Solids (SS) (mg/L), Color, Turbidity, Orthophosphates (PO_4^{3-}) (mg/L), Nitrates (NO_3^-) (mg/L), Nitrites (NO_2^-) (mg/L) and Ammoniac Nitrogen (NH_4^+) (mg/L) were measured with a DR/3900 spectrophotometer using the specific reagents. Heavy metals were determined by atomic absorption spectrophotometry (AAS) after acid digestion and filtration following standard procedures for water analysis.

2.5. Identification of Specimens

In the laboratory, the specimens were identified to the lowest possible taxonomic rank (family, genus or species), under a WILD M3B brand binocular stereomicroscope, using taxonomic keys such as those of [12]-[16].

2.6. Statistical Analysis

Prior to statistical analysis, the normality of the distribution of all quantitative data (physicochemical parameters) was tested (Kolmogorov-Smirnov test) and since the normality and homoscedasticity were not satisfied, the non-parametric Kruskal-Wallis and multiple comparisons post hoc tests were subsequently applied to verify significant differences in these variables among the studied types of water bodies and seasons. Organic pollution Index (O. P. I) [17] was calculated based on three parameters NH_4^+ (mg/L), NO_2^- (mg/L) and PO_4^{3-} (mg/L) generally resulting from organic pollution and a synthetic parameter (DBO_5 (mg/L). And the Pearson correlation coefficients were calculated with the physicochemical parameters and for the indicators of biodiversity of benthic macroinvertebrates. Significant or highly significant positive or negative correlations were assumed when the p-calculated value was <0.05 or 0.01, respectively. The diversity of benthic macroinvertebrate communities was calculated by means of multiple metrics based on abundance, richness, dominance of Simpson, Shannon Weaver (H'), and Pielou Equitability (J) at the family level. It was calculated according to the formula:

$H' = -\sum Pi\log 2Pi$, with H' = Shannon and Weaver diversity index: Pi = relative abundance of taxon i; ni = relative abundance of taxon i; N = total abundance.

Piélou's Equitability index (J) was calculated according to the formula:

$J = \frac{H'}{\log 2S}$, with J = Piélou's Equitability; H' = Shannon and Weaver index and S = total number of taxa in the sample.

The data analysis was made with the XL STAT program (version 16.0).

3. Results

3.1. Physicochemical and Quality of Water

Table 1 show the Mean ± SD of the physicochemical parameters of the water quality of Achichem stream, considering the sampling period. The various physical parameters significantly ($P < 0.01$) increased from station A_1 to A_3. The average temperature value obtained throughout the respective stations were; 22.9 ± 0.46 and 24.6 ± 0.94 in the rainy season and 23.9 ± 3.84 and 25.1 ± 0.75 in the dry season. However, no significant difference was observed between the different temperature values.

Table 1. Mean ± SD of physicochemical in rainy and dry season of water quality on the Achichem stream.

	Rain season			Dry season		
Parameters	A1	A2	A3	A1	A2	A3
Temperature (˚C)	22.9 ± 0.46	23.6 ± 0.91	24.6 ± 0.94	24.5 ± 4.39	23.9 ± 3.84	25.1 ± 0.75
Color (Uptco)	52 ± 40.40	252 ± 83.90	404 ± 434.60	134 ±83.90	345 ± 84.10	673 ± 124.30
Turbidity (FTU)	136 ± 1.05	576 ± 72.40	326 ± 6.20	852 ± 15.50	945 ± 6.90	2235 ± 71.80
Suspended solids (mg/L)	2 ± 0.67	25 ± 10.90	27 ± 5.00	8 ± 3.78	15 ± 7.80	35 ± 3.90
Electrical conductivity (µS/cm)	542 ± 2.76	647.1 ± 6.45	720.3 ± 17.30	1456.4 ± 51.53	831 ± 28.57	1626.29 ± 10.13
Dissoved Oxygen (%sat)	45.3 ± 2.65	36.5 ± 1.40	21 ± 6.21	15 ± 2.53	11 ± 3.72	10 ± 2.13
pH (UC)	7.85 ± 0.60	7.82 ± 0.30	7.61 ± 0.30	7.51 ± 0.50	7.54 ± 0.50	7.67 ± 0.30
Alkalinity (mg/L)	12.57 ± 6.78	17.5 ± 11.23	11.2 ± 8.12	16.33 ± 14.67	22.5 ± 12.21	8.5 ± 4.61
DBO_5 (mg/L)	15 ± 9.03	115 ± 105.90	230 ± 78.32	65 ± 55.78	185 ± 44.20	262 ± 121.78
COD (mg/L)	0.3 ± 0.56	2.2 ± 1.01	1.3 ± 0.67	1.1 ± 0.21	2 ± 0.78	3.1 ± 1.42
NH_4^+ (mg/L)	0.12 ± 0.70	3.42 ± 2.60	6.71 ± 4.65	0.45 ± 0.20	4.2 ± 2.60	5.31 ± 3.24
NO_3^- (mg/L)	7.6 ± 3.10	18.7 ± 6.56	29.9 ± 8.56	8.6 ± 5.67	14.1 ± 6.56	19.1 ± 6.12
NO_2^- (mg/L)	0.001± 0.01	0.031 ± 0.04	0.041 ± 0.034	0.005 ± 0.012	0.812 ± 0.125	0.22 ± 0.031
PO_4^{3-} (mg/L)	0.61 ± 0.20	1.59 ± 0.60	0.33 ± 1.3	1.4 ± 0.78	2.3 ± 2.12	2.56 ± 1.89
Cadmium (mg/L)	0.03 ± 0.16	0.23 ± 0.5	1.48 ± 1.45	0.78 ± 0.12	3.71 ± 0.67	7.05 ± 0.23
Lead (mg/L)	0.13 ± 0.32	0.52 ± 0.67	0.72 ± 0.45	0.21 ± 0.05	0.91 ± 0.15	0.67 ± 0.56
Mercury (µg/L)	0	0.001 ± 0.01	0	0	0	0.003 ± 0.02
Arscinic (mg/L)	0	0.01 ± 0.01	0.04 ± 0.01	0.052 ± 0.02	0.78 ± 0.31	1.02 ± 0.52

The parameters such as turbidity, color and suspended solids varied significantly from upstream to downstream ($P < 0.05$). The smallest turbidity value was 136 ± 1.05 FTU recorded at station A_1 at rainy seasons and the largest 2235 ± 71.80 FTU recorded at station A_3 at dry seasons. The color and suspended solids were increasing from upstream (A_1) to downstream (A_3). However, it should be noted that the values were significantly variable between stations. During this study, the lowest color value obtained was 52 ± 40.40 Upt.co recorded at rainy seasons at station A_1 and the highest was 673 ± 124.30 Upt.co recorded at dry seasons at station A_3. As for suspended solids, the smallest value was 2 ± 0.67 mg/L recorded at station A_1 rainy seasons and the large value was 35 ± 3.90 mg/L recorded at station A_3 at dry seasons.

The chemical parameters (pH, electrical conductivity, alkalinity, and disolved oxygen) varied between stations during this study, with significant differences ($P < 0.05$) for parameters such as pH, electrical conductivity and dissolved oxygen. Chemical parameters significantly ($P < 0.01$) increased from station A_1 to A_3 except the alkalinity and pH. Achichem water was basic with overall pH values above 7.5 UC. The lowest value (7.51 ± 0.50) was recorded at station A_1 respectively at rainy seasons. Electrical conductivity values were increasing from station A_1 (upstream) to station A_3 (downstream) in rainy season. The lowest value (542 ± 2.76 μS/cm) was recorded at station A_1 at rainy season and the highest value (1626.29 ± 10.13 μS/cm) was recorded at station A_3 at rainy seasons. Alkalinity evolved in a sawtooth fashion during this study, but overall values remained low around mean values of 11.2 ± 8.12 to 17.5 ± 11.23 mg/L in rainy season. The highest value 22.5 ± 12.21 mg/L was recorded at station A_2 at dry season.

There was low oxygenation of 10 ± 2.13% at station A_3 at dry season and high oxygenation of 45.3 ± 2.65 at station A_1 in rainy season. The values of nitrate, ammonium and orthophosphate ions varied significantly ($P < 0.05$). Nitrate ions remained overall above 7 mg/L at all study stations at all seasons. The lowest value (7.6 ± 3.10 mg/L) was recorded at station A_1 and the highest value (29.9 ± 8.56 mg/L) was recorded at station A_3 in rainy seasons. Ammonia significantly ($P < 0.01$) increased from A_1 to A_3 (upstream to downstream). The means value was 0.12 ± 0.70 to 6.71 ± 4.65 mg/L and 0.45 ± 0.20 to 5.31 ± 3.24 mg/L in dry season.

The lowest value 0.12 ± 0.70 mg/L was recorded at station A_1 in rainy season and the highest value 6.71 ± 4.65 mg/L was recorded at station A_3 at dry seasons. As for orthophosphate the peak mean of 2.56 ± 1.89 mg/L was recorded at station A_3 at dry seasons. However, significant difference was observed between the different nitrites values. The smallest nitrite value was 0.001± 0.01 mg/L recorded at station A_1 at rainy seasons and the largest 0.812 ± 0.125 mg/L recorded at station A_2 at dry seasons.

Organic elements were generally variable at all stations during this study. Significant differences were obtained between the BOD_5 values in the different stations ($P < 0.05$). From this study, it appears that the elements indicating the non-oxidizable organic matter significantly ($P < 0.01$) evolve in a gradual way from the upstream (A_1) to the downstream (A_3). The mean value of oxidizable organic matter elements (COD), fluctuated around 0.3 ± 0.56 mg/L to 1.3 ± 0.67 mg/L in rainy season and 1.1 ± 0.21 mg/L to 3.1 ± 1.42 mg/L in dry season.

The trace metals were generally present at all stations during this study. No significant differences were obtained between the different values. The trace metals significantly ($P < 0.01$) increased from A_1 to A_3 in general except mercury which significantly ($P < 0.01$) increased from A_3. The mean concentration for cadmium fluctuated to 0.03 ± 0.16 mg/L to 1.48 ± 1.45 mg/L in rainy season and 0.78 ± 0.12 mg/L to 7.05 ± 0.23 mg/L in dry season. The smallest mean concentration of Lead 0.13 ± 0.32 mg/L was recorded in station A_1 in rainy season and the highest concentration 0.91 ± 0.15 mg/L was recorded in station A_2 in dry season. Mercury was absent at station A_1 during the two seasosns and present at very low concentrations at stations A_2 and A_3. The highest mean concentration of mercury (0.003 ± 0.02 μg/L) was recorded at station A_3 at dry seasons. The highest mean concentration of Arscinic 1.02 ± 0.52 mg/L was recorded in station A_3 in dry season.

Figure 2 shows the variation of Organic Pollution Index in the Achichem stream from. The OPI index shows that their quality of water is different from upstream (A_1) to downstream (A_3). The level of pollution of water is moderate in station A_1 during the two seasons, and the level of pollution of water is high and very high in station A_3 during rainy and dry seasons respectively according to the Leclerf gri. At the rainy seasons the lowest value (1.75) was recorded at station A_3 and the highest value (3.25) was recorded at station A_1. In the dry seasons the lowest value (1.25) was recorded at stations A_2 and A_3, the highest value (2.75) was recorded at station A_1.

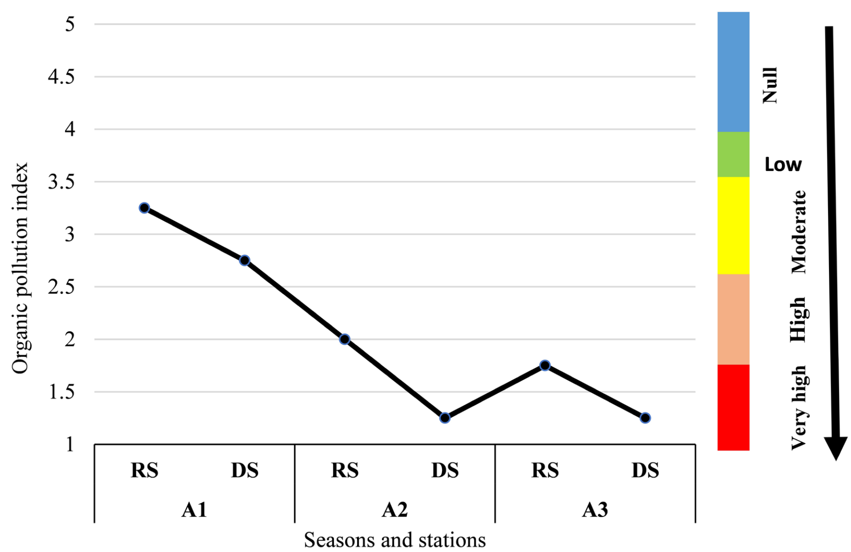

Figure 2. Spatial variation of organic pollution index of the Achichem stream during the study period.

3.2. Population Dynamics of the Benthic Macroinvertebrates

Table 2 shows the list and the abundance of benthic macroinvertebrates taxa collecting during this work. A total of 3889 individuals were sampled in the rainy season accounting for 60% of total individuals sampled during the period of study. 2549 individuals were sampled in the dry season which accounts for 40% of the total individuals sampled. More species were recorded in the rainy season than in the dry season during the period of study. A total of 54 morphotypes were counted and identified belonging to 53 genus, 36 families, 9 orders, 3 classes (Insects, Achaeta and Gastropoda), and 3 phyla (Arthropoda, Annelida and Mollusca). In the two seasons the class of Insects dominated with 7 orders, 34 families and 49 taxa following by that of Gastropoda counting a single order, 2 families and 3 species. In the Achichem stream, macroinvertebrate communities are dominated by *Caenis femina*, *Procloeon pennulatum*, *Chironomous* sp., *Helobdella stagnalis*, *Petrophysa zionis* and *Archephysa lordi* during the rainy season. And by *Calopteryx maculata*, *Tramea* sp., *Chironomous* sp, *Radotany florens*, *Petrophy zionis* and *Archephysa lordi* during the dry season. The most diversified Order was Odonata with 12 taxa, followed by Diptera with 11 taxa, Ephimeroptera, Coleoptera and Ephimeroptera 8 taxa, Trichoptera and Basommatophora with 5 taxa respectively.

Table 2. List and abundance of benthic macroinvertebrates taxa sampled on the Achichem stream (A_1, A_2 and A_3 sampling points) during the study period.

Phylum	Class	Order	Family	Genus	Species	Achichem Stream					
						A1		A2		A3	
						RS	DS	RS	DS	RS	DS
Arthropoda	Insecta	Coleoptera	Gyrinidae	*Gyretes*	*Gyretes* sp.	0	3	0	0	2	0
				Gyrinus	*Gyrinus* sp.	1	0	0	0	0	2
			Dytiscidae	*Cybista*	*Cybista* sp.	0	6	0	0	0	0
				Copelatus	*Copelatus* sp.	0	3	0	0	5	0
			Dryopidae	*Dryops*	*Dryops* sp.	1	0	0	0	2	1
			Salpingidae	*Aegilites*	*Aegilites* sp.	7	4	0	1	7	2
			Haliplidae	*Peltodytes*	*Peltodytes* sp.	0	3	0	0	0	0
			Elmidae	*Lara*	*Lara* sp.	5	0	0	0	0	2
		Odonata	Libellulidae	*Pantala*	*Pantala falvesceus*	17	27	1	22	18	38
				Tramea	*Tramea sp*	11	40	9	31	49	43
			Coenagrionidae	*Nehalennia*	*Nehalennia spaciosa*	0	0	3	1	7	1
			Calopterygidae	*Calopteryx*	*Calopteryx maculata*	27	30	10	47	106	51
				Hetaerina	*Hetaerina titia*	20	22	4	29	60	38
				Hetaerina	*Ventidius pulai*	4	3	0	0	0	0
			Gerridae	*Limnometra*	*Limnometra ciliata*	0	1	0	0	0	0
					Limnometra sp.	0	3	0	0	0	0

Continued

		Ventidius	*Ventidius malayensis*	0	8	0	0	0	0
	Aeshnidae	*Gynacantha*	*Nervosa Rambus*	3	0	0	0	0	0
		Nepa	*Nepa* sp.	3	11	3	3	1	1
		Curictini	*Curictini* sp.	0	0	0	0	2	0
Hemiptera	Nepidae	*Ranatra*	*Ranatra fabricius*	0	1	0	0	2	10
	Veliidae	*Rhagovelia*	*Rhagovelia mayr*	0	0	16	6	0	0
		Abedus	*Abedus* sp.	6	3	11	4	15	0
	Belostomatidae	*Belostoma*	*Belostoma latreille*	30	18	12	18	64	30
	Naucoridae	*Pelocoris*	*Pelocoris shoshone*	11	0	0	0	9	2
Ephimeroptera	Caenidae	*Caenis*	*Caenis femina*	63	0	101	64	66	29
	Macroveliidae	*Macrovelia*	*Macrovelia hornii*	0	0	0	13	0	14
	Siphlonuridae	*Brachycerus*	*Brachycerus* sp	41	0	52	33	13	14
		Siphlonurus	*Siphlonurus* sp.	2	0	0	0	0	0
	Polymitalyiidae	*Ephoron*	*Ephoron* sp.	7	3	5	12	13	11
	Baetidae	*Procloeon*	*Procloeon pennulatum*	112	0	223	0	43	0
	Limnephilidae	*Anabolia*	*Anabolia* sp.	4	0	1	0	0	0
	Baetidae	*Procloeon*	*Procloeon pennulatum*	0	0	0	46	0	5
Trichoptera	Brachycentridae	*Brachycentrus*	*Brachycentrus* sp.	7	0	2	0	0	0
	Philopotamidae	*Chimarra*	*Chimarra* sp.	5	0	0	0	0	0
	Notonectidae	*Notonecta*	*Notonecta Linnaeus*	0	3	0	0	0	0
	Hydropsychidae	*Hydropsyche*	*Hydropsyche* sp.	68	0	2	0	12	0
Plecoptera	Perlolidae	*Clioperla*	*Clioperla llio*	23	13	1	0	0	0
Diptera	Dolichopodidae	*Rhaphium*	*Rhaphium campestres*	0	0	3	3	0	2
		Dictya	*Dictya pictipes*	3	0	1	0	0	0
		Ilybius	*Ilybius* sp.	2	0	0	0	0	0
		Sepedon	*Sepedon* sp.	1	0	8	0	0	0
	Hydropsychidae	*Hydropsyche*	*Hydropsyche* sp.	0	0	0	0	0	8
	Sciomyzidae	*Tetanocera*	*Tetanocera vicinan*	8	0	2	3	0	0
	Syrphidae	*Eristalis*	*Eristalis tenax*	3	0	10	2	4	9
	Tipulidae	*Tipula*	*Tipula eluta*	3	0	2	1	0	0
		Hexatoma	*Hexatoma* sp.	0	0	0	1	0	0
	Simullidae	*Simulium*	*Simulium* sp.	36	0	25	67	12	6
	Chironomidae	*Chironomous*	*Chironomous* sp.	146	27	568	401	491	611

Continued

Annelida	Achaeta	Rhynchobdellida	Glossiphoniidae	*Helobdella*	*Helobdella stagnalis*	18	11	77	19	63	12
				Haementeria	*Haementeria Costata*	9	30	4	0	30	0
Mollusca	Gastropoda	Basommatophora	Physidae	*Archephysa*	*Archephysa lordi*	0	0	608	0	109	0
				Petrophy	*Petrophy zionis*	0	15	172	63	37	83
				Archephysa	*Archephysa lordi*	0	37	0	203	0	106
			Planorbidae	*Vorticfex*	*Vorticfex* sp.	0	0	4	0	0	0
				Taxonomic richness		**34**	**25**	**30**	**25**	**27**	**26**

3.3. Seasonal and Spatial Variation of the Main Benthic Macro Invertebrate Orders

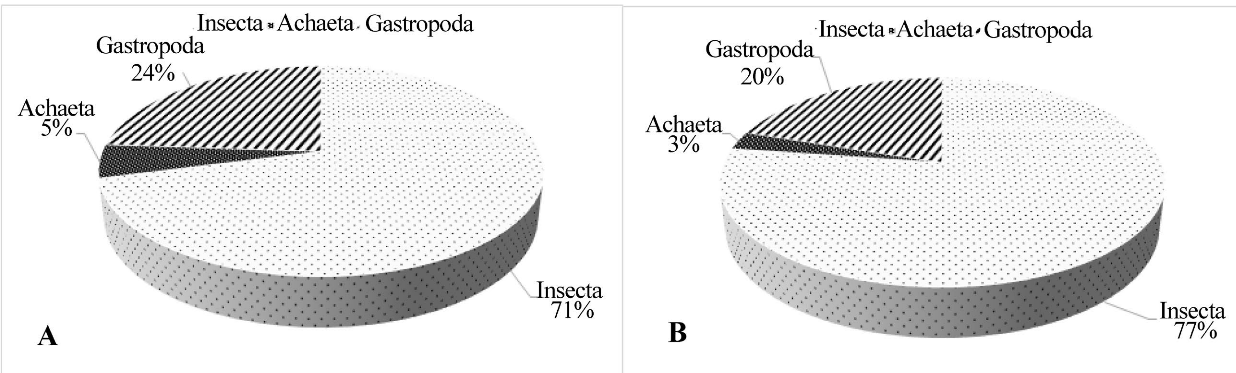

Figure 3. Relative abundance of benthic macroinvertebrates sampled per season in the streams studied ((A)= Rainy seasons; (B) = Dry seasons).

Figure 3 shows the relative abundance of benthic macroinvertebrates sampled per seasons. At the rainy seasons the class of insecta was represented with 71% following by Gastropoda 24% and Acheata 5%. At the dry seasons the class of insecta was represented with 77% following by Gastropoda 20% and Acheta 3%. **Figure 4(A)** shows variations in total number of individuals collected in the sampling stations for the two seasons. The highest number of individuals (1940) sampled in the rainy season during the period of study was collected in A_2 sampling station accounting for 49.88% of the total individuals collected in the rainy season during the period of study. In the dry season samples, the highest number of individuals (1131) was collected in A_3 sampling station accounting for 44.37% of the total individuals collected during the period of study. Looking at the abundances of the different taxa as per sampling station, we noticed that the group of Ephemeroptera, Plecoptera and Trichoptera (EPT) are most abundant at the A_2 than the other two sampling points (**Figure 4(B)**). At this station (A_2), the EPT groups represent by 9 families and 10 species, followed by A_1 having 8 families and 9 species and A_3 was the least with 4 families and 5 species. **Figure 5** shows the spatial variation of relative abundance of the main benthic macro invertebrate orders identified in each station. The A_1 station was dominated by Ephemeroptera (35.1%) which was followed by Diptera (22.4%) in the dry season. In the rainy season, Odonata was the most represented (44.6%) and Basommatophora was still came second. At A_2 the population was dominated by Basommatophora (42.3%) in rainy season, following by Diptera (22.4%) in dry season. At the third station A_3, Diptera still had a high relative abundance in the two seasons (39.3% rainy season and 38.4% dry season).

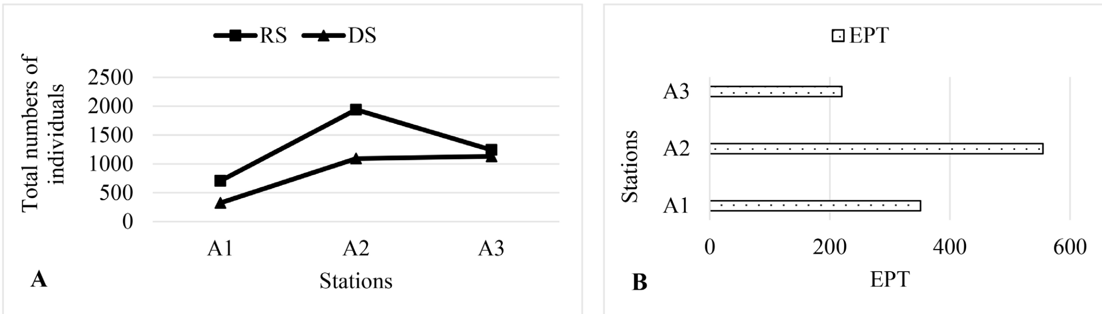

Figure 4. Seasonal variations in total number of individuals (A) and metrics abundance category at EPT (Ephemeroptera Plecoptera Trichoptera); (B) on the Achichem River.

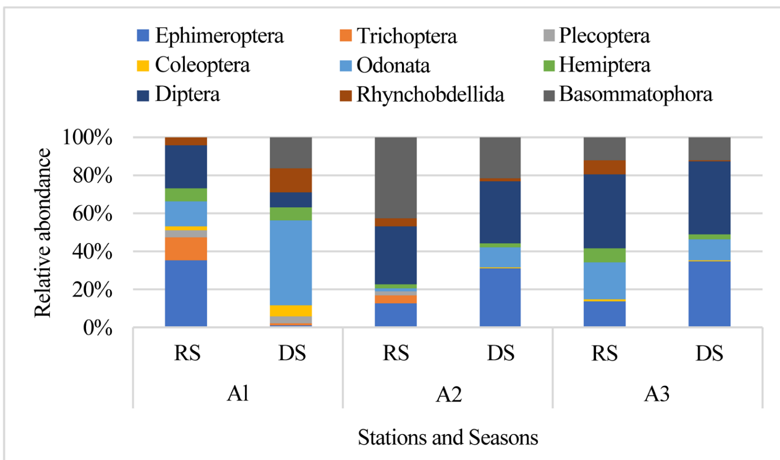

Figure 5. Spatial variation of relative abundance of the main benthic macro invertebrate orders identified in each station.

3.4. Species Diversity and Richness Indices

Table 3 presents the species diversity and richness indices of the study areas for the period of study. Concerning the total species diversity index, the highest value of 34 species was recorded

at station A_1 in rainy season. The low value of 25 species was recorded at stations A_1 and A_2 at dry season respectively. The highest Shannon Weaver index (4.04) was recorded at station A_1 at the dry season and the low (2.70) in the station A_3 at the same season. The highest (0.70) and lowest (0.49) Piélou's Equitability index was also recorded in dry season and at the same sampling station.

Table 3. Species diversity and richness indices.

Bio-indices	Achichem Stream					
	A1		A2		A3	
	RS	DS	RS	DS	RS	DS
Abondance totale	707	325	1940	1093	1242	1131
Total species diversity (S)	34	25	30	25	27	26
ShannonWeaver Index (Hs)	3.96	4.04	2.82	3.19	3.34	2.70
Piélou's Equitability (J)	0.69	0.70	0.49	0.55	0.58	0.47

3.5. Relationships of the Physicochemical and the Diversity of Benthic Macroinvertebrates of Achichem Rivers

Table 4 shows the results of correlation between the species diversity and richness indices of benthic macroinvertebrates and physicochemical parameters. It is observed that the correlation is positive and significant ($p < 0.05$) to high significant ($p < 0.01$). Richness were correlated and high significant to color, turbidity and lead in rainy season and significant to DBO_5, NO_3^- in dry season. Shannon and Pielou were highly correlated to COD in rainy season. In rainy season we observed the high correlation between OPI and Dissolved Oxygen, and the dry season the correlation was observed between Electrical conductivity, Dissoved Oxygen, NH_4^+ and PO_4^{3-}. They were no significant correlation between Simpsom and the physicochemical parameters in the two seasons ($p > 0.05$).

Table 4. Correlation between the diversity, species diversity and richness indices of benthic macroinvertebrates and physicochemical parameters.

	Variables and seasons											
	Abundance		Richness		Shannon		Pielou		Simpsom		OPI	
Parameters	**RS**	**DS**	**RS**	**DS**	**RS**	**DS**	**RS**	**DS**	**RS**	**DS**	**RS**	**DS**
Color (Uptco)	0.665	0.795	0.002*	0.132	0.586	0.716	0.586	0.716	0.412	0.542	0.184	0.313
Turbidity (FTU)	0.654	0.931	0.008*	0.406	0.575	0.991	0.575	0.991	0.401	0.816	0.173	0.588
Electrical conductivity (µS/cm)	0.989	0.475	0.349	0.188	0.933	0.396	0.933	0.396	0.759	0.222	0.530	0.006*
Dissoved Oxygen (%sat)	0.462	0.440	0.200	0.223	0.384	0.361	0.384	0.361	0.210	0.187	0.018*	0.041*
DBO5 (mg/L)	0.741	0.635	0.078	0.027*	0.662	0.557	0.662	0.557	0.488	0.383	0.260	0.154
COD (mg/L)	0.068	0.752	0.595	0.089	0.010*	0.673	0.010*	0.673	0.185	0.499	0.413	0.271
NH_4^+ **(mg/L)**	0.715	0.522	0.052	0.141	0.636	0.443	0.636	0.443	0.462	0.269	0.233	0.040*
NO_3^- **(mg/L)**	0.717	0.698	0.054	0.034*	0.638	0.619	0.638	0.619	0.464	0.445	0.236	0.216
PO_4^{3-} **(mg/L)**	0.421	0.519	0.917	0.144	0.499	0.440	0.499	0.440	0.673	0.266	0.902	0.037*
Lead (mg/L)	0.648	0.344	0.014*	0.319	0.569	0.265	0.569	0.265	0.395	0.091	0.167	0.137

OPI: Organic Pollution Index.

4. Discussion

4.1. Physicochemical Characterization of the Stream Studied

In the course of this study, the physicochemical quality of water varied significantly from one sampling point to another and from one season to another. Monthly rainfall volumes observed before, during and after the period of study is typical of a bi-modal rainfall distributive pattern recorded by earlier authors [18] [19]. The results of the air and water temperatures for all the stations during the period of study showed that temperature differences in the two seasons are highly negligible. This result agrees with earlier studies [18] that temperature is not a major factor in tropical aquatic ecosystem. The low values of temperatures (22.9˚C) registered at A_1 stations at rainy and dry seasons could be due to low sun rays reaching the water colon. This is because of the important tall grasses and tress cover line along the stream banks which constitute a barrier that reduces the impact of sun rays on the temperature variation along the streams. This riparian vegetation affects water temperature by adsorbing some of the incoming radiation [20] [21] suggested that, streams located at the upper part of the drainage basin in forest zone, temperatures are low and do not vary much. This temperature range is similar and close to that obtain by [22] in the Mezam river systems in Bamenda, North West Region (18.5 - 25).

The water samples were more turbid in the dry season than in the wet season at station A_1 during the period of study. We noticed that these sampling points are located at the periphery of the town. So, the water at this point is less turbid which gives much time for particles to settle to the bottom of the stream. These results are in concurrent with those of [23] [24] in sub urban streams of Yaoundé, Center Region. But the observed results are the same as those obtain by [25] in the sub urban towns of Douala, Littoral Region (2 - 66 NTU).

The pH observed in all sampling stations, ranges between neutral. This observation differed from that of [22] who showed that the waters of Bamenda were slightly acidic. According to [26], the soils in Bamenda are composed of fine sand, fine clayey, silt and clay giving it a slight acidic to neutral. To this effect, [27] proposed that, the physicochemical properties of a river are directly linked to the soils of its drainage basin. This almost basic nature of the water could be explained by the large influx of urban and domestic residue into the streams. According to [28], pollution contributes to an increase in the pH of streams.

Dissolved oxygen was also higher in the wet season and positively correlated with turbidity. [27] had attributed high level of dissolved oxygen to the perturbation of water and this was prevalent in the wet season. A higher level of dissolved oxygen recorded during the wet season could also be linked to floodwater dilution and reduced resident time of the polluted water. This may be due to the combined effects of higher wind energy and heavy rainfall which causes mixing of freshwater. A previous study by [29] observed similar results. These streams are the main receptacles of all sorts of waste from the population.

Looking at the mineral nitrogen forms (NH_4^+ and NO_3^-) and orthophosphates (PO_4^{3-}), we noticed that their levels were low showing a low mineralization process of the streams which is distinguish by a low influx of substances, low organic matter, low nitrogenous and phosphate metabolic waste from human activities. These results are similar to those obtain by [24] in streams situated in suburban towns of Yaoundé. Low levels of mineral nitrogen and orthophosphates were also noted by [30] in the Mountain and Upland Rivers of southern Poland.

The spatio-temporal fluctuations of mineral ions (moderately higher) in Achichem streams could be related to the input of urban or domestic waste into the streams. The moderately high water content in mineral nitrogen and orthophosphates would reflect the high content of these waters in decomposing organic matter and their low dissolved oxygen. Indeed, average levels of this variable above 1 mg /L in the different stations, highlight critical water pollution [31]. This predict sources of pollution upstream of the different sampling stations [32]. However, in this streams, mineral nitrogen contents increase from upstream to downstream and could be explained by the mineralization of the substances that accumulates gradually and whose residence time is greater downstream. These observations are in line with the concept of river continuum process, which considers that downstream sectors of rivers are sedimentation zones dominated by organic matter [33].

Based on the values of Organic Pollution Indice (OPI) obtain, it shows that the overall pollution state of Achichem streams in Bamenda are hight (average OPI = 2.04). But this varied from moderate pollution to very high pollution from one sampling point to another but was dominated by very high pollution). These results are similar to those obtained by [34] in Kondi stream in Douala where the levels of pollution varied between moderate to very high. This pollution level in Achichem stream, could be explained by the presence of dumpsite Bamenda City Council (BCC) where disposes off all refuse, also the number of households increases from A_2 and A_3. The moderate pollution as from A_1 was explained by little or no obstacles, at the station is located before dumpsite.

As for what concern heavy metals, the concentrations of cadmium, Led, Arscinic and Mercury remained very low throughout the study period. [32] pointed out that, these metals are usually found in trace quantities in natural water (ranging from a few µg/L to the order of tens µg/L); this was exactly the case with these metals in Achichem stream. These results are similar to those obtained by [35] in the Urban and Peri-Urban Wetlands of Bamenda. Variations of the concentrations of these metals were tandem to specific site activities. This behavior can be attributed to pollution sources existing in the surrounding area.

4.2. Biological Characterization of the Stream Studied

The composition, abundance and distribution of the benthic macroinvertebrates in the study area for the two seasons are presented in **Table 1**. We noted a variation in the taxonomic richness of the different station drainage basin. This taxonomic richness of taxa reduces as we move from less polluted quarters to highly polluted ones, and that wate season to dry season. We noted 57 taxa in wate season and 47 taxa in dry season. [36] assumed that the quality of water bodies increased along an urban-sub-urban gradient. The dominance of insects in terms of species richness would be due to the fact that they represent, according to [37], nearly 95% of organisms present in aquatic environments [38]. Indeed, insects are ubiquitous due to their very extensive distribution area. Furthermore, the high representativeness of insects and gastropods has also been reported by some authors [39]-[41] [25] in the rivers of tropical African regions. The high diversity and abundance of gastropods could also be linked to the coverage of sampling stations by aquatic plants and the presence of rocky substrates in the Achichem river. Indeed, aquatic plants and rocky substrates are an important component of gastropod ecology at several levels. In that they serve as food sources and support for the growth of periphyton, the main food source of gastropods. In addition, they provide well-oxygenated spawning sites for reproduction and serve as shelters against various predators [42]. The analysis of the species distribution shows *Caenis femina* (Caenidae); *Brachycerus* sp. (Siphlonuridae); *Simulium* sp. (Simullidae); *Chironomous* sp. (Chironomidae); *Petrophy zionis*, *Archephysa lordi* (Physidae) as being common species at all sampling stations of the Achichem stream. These families are characteristic of highly polluted environments. The high presence of these pollutant-tolerant species at these stations could be explained by the fact that the Achichem stream is under the influence of discharges from the landfill which probably lead to its degradation. Indeed, it receives a constant and regular supply of leachates from the landfill under the action of runoff water. The arrival of leachates at these stations is associated with the low values of dissolved oxygen content, but also with the high values of turbidity and conductivity recorded. According to [43], pollutant-tolerant species generally abound in waters with very degraded ecological conditions. Conversely the low taxonomic richness registered in the station A2 and A3, it could be analyzed as a result of a poor physicochemical quality of water and the physical modification of the different microhabitats due to a flashier hydrograph, elevated concentration of nutrients and contaminants, altered channel morphology (symptoms of the urban stream syndrome [44]. In fact, in addition to the multiple sources of domestic, municipal and agricultural pollution, the inhabitant along these streams frequently engage in the straightening of river channels, so as to ease the flow of water and avoid flooding. This is done through construction of embankments, raising foundations, widening stream channels and land reclamation along the streams [45]. These activities destabilize the benthic communities, destroy riparian vegetation, micro-habitants, homogenize stream bed and reduce benthic macro invertebrates' diversity [46].

4.3. Correlation between Physicochemical Parameter and Diversity of Benthic Macroinvertebrates

The positive correlations obtained between specific richness, water colour, turbidity and BOD5 during the rainy season could be justified by the increase in the quantity of food available for macro-invertebrates, such as algae, bacteria and organic debris entrained by water run-off [47]. The correlations obtained between nitrate ions and the specific richness of macro-invertebrates during the dry season, and between the Shannon index and dissolved organic carbon during the rainy season can be explained by the fact that nitrate ions are an important source of nutrients for aquatic plants and algae, and COD stimulates the growth of algae and aquatic plants. They can therefore influence primary productivity in aquatic ecosystems, which can have an impact on the food chain. On the other hand, macro-invertebrates often depend on primary productivity for their food, either directly by consuming algae or plants, or indirectly by consuming organisms that feed on these primary producers [48]. The relationship obtained between the organic pollution index and dissolved oxygen during the dry season could be justified by the fact that dissolved oxygen concentration can influence water quality, since a low dissolved oxygen concentration can lead to a reduction in water quality. Organic matter in the water can consume dissolved oxygen as it decomposes, which can lead to a drop in dissolved oxygen concentration. During the dry season, dissolved oxygen concentration may be lower due to reduced water flow and increased water temperature, which can exacerbate the impact of organic pollution on water quality.

5. Conclusion

In this study, we gathered all the available information about the macroinvertebrate fauna of Achichem rivers in Bamenda. Strong differences were highlighted in the physicochemical parameters and the associated diversity of benthic macroinvertebrates of Achichem rivers during the different seasons. It is essential to properly understand the link between climate habitat conditions and biodiversity. The macrobenthic abundance and composition at the study stations were low. This could be attributed to some ecological imbalance arising from alterations of some important factors governing the abundance and distribution of the benthic communities. Such factors include water quality, immediate substrates for occupation and food availability. Therefore, it appears that the low macrobenthic invertebrate community abundance, composition and diversity may have been greatly affected by stress imposed by land based pollutants.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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