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Water Quality of a Lowland and An Urban Stream by Analyzing the Structure of the Benthic Macroinvertebrates Population

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Abstract:

A study was carried out with the mean aim to compare the water of a lowland of Ezazou with that of an urban stream of Bonamoussadi, based on the physico-chemical analysis and the structure of benthic macroinvertebrates. The physico-chemical analysis revealed that the water of the Ezazou lowland is more oxygenated ($O2 = 25.7 \pm 7.29$ %) and loaded with nitrates ($NO3- = 21.67 \pm 17.98$ mg/L) and nitrites ($NO2- = 0.87 \pm 0.3$ mg/L) than the water of the Bonamoussadi stream ($O2 = 21.85 \pm 10.96$ %; $NO3- = 5.36 \pm 0.74$ mg/L; $NO2- = 0.36 \pm 0.21$ mg/L). In addition, the water of the Bonamoussadi stream is higher in suspended solids ($SS = 35.66 \pm 18.72$ mg/L) with higher pH ($pH = 8.43 \pm 0.07$ CU) than the water of the Ezazou lowland ($SS = 19.43 \pm 5.05$ mg/L; $pH =8.04 \pm 0.14$ CU). Concerning benthic macroinvertebrates, the population of the Ezazou lowland is composed of 3 phyla, 6 classes, 12 orders and 59 families, while that of the Bonamoussadi stream includes 3 phyla, 5 classes, 10 orders and 42 families.

Keywords: **lowland, urban stream, physico-chemical analysis, benthic macroinvertebrates, Yaounde**

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I. INTRODUCTION

The demographic growth of metropolitan areas due to natural population increase and massive rural exodus has led to anarchic occupation of urban space and high pressure on natural resources [40]. In addition, the increasingly recurrent poverty in certain developing countries is at the origin of the anarchic occupation of areas that are not very suitable, such as lowlands and the banks of urban streams, which are nevertheless classified as off-limits [19]. Moreover, the poor management of waste from human activities causes the degradation of the quality of the water in these areas, which is used for irrigation of vegetables and for various domestic activities [10]. The concern to assess the water quality of these aquatic ecosystems and the impact of pollution on them has long motivated several studies and the results revealed that all these pressures lead to a degradation of water and habitat quality [3] as well as an alteration of the composition of biological communities, more particularly the reduction of biological diversity in the aquatic ecosystem [7]. The objective of the present study is to compare the water quality of a lowland in Ezazou with that of an urban stream in Bonamoussadi using the structure of the benthic macroinvertebrates population, which are bioindicator organisms of the ecological quality of aquatic environments. The choice of benthic macroinvertebrates is justified by their sedentary nature, their varied life cycle, their large taxonomic diversity, their power of bioaccumulation and bioconcentration and above all their variable tolerance to pollution and habitat degradation [37]. Indeed, benthic macroinvertebrates are persistent and integrate physico-chemical variation. They can thus bear witness to pollution that is more or less toxic, old, acute or chronic. This ability to integrate the cumulative and synergistic effects of various types of disturbances with subtlety makes them the tools of choice for assessing water quality [37].

In Cameroon, and more particularly in Yaounde, several studies have been carried out on the assessment of the state of aquatic ecosystems health and their biodiversity [21]; [22]; [23]; [2]. These studies reveal that the physico-chemical of water and their biodiversity are closely linked to the type and intensity of pollution to which they are subjected. The Ezazou lowland is subject to pollution from agricultural inputs due to the intense agricultural activity practised, while the Bonamoussadi stream is subject to pollution from household waste and from the toilets of the student housing estates. These different types of pollution have an impact on the physico-chemical parameters of the water and structure of biodiversity of each of these sites in a particular way. However, no comparative study has been carried out in this respect. Furthermore, few studies has been carried out at the same time on a stream and in a lowland, under the same conditions, using the same techniques sampling and analysis based on the same organisms as the benthic macroinvertebrates. It is in this perspective that the present study is carried out.

II. MATERIAL AND METHODS

Study area

This study was carried out in two localities in the city of Yaounde, Ezazou and Bonamoussadi. Yaounde is located in the Centre region and the Mfoundi division, between 3°30'-3°58' North latitude and 11°20'-11°40' East longitude at an altitude of about 750 m [4]. The city is characterized with an equatorial forest climate with four-season [36]. The hydrographic network is mainly made up of the Mfoundi and its tributaries. The soils are derived from a more or less micaceous quartzo-feldspathic material and are of two types: ferralitic and hydromorphic [32].

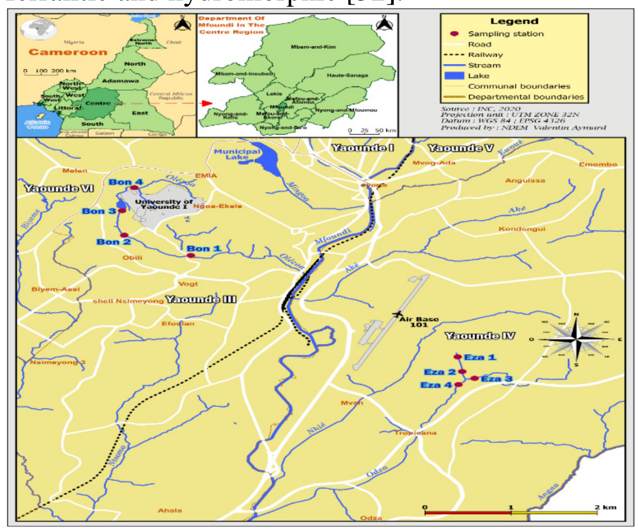


Figure 1: Sampling stations in different streams in Mfoundi department, modified.

Ezazou is a sub urban area on the outskirts of Yaounde located in the council of Yaounde IV. The lowland of Ezazou is criss-crossed by the streams of Nkie, Odza and Missole. This lowland is characterised by agricultural activities with the main plants being Amaranthusviridis (amaranth or folon), Apiumgraveolens (celery), Lactucasativas (lettuce), Ocimumbasilicum (basil) and Solanumnigrum (nightshade or zom). To improve crop, farmers use pesticides and chemical fertilisers including Agrovert, Cyperfresh, Foligad, N-force plus and Cypercot as well as natural fertilisers such as chicken droppings.

Bonamoussadi is an area in the Ngoa-ekelle district, located in the council of Yaounde III. The

Olezoa stream that watered this area flows through the University residences and receives wastewater from the surrounding latrines, car washes and garages.

Thus, taking into account accessibility, the nature of the pollution and the intensity of anthropogenic activities, 4 sampling stations designated Eza 1, Eza 2, Eza 3 and Eza 4 were chosen in the Ezazou lowland and 4 other stations designated Bon 1, Bon 2, Bon 3 and Bon 4 in the Bonamoussadi stream (Fig. 1)

II.2 Sampling

Water and benthic macroinvertebrate sampling took place from July 2019 to July 2020 at a monthly frequency.

II.2.1. Physico-chemical parameters

Physico-chemical parameters were measured in the field and in the laboratory using Rodier's techniques [35]. In the field, parameters such as temperature (°C), pH (UC), electrical conductivity (µS/cm) and dissolved oxygen (%) were measured using HANNA HI 98130 multimeter.

For the measurements to be carried out in the laboratory, the water samples were taken at each sampling station using double-capped polyethylene bottles without bubbles and transported in a cool shielded cell. Parameters such as suspended solids, orthophosphates and nitrogen forms were determined spectrophotometrically using a Palintest Photometer 7500 Wagtech and the results expressed in mg/L.

II.2.2. Benthic macroinvertebrates

Sampling of benthic macroinvertebrates was carried out using the multi-habitat approach, using a 30 cm square net with a 400 µm conical mesh opening and a depth of 50 cm [29]. At each station, about twenty dip net strokes were made over a length of about 50 cm, equivalent to an approximate area of 3 m2 [39]. The organisms retained by the mesh of the net were collected with fine tweezers and then gently introduced into pillboxes containing a 10% formalin solution.

In the laboratory, the collected organisms were washed with running water using sieve and then identified with a binocular magnifying glass with episcopic illumination, brand WILD M3B and BRESSER HG 878513, using the identification keys and books proposed by [15], [11], [24], [13], [28] and [37].

II.2.3. Data analysis

The kruskall-Wallis test was used to determine the significance level of differences in abiotic parameters, taxonomic richness and diversity indices. Sorensen's Similarity Coefficient S was used to calculate the similarity rate of the benthic macroinvertebrate communities of the stations taken 2 by 2. Biocenotic indices such as Shannon and Weaver index, Simpson index, and Piélou equitability were used to analyse the structure of the macroinvertebrate population. Spearman's rank correlation coefficient was calculated to measure the degree of linkage between abiotic variables on the one hand and between abiotic and biological variables on the other. Hierarchical clustering analysis (HCA) was used to group the stations according to their abiotic similarity. Principal component analysis (PCA) was used to establish an abiotic typology of the stations on the basis of all the environmental parameters measured. Kohonen's self-organising map was used to establish the biotypology of the stations on the basis of the taxa abundance matrix.

III. RESULTS

III.1 Physico-chemical parameters

III.1.1. Temperature

In the lowlands of Ezazou, the temperature varied between 21.2°C (Eza 2 in December) and 26.7°C (Eza 3 in June) with an average of 24.35 ± 0.27°C, and between 23.1°C (Bon 3 in August) and 29.5°C (Bon 4 in January and February) in the Bonamoussadi stream with an average of 26.31 ± 0.98°C (Fig.2A) . The analysis of the values shows that the temperature is significantly higher in the Bonamoussadi stream than in the Ezazou lowland ($P < 0.05$).

III.1.2 pH

The pH of the water in the Ezazou lowland varied between 5.8 CU (Eza 1 in February) and 9.51 CU (Eza 2 in November) with an average of 8.04 ± 0.14 CU, and between 6 CU (Bon 1 in February) and 9.53 CU (Bon 4 in November) in the Bonamoussadi stream, with an average of 8.43 ± 0.07 CU (Fig.

2B). The analysis of the values shows that the pH is significantly higher in the Bonamoussadi stream compared to the Ezazou lowland ($p < 0.005$).

III.1.3. Electrical conductivity

The electrical conductivity of the water of the Ezazou lowland varied between 120 µS/cm (Eza1, Eza 2 and Eza 3) and 330 µS/cm (Eza 1 in May) with an average of 186.35 ± 15.23 µS/cm, and between 220 µS/cm (Bon1 and 2 in May) and 620 µS/cm (Bon 4 in January) in the Bonamoussadi stream with an average of 334.61 ± 85.41 µS/cm. (Fig. 2C). The analysis of the values shows that the electrical conductivity is significantly higher in the Bonamoussadi stream compared to the Ezazou lowland ($p < 0.05$).

III .1.4. Suspended Solids

In the Ezazou lowland, the suspended solids content of the water varied between 1 mg/L (Eza 2 in October) and 59 mg/L (Eza 3 in June) with an average of 19.43 ± 5.05 mg/L, and between 0 mg/L (Bon 2, August) and 371 mg/L (Bon 4 in September) in the Bonamoussadi stream, with an average of 35.66 ± 18.72 mg/L (Fig. 2D). The analysis of the values shows that the waters of the Bonamoussadi stream are significantly richer in suspended solids ($p <0.005$).

III.1.5. Dissolved oxygen

In the Ezazou lowland, the percentage of dissolved oxygen in the water varied between 5% (Eza 1, January) and 76.7% (Eza 1, July 2019) with an average of 25.7 ± 7.29mg/L. In the Bonamoussadi stream, it varied between 5% (Bon 4, January) and 126% (Bon 2, December) with an average of 21.85 ± 10.96% (Fig. 2E). Analysis of these results showed that the water was significantly more oxygenated in the Ezazou lowland than in the Bonamoussadi stream ($p = 0.002$).

III.1.6. Ammoniacal nitrogen

In the Ezazou lowland, water concentrations of ammoniacal nitrogen varied between 0 mg/L (Eza 2 in March) and 0.95 mg/L (Eza 1 in March) with an average of 0.16 ± 0.03 mg/L, and between 0 mg/L and 1.98 mg/L (Bon 1 in March) in the Bonamoussadi stream, with an average of 0.24 ± 0.11mg/L (Fig. 2F). Analysis of the values showed no significant difference between the two sites ($P> 0.05$).

III.1.7 Nitrates

In the Ezazou lowland, nitrate levels in the water ranged from 0.96 mg/L (Eza 4 in November) to 412 mg/L (Eza 3 in August) with an average of 21.67 ± 17.98 mg/L, and from 0.12 mg/L (Bon 4 in September) to 32 mg/L (Bon 2 in July 2019) in the Bonamoussadi stream, with an average of 5.36 ± 0.74 mg/L (Fig. 2G). The analysis of the values reveals that the water is significantly richer in nitrates in the Ezazou lowland ($p < 0.05$).

III.1.8. Orthophosphates

In the Ezazou lowland, the concentrations of orthophosphates in the water varied between 0 mg/L (Eza 4 in August) and 0.23 mg/L (Eza 3 in June) with an average of 0.06 ± 0.01 mg/L, and between 0 mg/L (Bon 1, Bon 2 and Bon 3) and 0.57 mg/L (Bon 1 in August) in the Bonamoussadi stream, with an average of 0.09 ± 0.05 mg/L (Fig. 2H) Analysis of the values showed no significant difference between the two sites ($p> 0.05$).

III.1.9. Nitrites

In the Ezazou lowland, nitrite levels in the water varied between 0.06 mg/L (Eza 4 in March) and 1.86 mg/L (Eza 2 in April) with an average of 0.87 ± 0.3 mg/L, and between 0 mg/L (Bon 2 in August) and 1.74 mg/L (Bon 3 in June) in the Bonamoussadi stream, with an average of 0.36 ± 0.21 mg/L (Fig. 2I). Analysis of the values reveals that the water is significantly richer in nitrites in the Ezazou lowland ($p < 0.05$).

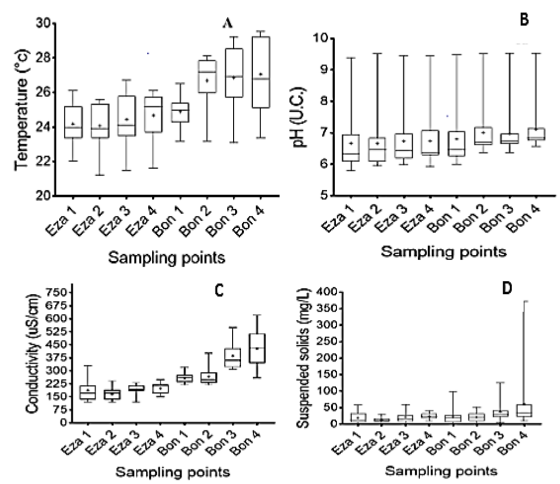


Figure 2: Spatial variation of physico-chemical parameters of water in the Ezazou stream lowland and Bonamoussadi stream

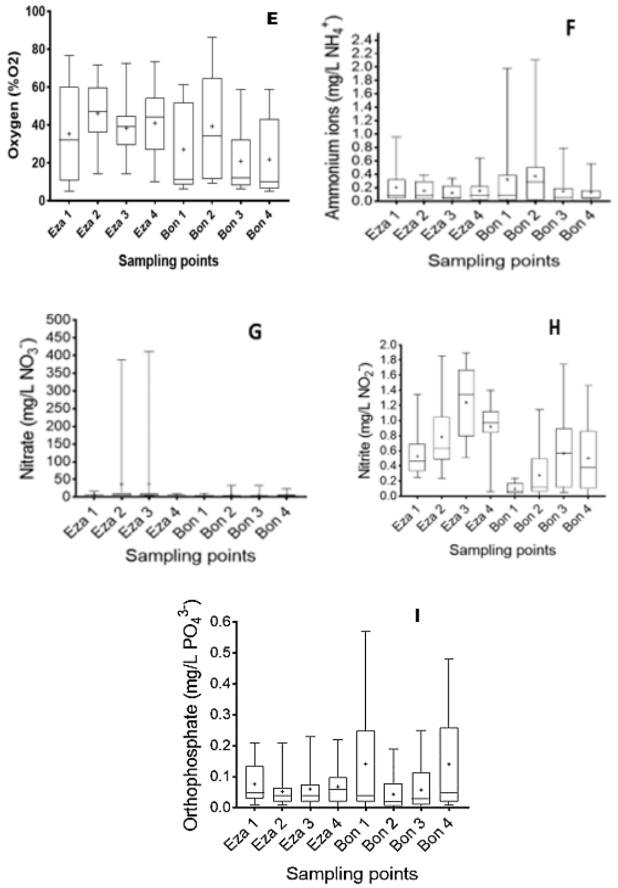


Figure 2(continued)**:** Spatial variation of physico-chemical parameters of water in the Ezazou stream lowland and Bonamoussadi stream

III.2 Abiotic characterisation of the stations

III.2.1. Hierarchical Classification Analysis (HCA)

The hierarchical classification analysis carried out on the basis of the physico-chemical parameters enabled the sampling stations to be classified into two groups (I and II). Group I is composed of the stations Eza 1, Eza 2, Eza 3, Eza 4, Bon 1 and Bon 2. Indeed, the most similar stations are Eza 1 and Bon 2 (99%) and Eza 3 and Bon 1 (98%). All these stations are similar to Eza 1 and Eza 4 at 98%. Group II consists of stations Bon 3 and Bon 4, which are 91% similar. The analysis of these dendrograms reveals that the stations of the Ezazou lowland have very similar physico-chemical characteristics, contrary to the stations of the Bonamoussadi stream. Moreover, in the latter site, only the Bon 3 and Bon 4 stations have fairly similar characteristics.

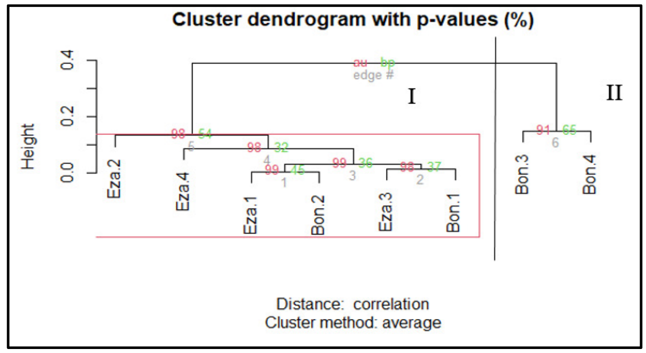


Figure 3: Hierarchical cluster analysis (HCA) based on physico-chemical parameters.

III.2.2. Principal Component Analysis (PCA)

The principal component analysis carried out on the basis of physico-chemical parameters revealed that dimension 1 (59.3%) and dimension 2 (18.4%) account for 77.7% of the total variance. The map obtained shows that the different stations are divided into three groups (I, II and III). Group I, consisting of the stations Eza 1, Eza 2 and Eza 3, contains the waters with relatively higher oxygen levels and high nitrate content. Group II, comprising the stations Bon 3 and Bon 4, is characterised by turbid, highly coloured water, rich in suspended solids and organic matter. These waters are also very alkaline, highly mineralised and have high temperatures and pH values. Finally, group III, consisting of stations Bon 1 and Bon 2, is characterised by water rich in ammoniacal nitrogen.

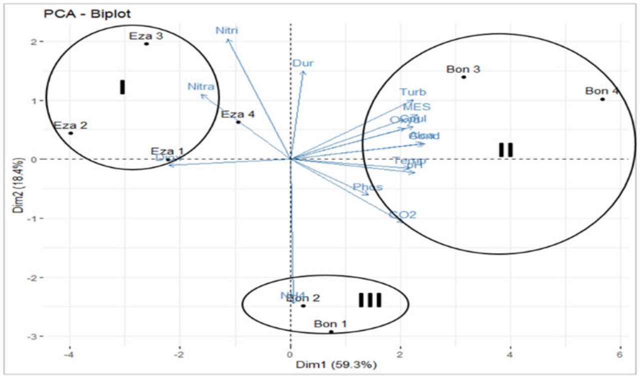


Figure 4: Principal Component Analysis (PCA) of physico-chemical parameters during the study period.

III.3 Benthic macroinvertebrates

III.3.1. Overall taxonomic composition

III.3.1.1. Ezazou lowland

A total of 8790 organisms belonging to 3 phyla (Arthropods, Annelids and Molluscs), 6 classes (Insects, Crustacea, Oligochaetes, Achaetes, Gastropods and Bivalves), 12 orders and 59 families were collected in the Ezazou lowland. The Arthropod phylum is the most diverse with 2 classes, 6 orders, 41 families and 71 taxa, followed by the Molluscs with 2 classes, 2 orders, 10 families and 22 taxa and the Annelids with 2 classes, 3 orders, 8 families and 13 taxa.

The insect class is the most represented with 7857 individuals, i.e. 89% of relative abundance. It includes 70 taxa divided into 40 families and 5 orders, followed respectively by the Oligochaetes with 389 individuals, i.e. 42% of relative abundance, including 8 taxa, 6 families and 2 orders, the Gastropods with 309 individuals, i.e. 4% of relative abundance, including 20 taxa, 8 families and 1 order, Bivalves with 182 individuals or 2% relative abundance with 2 taxa, 2 families and 1 order, Achaetes with 39 individuals or 1% relative abundance with 5 taxa, 2 families and 1 order and finally crustaceans with 14 individuals or 0.1% relative abundance with 1 taxon, 1 family and 1 order.

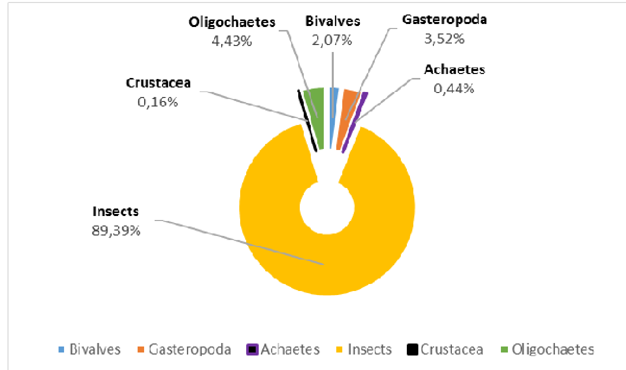


Figure 5: Relative abundance of different classes of benthic macroinvertebrates in the Ezazou lowland

Of the 5 orders listed in the insect class, Diptera and Coleoptera are the most represented with 12 families each, followed by Heteroptera with 8 families and finally Odonata and Ephemeroptera with 4 families each. At the level of families, the highest abundances are found in the Chironomidae, which alone represent 68.26% of relative abundance. Overall, the greatest taxonomic richness is found in the Hydrophilidae (9 taxa), the Chironomidae (6 taxa) and the Coenagrionidae (5 taxa).

III.3.1.2. Bonamoussadi stream

A total of 2821 organisms were collected in the Bonamoussadi stream. These organisms belong to 3 phyla (Arthropods, Annelids and Molluscs), 5 classes (Insects, Crustacea, Oligochaetes, Achaetes and Gastropods), 10 orders and 42 families. The Arthropods phylum is the most diverse with 6 orders, 28 families and 45 taxa followed by the Annelids with 2 classes, 3 orders, 8 families and 13 taxa and the Molluscs with 1 class, 1 order, 6 families and 11 taxa. The insect class is the most represented with 1909 individuals, i.e. 68.87% of relative abundance. It includes 44 taxa divided into 27 families and 5 orders. The class of Gastropods follows with 716 individuals, i.e. 25.83% of relative abundance, divided into 11 taxa, 6 families and 1 order. Next comes the class of Oligochaetes with 127 individuals, i.e. 4.58% of relative abundance, divided into 8 taxa, 6 families and 2 orders. Finally, the class of Achaetes with 15 individuals, i.e. 0.54% relative abundance, divided into 5 taxa, 2 families and 1 order, and the class of Crustacea with 5 individuals, i.e. 0.18% relative abundance, divided into 1 taxon, 1 family and 1 order.

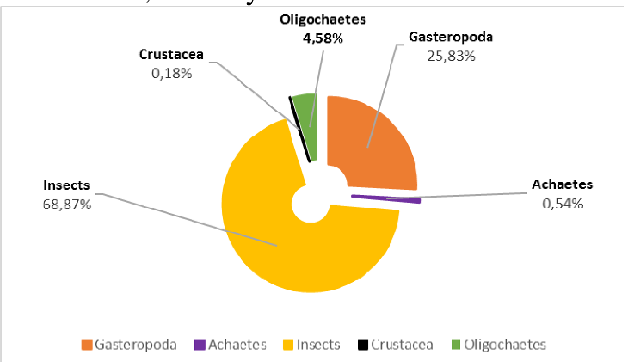


Figure 6: Relative abundance of different classes of benthic macroinvertebrates in the Bonamoussadi stream

Of the 5 orders listed in the insect class, the Diptera and Coleoptera are the most represented with 9 and 8 families respectively, followed by the Heteroptera with 5 families, the Ephemeroptera with 3 families and the Odonata with 2 families. The highest abundances of families are found in the Chironomidae, which represent almost half (51.36%) of the total abundance. Overall, the greatest taxonomic richness is found in the Hydrophilidae (5 taxa) followed by the Chironomidae and Scirtidae (4 taxa).

III.3.2. Sorensen's similarity coefficient "S"

The calculation of the similarity coefficient shows higher values between stations Bon 3 and Bon 4 (73.91%), reflecting their strong faunal similarity, followed by stations Eza 1 and Eza 2 (67.60%) and Eza 2 and Eza 3 (63.88%).

Table I: Sorensen's similarity coefficient based on biological variables

Stations	Eza1	Eza2	Eza3	Eza4	Bon1	Bon2	Bon3	Bon4
Eza1	100							
Eza2	**67,60**	100						
Eza3	**58,46**	**63,888889**	100					
Eza4	**57,14**	**60**	**68,75**	100				
Bon1	**54,16**	**50,909091**	44,897959	42,553191	100			
Bon2	**55,55**	45,901639	**54,545455**	**60,377358**	**57,894737**	100		
Bon3	**56,60**	**50**	**59,259259**	**61,538462**	**54,054054**	**51,162791**	100	
Bon4	45,61	**50**	**58,62069**	**53,571429**	39,02439	42,553191	**73,913043**	100

III.3.3. Shannon and Weaver, Simpson and Piélou Equitability Diversity Indices

The values of the Shannon and Weaver (H'), Simpson (S) and Piélou (J) diversity indices differ from one site to another. In the Ezazou lowland, the lowest values of diversity and equitability indices were recorded at Eza 1 (H'= 0.97; S = 0.23; J = 0.16) and the highest at Eza 2 (H = 2.98; S = 0.79; J = 0.49). In the Bonamoussadi stream, the lowest values were recorded in Bon 2 (H'= 1.54; S = 0.4; J = 0.25) and the highest in Bon 4 (H' = 2.47; S = 0.75; J = 0.41). These indices are slightly higher in the Ezazou lowland than in the Bonamoussadi stream, but the difference is not significant ($p > 0.05$).

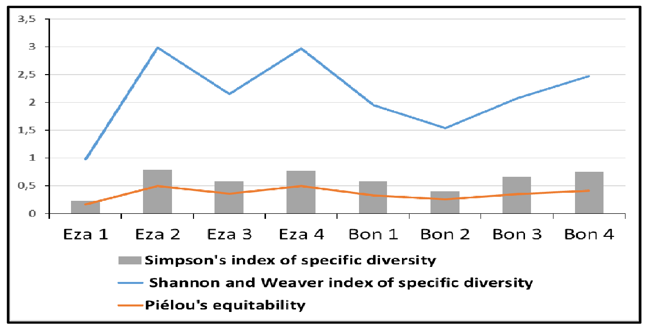


Figure 7: Indices of species diversity and equitability

III.3.4. Principal component analysis (PCA)

A principal component analysis was carried out on benthic macroinvertebrate families with a relative abundance of at least 1%. This analysis revealed that dimension 1 (32.5%) and dimension 2 (21.9%) account for 54.4% of the total variance, which is divided into four nuclei (I, II, III and IV). Group I groups together the families of benthic macroinvertebrates that show an affinity for the waters of the Eza 4 station: the families Melanidae, Lumbricidae, Glossiphonidae, Tubificidae and Hydrobiidae, which are correlated with each other. Group II shows that the families Enchytraeidae, Psychodidae, Physidae, Lymnaedae and Syrphidae are not only correlated with each other but also develop affinities for the water of stations Bon 3 and Bon 4. Group III shows that the families Nepidae and Chironomidae are related to each other and develop best at the Eza 1 station. Group IV shows that the families of Libellulidae, Baetidae, Coenagrionidae, Cordulidae, Belostomidae, Ceratopogonidae, Simulidae, Asellidae, Athericidae, Cordulegasteridae and Lumbriculidaehighycolonised the Eza 2 station.

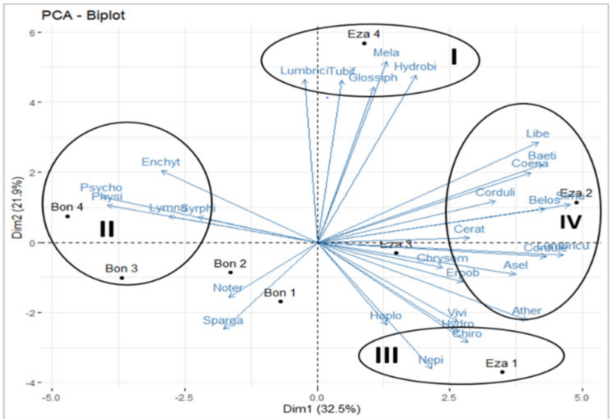


Figure 8: Principal Component Analysis (PCA) done on the families of benthic macroinvertebrates during the study period.

III.3.5. Kohonen's self-organising map

Kohonen's self-organising map (SOM), based on the abundance matrices of benthic macroinvertebrate families, was used to classify the 104 samples (8 stations × 13 field trips) on the basis of the distribution and probability of occurrence of families in the samples. A Kohonen map (Fig. 9) of 56 cells was selected, showing the distribution of organisms in two groups. Group I, located on the upper part of the map, comprises 64 samples, mainly from the Ezazou lowland and Bon 1 station. Group II on the lower part of the map consists of 40 samples located mainly in the last three stations of the Bonamoussadi stream (Bon 2, Bon 3 and Bon 4).

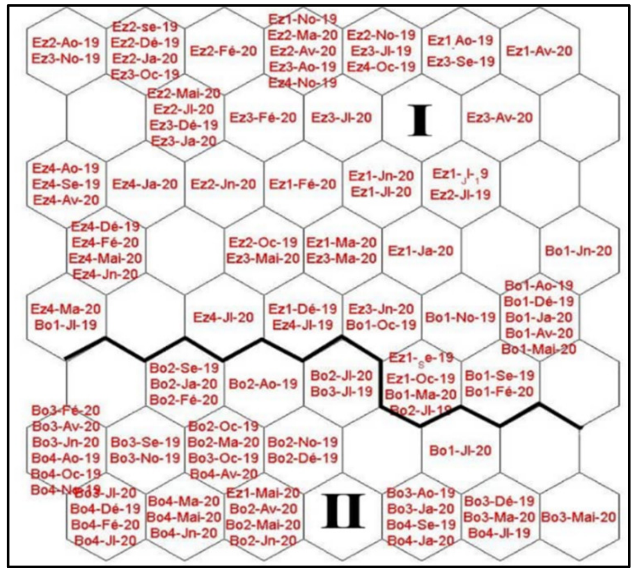
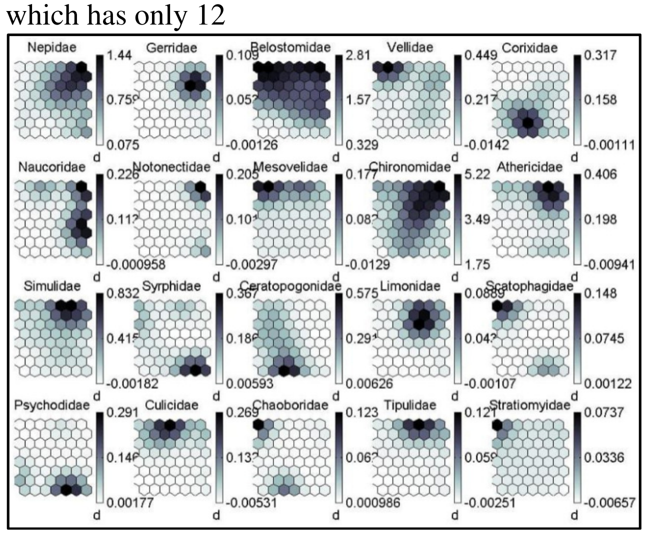


Figure 9: Distribution of samples on the SOM map based on the abundance matrix of benthic macroinvertebrate families. I and II: identified groups. Ez1, Ez 2 .....Bo 4: sampling stations; Jl, Ao ......JL: sampling months; 19, 20: sampling year.

The Figure 10 shows the distribution probability profile of the benthic macroinvertebrate families identified in the groups defined by the SOM. Figure 11 represents the summary of the distribution and shows that group I has the highest taxonomic richness with 29 families compared to group II which has only 12



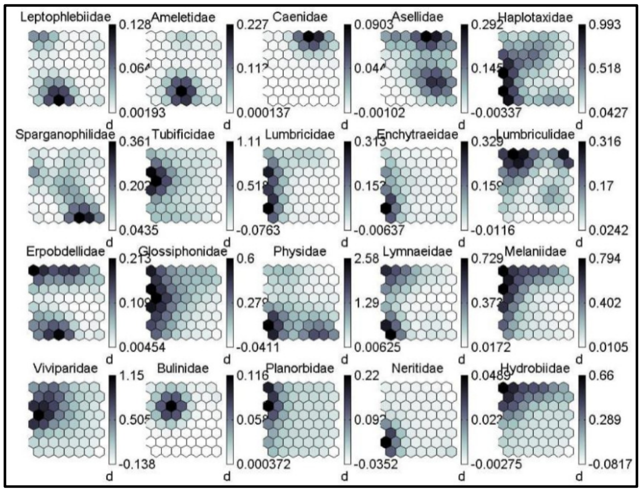


Figure 10 : Distribution pattern of benthic macroinvertebrate families collected on the SOM map, made from the abundance matrix: dark colour: high probability of presence; light colour: low probability of presence; d= scale.

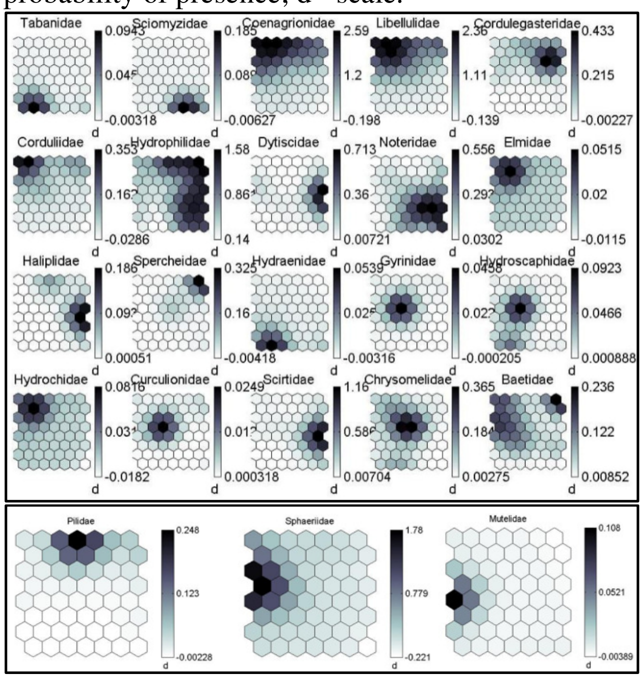


Figure 10 (continued) **:** Distribution pattern of benthic macroinvertebrate families collected on the SOM map, made from the abundance matrix: dark colour: high probability of presence; light colour: low probability of presence; d= scale.

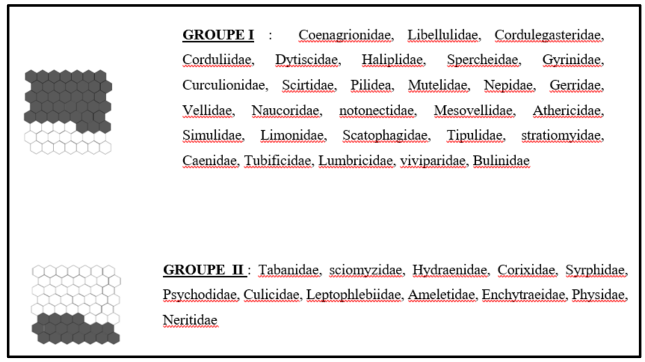


Figure 11: Distribution of benthic macroinvertebrate families in the different groups defined by the SOM, illustrated in Figure 10.

Of the 29 families identified in group I, only 9 are exclusive; these are: Cordulegasteridae, Spercheidae, Pilidae, Gerridae, Limonidae, Culicidae, Tipulidae, Caenidae and Bulinidae. The remaining 20 families are also present in Group II. Of the 12 families recorded in group II, only 2 are exclusive. These are the Tabanidae and Sciomyzidae(all Diptera) and the other 10 families are also present in group I.

IV-DISCUSSION

IV.1 Physico-chemical parameters

The significantly higher temperature values in the Bonamoussadi stream than in the Ezazou lowland could be explained on the one hand by a higher population density in the Bonamoussadi site and on the other hand by the fact that the samples were taken at later times of the day than in the Ezazou site. This corroborates the statements of [26] and [34] according to which anarchic occupation and overpopulation are factors that increase the ambient temperature and consequently that of the water. The pH at the stations is slightly acidic to neutral overall. This would be due to the fact that the physico-chemical characteristics of the stream depend closely on the nature of the soils in the catchment area [31] and [5], which in this case are slightly acidic [6], [33] and [42]. These obtained pH values are in the pH range (5-9 CU) of water suitable for aquatic life [16]. The fact that the pH is slightly more acidic at Ezazou could be explained by the fact that this site has a higher abundance of organisms because, according to [2], the metabolic activity of the organisms present in the water contributes to the conversion of carbonates into bicarbonate, thus favouring the acidification of the environment. Overall, the average electrical conductivity values (145-495 µs/cm) indicate weakly mineralised water, as according to [30], water with less than 500 µS/cm is classified as weakly mineralised. However, the water of Bonamoussadi is significantly more mineralised than the water of Ezazou. This can be explained by the fact that Bonamoussadi is more subject to permanent and chronic pollution of domestic wastewater than Ezazou. In fact, several pipes lead into the Bonamoussadi stream and thus increase the mineralization of the water. These conductivity values recorded in the Bonamoussadi stream are nevertheless lower than those obtained by [2] (533.7 ± 346.18 µS/cm) in some waters in the anthropised zone of the city of Yaounde.

The fact that SS values are significantly higher in the Bonamoussadi stream than in the Ezazou lowland can be explained by the fact that the Bonamoussadistream is located around the University residences and receives all their solid wastes, because according to [41], the quantity of SS is linked to exogenous inputs related to erosion and to the transport of non-soluble particles in the runoff water. The SS values obtained in the Ezazou lowland are lower than those obtained by [2] (average of 61.41 ± 21.44 mg/L) in some lowlands of Yaounde. However, these waters remain generally suitable for aquatic life because according to [8] and [1], suspended solids levels below 75 mg/L would not have adverse effects on the development of most aquatic organisms. In general, the waters showed low average dissolved oxygen saturation levels (35, 13 ± 9.39%) although the Ezazou lowland showed higher values than the Bonamoussadi stream. This would mean that in the latter, there is a low oxygenation of the water linked to a greater enrichment of organic matter due to an anthropogenic activities. The saturation percentages obtained in the Ezazou lowland are very low than those (above 75%) obtained by [22] and [23] in some peri-urban streams of the city of Yaounde where natural ventilation induced by foliage, turbulence and recirculation of water favour their reoxygenation at the air-water interface [18].

As for nitrates and nitrites, the higher levels obtained in the Ezazou lowland would be linked to the use of fertilisers in the agricultural activity. In fact, the fertilisers used here are nitrogenous in nature and reach the water through infiltration and run offs. These values are largely higher than those obtained by [2] on certain lowlands of the city of Yaoundé (0.3 - 6.9 mg/L) in which there was a low use of nitrogenous fertilisers. Regarding ammoniacal nitrogen, the fact that its values did not vary significantly between sites would indicate a certain approximation in terms of the degree of mineralization of the water, although the Principal Component Analysis indicates high values of ammoniacal nitrogen in some stations in the Bonamoussadi stream (Bon 1 and Bon 2). The mean value (0.2 ± 0.09 mg/L) obtained overall was low compared to that obtained by [22] on the Mefou, a peri-urban stream. The fact that orthophosphate levels did not vary significantly between the two sites could be explained by the low contamination of the waters at both sites by industrial effluents rich in synthetic detergents [25]. The values obtained at both sites were low (0.23 - 0.57 mg/L) compared to those obtained (0.28 - 1.96 mg/L) by [2] at some of the lowlands. According to [17], this water with low orthophosphate content are favourable for the development of many biological groups.

IV.2 Benthic macroinvertebrate population

The higher abundance of benthic macroinvertebrates in the Ezazou lowland (8790) compared to the Bonamoussadi stream (2821) could be explained by the current speed, which was lower in Ezazou than in Bonamoussadi, as high current speeds can cause organisms to drift [37]. This difference can also be explained by the physico-chemical conditions in the Ezazou lowland, which are more favourable to the development of these organisms. Indeed, the Ezazou lowland have higher dissolved oxygen saturation rates than the Bonamoussadi stream and conditions favourable to the harmonious development of benthic macroinvertebrates, which are essentially aerobic organisms. This higher abundance could be explained more by the fact that in the Ezazou lowland, the pollution is essentially organic, whereas in the Bonamoussadi stream it is organic and chemical and therefore more stressful. The abundance values obtained in the Bonamoussadi stream are nevertheless higher than those obtained by [22] on the Mefou (1801 individuals) and by [23] on the Nga (2553 individuals).

In both sites, the arthropod phylum is the most represented with the insect class predominating without significant difference between the two sites. This can be explained by the fact that arthropods, and more particularly insects, have a genetic plasticity and cosmopolitanism that gives them a great ability to colonise different ecological niches while adapting to the state of the environment [37]. This is further corroborated by the fact that the most represented orders at both sites were Diptera and Coleoptera, all insects. This predominance of insects would indicate poor water quality, as according to [9], insects other than EPT (Ephemeroptera - Plecoptera - Trichoptera) are abundant in degraded environments with unhealthy environments and highly polluted with organic matter due to domestic waste. This is the case of the Ezazou lowland, which is subject to pollution by pesticides, and the Bonamoussadi stream, which is subject to pollution by excrement and domestic waste. These observations were also made by [38] in some streams in the city of Douala where insects represented 79.78% of abundance and by [27] on some streams in the Western region where insects represented 86.5% of total abundance.

Concerning the families, there was no significant difference in their distribution in the two sites. In fact, the Chironomidae had the highest abundance and the Hydrophilidae the highest taxonomic richness. Organisms of these two families are generally abundant in environments with a high content of various organic matter [37]. Their predominance in the two sites could therefore indicate polluted waters. The predominance of certain groups of organisms to the detriment of others is reflected in the diversity indices. Indeed, the low values obtained indicate a low diversity of macroinvertebrates as a whole with the predominance of one group. This state of affairs would also reflect a certain environmental imbalance, since according to [20], high values of diversity indices indicate environmental conditions that are favourable to the establishment and maintenance of a varied and adaptable biological community. The fact that these indices are slightly higher (although this difference is not significant) in the Ezazou lowland than in the Bonamoussadi stream and would therefore indicate a better characteristics for the development of benthic fauna.

From the analysis of the results of the Principal Component Analysis (PCA) carried out on the basis of the families of organisms, we can deduce that the families of nucleus II (the families of Enchytraeidae, Psychodidae, Physidae, Lymnaedae and Syrphidae) are fond of the Bon 3 and Bon 4 stations, whose water is turbid, highly coloured, rich in suspended solids and organic matter, very alkaline and averagely mineralised, as revealed by the Principal Component Analysis carried out on the basis of physico-chemical parameters. These families of organisms could therefore be considered as indicators of poor ecological water quality.

The SOM map made it possible to distinguish the two sites and corroborates the results of Sorensen's similarity coefficient, according to which similarities are stronger between stations at the same site than between stations at different sites. Indeed, when we associate the families of organisms exclusive to each of the 2 groups of the SOM map with the physico-chemical analyses, we can affirm that the 9 families exclusive to group I would have a particular affinity for water more oxygenated and rich in nitrates (that of the Ezazou lowland water) whereas the 2 families exclusive to group II would prefer turbid water, highly coloured, rich in suspended solids and organic matter, very alkaline and highly mineralised (those of the Bonamoussadi stream). Thus, the water of the Ezazou lowland would be of better ecological quality than those of the Bonamoussadi stream and the two families (Tabanidae and Sciomyzidae) exclusive to the Bonamoussadi stream would be indicative of water strongly impacted by anthropogenic activities.

V- CONCLUSION

At the end of this study, which aim was to compare the water quality of a lowland of Ezazou and urbanized stream across Bonamoussadi, it emerged that, from a physico-chemical point of view, the waters of the Ezazou lowland are more oxygenated and richer in nitrates and nitrites, whereas those of the Bonamoussadi stream are richer in suspended solids and organic matter, more mineralised, with higher temperatures and pH levels. On the whole, the Bonamoussadi stream and the Ezazou lowland are disturbed and degraded environments, with water of poor physico-chemical quality, the degradation being less accentuated in Ezazou because of the nature of the site (lowland), the type of pollution (mainly agricultural) and the low surrounding population. In fact, given the intensity of agriultural activity in Ezazou and the associated practices, we expected water of more degraded physico-chemical quality, but the results are rather encouraging, and suggest that the hydrological function of the lowland may enabled a certain amount of water purification. In terms of biology, the Ezazou lowland showed a higher abundance with 8790 individuals and 107 taxa, whereas the Bonamoussadi stream only counted 2821 individuals and 69 taxa. In both sites, Arthropods are the most diverse phylum and Insects the most represented class. Diptera is the most represented order and families of Chironomidae and Hydrophilidae showed the highest abundance and taxonomic richness. Diversity indices showed low macroinvertebrate diversity at both sites, with low equi-partitioning of individuals resulting in the dominance of one group. Although the Ezazou lowland had slightly higher indices values than the Bonamoussadi stream, the species diversity was not significantly different between the two. Thus, the water of the Ezazou lowland would be of slightly better ecological quality than those of the Bonamoussadi stream.

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