

Water Quality And Benthic Macroinvertebrates Of Tropical Forest Stream In South-West Region, Cameroon

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Abstract – A study was carried out in Ndongo stream, located in Buea, from May to October 2017, to assess the water quality and evaluate the structure of benthic macroinvertebrates. Physicochemical analysis showed that water from Ndongo was well oxygenated (82.21 ± 6.59 %), slightly acidic ($\text{pH}=6.82 \pm 0.22$ UC) and alkaline with low quantities of nitrogen compound (2.9 ± 3.57 mg/L NO_3^+ ; 0.02 ± 0.02 mg/L NO_2^- and 0.89 ± 1.78 mg/L NH_4^+). Regarding the biology of macroinvertebrates, a total of 2058 individuals were collected and identified into 4 phyla, 5 classes, 11 orders, 32 families and belonging to 44 genera. The Shannon & Weaver and Pielou evenness reveal that the benthic macroinvertebrates were more diversified in upstream.

Keywords – Ndongo stream, benthic macroinvertebrates, water quality, diversity.

I. INTRODUCTION

Water is a natural resource necessary for any form of life on earth. It is necessary for Man's domestic needs as well as agro-pastoral and industrial activities [1]. Water covers about 71 % of the terrestrial surface with a volume of about 1.4 thousand million km^3 [2] ; [3]. Despite its abundance, only 1% of freshwater is available for the human population through streams, rivers and lakes [4].

In developing countries and notably in Cameroon, urban streams are used to collect various waste such as household and industrial wastes and wastewaters [5]. These activities have greatly contributed to water pollution causing a decrease in aquatic wildlife and flora [6] ; [7], which are useful in maintaining the integrity of freshwater. The evaluation of water integrity is based on measuring the physicochemical parameters coupled with the collection of organisms [8].

Although many aquatic organisms are involved in assessing the health status of these ecosystems [9] ; [10], benthic macroinvertebrates occupy a prominent place because of their taxonomic diversity, their abundance, their relative long life cycle (up to 3 years), their sedentary life style, their ability to bioconcentrate heavy metals and to colonize several environments [11] ; [12].

The present study aims to determine the benthic macroinvertebrate population structure in relation with the physicochemical quality of Ndongo stream, and tropical forest stream in the South-West Region, Cameroon. To achieve this main objective, (i) Some

physico-chemical parameters of Ndongo stream were measured and analyzed ; (ii) benthic macroinvertebrates were collected and analyzed and (iii) biocenotic index were calculated.

II. MATERIAL AND METHODS

2.1 Study Area

Ndongo stream flows through Buea town which is located down the Mount Cameroon between latitude 4°07' and 4°10' North and longitude 9°14' and 9°21' East. The climate is characterized by two seasons, a short dry season going from December to February and a long rainy season from March to November [13]. With abundant precipitation between 7000 mm to 12000 mm per year [14]. The stream flows over volcanic formations composed of ferrallitic soils on the interfluvial summit and hydromorphic soils in valleys [15].

The hydrographic network of Ndongo stream covers approximately 4,200 km² surface area of the Fako division. Length of not less than ten kilometers, the Ndongo stream runs from the Mbiaka neighbourhood in Buea at about 700 m of altitude. It flows at East-South direction to Mutenguene, Tiko before emptying itself into the Wouri mangrove. This basin includes secondary forest in its anterior end, followed by large plantations of rubber trees, cabbage palms and banana at its posterior end [16].

For this study, three sampling stations Ndongo 1 (ND1), Ndongo 2 (ND2) and Ndongo 3 (ND3) were selected according to their accessibility and the presence of microhabitats. As follows :

- Ndongo 1 (ND1), located in the upper course at about 100 m from the source at latitude 04° 09' 356" North and longitude 009°16' 373" East and 651 m of altitude. The stream bed is rocky-sandy and the banks occupied by dense vegetation;
- Ndongo 2 (ND2), located in the medium stream at about 2000 m from the station ND1 at 04°09' 136" North latitude and 009° 17' 162" East longitude and 571 m of altitude,. The stream bed is covered by rocky blocks, pebbles and sand.
- Ndongo 3 (ND3), located in the lower stream at about 3000 m from station ND2 at 04°08' 294" North latitude and 009°18' 448" East longitude and 480 m of altitude,. The stream bed is covered by rocky blocks, pebbles and sand (Figure 1).

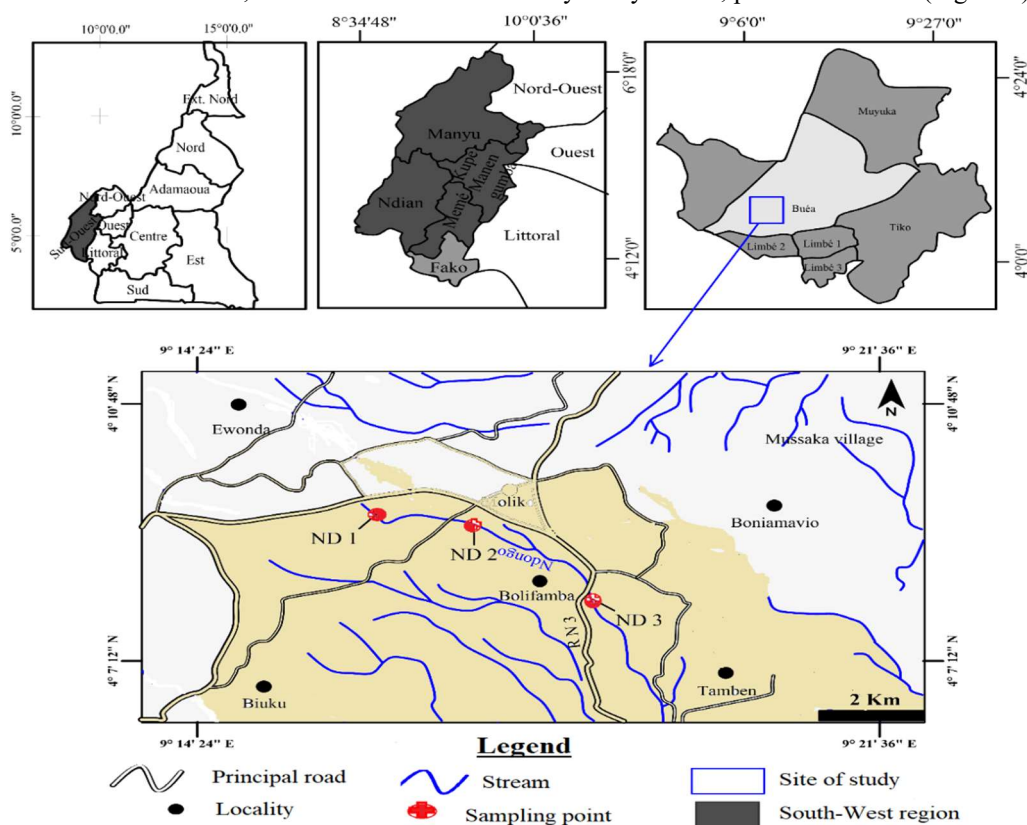


Figure1 : Ndongo stream watershed showing the sampling station (Buea section, [17] modified).

2.2. Sampling and Analysis of Variables Physicochemical

The evaluation of physicochemical parameters was done monthly, following the recommendations of [18]. Thus, the temperature (°C), the dissolved oxygen (%) and the pH(UC) were measured *in situ* using a portable multimeter HANNA HI 991301.

In the laboratory, the orthophosphates, mineral form of nitrogen and turbidity were determined by colorimetry using the HACH DR 2800 spectrophotometer, followed by dissolved CO₂ and oxidability by volumetry. The results were expressed in mg / L and NTU.

2.3 Sampling of the Benthic Macroinvertebrates

Collection of benthic macroinvertebrates was done monthly from May to October, according to the multi-habitat approach [19], using a kick-net (30 cm x30 cm side, 400µm mesh size). Thus, in each station, 20 drags of kick-net were done in different microhabitats, corresponding to a surface of 3m². The contents of each sample were introduced into polyethylene vials containing 10% formalin. In the laboratory, samples were rinsed with tap water using a 400µm sieve and all specimens caught were identified under a binocular stereomicroscope WILD M3B, using appropriate literature of [20], [21], [22], [23], [24], [25], [26].

III. RESULTS

3.1 Physicochemical Parameters

The temperature of water varies from 22.4 °C (station ND1) to 28.4 °C (station ND2), with an average of 24.06 ± 1.51 °C. The saturation rate fluctuates between 65% (station ND3) and 95% (station ND1), for an average of 82.21 ± 6.59 % (Figure 2). About the space level, the Kruskal Wallis test shows that on the space plan, stocks of both parameters differ significantly ($p < 0.05$).

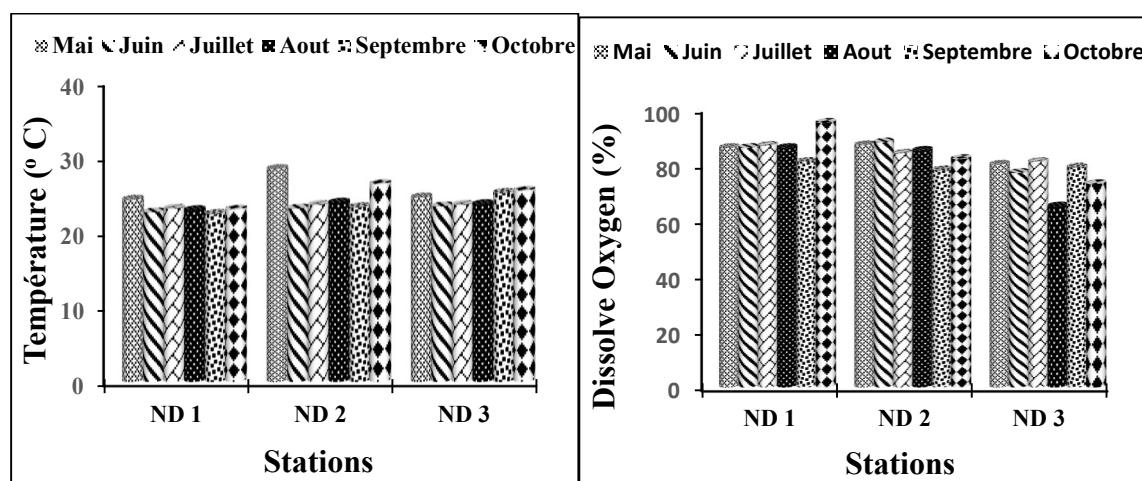


Figure 2 : Spatial variation of the temperature and dissolved oxygen in Ndongo stream during the study period.

The pH values range between 6.54 UC (station ND2) and 7.33 UC (station ND3), with an average of 6.82 ± 0.22 UC. The ammoniacal nitrogen water content is relatively weak, with an average of 0.89 mg/L. The nitrites ions content varies from 0.006 mg/L to 0.095 mg/L, with an average of 0.02 ± 0.02 mg/L. The nitrates offer the values spreading from 0.01 mg/L to 13.7 mg/L with an average of 2.9 ± 3.57 mg/L. As for orthophosphates, data range between 0.02 mg/L and 11.7 mg/L, with an average of 1.26 ± 2.71 mg/L (Figure 3). These five variables do not show a significant difference on the spatiotemporal plan ($p > 0.05$).

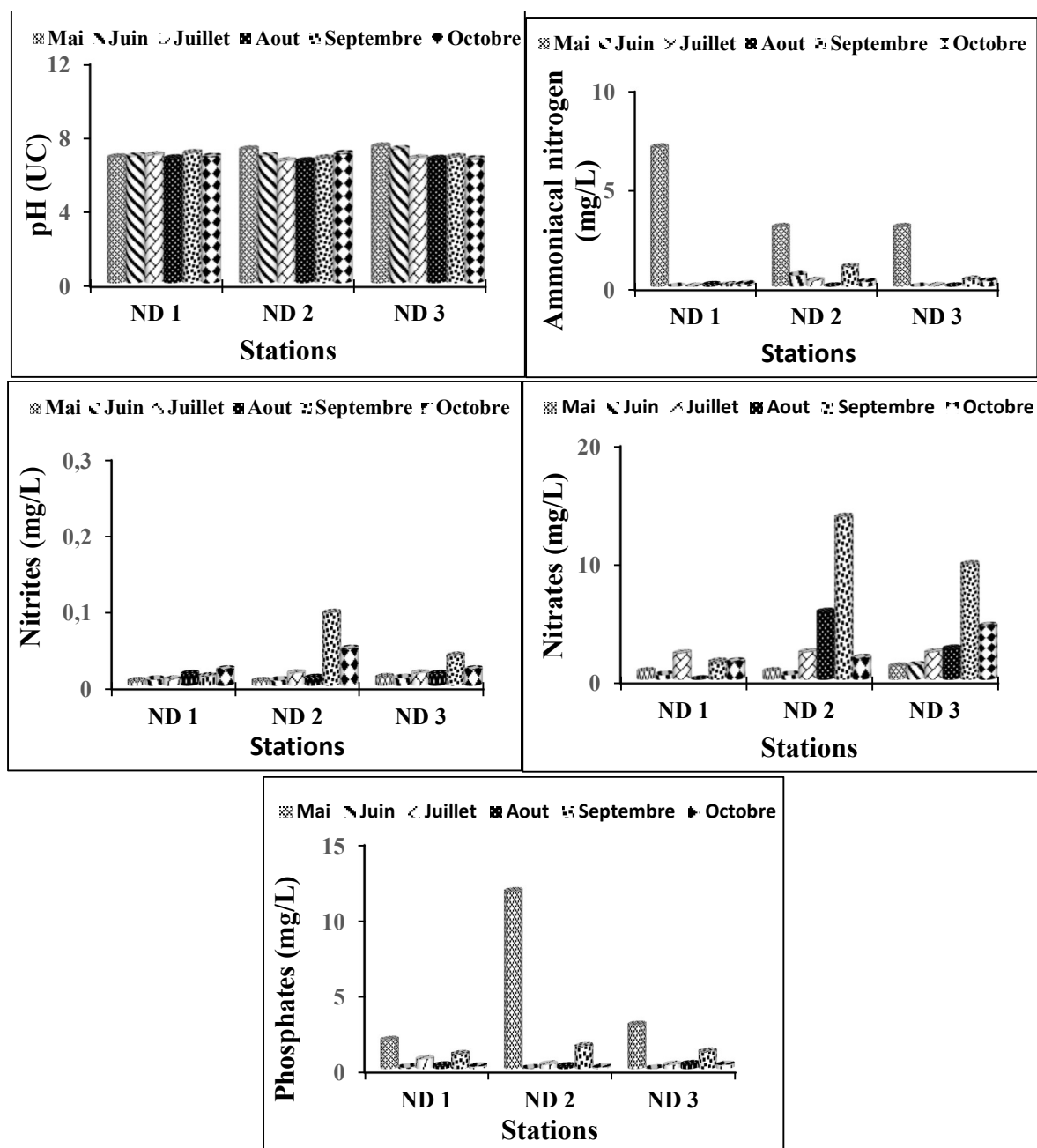


Figure 3 : Spatial variation of pH, nitrites, nitrates, ammonium and phosphates in Ndongo stream during the study period.

3.2 Benthic Macroinvertebrates

A number of 2058 benthic macroinvertebrates were collected, identified and divided into 4 phylums, 5 classes, 11 orders, 32 families and more than 44 genera. The Arthropods represent 83.87 % of relative abundance followed by Molluscs (15.45 % of relative abundance), Annelids and Plathelminthes with respectively 0.58 % and 0.1 % of relative abundance.

Among the arthropods phylum, the class of insects dominates with 81.10 % of relative abundance and count 6 orders, 23 families and more than 33 genera, followed by the class Gastropoda with 15.45 % of relative abundance and 1 order, 3 families and 5 genera. Then, comes the class of Shellfish with 2.77 % of relative abundance and divided into 2 orders, 4 families and 5 genera and lastly, the classes of Oligocheta and Annelids with respectively 0.58 % and 0.1 % of relative abundance (Figure 4). The order of Odonata dominates with 811 individuals and 39.40 % of relative abundance, followed by Ephemeroptera with 394 individuals and 19.14% of relative abundance, Mesogasteropods with 318 individuals and 15.45 % of relative abundance and Heteroptera with 245

individuals and 11.90 % of relative abundance. The 7 other orders (Diptera, Decapoda, Trichoptera, Coleoptera, Isopoda, Lumbriculida and Triclada) represent 14.09 % of total abundance. Among the 32 families, 6 belong to the order of Ephemeroptera, 5 to the order of Coleoptera, 4 to the order of Heteroptera. The order, of Diptera, Mesogasteropoda and Trichoptera count each 3 families, Decapoda, Isopoda and Odonata 2 families and Lumbriculida and Triclada one family (Figure 5A). The taxonomic richness shows that, the station ND1 is more diversified (26 families), followed by stations ND2 (16 families) and ND3 (15 families) (Figure 5B).

Furthermore, the station ND1 is dominated by the orders of Heteroptera (32.48 % of relative abundance) and Ephemeroptera (27.52 % of relative abundance), the Diptera and Oligocheta being absent. The station ND2 is characterized by the predominance of Odonata (74.61 % of relative abundance), followed by Ephemeroptera (9.95 % of relative abundance) and Diptera (6.51 % of relative abundance). The station ND3, is dominated by the Odonata (36.67 % of relative abundance), Gastropods Physidae (27.16 % of relative abundance) and Ephemeroptera (18.89 % of relative abundance) and 5 families, with two families (Caenidae and Baetidae) counting 2/3 of individuals.

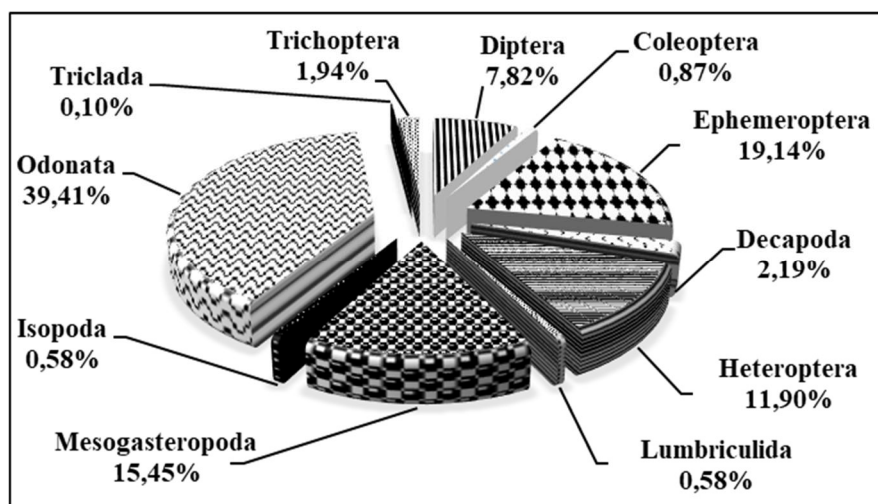


Figure 4 : Relative abundance of benthic macroinvertebrates orders collected in Ndongo stream

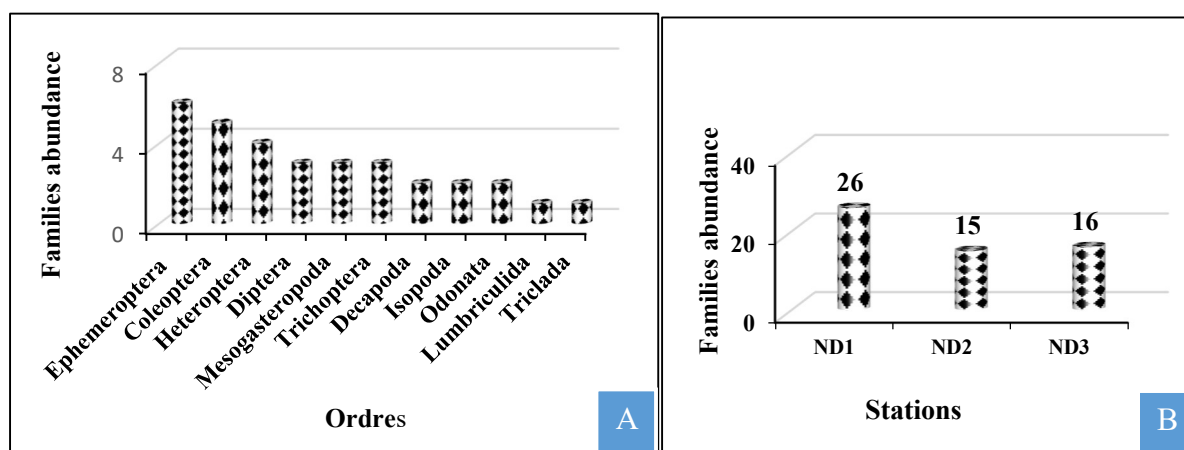


Figure 5 : Relative abundance of benthic macroinvertebrate families per order (A) and per station (B) in Ndongo stream during the study period.

The diversity index of Shannon & Weaver (H') shows a low value (1.96 bits / ind.) at the station ND2, and a high value (3.69 bits / ind.) at the station ND1. Also, the evenness index of Pielou varies in the same meaning with a relatively low value (0.45 bits/ind) at the station ND2 and a high value (0.75 bits/ind) at the station ND1 (Figure 6).

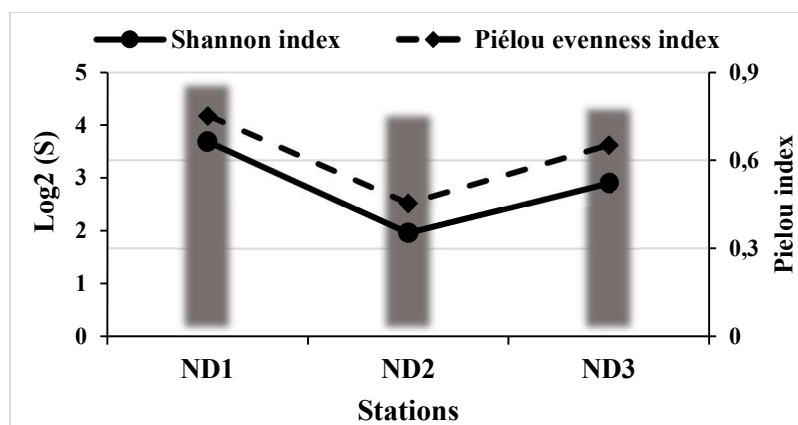


Figure 6 : Shannon & Weaver index and Pielou evenness in Ndongo stream during the study period.

The EPT index varies from 6 families at the stations ND2 and ND3 to 9 families at the station ND1 with an average of 7 ± 1.73 families. The EPT density/Chironomidae density oscillated between 1.29 at the station ND3 and 1.89 at station the ND2 with an average of 1.04 ± 0.94 . These values are higher than 1.00 and showing a perturbation of the environment.

3.3 Principal Component Analysis (PCA)

The Principal Components Analysis (PCA) was used with the aim of discriminating the stations and to correlate affinities between the environmental factors and some organisms. The correlation index organizes the stations into three groups. The first group (N1) found around the station ND1, is colonised by the polluosensitives organisms as Veliidae, Thiaridae, Atyidae, Ephemerellidae, Hydropsychidae and Leptophlebiidae. Water here is characterised by a high rate of dissolved oxygen and low ammonium concentration. The second group (N2) organized around the station ND2, is dominated by the family of Coenagrionidae which show an adaptation to high temperatures in water and poor in nitrites and nitrates. The third group (N3) formed around the station ND3, includes polluosensible (Baetidae and Caenidae) and polluotolerant organisms (Physidae and Chironomidae) (Figure 7).

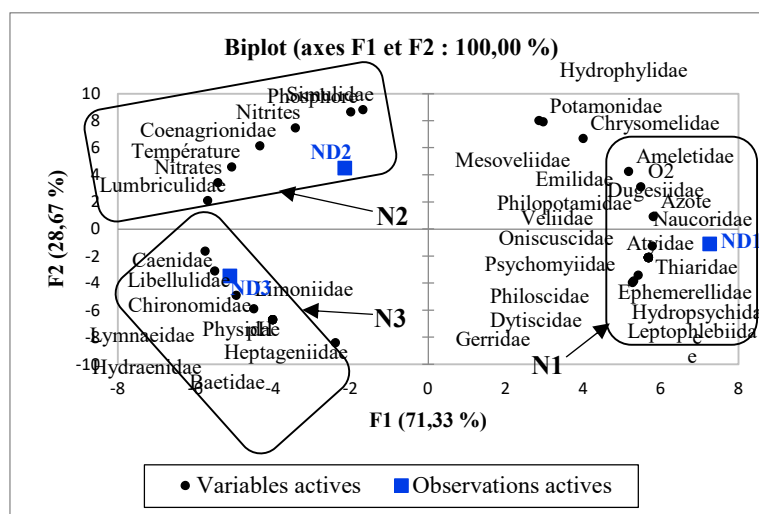


Figure 7 : Principal Components Analysis (PCA) of physico-chemical and biological parameters in Ndongo stream during the study period.

IV. DISCUSSION

4.1 Physicochemical parameters

The low temperatures obtained at different stations of Ndongo stream could be explained by the important vegetable cover which would constitute a great barrier reducing the sun's rays impact on the water. These observations follow those of [27], [11]

who noticed that in the forest streams, temperatures are low because of the influence of the canopy. Furthermore the high value of temperature (28.4°C) raised at the station ND2 is due to its opening to sun's rays. These observation are similar to those of [28], [29] who suggested that there is a linear relationship between the temperature of the water and the air temperature. The rate of dissolved oxygen obtained along the stream (> 70%) can be explained by the important vegetable cover which maintains a natural ventilation upstream [30], [11], [12] and also by the presence of rocky blocks involving a high turbulence of water and oxygenizing it [31], [32]. The relatively acid values of the pH (6.82 CU) would be related to the volcanic soil [33]. Similarly, the degradation of the organic matter or the respiratory activity could involve the acidification of the water [34], [35]. The low value of mineral nitrogen (NH_4^+ , NO_2^- , and NO_3^-) indicates the high rate of dissolved oxygen and low mineralisation activity of the water [30], [11], [12]. [36] mentioned that the nitrites are maintained in the watercourse only when the medium is not well oxidized. On the other hand, the high value of nitrates observed in September at the station ND2 and the high orthophosphates value recorded in May and September would be due to runoff of rains. A similar observation made by [37] which notice that runoff induces great variations of phosphates, nitrates, ammoniacal nitrogen, and decomposition of the organic matter specially after the rains.

The low concentration of the organic pollution indicator parameters (Nitrates, Ammonium), the high value of dissolved oxygen and the low temperature of water show the low anthropogen activity and leads to a good ecological quality of Ndongo stream, favourable to the development of the aquatic communities [30].

4.2 Biology

The taxonomic richness of benthic macroinvertebrates collected in the Ndongo watercourse is low compared to those of Mah Fontie [38], and Abumucchui [39]. Nevertheless, the domination of the insects could be explained by their genetic plasticity, their cosmopolitanism and thus their aptitude to colonize the heterogeneous ecological zones [40], [41]. Besides, the abundance and the diversity of this group testify the little anthropized character of the Ndongo stream [21], [42].

The prevalence of Heteroptera followed by Ephemeroptera at the station ND1 would involve a good ecological quality of water of this portion of the stream. Indeed, Ephemeroptera constitutes one of the polluosensible faunistic groups [20], [42]. Also, the absence of Diptera and Annelida in the same station would be an indication of a very low pollution of the station ND1. These results are different to those of the station ND3 which is characterised by the predominance of Odonata, followed by Gastropoda, Physidae and Ephemeroptera. This shows that the station ND3 is subjected to an organic pollution due to anthropic activities.

In fact, [21], [42] reveal that in the polluted hydro systems, the benthic macrofauna is largely dominated by saprophil and saprobiont taxa such as Physidae, Hydrobiidae, Tubificidae, Chironomidae. The coexistence of the polluosensible organisms (Ephemeroptera : Baetidae and Caenidae) with the polluo-resistant organisms (Physidae) observed at the station ND3 could be explained by the low polluosensible character of the Ephemeroptera which develops tendencies to the tolerance. This coexistence is seen between Baetidae, Caenidae and molluscs Physidae [20], [42].

4.3 Biocenotic Index

The values of Shannon & Weaver index and Pielou evenness show a diversification and tendency to the equi-repartition of the species. Furthermore, the low values of Shannon & Weaver index and Pielou evenness observed at the station ND2 indicated a low diversity and population of benthic macroinvertebrates dominated by Coenagrionidae *Coenagrion sp* of relative abundance of 70 %. These observations are similar to those of [43] and [44], which indicated that Shannon & Weaver diversity index decreases with very high relative abundances.

In general, Ndongo stream contained a great number of sensitive organisms which require good health conditions to their development. At the station ND1, the predominance of Heteroptera (Veliidae) and the Decapods (Atyidae) are observed. Some authors consider that these groups are not sensitive to pollution. These observations are not similar to our results. Indeed, Veliidae and Atyidae are generally collected in stream of good ecological water quality. [45] showed the order of Decapoda which would be assimilated to average tolerance taxa are more sensitive in our environment. Also, [46] notice that Coleoptera and Hemiptera are sensitive and should be considered as water quality bioindicators in Cameroon. On the other hand, at the station ND3, we observe the predominance of the polluosensitives organisms belonging to EPT group (Ephemeroptera, Plecoptera, Tricoptera) notably Baetidae and Caenidae, and polluotolerant organisms. This cohabitation shows that Baetidae and Caenidae are more polluotolerant than polluosensitive. some observations were made by [20], [42] which givethese organisms a weak indicating capacity as polluotolerant organisms (Chironomidae and Physidae).

V. CONCLUSION

The Ndongo stream water is well oxygenated, slightly acid, with low tenors of mineral nitrogen. The benthic macroinvertebrates population is rich, diversified and balanced. A total of 2058 individuals was collected and divided into 4 phyla, 5 classes, 11 orders, 32 families and more than 44 genera. The Arthropod phylum is more abundant and dominated by the class of Insects, followed by Gastropoda and Shellfishes. The dynamics of the benthic macroinvertebrates population vary from upstream to downstream. Ndongo stream has good ecological water quality, upstream characterized by a high diversity of benthic macroinvertebrates and low anthropic activities. However, the diversity decreases from upstream to downstream, due to the proliferation of pollutotolerant taxa. Also, the Baetidae and Caenidae families although belonging to the EPT group (Ephemeroptera, Plecoptera Tricoptera), would be more pollutotolerant than pollutosensible

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