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Chironomid bio-ecology in an anthropisized aquatic ecosystem in Yaounde (Cameroon):community diversity and relationship with the environmental variables of the water system

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ABSTRACT

In this study, the Olezoa stream in Yaounde was assessed from November 2013 to May 2014 to identify the chironomid genera that are present in the water system, determine the physicochemical properties of the water, and describe the relationships between species composition of chironomid communities and environmental parameters. Samplings were carried out on monthly basis at three different stations of the hydrosystem.The results showed that, Olezoa stream is slightly acidic (6.8 ± 0.2 CU), moderately mineralized (312.8 ± 95.4 µS/cm), rich in organic matter and less oxygenized (1.8 ± 1.3 mg/L) and rich in suspended solids (247.4 ± 172.4mg/L). The low values obtained for most physicochemical quality of the aquatic ecosystem justifies the high biodiversity of the Chironomidaecommunity suggest their degree of tolerance and sensitivity to aquatic pollution. This is due to the fact that the chironomidae developmental stages exhibit a variety of adaptations in polluted areas which could be: morphological, physiological and behavioral, occurring simultaneously within each developmental form and the different genera. The relationship between the dynamics of the different genera and the physicochemical variable were confirmed by the Spearman correlation index. This indicated a positive correlation between the distribution of chironomid genera and some environmental variables such as Turbidity (r= -0.517 p<0.05), Suspended solids (r= 0.490, p<0.05) and Total Dissolved Solids (TDS) (r =-0.555, p=0.05) revealing their ecological impetus in the biological management of aquatic ecosystems.

Key words: Chironomid,Olezoa stream, pupalexuviae,Larva instars, aquatic pollution.

INTRODUCTION

Since the appearance of life in water, organisms have continuously increased in their number by multiplying and diversifying considerably[1]. Maintaining its ecological quality and conserving its biodiversity are converging goals because, the healthy functioning of these systems is attested by their high biodiversity for many years to come [2,3] aquatic macroinvertebrates have been applied in water quality assessment due to theirlowdispersal capabilities, long life cycles, sedentary natureand the range of responses to environmental stresses by different species [4]. As a result, certain species are tolerant to pollution while others are sensitive and will be absent from water systems with lowquality. The sampling of aquatic macroinvertebrates should be used to infer the current conditions and recent quality of specific water bodies [5]. Among the species of macroinvertebrates present in water, one quarter belong to the class of Insects with 27 known orders[6]. They constitute a highly diversified ecological group which colonized almost all water systems, showing varied adaptation with the most renowned adaptation being that to aquatic life [7].Dipterans also known as true flies, are the most abundant insect groups found in an aquatic medium and also the most diversified aquatic macroinvertebrates collected in many fresh water habitats. Some taxa are extremely tolerant and well adapted, occurring in heavily polluted water bodies [8].*Chironomids* are broadly distributed worldwide and are the most abundant Diptera group in many polluted fresh water ecosystems. Certain species show ecological adaptations in ecosystems at different trophic levels to extreme environmental situations that are related to high temperature, pH, organic matter content and low dissolved oxygen in the water sediment interface [9].

Although many research works has been carried out on macroinvertebrates in and around Yaounde, such as those carried out by[10]and [11] at different times till date in Cameroon, they have been almost no comprehensive studies on chironomidae communities and their relationships with limnological parameters. The present study realized in the Olezoa stream in Yaoundé, seeks to show the most resistant *chironomid* genera in this streamwhich is under human influence and activities, indicating the pollution of the ecosystem.This will be achieved byevaluating the physicochemical quality of the stream,evaluating the influence of the various physicochemical variables on the bio-ecology and its impact on the distribution of chironomids in the urban water system under scientific evaluation.

MATERIALS AND METHODS

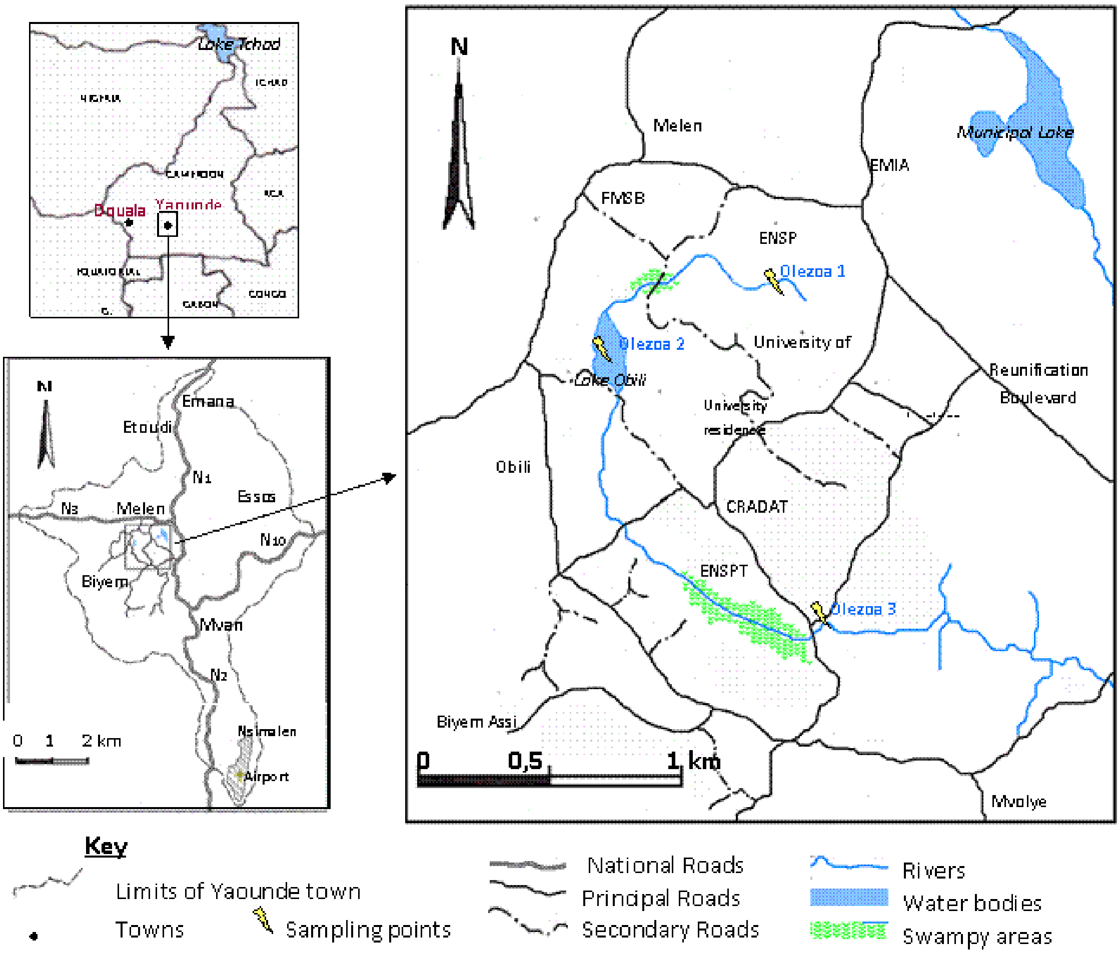

Figure 1: Map of Yaounde showing the different sampling points [12](Source: Plan guide de Yaounde, INC, 2014.

Sampling period and Site description

This research work was realised over a period of seven months, beginning from the month of November 2013 to May 2014 with biostatistical assessment in 2016. It all started with the prospection of the site during the month of November which permitted for the selection of the different sampling points based on a number of factors. A total of three points were chosen along the stream denoted as upstream (Ol_1), lake(Ol_2) and downstream(Ol_3) as seen on figure 1 below. From December 2013 to May 2014 the sampling proper for both the physicochemical and biological parameters were carried out once each month. The sampling point, upstream (Ol_1)has as geographical coordinate's latitude 3º51´33" N and longitude 11º30´8" E with an altitude of about 747m, situated about 500m after the source at the beginning of habitations. The station is characterized by the presence of farmlands, homes, vegetations such as*Panicum sp.*, *Pennisetumpurpureum* (commonly known as elephant grass), *Sidarhombifolia*, *Echinocloapyramidalis*. Water crosses latrines, poultry farms, piggery andgarbage deposites. The second point is theLake (Ol_2) situated some 1km from the source with geographical coordinates of 3º51´23"N and 11º29´43" E and has an altitude of about 731m. This lake measures about 60m large, 100m long and about 1.5m deep, it being employed for fish culture such as, *Oreochromis*, *Hemichromis*, *Heterotis sp.* and *Claria sp.* Around the lake is a huge garbage pit, farmlands, homes and a pisciculturecentre. Downstream (Ol_3) has an altitude of about 720m, with geographical coordinates of 3º51´52" N and 11º29´45" E. The station is situated about some 3km from the source near public institutions. We observe the presence of suck-away pipes from latrines that empty themselves directly into the stream, and scattered distribution patterns of houses and hostels.

Measuring of physico-chemical parameters this was achieved following the recommendation of [13,14]. On the field, parameters like temperature (°C), pH (CU), electrical conductivity (µS/cm), turbidity (FTU) where measured using appropriate instruments. Oxygen was fixed with a Winkler reagent. Back in the laboratory, other parameters such as colour(Pt.Co), alkalinity (mg/L), oxydability (mg/L), nitrate (mg/L), orthophosphates (mg/L), oxygen (mg/L), carbondioxide (mg/L) where measured.

Collection and observation of larvae: On the field with the help of a hand net with very fine mesh about 300µm the aquatic vegetation of the stream was swept across upstream and downstream. At the lake, the hand net was submerged until it touched the benthic zone, a mixture of the specimens and mud was collected. This was latter washed using a 250µm mesh sieve. The specimens were then picked out and conserved in 100ml polythene bottle containing 10% formalin before their transportation to the laboratory[15]. In the laboratory the specimens brought from the field assessment were washed in a 250µm mesh sieve with tap water counted, measured and conserved in 70 % alcohol. The aim of the counting was to better appreciate the relative abundance of the different larva instars. The measurement of larvae instars and was based on their lengths from their anterior to their posterior extremes [16]. A maximum of 50 larva instars were measured per sampling points and sampling periods as recommended by some eco-environmental studies on community structure [17].

Statistical analysis: Spearmanrank correlation coefficient (r) was calculated using the SPSS software version 17.0. This coefficient permits the establishment of a presumed inter-relation between two variables that are in correlation. Using the SPSS software, a Normality Test was conducted.This test permitted for the appreciation of the homogenous or heterogeneous distribution of the data collected.The Chi-two (X^2) test was effected in order to compare the results registered with respect to the sampling points and sampling periods so that a significant difference could be established since the distribution was not homogenous. Measurement of the lengths of the various larvae and pupalexuviae was done using a graduated magnifying lens. Theresults obtained were expressed in micrometres and were then converted into millimetres with the help of the Microsoft Excel 2007 software.

RESULTS AND DISCUSSION

III.1.RESULTS

III.1.1.Spatio-temporal evaluation of physicochemical parameters:

Table 1 below shows the mean, minimum and maximum values for physic-chemical parameters during the study period. We notice that, water temperature of the stream varies between 20.5 ºC and 26.8 ºC. The highest temperature value of 26.8 ºC was recorded at upstream (Ol_1)in the month of May, while the lowest value of 20.5 ºC was recorded at Ol_2 still in the month of May. Turbidity values fluctuate between 119 and 461 FTU. The lowest value of 119 FTU was recorded at upstream ($Ol_{1)}$ and in the lake(Ol_2) in the month of February while the highest value of 461 FTU was recorded at Ol_3 in the month of January. The values of suspended solids ranged from 107 to 825 mg/L with the lowest value being recorded at Ol_2 in the month of March while the highest value of 825 mg/L was recorded at Ol_3 in the month of January. Values of colour vary between 266 and 2800 Pt.Co. The lowest value of 266 Pt.Co was recorded at downstream (Ol_3) in the month of December while the highest of 2800 Pt.Co was recorded at Ol_2 in the month of May. pH varied slightly across the three sampling points ranging between 6.40 to 7.52 CU. The minimum value of 6.40 CU was recorded at Ol_1 in the month of March while a maximum value of 7.52 CU was recorded at Ol_3 in the month of May. Also, TDS values fluctuate between 108 and 266 mg/L. The least value was recorded at Ol_2 in the month of April and May, while the highest value was recorded at upstreamin the month of April. Dissolved oxygen values ranges between 0.6 and 6.3 mg/L with the lowest value of 0.6 mg/L recorded at Ol_3 in the month of February while the highest value of 6.3 mg/L was recorded still in the month of February at Ol_1. On the other hand, values of dissolved carbondioxide fluctuate between 0 and 35.2 mg/L. The lowest value was recorded at Ol_1 in the month of March while, the highest value of 35.2 was also recorded at Ol_1in the month of April. The values of electrical conductivity fluctuate between 194 and 505 µS/cm. The least value was recorded at Ol_3 in the month of January, while the highest value 505 µS/cm was recorded at Ol_1 in the month of February. The values of alkalinity ranges between 48 and 196 mg/L. the minimum and maximum values were recorded at Ol_2 in the month of March and May respectively. Nitrates and orthophosphates ranges from 0.2 to 10.9 mg/L and 0.03 to 2.67 mg/L respectively. Their minimum values (0.2 mg/L of nitrates and 0.03 mg/L of orthophosphates) were both recorded at Ol_2 in the month of March while their maximum values (10.9 mg/L of nitrates and 2.67 mg/L of orthophosphates) were also recorded at Ol_3 in the month of February. Oxydability values range between 0,2 to 15.6 mg/L with a minimum value of 0.2 mg/L recorded at Ol_2 while it maximum value of 15.6 mg/L was recorded at Ol_3in the month of March.

Table 1: mean, minimum and maximum values for physicochemical parameters during the study period.

Parameters	Minimum	Maximum	Mean	±Std. Deviation
Temperature (ºC)	20.5	26.8	24.811	1.5412
Turbidity (FTU)	119	461	214.17	109.261
Suspended solid (mg/L)	107	825	247.39	172.397
TDS (mg/L)	108	266	169.89	51.430
Colour (pt.Co)	266	2800	917.17	643.507
pH (CU)	6.40	7.13	6.8083	0.24030
Electrical conductivity (µS/cm)	194	505	312.76	95.447
Dissolved oxygen (mg/L)	0.6	6.3	1.783	1.3192
Dissolved carbondioxide (mg/L)	0.00	35.20	9.5689	9.43704
Alkalinity (mg/L)	48	196	97.11	43.366
Phasphate (mg/L)	0.03	2.67	0.8353	0.83071
Nitrate (mg/L)	0.2	10.9	2.875	3.8882
Oxidability (mg/L)	0.20	15.60	8.9556	4.81129

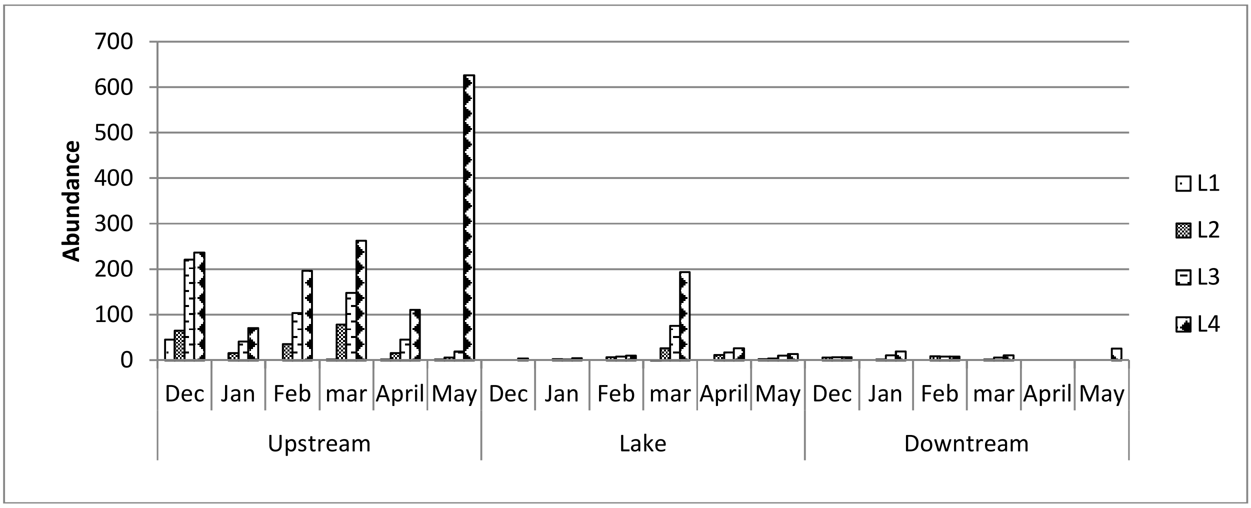

Figure 2:Spatio temporal variation of larvae instars per sampling station.

III.1.2.Abundance of chironomid larva instars

Generally, the development of the larva comprises four embryonic forms which are known as instars. A total of 2903 larvae instars were collected throughout the sampling period, their proportions were as follows; 1.93 % L 1, 9.99 % L 2, 24.97 % L 3 and 63.11 % L 4. The spatial abundance of each developmental form shows that the highest number of L1 larvae was recorded at Ol_1 in the month of December. Also, values of L 2 larva instars range from 0 – 79 individuals, the highest number was recorded at Ol_1 in the month of March while the lowest number was recorded in the month of December at Ol_2, April and May at Ol_3. On the other hand, L3 larva instars vary from 0 – 221 individuals. The Ol_1 station recorded the highest number of L3 individuals in the month of December while Ol_3 recorded the lowest number of individuals in the month of April and May. For the L 4 larva instars, it's number range from 0 – 627 individuals. Ol_1 was rich in these instars, recording the highest number in May while Ol_1 recorded the lowest number of individuals in the month of April as presented in figure 2

III.1.3.Spatial variation of chironomid genera:

The spatial variation of these genera show that, Ol_2 was much more diversified while Ol_3 was least diversified. The three genera collected belong to the sub- family of chironnminae, tribe of chironimini. The number of *Goeldichironomus*[18] sampled, vary from 0 – 37 individuals, with the highest number of individuals recorded at Ol_1 in the month of January while the least number of individuals were recorded in the months of January, March to May. On the other hand, the number of *Chironomus*[18]collected range between 0 and 26. The highest number of individuals was recorded at Ol_3 in the month of December while the least number of individuals were recorded at Ol_3 in the months of February to May. We noted a complete absent of *Nilothauma*[19] at Ol_1. Values of the *Nilothauma*genera vary from 0 – 29 with the highest number of individuals recorded in the month of April at Ol_2 while the least values were recorded at Ol_1,and Ol_3 in the months of January, to May as seen on figure 3

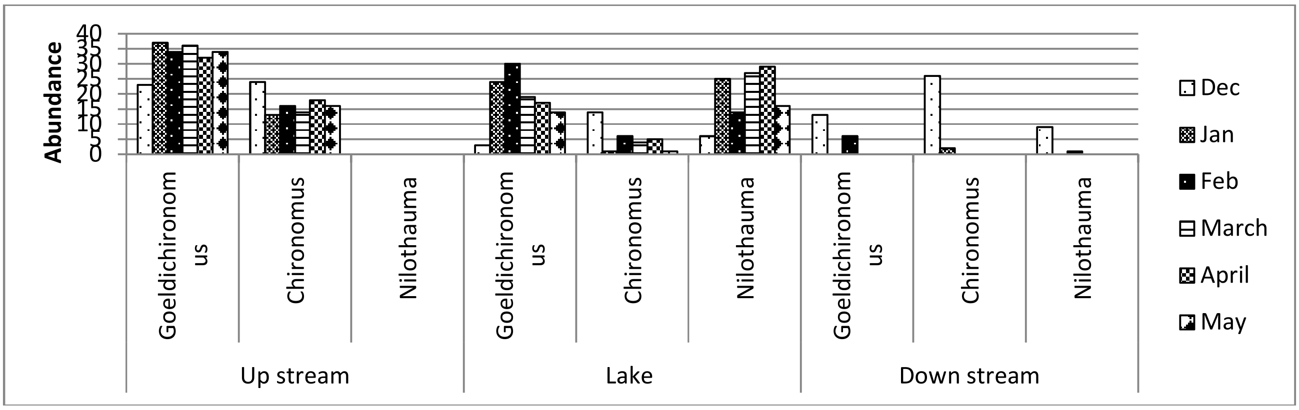

Figure 3: Spatial variation of Chironomidgenera

DISCUSSION

III.2.1.Physicochemical characteristics of Olezoa stream

The physico-chemical results are presented from figure 6 to figure 8. The study show that, temperature varies slightly across the different sampling points along the stream with mean temperature of 24.81 ±0.41°C figure 6A.The temperature value of the stream is influenced by the tropical environmental temperature[20].

The mean pH value of 6.81 ±0.1 CU was influenced by dissolve carbon dioxide (9.57± 3.84mg/L) coming from the dissolution of atmospheric carbon dioxide gas and biological activities taking place in the stream which both favors the conversion of carbonates to bicarbonate ions that acidifies the milieu.

The relatively high values of electrical conductivity (313.72 ± 15.72 µS/cm) and TDS (169.89 ± 84mg/L) as seen in figure 7 and 8, attests for the high rate of mineralization of the stream. The test of Kruskal-Wallis and that of Mann-Whitney shows that, there is a significant difference in TDS across the three stations. This enriches the milieu with free ions that originates from household wastes and effluents coming from the population living along the banks of the stream. The addition of $CaCO_3$ (917.17±218.29 mg/L) at the level of the lake influences the turbidity and the colour of the stream. As stipulated by[21], the high conductivity values could be due to a high concentration in ionic and nutrient substances coursed by fast mineralization rate [11]. Conductivity values between 200–333µS/cm and 333–666µS/cm indicates an average rate and a fast rate of mineralization respectively[14]. The test of Kruskal-Wallis and that of Mann-Whitney shows that, there is a significant difference in conductivity upstream(Ol_1) and downstream (Ol_2). The value of suspended solids (247.39± 56.13mg/L) was relatively high along the stream due to the presence of house hold wastes that is emptied directly into the stream by the population. This value recorded in this tropical ecosystemis higher than that recorded in some Boreal rivers and lakes [11]. The average values of

Nitrates (2.88±2.06mg/L) and orthophosphates (0.84 ± 0.34mg/L) recorded confirms the high degree of mineralization of all organic wastes, fertilizers, animal wastes as well as domestic wastes deposited in the stream. It can also be due to the complete oxidation of Nitrogen, Ammonium and phosphorus compounds into Nitrates and phosphates respectively. The mean value of oxydability (8.96 ± 1.60mg/L) is higher than the normal value of 1mg/L stipulated by[14] for surface water. As a result, the Olezoa stream is very rich in degradable organic matter that is coming from household wastes and effluents from the latrines of the population living nearby the stream.

The physico-chemical analysis of the water quality in the stream shows that the water is lowly oxygenated, highly mineralized, slightly acidic and rich in organic matter. Hence, the stream is highly polluted and not good for human consumption without treatment. This is according to the findings of[11].

III.2.2.Biological characteristics

The biological analysis of the stream showed a high biodiversity of the chironomidae genera and developmental forms, with the highest number collected upstream and the least number recorded downstream. A total of 609 individuals were identified into the tribe of Chironomini revealing 03 genera which are: *Chironomus, Goeldichironomus*andthe *Nilothauma* genera. The most represented genus is *Goeldichironomus* while the least represented genus is *Nilothauma*. The distribution of chironomidae genera in the stream between sampling periods and stations showed a considerable fluctuation during the study period ranging from zero *Nilothauma* genera collected upstream, zero *Goeldichironomus* and *Nilothauma*genera collected downstream at certain sampling periods. The low biodiversity and high number of the chironomidae community suggest their degree of tolerance and sensitivity to aquatic pollution especially the *Goeldichironomus*genera which usually presents dense populations in organically enriched systems[24]. The absence of *Nilothauma*genera upstream and their high abundance in the lake attest that this genus is adapted to a stagnant milieu that is rich in nutrients mean while, their low representation downstream may be due to the fact that the exuviae were being carried downstream from the lake by water currents.
The biodynamic of their different developmental stages attest for the monthly effects on their development and also the conditions which govern within each station, favoring the installation of each developmental form.[25] stipulates that many factors influencing pollution such as: temperature, Oxygen, pH and organic matter will stimulate the adaptation and consequently the growth and multiplication of the various developmental forms or species community in an aquatic milieu. This is due to the fact that the chironomidae developmental stages exhibit a variety of adaptations in polluted areas which could be: morphological, physiological and behavioral, occurring simultaneously within each species. Physiological adaptations such as: the presence of haemoglobin (erythrocruorin) enables them to exist even in complete absence of dissolve oxygen gas for a period of 30 to 120 days[26]their ability to combine the mechanisms of dormancy and anaerobic metabolism during extreme anoxic conditions has greatly favored their development in a polluted medium such as the urban stream [27]. Morphologically, their pupae possess highly specialized respiratory organs or thoracic horns with an apical respiratory surface or plastron plate which is in direct contact with the aerial environment at the water surface which favors respiration. Their posterior segment is modified to an anal lobe which ends with fringes that facilitates undulatory movements, propelling respiratory currents through the tube to ensure an effective respiratory movement[28]. Increase in temperature accelerates many physiological processes and therefore the rate of oxygen consumption and metabolic activities, hence increasing the community of the chironomidae genera in the stream.

Finally, we can say from our results that, the chironomidaefauna of Olezoa stream which is highly polluted consists mainly of taxa with wide ecological tolerance and extensive biological adaptations. These result recorded at an urban polluted ecosystem, shows a negative correlation between some physicochemical and biological parameters. An increase in Turbidity limit the development of the *Chironomus*genera ($r= -0.517$ $p<0.05$). Suspended solids also hinders the development of *Chironomus*genera ($r= -0.490$, $p<0.05$) while an increase in TDS can affects the development of *Nilothauma*genera ($r =-0.555$, $p=0.050$) mean while an increase still in TDS will limit the growth of L_1. ($r=-0.101$, $p<0.01$). An increase in Colour can also affect the developmentof *Chironomus*genera ($r=-0.488$, $p<0.05$) whereas the increase in Electrical conductivity will limit the development of L_1 and L_2($r= -0.499$, and $r = -0.537$ $p<0.05$). Dissolved oxygen is inversely proportional to *Nilothauma*genera ($r = -0.557$, $p<0.05$). These correlation results differ from that obtained in temperate regions[29] with a positive correlation registered between some of these parameters. This could be due to the difference in ecological factors such as climate, in a temperate medium.

CONCLUSION

The aim of this scientific investigation was based on the characterization of the physicochemical parameters and analyses of the different developmental forms and species of chironomidae in an anthropic medium. From the high values of some physicochemical parameters such as TDS (169.9±84), SS (247.4±56.1), turbidity (214.2±109.3) and low dissolved oxygen (1.8±1.3), we can say that, the stream has a high concentration of ionic substances and nutrient. This could be due to the high mineralization occurring in the stream, which translates a high degree of anthropogenic contaminants in the stream which influences both the structure and diversity of chironomidae community in the stream. This idea is further supported by the presence of well adapted and most resistant chironomid genera such as *Chironomus* (26%), *Goeldichironomus* (53%) and *Nilothauma* (21%).Their distribution in the stream was influence by some physico-chemical parameters. The pupae possess high respiratory organs or thoracic horns with the plastrom plate serving in aerial respiration. The *Nilothauma* general can be used as an indicator eutrophication since it was identified in the lake. These identified genera are indicators of environmental saprobity in the stream studied and could serve as an empirical tool for bio-assessment, aquatic monitoring and ecological research in urbanized watersheds.

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