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Health status of the Abiergué river in Yaounde (Cameroon): Diversity and abundance dynamics of protozoans

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Abstract

In Cameroon, particularly in urban areas, watercourses are often transformed into receptacles for all kinds of waste, resulting in significant deterioration quality. This is the case of the Abiergué watercourse, which flows through several densely populated neighbourhoods of Yaounde, such as Tsinga and Briqueterie. In order to determine the state of health (ecological health status) of the Abierguć watercourse, a study based on the diversity and abundance dynamics of ciliates (Protozoans) was conducted from October 2019 to October 2020. Physico-chemical parameters were measured using standard methods. Ciliated protozoans were collected and identified at monthly intervals using appropriate techniques and identification keys. Physicochemical analyses showed that the water of the Abierguć stream was moderately oxygenated (50.93 13.98%), slightly alkaline (7.14 ± 0.47 CU), high in organic matter (3.43 ±1.64mg L) and highly colored (353.52 ± 245.28 Pt-Co). Biological results revealed a total of 1511 organisms collected, divided into 2 subphyla, 10 classes, 21 orders, 29 families and about 50 species. The classes Oligohymenophora and Peniculida order were predominant. Parameciidae family predominated, represented by the species Parameciun caudatum. Calculation of the saprobic index indicated that the water of Abiergué was revolved from β- to α-mesosaprobes state. These results sufficiently demonstrate that the water of the Abiergué stream is subject to organic pollution of anthropogenic origin.

Keywords: Ciliate; Protozoa; Abiergué; Watercourse Diversity; Dynamics

1. Introduction

Rapid population growth, industrialization and urbanization are the main drivers of increasing urban waste production in urban waste production. Unfortunately, poor management practices are giving rise to serious environmental problems. The lack of adequate waste collection infrastructure obliges a large proportion of the population to dump their waste directly into watercourses, turning them into open-air dumping sites. As a result, water quality is severely degraded due to the intense organic pollution generated by this waste. Such polluted environments harbor a multitude of pathogenic germs, exposing local populations to significant risks of contamination and limiting the safe use of these water resources for domestic, recreational, or agricultural purposes [1]. Preservation of the quality of this resource requires a thorough assessment of its biotic and abiotic components. While physicochemical and ecotoxicological approaches remain essential, biological methods offer more reliable and long-lasting indicators for evaluating the overall health of hydrosystems ([2]; [3]). Certain aquatic organisms, due to their taxonomic and functional diversity, their lifespan, and their distribution, serve as excellent biondicators of the ecological status of hydrosystems [4]. Among

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these organisms are zooplanktons which includes rotifers, cladocerans, copepods and protozoa, with ciliates being the most diverse group. Ciliated protozoans are important components of nanoplankton and microzooplankton [5]. They consume bacteria and can contribute to the bacteriological purification of polluted waters [6]. These infusorians are excellent bioindicators of organic pollution due to their high sensitivity to environmental changes and their rapid response to variations in water quality ([7],[8]).

In Cameroon, and particularly in the city of Yaounde, watercourses receive large quantities of waste generated by diverse human activities, leading to significant pollution of these aquatic environments. The Abiergué River, which is one of the main tributaries of the Mfoundi River, is no exception and has been heavily impacted by these anthropogenic pressures. Extensive research has been conducted in Cameroon on the taxonomy and ecology of ciliates ([9]; [10]; [11], [12], [13]; [14], [15], [2];[16],[17]; [6]; [18];[5]; [19]; [20] and [21]; [22] and [23]). However, very few studies have focused on assessing the state of health of the waters of the Abiergué river using ciliated protozoans as bioindicators. This study aims to address this gap by evaluating the state of health of the Abiergué River through the diversity, abundance, and ecological dynamics of its ciliate communities.

2. Materials and methods

2.1. Study site

The Centre Region is located in the Centre–South Forest ecological zone of Cameroon, between latitude 4°45’ North and longitude 12°00’ East. The Mfoundi Division, where the Abiergué River is situated, lies between latitude 3°51’28’’ North and longitude 11°31’05’’ East. This region is characterized by a Guinean equatorial climate with four seasons (two rainy and two dry) that vary slightly from year to year. The landscape consists of a vast plateau between 700 and 800 m above sea level, bordered by hills reaching elevations of 1,000 to 1,300 m, with a succession of waterlogged valleys ([24]; [25]). Petrographically, the soils are predominantly ferralitic. The Abiergué River flows through the city of Yaoundé between latitude 3°48'00" N and longitude 11°32’13’’ E. Its source lies in a valley behind the Carrefour de la Foire. From there, it traverses several neighborhoods (Ntougou, Nkomkana, Tsinga, Mokolo, Messa, and Briqueterie) before finally emptying into the Mfoundi River. Three sampling stations were selected (Ab1, Ab2 and Ab3) (Figure 1) along the Abiergué River. Station Ab1 is located at 11°29'57.2" E and 03°53'48.9" N, at an altitude of 697 m. It lies in a rocky area behind the Tsinga forest. Previously far from human settlements, it is now increasingly affected by new construction sites, whose land-clearing activities are noticeably reducing the sandy and muddy riverbed. The riparian vegetation (*Colocassa esculenta, Ageratum conyzoïdes, Tithonia diversifolia, Ipomea batatas, Axonopus compressus, Cyathula prostrata, Zea mays*) remains typical of the area. Station Ab2, located at 03°53'03.8" N and 11°29'53.9" E at an altitude of 742 m, is approximately 2 100 m downstream of Ab1, in the Nkomkana district. The riverbed is partly sandy and rocky. The riparian vegetation mainly consists of shrubs and grasses (*Cocos nucifera,Musa paradisiaca Seteria megafylla)*. Station Ab3 is located at 11°30'36.3" E and 03°52'25.3" N, at an altitude of 716 m. Riparian vegetation is nearly absent, and the riverbed is heavily modified and graded.

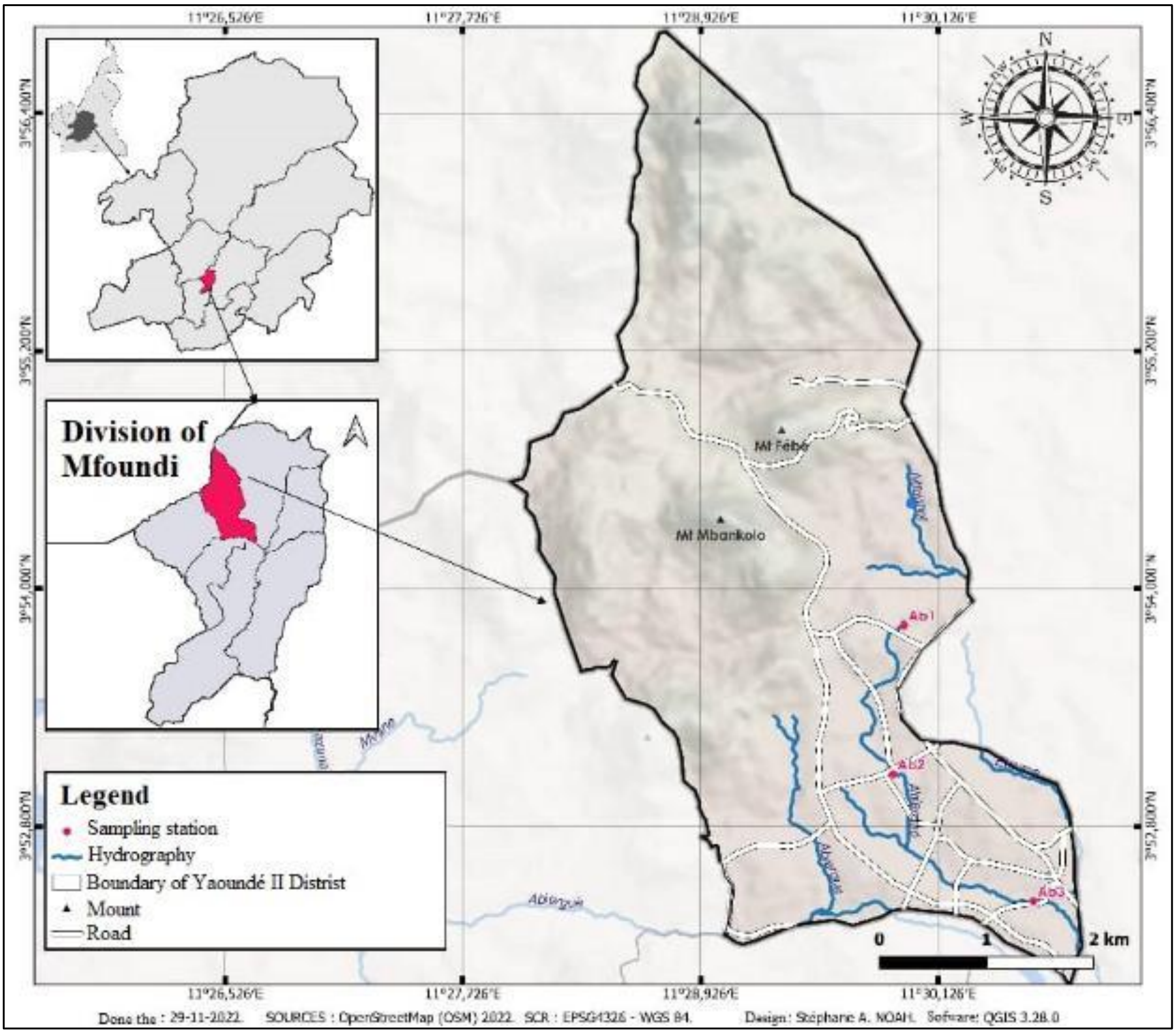

Figure 1 Sampling stations in Abiergué stream during the study period

Physicochemical variables were measured both in the field and in the laboratory using standard methods ([26]; [27]).

Measurements of electrical conductivity, TDS, pH and temperature were taken in situ using a HANNA HI 98130 multimeter, and dissolved oxygen levels were measured using a HANNA HI 9147 oxymeter. In the laboratory, turbidity, suspended solids, nitrate, nitrite, ammonia and orthophosphate levels were measured colorimetrically using a Hydro Test HT 1000 spectrophotometer.

2.2. Ciliates

Samples for biological analysis were collected in polyethylene bottles using the direct method as described by [28]. A total of 1000 ml of water was collected on the lentic facies and from the herbarium and transported to the laboratory for analysis. In the laboratory, after homogenizing the sample, 1 ml was withdrawn using a graduated pipette and distributed into a three-cavity counting chamber. Organisms were then identified and counted in the sample, using a BRESSER HG878513 binocular magnifier. When necessary, identification was completed under a BRESSER Biolux Touch microscope. Identification was made using the keys of [29],[30] , [10], [31], [32a,b], [33], [34], [35].

2.3. Data analysis

Kuskal-Walli's test carried out using software SPSS (version 20.0) was used to determine the degree of significance of the values. Diversity was assessed using the Shannon-Weaver and Pielou equitability indices

Spearmann rank correlations were used to determine the affinities between physicochemical and biological variables. The Pantle and Buck saprobic index was calculated to classify the sites according to their level of organic pollution.

3. Results

3.1. Physicochemical parameters

During this study, water temperature varied from 24.5°C (Ab2 in July) to 30.7°C (Ab3 in February) for an average of 27.13±1.42°C (Figure 2A). pH ranged from 5.82 (Ab1 in February) to 8.51 CU (Ab2 in October), with an average of 7.13 ±0.68 CU (Figure 2B). Dissolved oxygen saturation levels ranged from 9% (Ab2 in February) to 85% (Ab1 in June), with an average of 50.92±19.57% (Figure 2C). Electrical conductivity fluctuated from 240 uS/cm (Ab1 in December) to 770 uS/cm (Ab3 in July) for an average of 470.76±1 58.26 uS/cm (Figure 2D). Total Dissolved Solids (TDS) ranged from 120 mg/L (Ab1 in December) to 390 mg/L (Ab3 in July) for an average of 242.56±81.78 mg/L (Figure 2E). Total suspended solids (TSS) contents varied from 0 mg/L (Ab l in March, May, September: Ab2 in July) to 268 mg/L (Ab3, in July) for an average of 40.92 ±50.41 mg/L (Figure 2F). Turbidity values ranged from 0 (Ab1 in February, March, May, July) to 67 FTU (Ab3 in September, October) for an average of 23.74±20.31 FTU (Figure 2G). Ammonia levels ranged from 0 (Ab1 in October, December, May: Ab3 in December) to 15.98 mg/L (Ab2 in July) for an average of 2.19±2.91mg/L (Figure 2H). Nitrite levels ranged from 0 (Ab1 in December, June: Ab2 in November, December, January; Ab3 in October 2019, November, December, January) to 2.08 mg/L (Ab2 in May) for an average of 0.21±038 mg/L (Figure 2I). Nitrate levels ranged from 0.08 mg/L (Ab2 in December) to 5.8 mg/L (Ab2 in January) for an average of 0.90±1.09 mg/L (Figure 2J). Orthophosphate levels ranged from 0 (Ab1 in December, June and July; Ab2 in July) to 3.81 mg/L (Ab2 in February) for an average of 1.31±1.21mg/L (Figure 2K). Spatially, the Kuskal wallis H test showed significant differences between the values for temperature, dissolved pH, electrical conductivity. TDS, TSS, turbidity, ammonia nitrogen and orthophosphates ($p<0.05$). Temporally, significant differences were observed between nitrite, nitrate, temperature and pH levels ($p<0.05$).

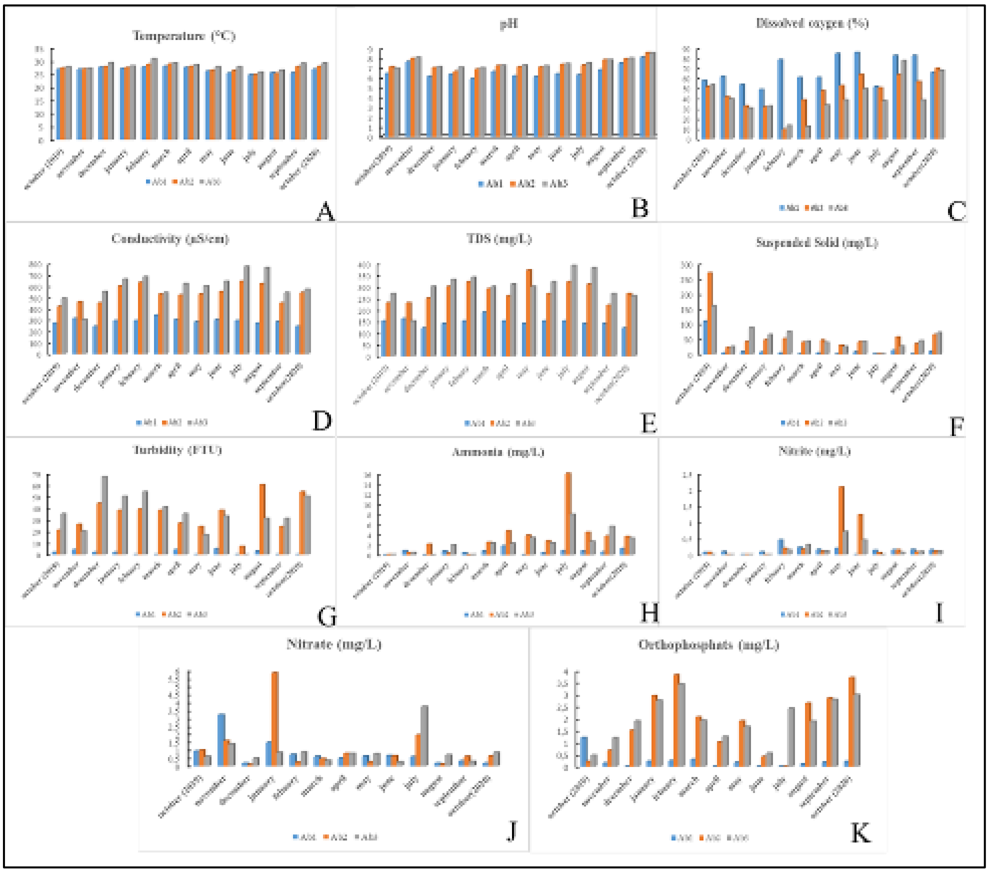

Figure 2 Spatial and temporal variations of physicochemical parameters in Abiergué watercourse during the study period

3.2. Biological parameters

During this study, a total of 1511 organisms were counted, belonging to 02 subphyla, 10 classes, 21 orders, 29 families and nearly 50 species. The class Qligohymenophora was predominant, represented by 06 orders and 11 families. Within this class, the order Peniculida dominated with 03 families and 07 species. The family Paramecidae was the most prominent, with 05 species, led by Paramecium caudatum which accounted for 11.3 19% of the relative abundance. The subphylum Intamactonucleatą was present throughout the watercourse and was illustrated by relative abundance of 99.5%, whereas the subphylum Postciliodesmatophora represented only 0.5% of the community. The dominance of Intramacronucleata reached its peak at station Ab2, where it recorded a relative abundance of 100%. This station hosted 911 individuals distributed among 15 families and 30 species. At stations Ab1 and Ab3, the relative abundances of the subphylum Postciliodesmatophora were very low, with values of 3.78% and 0.68% respectively. (Figure3).

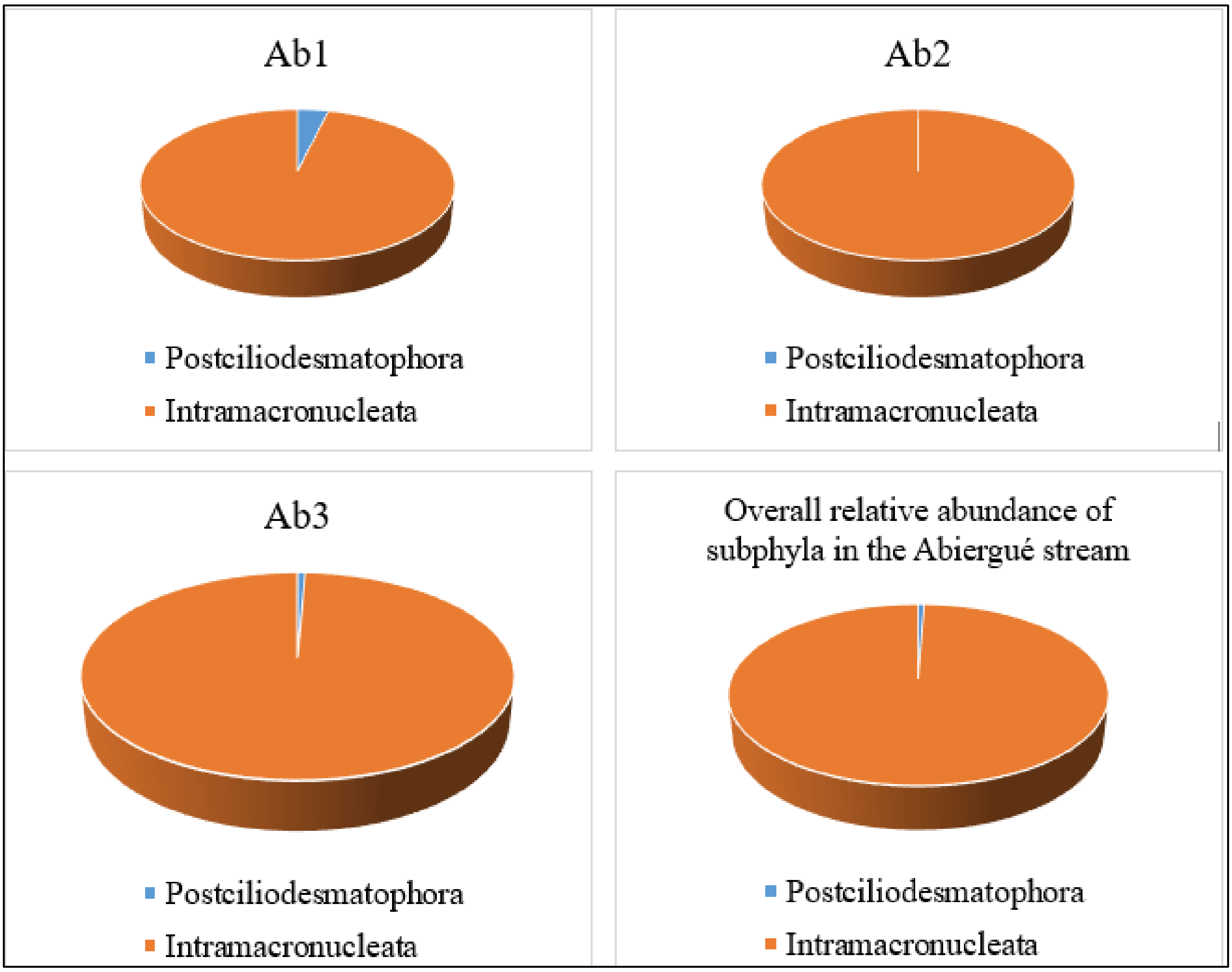

Figure 3 Relative abundance of the subphyla Intramacronucleata and Postciliodesmatophora in Abiergué stream during the study period

Station Ab3 stands out with 441 individuals distributed into 16 families and 27 species, 26 of which belong to the subphylum Intramacronuçleata and only 01 species to the subphylum Postciliodesmatophora, with a relative abundance of 29.18%. Station Abl hosted 157 individuals (10.520). Overall, the fauna of the Abiergué stream is dominated by the species *Paramecium caudatum*, which accounts for 11.31% of total relative abundance. At Sstation Ab1, the species Urocentrum turbo was dominant (38.85%). The species *Paramecium caudatum* was dominant at at station Ab2, with a relative abundance of 18.77%. Finally, at station Ab3,*Paramecium pseudotrichium* was the most abundant species accounting for 19.04% of the individuals.

Table 1 Abundance of species ciliated protozoans in the Abiergué watercourse during the study period

Phylum	Sub Phylum	Class	Order	Family	Species	Abundance in sampling stations		
						Ab1	Ab2	Ab3
Ciliophora	Postciliodesmatophora	Karyorelictea	Loxodida	Loxodidea	*Loxodes rostrum*	2	0	0
					Loxodes striatus	1	0	0
		Heterotrichea	Heterotrichida	Spirostomidae	*Spirostomum intermedium*	0	0	1
					Spirostomum minus	1	0	2
	Intramacronucleata	Spirotrichea	Euplotida	Euplotidae	*Euplotes amietti*	3	9	8
					Euplotes minuta	2	3	1
					Euplotes patella	5	37	8
				Reichenowellidae	*Reichenowella nigricans*	0	0	1
			Stichotrichida	Spirofilidae	*Strongylidium crassum*	4	0	0
			Sporadotrichida	Oxytrichidae	*Histriculus histriculus*	1	20	19
				Oxytrichidae	*Oxytricha chlorelligera*	5	42	1
				Oxytrichidae	*Tachysoma pellionella*	3	1	
			Urostylida	Urostylidae	*Uroleptus piscis*	1	0	0
			Strombidiida	Strombidiidae	*Strombidium gyrans*	31	13	18
		Armophorea	Armophorida	Metopidae	*Metopus extendus*	0	1	0
					Metopus pulcher	0	26	0
					Metopus sp.	0	85	8
		Litostomatea	Haptorida	Acropistidae	*Chaena limnicola*	0	0	1
				Didiniidae	*Didinium nasutum*	0	0	3
			Pleurostomatida	Amphileptidae	*Amphileptus claparedei*	1	0	0
					Heminotus caudatus	0	1	0
				Litonotidae	*Litonotus quadrinucleatus*	1	2	0
		Phyllopharyngea	Chlamydodontida	Chilodonellidae	*Chilodonella cucullulus*	0	1	0
		Nassophorea	Synhymeniida	Orthodonellidae	*Orthodon hamatus*	3	0	0
		Colpodea	Bryometopida	Bryometopidae	*Bryometopus sphagni*	0	0	1

			Bursariomorphida	Bursariidae	*Bursaria truncatella*	0	1	0
		Prostomatea	Prorodontida	Prorodontidae	*Prorodon africanus*	0	0	1
					Prorodon discolor	1	0	0
					Prorodon ovalis	1	2	1
					Prorodon viridis	0	1	0
				Urotrichidae	*Rhagadostoma completum v. candens*	1	0	0
					Rhagadostoma completum	3	0	0
		Oligohymenophorea	Peniculida	Frontoniidae	*Frontonia leucas*	0	0	1
				Neobursaridiidae	*Neobursaridium gigas*	1	0	0
				Parameciidae	*Paramecium africanum*	0	64	17
					Paramecium aurelia	0	12	13
					Paramecium bursaria	0	75	68
					Paramecium caudatum	2	171	81
					Paramecium pseudotrichium	0	75	84
			Urocentrida	Urocentridae	*Urocentrum turbo*	61	40	7
			Philasterida	Uronematidae	*Uronema nigricans*	13	3	1
					Uronema nigricans	13	3	1
					Uronema sp.	0	1	0
			Tetrahymenida	Tetrahymenidae	*Tetrahymena paravox*	1	0	0
				Turaniellidae	*Colpidium campylum*	6	168	77
			Tetrahymenida		*Colpidium colpoda*	1	53	16
			Ophryoglenida	Ophryoglenidae	*Ophryoglena catenulopsis*	1	1	0
			Sessilida	Vorticellidae	*Vorticella campanula*	0	0	1
					Vorticella sp.	1	1	0
					Telotroche de vorticellidae	2	1	1

3.3. Variation in Shannon and Weaver diversity, Pielou's equitability and Pantle and Buck indices during the study period

In the Abiergué watercourse, the values of the Shannon and Weaver diversity index (H) increased from 3.3 bits/ind upstream at station Ab1 to 3.62 bits/ind at station Ab2 before slightly decreasing downstream at station Ab3 (3.35 bits/ind). A similar pattern was observed for Pielou's equitability index, which rose from 0.49 at station Ab1 to 0.54 at station Ab2 before dropping slightly at station Ab3 (0.50)(Figure4).

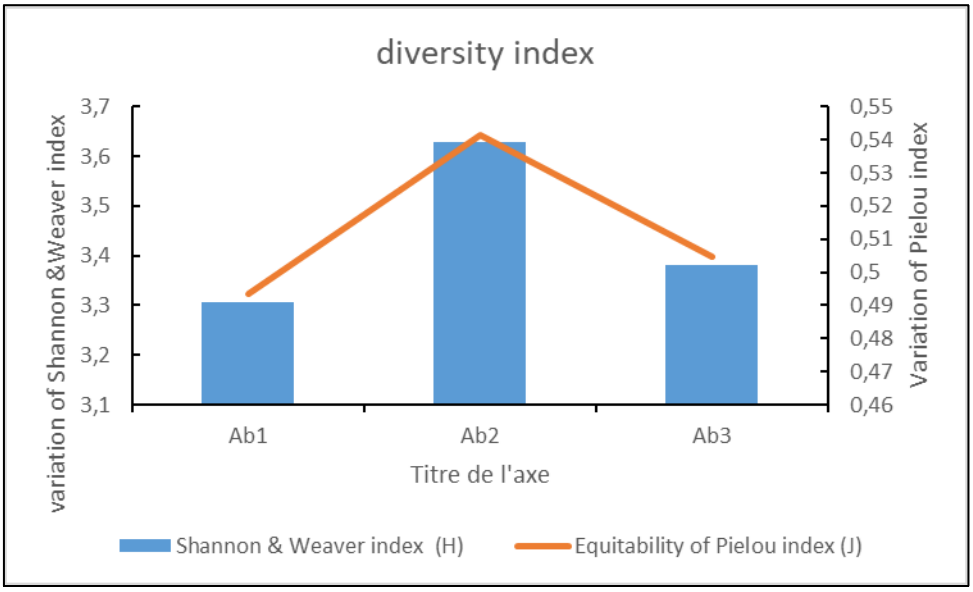

Figure 4 Variation in Shannon and Weaver index and Pielou's equitability

The Pantle and Buck index values increased from station Ab1 (2.5) to station Ab2 (3.30) then slightly decreased at station Ab3 (2.55). This spatial variation is indicative of β-mesosaprobic conditions upstream (station Ab1) and α –mesosaprobic conditions downstream (stations Ab2 and Ab3) (Figure 5).

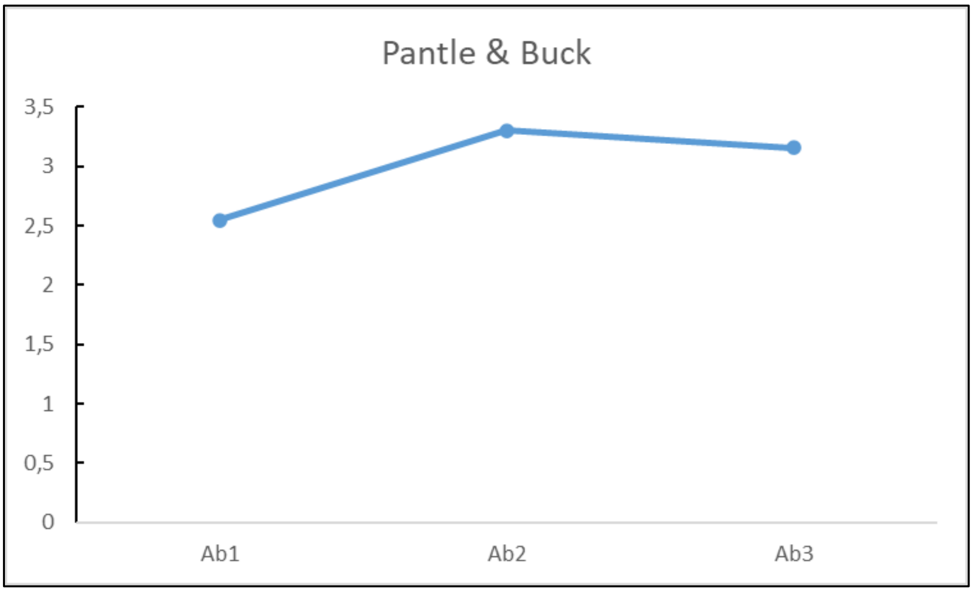

Figure5 Variation in saprobic index of Pantle and Buck

3.4. Influence of physicochemical factors on the biological diversity of ciliates: Spearman rank correlations

Positive, negative and significant correlations were observed at rank 0.001 between physicochemical and biological parameters (Table 2).

Table 2 Spearman rank correlations between physicochemical variables and ciliate species

Species	pH	NH_4^+	NO_2^-	Turbidité	Orthophosphates	Conductivité électrique	TDS
Euplotes amietti	0.545	0.678					
Euplotes patella	0.435	0.464					
Oxytrichia chlorellige	0.441		0.458				
Paramecium africanum				0.433	0.510		
Paramecium bursaria	0.426	0.478			0.594	0.494	0.489
Paramecium caudatum					0.5		
Paramecium pseudotrichium	0.572	0.639				0.418	
Uronema nigricans						-0.423	
Colpidium campyhum		0.453		0.426		0.480	
Colpidium colpoda	0.551						

Positive and significant correlations were observed between *Euplotes amietti* and ammonia (NH4+) (r=0.678), *Paramecium pseudotrichium* and ammonia (NH4+) (r=0.639), *Paramecium bursaria* and orthophosphates(r=0,594), *Parameciun Pseudotrichium* and pH (-0.572), *Colpidium colpoda* and pH (-0.551), *Euplotes amietti* and pH(r=0,545), then between and orthophosphates (r=0,510).

4. Discussion

4.1. Physicochemical characterization

In the course of this study, the high temperatures observed could be due to the absence of the riparian cover, favoured by the anarchic construction of dwellings along the riverbanks. In this regard, [36] pointed out that the anarchic use of river banks and land, combined with overpopulation and industrialization are factors that contribute to an increase in ambient temperature and, consequently, to higher river temperatures in urban areas. The average pH values indicate that, on the whole, the water tends to be basic. This basicity could be attributed to exogenous inputs consisting mainly of waste containing organic matter. Dissolved oxygen levels showed very oxygenated water upstream at station Ab1, reflecting the presence of a canopy at this station. On the other hand, at stations Ab2 and Ab3, the relative oxygenation of the water is linked to mixing phenomena encouraged by the steep slopes created during the recalibration of the riverbed. The high electrical conductivity and TDS values could be justified by the more pronounced mineralization process favoured by strong anthropogenic pressure in this sub-catchment [2]. The high levels of nitrogenous elements (NH4+, NO2- et NO3-) and orthophosphates (PO4-) were likely linked to inputs of urban discharges, domestic wastewater and the mineralization of large quantities of organic matter discharged either directly into the river or transported by runoff. In this line, [37] noted that the metabolic activity of denitrifying bacteria decreases with urbanization which increases environmental stress factors... These values remain lower than those obtained by [38] in the Hassan Addakhi dam in Morocco and by [39] in the Merzeg stream in the peri-urban area of Casablanca in Morocco.

4.2. Biological characterization

The taxonomic richness of ciliates (50 species) observed in the Abiergué stream was similar to that reported by [2] in an urban area and relatively higher than the 34 species recorded by [19] in the Nga River located in a peri-urban area of Cameroon. This difference could be explained by the availability of food resources and the physicochemical characteristics of each sampling point during the study period. [40] points out that the taxonomic richness of ciliates varies from one region to another and depends on a number of environmental factors. [41] also emphasized species respond differently to environmental changes. The high abundance observed at station Ab2 was justified by the availability of the resource, essentially bacteria whose density depends on the amount of urban organic waste. In fact, the intense discharge of urban waste at the Ab2 station created a highly favourable environment for the exponential growth of bacteria responsible for mineralizing organic matter. These bacteria serve as a primary food source for ciliates, which in turn benefit from these conditions to increase their growth and establishment in this respect, [42] revealed that the availability of food resources is an essential element for the distribution of ciliates.

The predomınance of the species *Urocentrum turbo* and *Strombidium gyrans* at station Ab1 with relatıve abundances of 38.86% and 15.50% respectively, combined with their saprobic status of α-mesosaprobic and oligosaprobic, respectively (Foissner, 1988 confers on this station an oligosaprobic tendency, shifting towards α-mesosaprobic conditions, and therefore overall β-mesosaprobic..At station Ab2, the predominance of *Parameciun caudatum* (18.77% relative abundance) and *Colpidium campyhum* (18.44% relative abundance), classified respectively as α-mesosaprobic and poly- to isosaprobic, confers on this station an overall α-mesosaprobic to polysaprobic character, with a tendency towards isosaprobic conditions.. Station Ab3, which hosts the dominant species *Paramecium pseudotrichium* (19.04% relative abundance) and *Paramecium caudatum* (18.36% relative abundance) and *Colpidium campylum* (17.46% relative abundance), include taxa classified as α-mesosaprobic (P. caudatum) and poly-isosaprobic (C. campylum). The simultaneous occurrence and high abundance of these species justify the attribution of a predominantly polysaprobic character to this station. The positive and significant correlations observed between the species *Colpidium colpoda*. *Colpidium campylum*, *Paramecium caudatum Paramecium bursaria* and the chemical indicators of organic pollution (nitrogenous and phosphorus-based compounds) revealed environments that are heavily loaded with organic matter, and therefore subject to a high level of organıc pollution. The Shannon and Weaver diversity and Pielou's equitability indices revealed a poorly diversified with an unevenly distributed population. The Pantle and Buck index values showed a progression of organic pollution from upstream to downstream with station Ab1 classified as β-mesosaprobic and stations Ab2 and Ab3 classified as α-mesosaprobic with a tendency to polysaprobic conditions. Given the level of pollution observed in the Abiergué watercourse, it is necessary to implement a restoration policy to rehabilitate water quality, re-establish the former biodiversity, and promote healthier conditions conducive to various human uses.

5. Conclusion

The Abiergué stream, an urban watercourse and tributary of the Mfoundi River located in Yaoundé, shows clear signs of environmental degradation. Physicochemical results revealed moderately oxygenated waters, a slightly basic pH and high coloured water, indicative of elevated organic matter. Moreover, the marked predominance of α-mesosaprobic and polysaprobic ciliate species provides strong evidence that the Abiergué watercourse is subjected significant to anthropogenic pressures, resulting in progressive deterioration of its water quality.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors declared that there is no conflict of interest to be disclosed.

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