GSC Biological and Pharmaceutical Sciences
eISSN: 2581-3250 CODEN (USA): GBPSC2
Cross Ref DOI: 10.30574/gscbps
Journal homepage: https://gsconlinepress.com/journals/gscbps/

(Research Article)

Check for updates

Limnology of the Ndongo stream (South-West Cameroon): wastes management, water physicochemical quality and phytoplankton species richness

Daniel Brice Nkontcheu Kenko [1, 2, *], Fabiola Mba Maffo [1], Aimerance Donhachi Kenfack [3], Constantin Alega Amougou [4] and Norbert Tchamadeu Ngameni [2]

[1] *Department of Animal Biology and Conservation, Faculty of Science, University of Buea, Cameroon.*
[2] *Department of Animal Biology, Faculty of Science, University of Dschang, Cameroon.*
[3] *Department of Agriculture, Livestock and Fisheries Sciences, Advanced School of Agriculture, Forestry, Water Resources and Environment, University of Ebolowa, Cameroon.*
[4] *Department of Plant Science, Faculty of Science, University of Buea, Cameroon.*

GSC Biological and Pharmaceutical Sciences, 2023, 24(01), 072–086

Publication history: Received on 29 May 2023; revised on 11 July 2023; accepted on 14 July 2023

Article DOI: https://doi.org/10.30574/gscbps.2023.24.1.0266

Abstract

Freshwater ecosystems are subject to anthropogenic contaminants. This study aimed at assessing waste management stratagem by the local population and implications on water abiotic variables as well as phytoplankton species richness of the Ndongo stream, South-West Cameroon. For this purpose, 144 structured questionnaires were randomly administered to inhabitants around the stream to assess wastes management practices. Water and phytoplankton analysis was done in three selected sites. The mainstream of inhabitants (67%) dumped wastes in facilities provided by the Buea Council. The sorting of wastes before disposal was not common among respondents (72%). Recycling of wastes was done by only 37.8% of inhabitants. Half of the respondents (50.7%) claimed being ready to contribute financially for waste management while 81.2% said they were aware of the consequences of poor waste management. The main source of domestic water in the area was tap water (89.6%) and the Ndongo stream was mainly utilised for washing clothes (47.9%). Water abiotic variables that exhibited significant spatial trends included conductivity, TDS, velocity, width, depth and flow rate. There was no significant difference in the spatial distribution of temperature, pH, salinity and dissolved oxygen. The phytoplankton community was made of 36 species distributed in 37 families. Taxa such as *Lynbya* sp., *Oscillatoria* sp. *and Closterium* sp. were found in all the sampling sites, making them resident species of the stream. The sampling site at the lower course of the stream had the highest phytoplankton species richness. The highest algal pollution index was found in site 3at the lower course of the stream. Species richness had a positive and non-significant correlation with temperature, conductivity, TDS, salinity, velocity, depth and discharge. Water pH, dissolved oxygen and width had a negative and non-significant correlation with species richness. The local population should be educated on wastes management and its implications on the environment.

Keywords: Wastes; Phytoplankton; Freshwater Ecosystem; Ndongo Stream; Aquatic Biota

1. Introduction

Water is an indispensable natural resource [1] and freshwater streams in particular are an important natural resource for humans, providing water for agriculture, industry and domestic use [2, 3]. Inland waters in addition to their rich biodiversity are used for many purposes such as fishing, aquaculture, production of electricity, agriculture, navigation, tourism, water supply to urban and industrial areas, and disposal of wastes [4]. Inland waters have a very rich biodiversity including viruses, bacteria, fungi, algae (periphyton and phytoplankton), macrophytes, protozoans, invertebrates (rotifers, flatworms, nematodes, annelids, sponges, molluscs, crustaceans and insects) and vertebrates

* Corresponding author: Daniel Brice Nkontcheu Kenko; Email: kenko.daniel@ubuea.cm

(fishes, amphibians, reptiles, birds and mammals). These aquatic organisms interact with each other and abiotic factors to guarantee a sustainable ecosystem [5]. The aquatic biota is closely linked to water properties and changes in water abiotic variables will affect their population structure. For instance, phytoplankton, that form the basis of aquatic food webs may be used a biomonitors of water abiotic condition [6-11]; macrophytes are very useful in nutrient and heavy metals retention and may be exploited in the bioremediation of polluted ecosystems [12, 13]; groups such as macroinvertebrates have been reported to be good bioindicators in tropical freshwaters bodies [14-19].

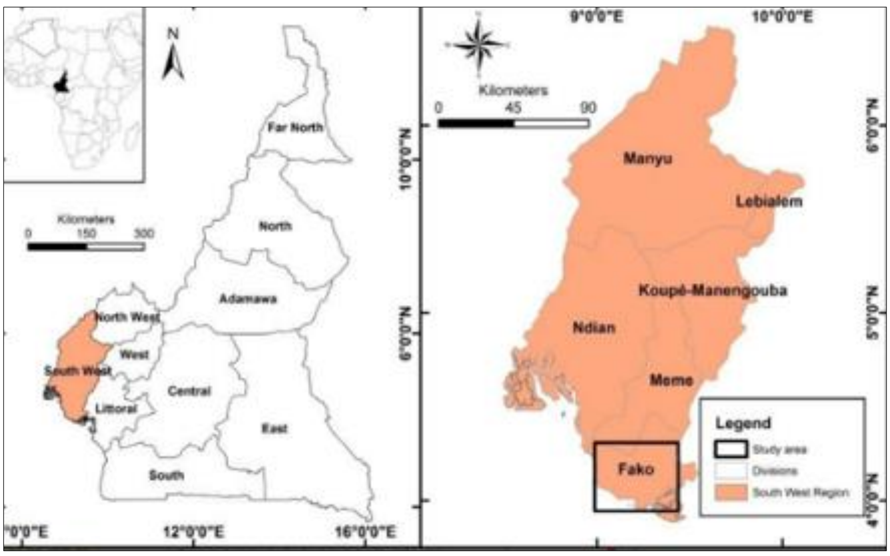
The continuous cycling of water from atmosphere to earth and oceans, and back again make water vulnerable to environmental pollution [2, 20]. The aquatic ecosystem is being threatened by many sources of pollution that may lead to reduced economic potential and severe consequences on human health [21]. There are four main sources of aquatic pollutants including industrial wastes, municipal wastes, agricultural run-off and accidental spillage [22]. Contaminants find their way into the aquatic system through leaching, run-off, spray drift, soil erosion and volatilisation wherein they exhibit toxic effects on non-target organisms [23]. Aquatic pollutants such as heavy metals are able to accumulate in water, sediments and fish such as *Oreochromis niloticus* and *Coptodon rottae* [5]. Moreover, agricultural pesticides have been reported to be very risky to the aquatic ecosystems, modelling moderate to high risk to water, fish, *Daphnia* and primary producers [24-26] as well as amphibians [27, 28].

The Ndongo watersheds belong to the mono-modal equatorial agroecological zone of Cameroon in which two main studies are documented on water physicochemical quality and phytoplankton diversity; one on the Benoe stream, assessing the bioindication potential of phytoplankton [6] and one in the Tiko plain, assessing the effect of agriculture [8]. It is a necessity to document more bioindicators as each stream has its own characteristics influenced by climatic, geomorphological and hydrological factors within the hydrographic basin, making it an individualized ecosystem [29]. The Ndongo stream in the Fako Division (South West Cameroon), takes its sources around Wokoko (Buea), passes via Molyko (Buea), Mile 16 (Buea), crosses Mutengene and the Tiko plain, where it enters the mangrove to join the sea. As a result, the water body may be subject to anthropogenic pressure with many implications of water quality and the biota. In order to contribute the limnological studies in Cameroon, this work aimed at assessing wastes management stratagem by the local population and implications on water abiotic variables as well as phytoplankton species richness of the Ndongo stream, South-West Cameroon. The outcome of this work is better proposals for wastes management, and other forms of anthropogenic pressure on freshwater bodies, in order to avoid stream contamination.

2. Material and methods

2.1. Study area

The study was carried out between November 2018 and June 2019 in Buea, the capital of the South-West Region of Cameroon. Buea lies in the Eastern slopes of Mount Cameroon. The Ndongo stream is principally fed by precipitation and run off from surfaces during the rainy season and underground water during the dry season. The stream substratum consists mainly of coarse sand and stones, decaying macrophytes and debris also form part of the substratum. In the study area, the dry season is from November to March and the rainy season from April to October.



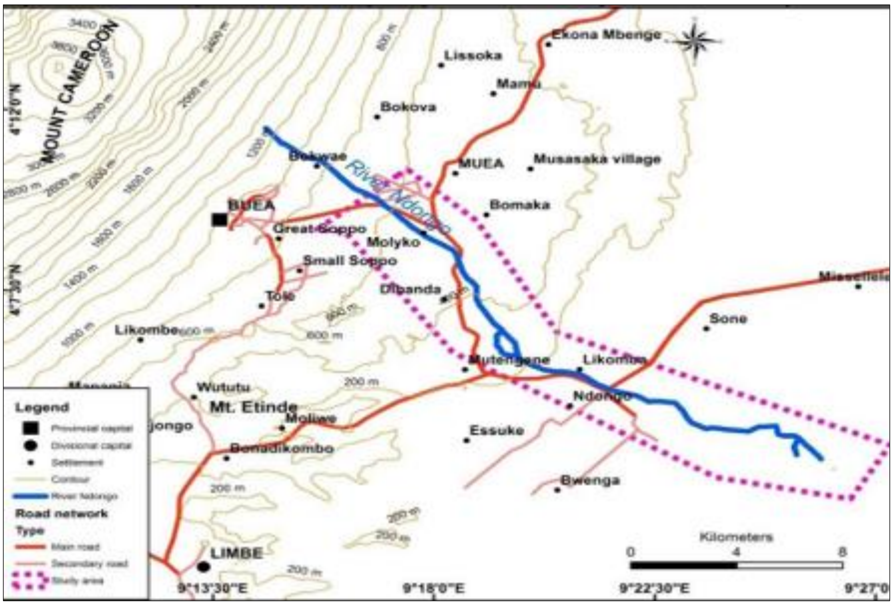


Figure 1 Map of the Ndongo watersheds ; Source: [30]

2.2. Choice of sampling sites

Based on land use, accessibility and tributary inputs, three sampling sites were chosen for this study. The GPS Coordinates (Table 1) of each sampling site were measured using a Garmin Etrex10™ GPS Receiver.

Table 1 The GPS coordinates of the sampling stations

Sampling Stations	Latitude	Longitude	Elevation (m)
Station I (Biaka)	4°15.622N	09°27.180E	653
Station II (University of Buea)	4°15.259N	09°28.465E	584
Station III (Mile 16)	4°14.393N	09°30.012E	511

2.3. Evaluation of wastes management by the local population

The assessment of waste management practices by populations around the stream was done using 144 structured questionnaires randomly administers to inhabitants around the three selected sampling sites. After explaining the research and assessing participant comprehension, informed consent was obtained from all the respondents. Inclusion criteria: Living around the stream, being ready to answer our survey. Each questionnaire had four main sections: (1) basic information, (2) waste management practices, (3) usage of aquatic resources and (4) perspectives.

2.4. Water geometrical, hydrological and physicochemical quality analysis

2.4.1. Geometrical features

From March to June 2019, the canal bottom width (b), surface width (L) and depth (h) in each sampling point was determined using a measuring tape and results expressed in m.

2.4.2. Hydrological variables

Water velocity (V) was determined using the float method [31]. To determine the velocity, a 25 ft. (7.62m) long section of the channel was marked off from point A to point B using a tape. The float was gently released into the channel slightly upstream from the beginning of the section. The amount of time (s) taken by the float to travel from A to B was measured with a stop watch. The process was repeated three times to get the average time. The velocity was then computed following Equation 1.

$$\mathbf{V} = \frac{\mathbf{L}}{\mathbf{T}} \ldots\ldots(1)$$

Where: V is the flow velocity (m/s), L is the length of the section (m) and t is the time (s) it took the float to move through the section.

The discharge was determined following [31] and according to Equation 2:

$$\mathbf{Q = V\ x\ Cross - Sectional\ Area\ x\ 0.8\ \ldots\ldots\ldots}\ (2)$$

Where; Q is the flow rate (m^3/s), V is the flow velocity (m/s), Cross-sectional Area (m^2) = Length (m) x Depth (m) and 0.8 is the Correction Factor.

2.4.3. Physicochemical parameters

Temperature, TDS and EC were measured *in situ* using a COM-100™ Multiparameter Conductivity Meter. The mode of measurement was changed gradually on the meter to get the value and units of various parameters. The probe was rinsed in distilled water after each reading. Temperature was expressed in °C, TDS in ppm and EC in µS/cm. DO was measured with a Milwaukee MW600™ Dissolved Oxygen meter and values were expressed in mg/L. Before use, the oxygen meter was calibrated using the solutions provided by the manufacturer (zero oxygen solution, and the 8.4 mg/L oxygen solution). Water pH was measured with a pH meter (Dr. Meter™). The pH meter was calibrated at two points using the solutions provided by the manufacturer (4.01 and 6.86 pH solutions). Salinity was measured with an EC170™ salinity meter and results expressed in g/L.

2.5. Phytoplankton species richness assessment

In each sampling site and along with water analysis, phytoplankton samples were collected by filtering 100 litres of stream water in to small, white, plastic, transparent containers with a 30µm mesh sized phytoplankton net and the collected samples were placed inside three transparent plastic containers. The collected samples were fixed in 5% formalin solution and taken to the Life Sciences Laboratory at the University of Buea. Observation was conducted under a light microscope. The identification of phytoplankton taxa followed phytoplankton determination keys [3, 32-35].

2.6. Data Analysis

Data was compiled with Microsoft Excel 2021. A Shapiro-Wilk normality test as carried out to check normality then, ANOVA was performed to assess spatial trends in water abiotic variables at 5% significant level. The relationship between water abiotic and biotic variables was assessed via a correlation plot and variable were grouped using the ward method. Two main programmes were used for statistical analyses: SPSS version 23 and R version 4.3.0 [36].

3. Results

3.1. Wastes management by the local population

A total of 144 individuals were interviewed for this study distributed as shown in Table 2.

Table 2 Distribution of respondent in terms of gender and level of education

	Primary	**Secondary**	**University**	**Total**
Female	11	21	38	70
Male	7	26	41	74
Total	18	47	79	144

3.1.1. Age groups

Respondents were aged between 11 and 61 years old (Table 3), with a mean age of 26.0±1.0 years old. The most represented age group was 21-30 with 93 respondents (64%), followed by 11-20 with 27 respondents (19%). The age group 31-40 had 10 respondents (7%), 41-50 had 11 respondents (8%), 51- 60 has just 1 (1%) while 61-70 had 2 respondents (1%).

Table 3 Age groups of respondents

Age groups (Years)	Frequency (N)	Percentage (%)
11 to 20	27	18.75
21 to 30	93	64.58
31 to 40	10	6.94
41 to 51	11	7.64
51 to 60	1	0.69
61 to 70	2	1.39
Total	144	100

3.1.2. Main places used by the local population to dump domestic wastes

The majority (67%) of respondents dumped domestic wastes in authorized spots (Table 4). Some inhabitants (15%) dumped wastes in the bush while other (13%) throw them into the stream. A few (1%) used it as manure or burned (1%) while some (4%) had nothing to say.

Table 4 Wastes dumping sites by the local populations

Variables	Frequency (N)	Percentage (%)
Authorized HYSACAM* Spots	96	66.67
Manure	2	1.39
Bush	21	14.58
Stream	18	12.50
Burned	1	0.69
No Answer	6	4.17
Total	144	100

*HYSACAM: Hygiène et Salubrité du Cameroun (Contractor in charge of wastes in the municipality)

3.1.3. Perception of the Buea inhabitants on wastes management

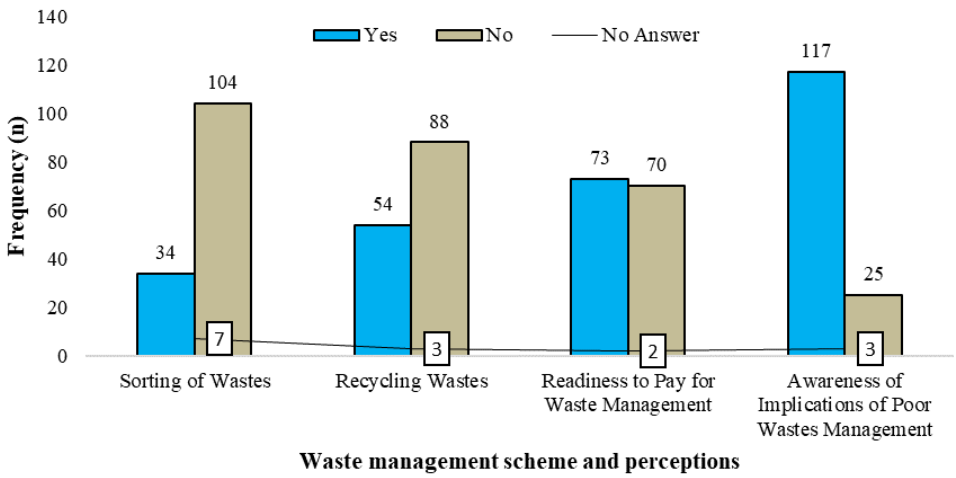


Figure 2 Wastes management practices by the local population

Solids wastes were recycled (N = 54; 37.5%) and used for storage (Figure 2). Respondents who were ready to pay for the collection (N = 73; 50.7%) of their domestic wastes gave reasons such as: their contribution to clean the environment, increase hygiene, improve the working condition and motivate cleaners. Those who said they couldn't pay for the collection of their domestic wastes (N = 70; 48.6%), claimed it is the duty of the government, they are poor, cleaners have salaries, they are not responsible for it or the work done by cleaners is not efficient. Many respondents (N = 117; 81.3%) were aware of the consequences of poor wastes management: they made mention of consequences such as: water pollution, diseases, air pollution, poor environment, unpleasant odours and flooding as a result of poor drainage.

3.1.4. Main source of domestic water in the study area

The main source of water for domestic use claimed by inhabitants was tap water (89.58%). About 3% of respondents declared they used stream water for domestic purposes (Table 5).

Table 5 Main source of water for domestic use by populations

Variables	Frequency (N)	Percentage (%)
Bore Hole	5	3.47
Stream	4	2.78
Tap	129	89.58
Well	2	1.39
NA	4	2.78
Total	144	100

3.1.5. Main uses of the Ndongo stream

The Ndongo stream provides several benefits and ecosystems services to the local population: cleaning, swimming, drinking, fishing, irrigation (Table 6). Unfortunately, the stream is used by some inhabitants (8%) to dump domestic wastes.

Table 6 Ecosystem services provided by the stream to the population

	Frequency (N)	Percentage (%)
Flushing toilets	9	6.2
Cleaning house	4	0.4
Drinking	1	0.7
Dumping domestic wastes	11	7.6
Fishing	2	1.4
Irrigation	13	9.0
Swimming	9	6.2
Washing motorbike	1	0.7
Washing clothes	69	47.9
NA	25	17.4
Total	144	100

3.2. Water geometrical, hydrological and physicochemical variables

Parameters such as conductivity, TDS, velocity, width, depth and discharge exhibited significant change across sampling sites while temperature, pH, salinity and dissolved oxygen did not exhibit any significant change across sampling sites (Figure 3-5).

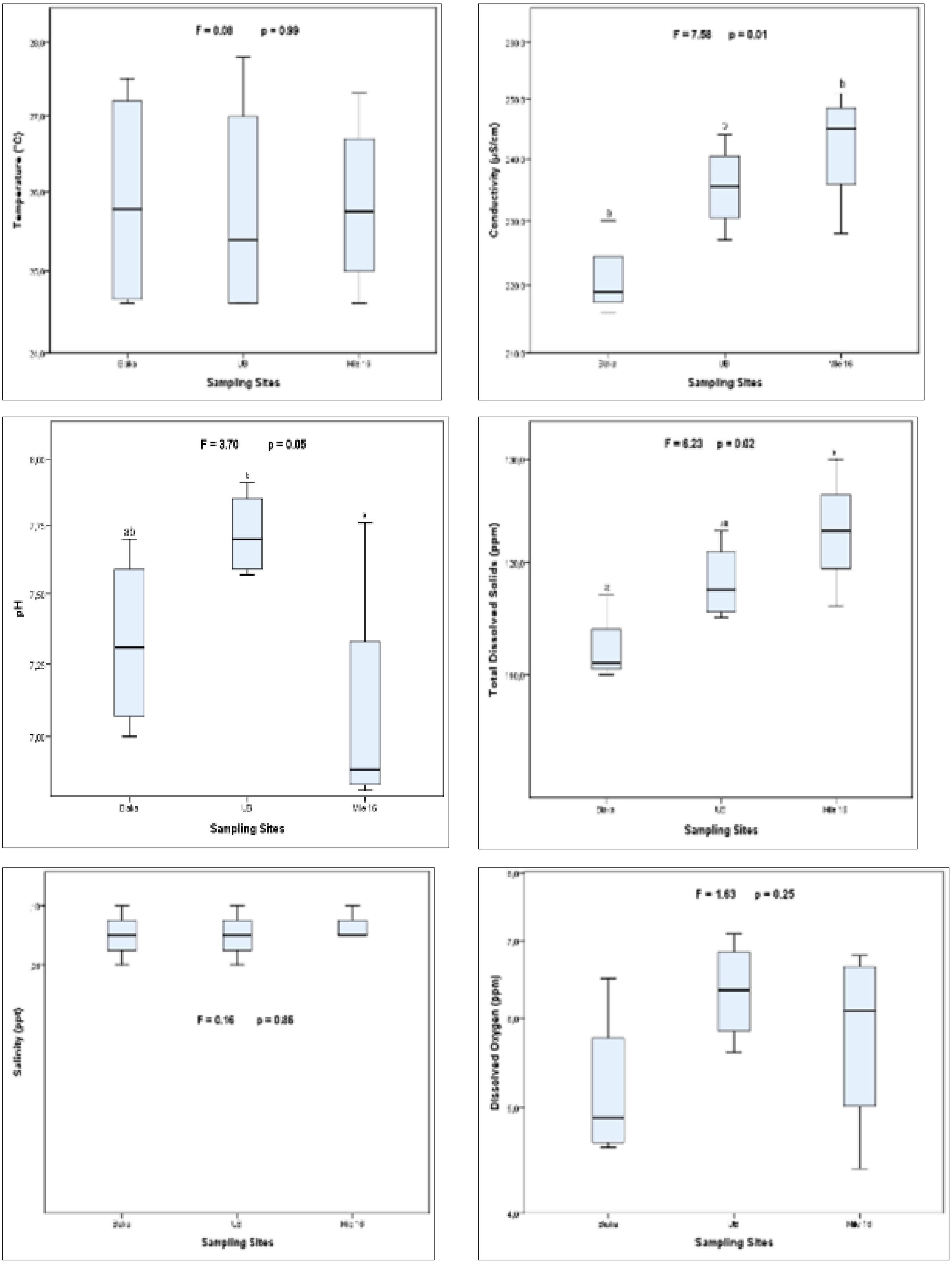


Figure 3 Distribution of water physicochemical quality variables (Bars carrying the same letters are not significantly different (α=0.05); DO: Dissolved Oxygen, TDS: Total Dissolved Solids; UB: University of Buea)

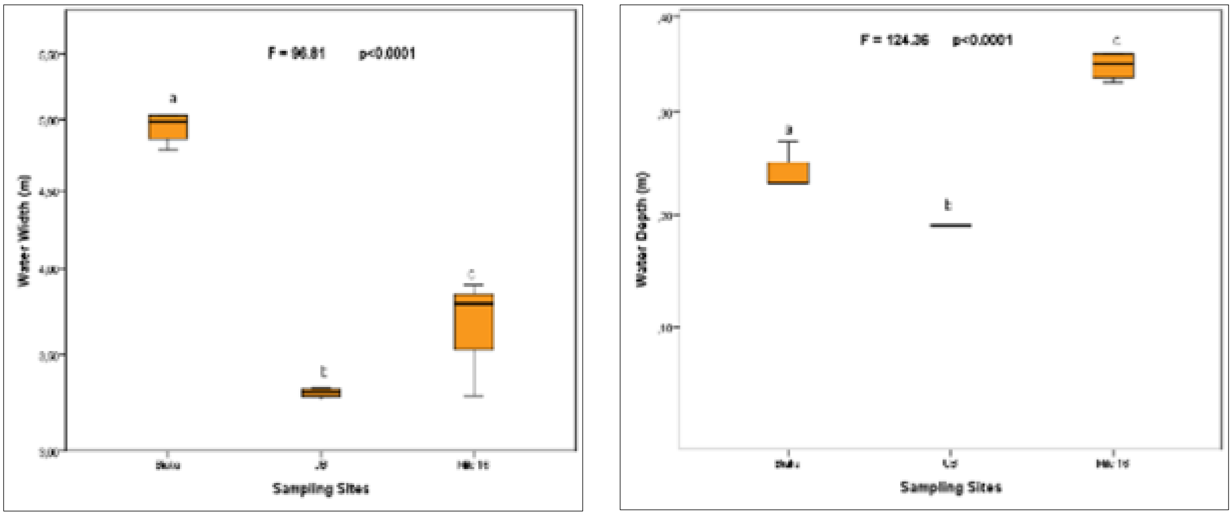


Figure 4 Distribution of water geometrical variables (Bars carrying the same letters are not significantly different (α=0.05); UB: University of Buea)

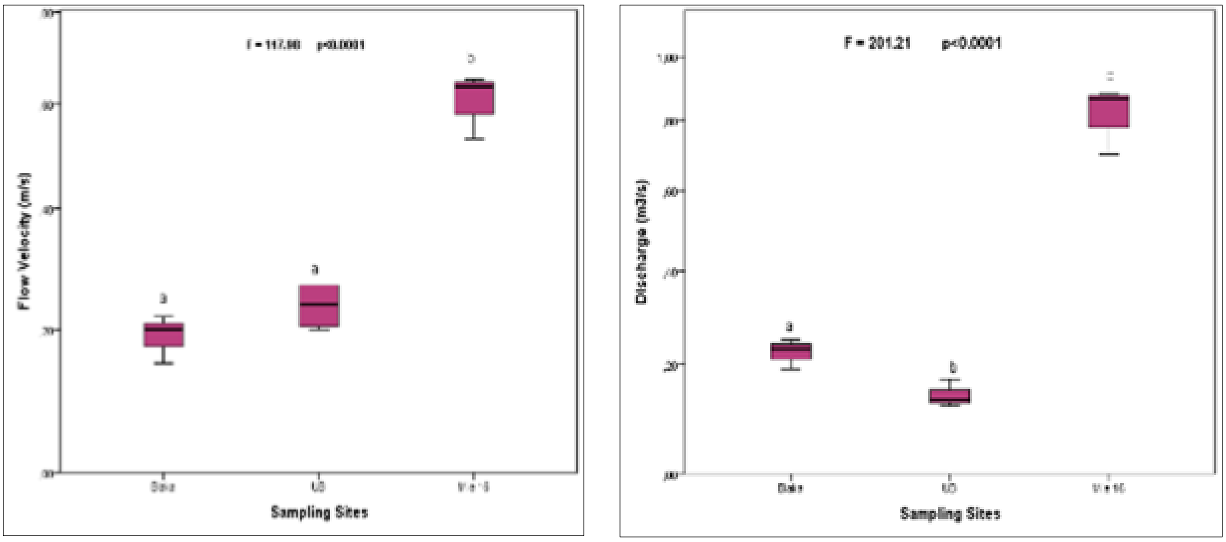


Figure 5 Distribution of water hydrological quality variables: flow velocity and flow rate (Bars carrying the same letters are not significantly different (α=0.05); UB: University of Buea)

3.3. Phytoplankton species richness

The highest species richness occurred at the lower course of the water body where 20 taxa were sampled while the upper course had the lowest richness with 15 taxa (Table 7). *Closterium*, *Lyngbya* and *Oscillatoria* were found in all the sampling sites while *Fragilaria, Chlorogonium, Nostoc, Stephanodicus* and *Spirogyra* were found only toward the source (upper course) of the stream.

Table 7 Species richness across sampling stations

Families	Genera	Sampling Sites		
		Biaka	UB	Mile 16
Chlorellaceae	*Actinastrum sp.*	-	*	-
Microcystaceae	*Microcystis sp.*	*	*	-
Aulacoseiraceae	*Aulacoseira sp.*	*	-	*
Bacillariophyceae	*Diatoma sp.*	-	*	*
	Pleurosigma sp.	-	*	-
Chaetophoraceae	*Stigeoclonium sp.*	*	-	*
Chroococcaceae	*Gloeocapsa sp.*	-	-	*
Cladophoraceae	*Cladophora sp.*	-	*	-
Closteriaceae	*Closterium sp.*	*	*	*
Cocconeidaceae	*Cocconeis sp.*	-	-	*
Cymbellaceae	*Cymbella sp.*	-	*	*
Desmidiaceae	*Desmidium sp.*	-	*	-
	Euastrum sp.	-	*	-
Euglenaceae	*Euglena sp.*	-	-	*
Fragilariaceae	*Asterionella sp.*	-	-	*
	Fragilaria sp.	*	-	-
	Meridion sp.	*	*	-
	Synedra sp.	*	-	*
Haematococcaceae	*Chlorogonium sp.*	*	-	-
Klebsormidiaceae	*Klebsormidium sp.*	*	-	*
Melosiraceae	*Melosira sp.*	-	*	-
Naviculaceae	*Navicula sp.*	-	-	*
Nostocaceae	*Anabaena sp.*	-	*	-
	Nostoc sp.	*	-	-
Oscillatoriaceae	*Lyngbya sp.*	*	*	*
	Oscillatoria sp.	*	*	*
Phormidiaceae	*Phormidium sp.*	-	-	*
Pinnulariaceae	*Pinnularia sp.*	-	-	*
Selenastraceae	*Monoraphidium sp.*	-	*	*
Spirulinaceae	*Spirulina sp.*	-	*	-
Stauroneidaceae	*Craticula sp.*	-	-	*
Stephanodiscaceae	*Cyclotella sp.*	*	-	*
	Stephanodiscus sp.	*	-	-
Vaucheriaceae	*Vaucheria sp.*	-	-	*

Zygnemataceae	*Mougeotia sp.*	-	*	-
	Spirogyra sp.	*	-	-
27	36	15	17	20

* = Present; - = Absent

3.4. Bioindication

3.4.1. Pollution index

Site 1 (Biaka) and site 2 (University of Buea entrance) had low organic pollution while site 3 (Mile 16) had probable high organic pollution (Table 8).

Table 8 Algal pollution index of the Ndongo stream during the study period

	Sampling Sites		
	Biaka	**UB**	**Mile 16**
Stigeoclonium sp.	2	-	2
Closterium sp.	1	1	1
Euglena sp.	-	-	5
Synedra sp.	2	-	2
Melosira sp.	-	1	-
Navicula sp.	-	-	3
Oscillatoria sp.	4	4	4
Cyclotella sp.	1	-	1
Total	10	6	18

0-10= Low organic pollution; 10-15= Moderate pollution; 15-20= Probable high organic pollution; 20 or more = high organic pollution [37]

3.4.2. Association between water abiotic variables and plankton species richness

Species richness had a positive and non-significant ($p \geq 0.05$) correlation with temperature, conductivity, TDS, salinity, velocity, depth and discharge. Water parameters such as pH, dissolved oxygen and width had a negative and non-significant ($p \geq 0.05$) correlation with species richness (Figure 6).

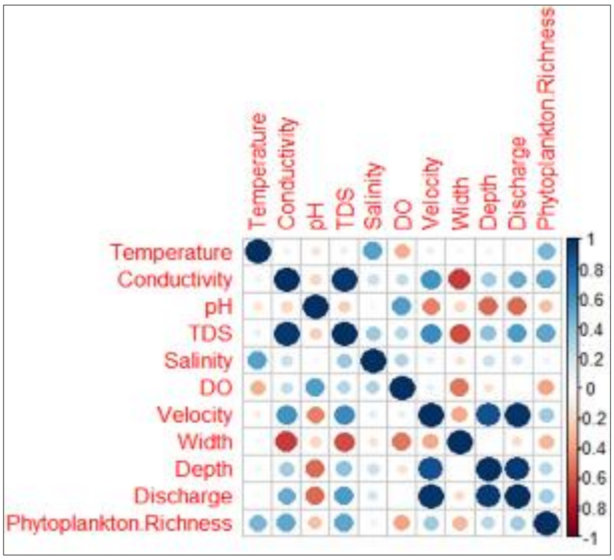


Figure 6 Correlation plot between water abiotic variables and species richness

There was a strong positive and significant ($p < 0.05$) correlation between TDS and conductivity (r = 0.96), depth and velocity (r = 0.88), discharge and velocity (r = 0.97), discharge and depth (r = 0.95). A moderate and significant correlation was recorded between velocity and conductivity (r = 0.59), velocity and TDS (r = 0.64). A negative and significant correlation was recorded between water width and conductivity (r = -0.7), width and TDS (r = -0.64) (Figure 6).

The ascending hierarchical classification grouped variables into two main branches, each having two clusters. The first cluster had pH and DO; the second was formed by width, temperature and salinity; all these five variables were on the first branch. The third cluster was constituted by depth, velocity and discharge, whereas the 4th had three variables: species richness, conductivity and TDS: all these six variables were found on the second branch (Figure 7).

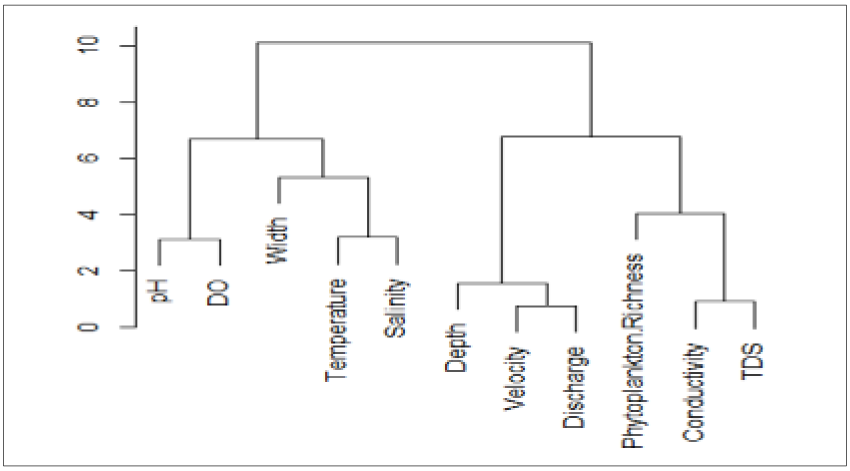


Figure 7 Ascending hierarchical classification of the Ndongo stream abiotic variables and phytoplankton species richness

4. Discussion

This work assessed wastes management stratagem by the local population and implications on water abiotic variables as well as phytoplankton species richness of the Ndongo stream, in the monomodal equatorial agroecological zone of Cameroon.

4.1. Wastes management

The research revealed that the majority of respondents dumped wastes at authorised point by the municipality. Such good practices should be encouraged ad reinforced among the local population. Nevertheless, some carried out poor wastes management practices by dumping wastes into the stream and in the bush which may contribute to stream pollution from urban wastes. In the same line of thoughts, previous reports have documented that water bodies are often used to dump wastes in Cameroon [38, 39]; this practice is a driver of microbial contamination of water bodies [40].

Sorting wastes was not a common practice among the local population, hence the necessity to educate them on the use of biodegradable wastes as fertilisers (composts). Encouraging the practice of recycling wastes will reduce environmental pollution and improve crop yield. Wastes sorting and recycling remains a challenges in Cameroon cities [41], stressing the necessity of incorporating waste recycling and composting as institutional priorities [42]. Wastes separation, infrastructure and finance remain a challenge in waste management in Africans cities [43].

More than half of the respondents declared to be ready to pay for wastes collection and were aware of the consequences of poor waste management. The willingness to pay has been reported to be significantly associated to the level of education and the occupation of the respondent [44]. Some European countries such as Sweden has put into place a weight-based billing for waste management, a practiced said to have booster the spirit of recycling wastes (composting, use of solids wastes as containers…) among the local population [45]. In facts, waste dumping by the population is tributary to the availability of dumping sites to solve the transportation issue; when the closer dumping site is authorised, waste dumping will also be legal; those living near an illegal dumping site, will also have the preference of dumping wastes at an illegal spot as previously documented in the Yaoundé Municipality [42].

In the study area, tap water was the main source of water for domestic use but some used water from the stream for several purposes. In facts, freshwater bodies are known to provide many ecosystem services to the population [46]. The contamination of the stream may then have severe consequence on inhabitants.

4.2. Water abiotic variables

The distribution of pH gave evidence of an alkaline water body. All the pH values were within the optimum range (6.5 - 8.5) for good aquatic productivity. Water bodies of the monomodal equatorial agroecological zone of Cameroon have an alkaline tendency as documented other limnological studies; the Benoe stream [6], the Lake Barombi Kotto [5], the Tiko agro-industrial complex [8].

The significant spatial change in the flow velocity and flow rate may be related to tributary inputs. Changes in TDs and conductivity, especially en increase towards the lower course of the stream may be related to various anthropogenic activities around the water bodies at the upper and middle course such as car washes spots, dumping of domestic wastes. TDS and electrical conductivity were closer to species richness (Figure 7) as compared to other water abiotic variables.

4.3. Phytoplankton species richness and bioindication

The number of phytoplankton taxa recorded in this study (36) is in line with previous studies according to which second and third order streams don't have a very high plankton diversity [6, 47]. Phytoplankton diversity is usually higher in ponds especially when ponds are fertilised; for instance, up to 220 species where reported in the western highlands agroecological zone of Cameroon [48].

Phytoplankton taxa such as *Closterium*, *Lyngbya* and *Oscillatoria* may be considered resident species of the stream as they were encountered in all the sampling sites. Taxa such as *Fragilaria, Chlorogonium, Nostoc, Stephanodicus* and *Spirogyra* were found only toward the source and completely absent in subsequent sampling sites. This may be related to their high sensitivity to anthropogenic factors. Taxa appearing only at the lower course of the stream comprised *Vaucheria*, *Craticula, Phormidium, Pinnularia, Navicula, Asterionella, Euglena* and *Cocconeis*. In fact, the highest species richness was found in station 3 (Mile 16), toward the lower course of the stream. Most of the taxa encountered toward the lower course are pollution resistant or the load of organic matter at the upper and middle course of the stream may contribute to algal proliferation [49].

According to the Algal Pollution Index [37], the Ndongo stream was under low (Site 1 and 2) to probable high (Site 3) organic pollution. This may be related to activities carried out around this urban stream, receiving domestic wastes and bordered car wash points, student's hostels.

5. Conclusion

All in all, this study revealed that the local population has many interactions with the Ndongo River and exhibited poor waste management practices. Water abiotic variables exhibited significant spatial trends evidence of anthropogenic pressure. The phytoplankton community was made of 36 species distributed in 37 families. The stream gave evidence of low to probable high organic pollution. The local population should be educated on wastes management and its implications on the environment.

Compliance with ethical standards

Acknowledgments

The authors are very grateful to all the participants of this study for their cooperation.

Disclosure of conflict of interest

The authors declare that they have no conflict of interest

Statement of informed consent

Informed consent was obtained from all individual participants included in the study.

References

[1] El Morhit M, Mouhir L. Study of physico-chemical parameters of water in the Loukkos river estuary (Larache, Morocco). Environmental Systems Research 2014, 3:17.

[2] Festy B, Hartemann P, Ledrans M, Levallois P, Payment P, Tricard D. Qualité de l'eau. Environn ement et santé publique-Fondements et pratiques 2003:333-68.

[3] Mahar MA. Ecology and Taxonomy of Plankton of Manchhar lake (Distt. Dadu), Sindh, Pakistan. Unpublished PhD Thesis University of Sindh, Pakistan Retrieved from: http://usindh edu pk mukhatiar ahmadlDesse rtation_mukhatiar 2003.

[4] FAO. Rapport du Symposium sur l'Eau et le Développement Durable des Pêches et de l'Aquaculture dans les Eaux Intérieures: Food & Agriculture Org., 1999.

[5] Awo ME, Tabot PT, Fonge BA, Ngole-Jeme VM. Heavy metal exposure risk associated with ingestion of Oreochromis niloticus and Coptodon kottae harvested from a lacustrine ecosystem. Environmental Monitoring and Assessment 2023, 195:427.

[6] Fai PBA, Kenko DBN, Tchamadeu NN, Mbida M, Korejs K, Riegert J. Use of multivariate analysis to identify phytoplankton bioindicators of stream water quality in the monomodal equatorial agroecological zone of Cameroon. Environmental Monitoring and Assessment 2023, 195:788.

[7] Fonge B, Tening A, Egbe E, Yinda G, Fongod A, Achu R. Phytoplankton diversity and abundance in Ndop wetland plain, Cameroon. African Journal of Environmental Science and Technology 2012, 6:247-57.

[8] Fonge BA, Tabot PT, Mange CA, Mumbang C. Phytoplankton community structure and physico-chemical characteristics of streams flowing through an agro-plantation complex in Tiko, Cameroon. Journal of Ecology and The Natural Environment 2015, 7:170-9.

[9] Kemka N, Njiné T, Togouet S, Niyitegeka D, Nola M, Monkiedje A, et al. Phytoplankton of the Yaoundé municipal lake (Cameroon): ecological succession and populations structure. Revue des Sciences de l'Eau/Journal of Water Science 2004, 17:301-16.

[10] Kenfack Donhachi A, Kenko NDB, Davy ZTP, Thomas EE. Species Richness, Diversity and Distribution of Phytoplankton in Fertilised Ponds of the Western Highlands Agro-Ecological Zone of Cameroon. Asian Journal of Environment & Ecology 2022, 19:115-34.

[11] Kengne E, Nguetsop V, Foubi I, Akoa A, Strande L. Algal diversity and distribution in Waste Stabilization Ponds treating faecal sludge leachate from drying vegetated beds. International Journal of Biological and Chemical Sciences 2014, 8:946-55.

[12] Awo ME, Tabot P, Kenko NDB, Fonge BA. Occurrence and nutrient retention of aquatic macrophytes in roadside streams in the Mount Cameroon region. GSC Biological and Pharmaceutical Sciences 2023, 22:025-37.

[13] Fonge BA, Awo ME, Tabot PT, Akango C, Kenko NDB, Djeugo C. Accumulation of Heavy Metals by Some Aquatic Macrophytes in Two Streams along the Tiko-Douala Highway, Cameroon. International Journal of Plant & Soil Science 2023, 35:1-13.

[14] Ajonina A. Impacts of climate variability and anthropogenic factors on composition, distribution and abundance of macroinvertebrates along the shores of River Ndongo, Buea south west region Cameroon. Int J Curr Microbiol Sci, ISSN: 2319 2014, 7706:454-68.

[15] Ngameni TN, Fai AP, Mbida M, Kenko NDB. Impact De L'exploitation Artisanale De La Sabliere De Toutsang Sur La Structure Des Communautes De Macroinvertebres Du Cours D'eau Doulahang A Dschang (Ouest Cameroun). European Scientific Journal 2017, 13:254-74.

[16] Ngameni TN, Fai PBA, Mbida M, Kenko NDB. Bioévaluation De La Qualité Des Eaux Du Cours D'eau Menoua En Zone Périurbaine De Dschang, Ouest Cameroun. European Scientific Journal 2017, 13:368-89.

[17] Onana FM, Togouet SHZ, Tamsa AA, Tchatcho NLN, Tchakonte S, Koji E, et al. Comparing freshwater benthic macroinvertebrate communities in forest and urban streams of the coastal ecological region of Cameroon. Open Journal of Ecology 2019, 9:521.

[18] Menbohan F, Tchakonte S, Ajeagah Gideon A, Bilong Bilong C, Njiné T. Water quality assessment using benthic macroinvertebrates in a periurban stream (Cameroon). The International Journal of Biotechnology 2013, 2:91-104.

[19] Mamert OF, Hubert ZTS, Ernest K, Tchatcho N, Lié N, Siméon T. Influence of municipal and industrial pollution on the diversity and the structure of benthic macro-invertebrate community of an urban river in Douala, Cameroon. J Bio Approx Science 2016, 8:120-33.

[20] Allan JD, Castillo MM. Stream Ecology: Structure And Function Of Running Waters: Springer Science & Business Media, 2007.

[21] El Morhit M. Hydrochimie, éléments traces métalliques et incidences Ecotoxicologiques sur les différentes composantes d'un écosystème estuarien (Bas Loukkos). 2009.

[22] Brugneaux S, Pierret L, Mazataud V. Les agressions d'origine anthropique sur le milieu marin côtier et leurs effets sur les écosystèmes coralliens et associés de la Martinique. Les cahiers de l'observatoire 2004.

[23] Åkerblom N. Agricultural pesticide toxicity to aquatic organisms: a literature review: Sveriges lantbruksuniv., 2004.

[24] Kenko NDB, Fai PBA, Taboue C, Tchamadeu NN, Ngealekeleoh F, Mbida M. Assessment of Chemical Pollution With Routine Pesticides using PRIMET, a Pesticide Risk Model In The Benoe Stream in the South-West Region of Cameroon. European Scientific Journal 2017, 13:153-72.

[25] Ngameni NT, Njikam NA, Kenko DBN, Fodouop EJT, Douatsop VCT. Ecological risk assessment of pesticides in the Ngouoh Ngouoh watershed of the Foumbot Municipality in the west region of Cameroon using the PRIMET model. Environmental Monitoring and Assessment 2023, 195:1-12.

[26] Fai PBA, Ncheuveu NT, Tchamba MN, Ngealekeloeh F. Ecological risk assessment of agricultural pesticides in the highly productive Ndop flood plain in Cameroon using the PRIMET model. Environmental Science and Pollution Research 2019, 26:24885-99.

[27] Kenko DBN. Effects of pesticides on amphibians and tentative solutions. Journal of Asian Scientific Research 2022, 12:218-36.

[28] Kenko NDB, Patricia BAF, Ngameni TN, Mpoame M. Environmental and Human Health Assessment In Relation To Pesticide Use By Local Farmers and the Cameroon Development Corporation (CDC), Fako Division, South-West Cameroon. European Scientific Journal 2017, 13:454-73.

[29] Salomoni S, Rocha O, Leite E. Limnological characterization of Gravataí River, Rio Grande do Sul State, Brazil. Acta Limnologica Brasiliensia 2007, 19:1-14.

[30] Tchounda T, Mboudou GMM, Agyingi CM. Heavy metal concentration and distribution in stream sediments of Ndongo River, Buea, Cameroon-environmental impact. World Scientific News 2019, 131:15-36.

[31] Michaud J, Wierenga M. Estimating discharge and stream flows. A guide for sand and gravel operators. Ecology Publication 2005, 70.

[32] Bellinger E, Sigee D. Introduction to Freshwater Algae. Freshwater Algae: Identification And Use As Bioindicators 2010:1-40.

[33] Bowling L. Freshwater Phytoplankton: Diversity And Biology. In: Suthers IM, Rissik D, editors. Plankton: A Guide to Their Ecology and Monitoring for Water Quality. Melbourne, Australia: CSIRO Publishing, 2009. p. 115-39.

[34] Van Vuuren SJ. Easy identification of the most common freshwater algae: a guide for the identification of microscopic algae in South African freshwaters: Resource Quality Services (RQS), 2006.

[35] Verlecar X, Desai S. Phytoplankton Identification Manual. National Institute of Oceanography, Goa, 2004.

[36] R.Core.Team. R: A Language and Environment for Statistical Computing. In: Computing RFfS, editor. Vienna, Austria2023.

[37] Palmer CM. A composite rating of algae tolerating organic pollution 2. Journal of Phycology 1969, 5:78-82.

[38] Kometa SS, Akoh NR. The Hydro-geomorphological implications of urbanisation in Bamenda, Cameroon. Journal of Sustainable Development 2012, 5:64-73.

[39] Nganje T, Agbor E, Adamu C, Ukpong A, Katte B, Edet A, et al. Public health challenges as a result of contaminated water sources in Kumba, Cameroon. Environmental geochemistry and health 2020, 42:1167-95.

[40] Viban TB, Herman O-NN, Layu TC, Madi OP, Nfor EN, Kingsly MT, et al. Risk factors contributing to microbiological contamination of boreholes and hand dug wells water in the Vina Division, Adamawa, Cameroon. Advances in Microbiology 2021, 11:90-108.

[41] McKay T, Mbanda JT-D, Lawton M. Exploring the challenges facing the solid waste sector in Douala, Cameroon. 2015.

[42] Sotamenou J, De Jaeger S, Rousseau S. Drivers of legal and illegal solid waste disposal in the Global South-The case of households in Yaoundé (Cameroon). Journal of environmental management 2019, 240:321-30.

[43] Regassa N, Sundaraa RD, Seboka BB. Challenges and opportunities in municipal solid waste management: The case of Addis Ababa city, central Ethiopia. Journal of human ecology 2011, 33:179-90.

[44] Babaei AA, Alavi N, Goudarzi G, Teymouri P, Ahmadi K, Rafiee M. Household recycling knowledge, attitudes and practices towards solid waste management. Resources, Conservation and Recycling 2015, 102:94-100.

[45] Dahlén L, Lagerkvist A. Pay as you throw: strengths and weaknesses of weight-based billing in household waste collection systems in Sweden. Waste management 2010, 30:23-31.

[46] Postel S, Carpenter S. Freshwater ecosystem services. Nature’s services: Societal dependence on natural ecosystems 1997, 195.

[47] Kenko NDB. Pesticide Risk Assessment and Study of the Phytoplankton Community for the Biomonitoring of the Benoe Stream, South-West Cameroon. Cameroon: PhD Thesis, Department of Animal Biology, University of Dschang, p.150., 2020.

[48] Kenfack DA, Kenko NDB, Zebaze TPD, Efole ET. Species Richness, Diversity and Distribution of Phytoplankton in Fertilised Ponds of the Western Highlands Agro-Ecological Zone of Cameroon. Asian Journal of Environment & Ecology 2022, 19:115-34.

[49] Radwan MA-A, Tayel TF, Morsy MA, Abdelmoneim A, Basiony IA. Monitoring of water pollution and eutrophication using phytoplankton as bioindicator in Burullus Lake, Egypt. Journal of Environmental Sciences Mansoura University 2018, 47:63-74.