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Physico-chemical characteristics of biotope and sediment texture of invasive aquatic plants in the lower Nyong River at Lokoundjé in the Ocean Division (South-Cameroon)

R. D. Nwamo*[1], G. N. Ajonina[2], N. E. Ekungwé[3], Essiane Obono Anne Emeline[1], Tomedi Eyango Minette[4]

[1]*Department of Aquatic Ecosystems Management, Institute of Fisheries and Aquatic Sciences at Yabassi, University of Douala, Douala, Cameroon*

[2]*Institut of Agriculture Research for Development at Limbe, Minister of Scientific Research and Innovation, Limbe, Cameroon*

[3]*Cameroon Wildlife Conservation Society, Mangrove & Coastal Wetlands Research Centre, Cameroon*

[4]*Department of Aquaculture, Institute of Fisheries and Aquatic Sciences at Yabassi, University of Douala, Douala, Cameroon*

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Key words: Nyong river, Physicochemistry, Bottom substrate, Invasive aquatic plants

Abstract

The objective of this study was to provide information on the habitat characteristics of these plants that facilitate their recovery. To this end, a total of 16 monthly samples were taken at each of the three stations: Dikobé (DIK), Donenda (DON) and Béhondo (BEH). Water and bottom substrate samples were collected and examined using appropriate analytical methods. Depending on the sites and seasons, a significant variation exist in temperature (T°C) from 31.1 to 32°C; salinity from 0.01 to 25.57 ‰; total dissolved solids (TDS) from 0.011 to 20.14 mg/l; electrical conductivity from 0.023 to 38.42 µS/cm; pH from 7.09 to 8.96 and dissolved oxygen from 2.92 to 5.96 mg/l. Sediment analyzes reveal very high values of total phosphorus (689 to 1286 mg / kg) at the 3 stations compared to lower values of total nitrogen at these same stations. Total Organic Carbon (TOC), Organic matter (OM) and total nitrogen, BEH has the lowest value while DON has the high value. The results of the sedimentary profile revealed that the soil at Dikobe had a clay-silt texture on the 30 cm studied. At DON, the texture in the first 10 cm was silty-sandy, clayey-silt from 10 to 20 cm and clayey in the last 10 cm. At Béhondo, the texture was clayey from 0 to 8.5 cm and sandy up to 30 cm. These results are important for a better understanding of the expansion of invasive aquatic plants.

***Corresponding Author:** R. D. Nwamo ✉ nwamodidier@gmail.com

Introduction

Invasive aquatic plants are a particularly acute problem in tropical and intertropical zones (N'dah and Arfi, 1996). As a result, they pose a threat to freshwater rivers and basins both in areas close to the sea and inland (Labrada and Fornasari, 2002). Because of their extremely high growth rate, they can rapidly cover large areas and considerably alter the functioning of the ecosystems concerned (N'dah and Arfi, 1996). The main factors contributing to the proliferation of aquatic macrophytes are temperature, fertilisers and the absence of predators (ACTA, 1987). Nowadays, as a result of human activity, the frequency of biological invasions has increased considerably and certain species that would never be dispersed naturally have been introduced into different regions of the world (Hanfling and Kollmann, 2002). As a result of these deliberate or accidental introductions, some species have become established and have thrived to the point of escaping control and proving harmful in the new environment (Williamson, 1996; Richardson, 2001). However, the micro-distribution of species in rivers and lakes, enabling them to form meadows, corresponds to different patterns between these types of environment (Haury and Muller, 1991). In water bodies, depending on depth and substrate, vegetation belts form (Haury and Muller, 1991).

Many of Cameroon's rivers, such as the Wouri, Nkam, Moungo, Nyong and their tributaries, have been invaded by invasive aquatic plants. Invasive plant species have therefore become a real problem in recent decades. However, in Cameroon, there is still very little known about and widespread use of enhancement as a method of combating these plants. Most of the only information available relates to their harmful effect on aquatic ecosystems. In addition, there are a number of threats to the development of this recovery activity, in particular its invasive nature and its impact on people's lives. The ease with which invasive aquatic plants can spread in different environmental conditions and their mobility make them difficult to control. However, certain species of invasive aquatic plants have interesting characteristics for the development of agronomy in general and agriculture and fish farming in particular.

In view of the above, it is therefore important to carry out a study that takes into account the physico-chemical characteristics of the water and substrate of invasive aquatic plants in the lower reaches of rivers which in this case we choosed the Nyong river at Lokoundjé in the Ocean Division of South Cameroon. Another advantage of such a study would be to provide an essential database for the management and enhancement of the clam population in the estuarine zone, and even to provide a basis for future assessments of changes in the characteristics of the water and sediment in the estuary. In addition, the various development phases of invasive aquatic species throughout the world take place mainly in natural environments with specific characteristics. With this in mind, the aim of this study was to assess the physicochemical characteristics and sediment profile of the sediments that make up the substrate in the lower reaches of the Nyong river.

Materials and methods

Location of the study area and study period

The stations were chosen on the basis of the diversity and accessibility of the plant species. The study was carried out from April to July 2020 at three stations, the main sites for the exploitation of fishery resources (Dikobé, Donenda and Béhondo) in the downstream part of the Nyong river, located in the Lokoundjé district, Ocean Division, South region of Cameroon. In view of the potential of the study area in terms of the availability of little-known biodiversity, the choice of this site is based on the fact that this study will not only help to redirect the anthropic activities carried out around the Nyong river, but will also contribute to the preservation of biodiversity and the biotope and to the strengthening of the database. After the prospecting phase and consultation of resource persons, three (03) stations were selected and geolocalised using a Garmin GPS (Global Positioning System). These were the Donenda upstream station (DON), located between latitude 03°19'30'' North and longitude 10°1'30'' East and 16 km from the river mouth. Dikobé (DIK), an intermediate station, is a transitional zone between Donenda and Béhondo located between latitude 3°18'0'' N and longitude 10°0'0'' E and 14 km from the mouth. The downstream station, Béhondo (BEH), is dominated by islets and located 4 km from the mouth between latitude 3°16'30'' N and longitude 9°55'30'' E (Fig. 1).

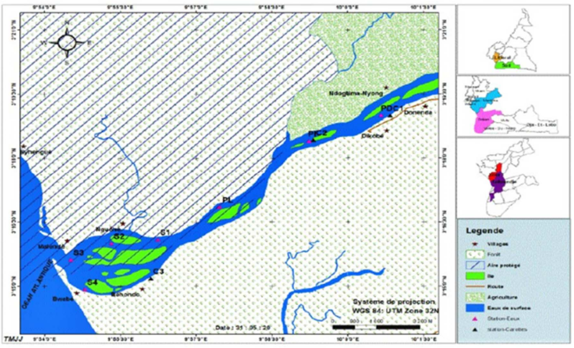

Fig. 1. Water and sediment sampling points

Sampling and environmental data collection

A total of 24 monthly samples were taken at each of the three sites on the River Nyong selected for this study. During the study period, monthly samples were taken morning and evening over four days (8 replicates) regardless of whether the tide was high or low. The various points were defined along the study area by visual identification after the survey phase. At each site, three points were selected for sampling, based on the following criteria: the accessibility of the site and the presence or absence of sources of pollution likely to affect the quality of the water in the river and the anthropogenic input of nutrients necessary for the proliferation of invasive plants in the river. The data collected consisted of taking a number of physicochemical parameters of the water. The physicochemical analysis of the water was carried out *in situ* in the laboratory.

Physico-chemical parameters

Water samples for the analysis of physical parameters were taken successively at the 3 stations just above the bottom substrate. The physical parameters measured *in situ* were temperature, total dissolved solids (TDS) and conductivity. The pH, dissolved oxygen and salinity were measured using a HORIBA multiparameter. Other chemical parameters, such as salinity and redox potential, were analysed at the Hydrobiology and Environment Laboratory of the University of Yaoundé I.

The water was collected before the sun came out. Translucent, watertight 1L polystyrene bottles were used, representing the 3 study sites. After rinsing the jar, it was gradually immersed in water in the opposite direction to the water current, taking care not to create air bubbles inside. Once all the samples had been taken, the bottles are packed in a cool box and taken to the Hydrobiology and Environment Laboratory at the University of Yaoundé I for analysis of the physico-chemical parameters.

Evaluation of texture, total nitrogen, total phosphorus, total organic carbon and organic matter in the sediment

The sediments were taken at the same points where the water samples were taken at low tide, for easy access at bank level. 03 cores were taken using PVC pipes 100 mm in diameter and 50 cm high. Using a board, the pipe was driven vertically into the ground to a depth of around 40 cm. Once the core had been taken, it was immediately covered at the base with a polystyrene clasp, ballooned with plastic paper and sealed with tape to limit water loss. Finally, each core was labelled according to where it was taken.

At CERECOMA's Fisheries Research Laboratory in Kribi, the cores are subjected to a physical description that consists of determining granoclassing, facies size, composition, appearance, texture and color. After this stage, the samples are sent to the Soil Analysis and Environmental Chemistry Research Unit (URASCE) at the University of Dschang for nutrient analysis. The sediment samples (0-30 cm) were analysed using URASCE methods.

Statistical analysis

The data collected were processed in Excel 2013. Surfer software was used to produce the sediment profiles. Google Earth and Arcgis.10.3 were used to draw up the maps, while Statistica 11 was used to establish correlations between the data.

Results and discussion

Physicochemistry of the water in the study area

Generally speaking, the results obtained on physicochemistry showed that temperature values (T°C) oscillated between 31.1 and 32°C, salinity had values ranging from 0.01 to 25.57 ‰ and TDS from 0.011 to 20.14mg/l. As for electrical conductivity (EC), it ranged from 0.023 to 38.42µS/cm and pH varied between 7.09 and 8.96. Dissolved oxygen values ranged from 2.92 to 5.96 mg/l and from 39.8 to 81%.

The correlation matrix between the physicochemical parameters of the water revealed perfect and highly significant correlations, both positive and negative (r=1; r=-1). Turbidity and CO_2 correlated positively with salinity, TDS and electrical conductivity, while ammonium correlated perfectly negative with all of them. There was also a significant correlation between TSS and salinity, TDS and electrical conductivity (r: 0.99) and a significantly negative correlation between these parameters and dissolved oxygen. Strong correlations were also noted between NH_4, temperature and color; between PO_4^{3-}, pH, TSS and NO_3^- and between NO_3^-, temperature and color (Table 1).

Physicochemistry by station

Temperature was relatively stable, with an average value of 30°C at all sampling points. Color had a higher value at DIK (75PtCo) and values of 66 and 71PtCo at DON and BEH respectively. TDS was higher at BEH (14 mg/l), 5mg/l at DON and 7mg/l at DIK. Turbidity showed a higher value at BEH (20FTU) and a value of 6 FTU at the other two stations. The pH was relatively stable at DIK (7.50) and DON (7) and slightly high at BEH (8.06).

Electrical conductivity showed a higher value at DIK (0.819µS/cm) and equal values (0.034µS/cm) at DON and BEH. TDS values are close to those of salinity. There is a value of 0.01‰ at DIK and DON and a slightly higher value at BEH (0.40‰). Dissolved oxygen content in mg/l was relatively stable at all three stations with values of 5.02, 4.81 and 4.59 at DIK, DON and BEH respectively. Redox potential values were high at DIK and DON (143.3 and 159.9mV respectively) and low (49.30mV) at BEH. As for organic carbon, a high value was found at BEH (15.62), and a value of 10.42 at DIK and DON (Fig. 2).

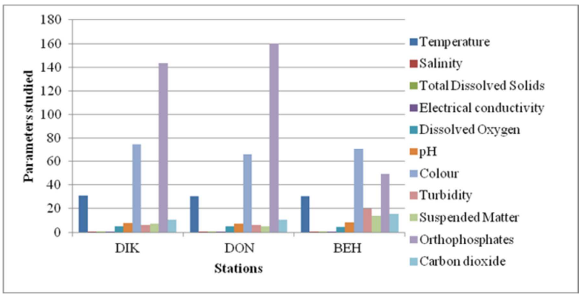

Fig. 2. Physicochemical parameters by station

The variation in physico-chemical parameter values observed at the three stations could be explained by the fact that the different stations do not receive the same incidence of seawater along the course of the study area. The DIK and DON stations are further from the mouth than the BEH station, which is closer. As a result, the average temperature concentrations (30°C) for the stations and (31.1 and 32°C) for all the sites recorded did not vary greatly from one station to another. These results are similar with who those had by Obono in 2020 when she ended their work in the same river. She went on that these physic-chemical values observed at the three stations could be explained by the fact that they did not receive the same incidence of seawater along the watercourse. In the same idea, Nana *et al.* (2023) concluded that the temperature profile of water varied from station to station. The maximum value was recorded 31.60°C and the minimum 30°C. Langford (1990) said that temperature is an important factor in maintaining the growth, reproduction, survival and distribution of organisms. This result is close to that of (Hassane, 2010), who worked in the River Niger and obtained mean temperature concentrations (29.43 and 28.4°C) that did not vary greatly from one site to another. The mean TSS value (13 mg/L) indicates the TSS content of a normally populated river (Nisbet and Vernaux, 1970). However, the highest value at BEH (14 mg/l) could be explained by the fact that particles transported from upstream are retained downstream and the water is not very turbulent at this sampling point.

Table 1. Pearson correlation matrix between physicochemical parameters

	Temp	Sal	TDS	Cond	OD	pH	Col	Tur	MES	CO_2	NH_4	NO_3^-	PO_4^{3-}
Temp	1												
Sal	-0,43	1											
TDS	-0,43	1	1										
Cond	-0,43	1	1	1									
OD	0,82	-0,87	-0,87	-0,87	1								
pH	0,04	0,88	0,88	0,88	-0,53	1							
Col	0,87	0,06	0,06	0,06	0,43	0,5	1						
Tur	-0,43	1	1	1	-0,87	0,88	0,06	1					
MES	0,23	0,98	0,98	0,98	-0,75	0,96	0,27	0,98	1				
CO_2	-0,43	1	1	1	0,87	0,88	0,06	1	-0,99	1			
NH_4	0,43	-1	-1	-1	0,87	-0,88	-0,06	-1	0,99	-1	1		
NO_3^-	0,80	0,19	0,19	0,19	0,31	0,63	0,99	0,19	-0,32	0,19	-0,19	1	
PO_4^{3-}	0,29	0,73	0,73	0,73	-0,31	0,97	0,73	-0,73	-0,82	0,73	-0,73	0,81	1

Table 2. Sediment texture in the study area

Code	Bandwidth (Cm)	Facies size	Grano ranking	Appearance and texture	Composition	Color
DIK	0-10	Clay (4) Silt (6)	Negative	Heterogeneous Silto-Clayuse	Rod, Leaf(+)	Light grey (7/1)
	10-20	Silt (3,5) Clay (6,5)	Positive	Homogeneous Silty-clay	/	Marron clair gray 6/2
	20-30	Silt (4) Clay (5)	Positive Negative	Heterogeneous Silty-clay	Leaf	Brown dark greyish4/2
BEH	0-10	Fine sand (1,5) Clay (8,5)	Positive	Heterogeneous Sandy-clay	Leaf (+)	Dark grey4/1
	10-20	Fine sand (2)	Constant	Heterogeneous /Sandblaster	Roots (+)	Light grey7/2
	20-30	Fine sand (2)	Constant	Heterogeneous /Sandblaster	Leaf,Rod (+)	Brown very pale 8/3
DON	0-10	Clay (1,8) Silt (2) Sand(3)	Negative Positive	Homogeneous Silto-Sandblaster	/	Brown very pale 7/3
	10-20	Silt (3,5) Clay (4) Sand (2,5)	Positive Negative	Homogeneous Silty-clay	/	Gray 6/1
	20-30	Clay (3,2)	Constant	Homogeneous Clayuse	/	Brown 5/3

However, the work of Kpoda *et al.* (2021) came to a different conclusion from that contained in this document. Following their work on aquatic ecosystems in Burkina Faso, it appears that the values of physicochemical parameters are higher overall. They went on to conclude that the species that invade wetlands can establish themselves in different parts of the system. But more often than not, they have a relationship with water that favors their establishment and helps them to spread more easily than they would in a purely terrestrial system. The color and turbidity values obtained are not high and reveal the lesser importance of macrophytes in the area. These low values can be explained by the low suspended solids content obtained. The abundance of suspended solids in the water favors the reduction of light and lowers biological production, particularly due to a drop in dissolved oxygen following a reduction in photosynthesis (Hassane, 2010). However, the considerable color values at DIK (75 PtCo) and BEH (71 PtCo) are thought to be due to run-off water from households, which may be loaded with all sorts of matter. This could also be explained by the fact that the detergents used by local residents inhibit the self-purification capacity of these points (Nisbet and Vernaux, 1970). Electrical conductivity is an index of the abundance of ions in water. It can be used to estimate the degree of mineralization and often shows an increasing gradient from upstream to downstream (Berryman, 2006). In the present study, the average value (0.29µS/cm) remains very low compared with the threshold set at 1500µS/cm (Barnabe and Barnabe-Quet, 2000). The electrical conductivity values obtained show extremely low mineralization of the Nyong waters in this zone (Nisbet and Vernaux, 1970). However, the considerable value at DIK (0.819µS/cm) would indicate some mineralization due to wastewater from neighbouring households (Makhoukh *et al.,* 2011). The average pH value is 7.5; which is a favorable zone for aquatic plant life. However, the basic character would be attributed to the low presence of organic matter in these waters (degradation of plants and excrement of all kinds) (Boeglin *et al.,* 2000); this may also be explained by the washing activities carried out nearby (Aboubakar *et al.,* 2016). (Atanle *et al.,* 2012) indicate instead that the humic acid that comes from the decomposition of dead macrophytes would contribute to lowering the pH. This result is similar to that of (Dibong and Ndjouondo, 2015) who conducted their study in the Kambo River in Douala and found an average pH value (7.08) indicating neutral water during the study period and a strong presence of attached macrophytes.

The low level of total dissolved solids indicates that the water in the River Nyong is only slightly polluted by surrounding activities. The dissolved oxygen values obtained (5.02, 4.81 and 4.59 mg/l) are almost all below the French standard (>5 mg/l). It is interesting to note that low dissolved oxygen levels can be attributed to a high degree of mineralization of the water (Billen *et al.,* 1999; Hassane, 2010) and high turbidity (SS concentration). However, these results are not consistent with those obtained by these authors, as the analysis revealed low levels of electrical conductivity and turbidity.

Results for nitrate showed values of 0.9, 0.3 and 0.7mg/l at DIK, DON and BEH respectively, while those for ammonium showed a low value (0.01mg/l) at BEH and a value of 0.1mg/l at DIK and DON. For orthophosphates, different values were observed: 7.9 at DIK, 5.1 at DON and 9.1mg/l at BEH (Fig. 2). Overall, nitrate levels were below 1 mg/l. These results are in the same range as those obtained by Dibong and Ndjouondo (2015) following an assessment of water quality in the Kambo and Longmayangui rivers. On this subject, Nwamo (2019) states that while the input remains mainly agricultural, nitrates also affect surface waters. They come from groundwater and urban wastewater discharges. Nitrates are also one of the parameters used to assess water quality. Their presence in excess can contribute to the imbalance of aquatic environments, with eutrophization phenomena in rivers, for example (Nwamo, 2019).

They also come from the mineralization of organic nitrogen and the oxidation of ammonium (El Ouali *et al.,* 2011). The high nitrate values recorded at DIK (0.9mg/l) and BEH (0.7 mg/l) could be explained by the domestic activities carried out by local residents, and these values are less than 2 to 5mg/l (Patrick, 2007). Like nitrates, orthophosphates are low at DON compared with other stations, which may be due to the large number of islands in the area, which retain some of the molecules. As the threshold for eutrophization in orthophosphates is set at 0.03mg/l (Hade, 2007), the significant values at DIK and BEH would be justified by the presence of households, which would indicate the start of eutrophization in these areas. (Priso *et al.,* 2012) found similar results in the Kondi River, but with lower values (0.664 mg/l upstream and 0.166mg/l downstream). The bulk of orthophosphates would therefore have an exogenous origin (Taffouo *et al.,* 2017). Low ammonium values indicate less critical pollution (Nisbet and Vernaux, 1970) and this can be explained by the non-use of chemical fertilizers in the area. At high pH levels, ammonium becomes toxic, whereas at pH levels below 8, ammoniacal nitrogen has little effect on flora and fauna (Hade, 2007). The associated nitrate, ammonium and orthophosphate values could therefore indicate domestic pollution (Makhoukh *et al.,* 2011). Despite the fact that phosphorus (along with nitrogen) is one of the main causes of eutrophization, there is no risk of eutrophization in this watercourse due to the river's high dilution capacity and the moderate development of plant cover on the water body (Hassane, 2010).

The orthophosphate trend curve shows a rising trend for DIK and BEH, while that for nitrate shows a constant trend despite the low value obtained at DON (Fig. 3).

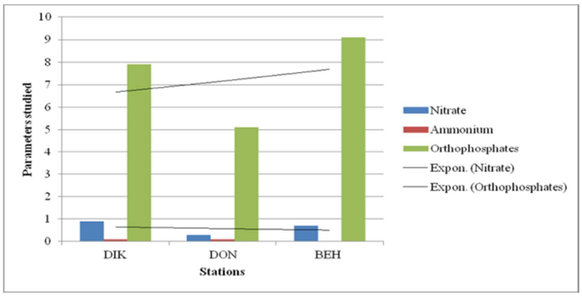

Fig. 3. Variations in organic pollution parameters according to sampling stations

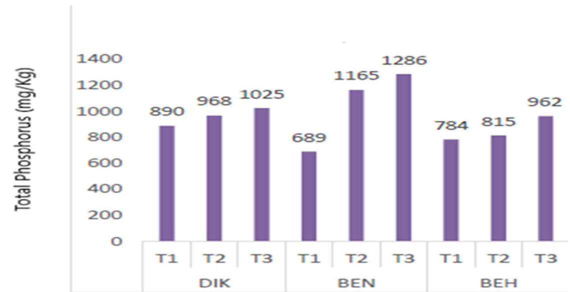

Fig. 4. Variation of Total Phosphorus as a function of depth

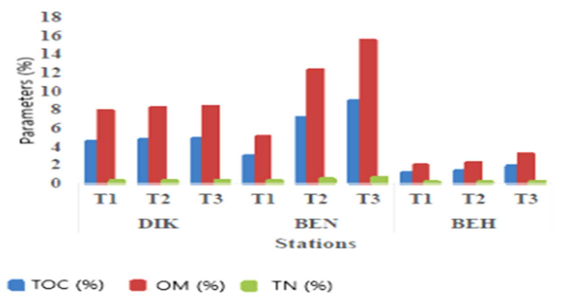

Fig. 5. Variation of parameters studied as a function of depth

T1: Depth 1, T2: Depth 2, T3: Depth 3, Total Organic Carbon: TOC, Organic Matter: OM, Total Nitrogen: TN

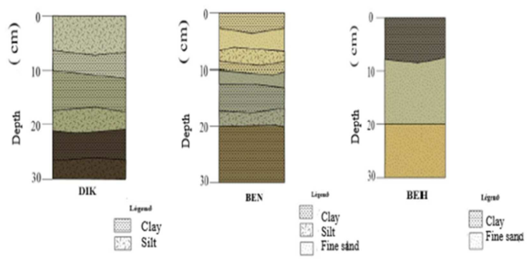

Fig. 6. Sediments profile

Total nitrogen, total phosphorus, total organic carbon and organic matter in the sediment

Sediment analysis results show that values for all parameters increased from the surface to bottom. At all stations, Total Phosphorus (TP) values were very high (689 to 1286mg/Kg) at BEN (Fig. 4). The Total Nitrogen (TN) values are low (0.11 to 0.61 %). Concerning Total Organic Carbon (TOC), Organic matter (OM) and total nitrogen, BEH has the lowest value while BEN has the high value (Fig. 5).

Sediments texture

Analysis of the sediment slices showed that they contain clay, silt and sand. Clay facies sizes range from 8.5 (BEH between 10 and 20cm) to 1.8 (DON between 0 and 10cm); silt facies values oscillated between 6 (DIK between 0 and 10cm) and 2 (DON between 0 and 10cm); fine sand facies values varied very slightly between 1.5 and 2 (BEH entre 0 et 10 cm, entre 10 et 20 cm et entre 20 et 30cm) ; and facies values varied very slightly between 2.5 and 3 (DON between 0 and 10 cm, and between 20 and 30cm) (Table 2). Granulometry was positive overall (DIK between 10 and 20cm and 20 to 30cm; BEH between 0 and 10cm; DON between 0 and 10 cm and between 10 and 20 cm). In terms of appearance and texture, the sediments generally have a heterogeneous appearance at DIK (between 0 and 10cm, between 10 and 20 cm and between 20 and 30cm) and at (BEH between 0 and 10cm, between 10 and 20 m and between 20 and 30cm), whereas at DON, the appearance is only homogeneous. In terms of texture, the sediments studied contain much more clay (DIK between 0 and 10 cm, between 10 and 20cm and between 20 and 30cm), (BEH between 0 and 10 m,) and (DON between 0 and 10cm, between 10 and 20cm and between 20 and 30cm) and sand (BEH between 0 and 10 cm, between 10 and 20cm and between 20 and 30cm) and (DON between 0 and 10cm). Stems, roots and leaves were only observed at DIK and BEH. Finally, sediment color was variable (Table 2). The data obtained on the color of the texture of the sediments reveal the presence of very similar colors: grey (DIK between 0 and 10cm, BEH between 0 and 20cm and DON between 10 and 20cm), light brown (DIK between 10 and 20cm), brown (DIK between 20 and 30cm, BEH between 20 and 30cm and DON between 0 and 10cm and between 20 and 30cm).

The results of the sediment profile showed that the soil at DIK has a clay-loam texture over the first 30cm. At DON, the texture in the first 10cm was silty-sandy, clayey-silty from 10 to 20cm and clayey in the last 10 cm. At BEH, the texture was clayey from 0 to 8.5cm and sandy up to 30cm (Fig. 6). These results are differents from those found by Tekou *et al.* (2020), following a study carried out on Sanaga river had concluded that whatever the site or season, the percentage of sand remained higher than the percentage of silt and clay.

Conclusion

The physicochemical characteristics of the water and the sediment profile of the substrate in the lower reaches of the Nyong fluctuate depending on the station. Dikobé is the station with the highest values, whereas Behondo is the station with the lowest parameter values. The main distinguishing feature between the sites is the redox potential. However, several recommendations can be made to science. So, the results of this study can serve as a basis for the competent authorities in the implementation of strategies to resolve the problem caused by invasive aquatic plants in the lower Nyong river and in the development of these plants as part of phytoepuration and the fight against plant invasion of watercourses in Cameroon.

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