Characterization of a Physicochemical Water Quality Reference Status for the Centre-South Forest Region of Cameroon

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Abstract: ***A study has been carried out on the rivers of the Centre-south forest region of Cameroon in the inter-tropical area of Central Africa. The aim was to determine the variability of the rivers' physicochemical state of this area and then to test the aptitude of IPO and SEQ-Eau to rigorously qualify the natural water of this area. Fourteen sampling stations were selected on six streams all located in suburban area less subjected to anthropogenic disturbances. Among these stations, nine were chosen in areas showing the characteristics of reference stations for the study region which are: habitat relatively not deteriorated, catchment area uninhabited and sheltered of any urban/industrial activity and absence or scarcity of adjustments of the river's bed. The reliability of the IPO index is reinforced in its ability to separate distinctly the waters of the upstream area, weakly loaded in organic matters, from those of the middle and downstream areas, moderately loaded. As per its current use, its application on affected mediums in which modified organic matter load is not transported is inaccurate. In addition, the response of reference sites to its application, marked by the low representation of the null organic pollution level class, allows it to be recalibrated for a better match between the response of the index and the observations made on the field. It is apparent from the application of the SEQ-Eau index that no study station belongs to the blue class, indicating acceptable waters requiring only a disinfection treatment before distribution in the drinking water supply network. In their majority, these waters are suitable to all types of rearing, including eggs, fingerlings and adults of sensitive fish species. As with the IPO index, these findings which breach somewhat with the status of reference site of the 9 sampling stations involved, put to test the reliability of the use in the current state of the SEQ-Eau index designed in the temperate region, for the assessment of water quality of the Center southern Forest Region of Cameroon.***

Keywords: Center southern Forest Region of Cameroon, water quality, IPO index, SEQ-Eau index, recalibration

1. Introduction

On the perspective of an emergent Africa by 2025, many countries count inter alia on their important natural resources, with the implementation of reasonable public management policies. It is all about ensuring a better use and a sustainable management of the natural resources: bases for the production of riches (DSCE, 2010). Specifically, concerning water resources management, it is advisable to equip the institutions in charge of aquatic environments, with suitable tools for a better understanding and a sustainable management of these ecosystems in all their complexity (Foto Menbohan *et al*., 2010).

A simplistic approach relies on the usage of the existing instruments for water quality assessment whose use have proven their efficiency in other geographical spaces. It is the case of the Water Quality Assessment System (SEQ-Eau), the Global Standardized Biotic Index (IBGN), the Belgian Biotic Index (IBB), and the Organic Pollution Index (IPO) which were elaborated in the temperate region. The knowledge of the specific functioning of freshwater ecosystems is essential for the optimal elaboration of a water quality assessment system (Bonnard *et al*., 2003).

The preliminary condition for such a step is based on the determination of the characteristics of natural rivers in the absence of any disturbance (Coste, 1978; Gueade *et al*., 2009). It is in this respect that the main objective of the study is to outline the physicochemical reference characteristics of water, which are a set of basic data specific to the rivers of an ecological region with the vegetation of their watersheds more or less in the natural state. The present study is carried out on the rivers of the Centre-South

Forest Region of Cameroon in the inter-tropical area of Central Africa. On the whole, the study was aimed at determining the variability of the rivers' physicochemical state of this area, then to test the efficacy of SEQ-Eau and IPO to rigorously qualify the natural waters of this area.

2. Materials and Methods

2.1. Study area and sampling stations

The ecological region of the Centre-South Forest of Cameroun is a dense forest zone with bimodal rainfall which extends to the major part of the Cameroonian southern plateau between 500 and 1000 m of altitude. It is located between 3°30' and 3°58' of latitude North and between 11°20' and 11°40' of longitude East (Ndam *et al.*, 2009) (figure 1). With an altitude of approximately 750 m (Santoir, 1995), its relief is globally hilly and the urban area extends over several high hills of 25 to 50 m above the plateau (Bachelier, 1959).

The climate of this region was classified as a wet tropical type characterized by four seasons (Suchel, 1972; Onguene Mala, 1993): a short rainy season (March to May), a short dry season (June to August), a long rainy season (September to November)and a long dry season (December to February). However, these seasons undergo variabilities from one year to another (Kuété, 1987). There is a seasonal variation of temperature between 16 and 31°Cwith a mean value of 23.5°C. Precipitations are closer to 1600 mm with an average wetness of 80%, showing a daytime variation of 35 to 98% (Olivry, 1986).

Fourteen sampling stations were selected on six streams (Mefou, Nga, Fam, Abouda, Nkoumou and Djobo) all located in suburban area less subjected to anthropogenic disturbances (figure 1). Among these stations, nine were chosen in areas showing the characteristics of reference stations for the study region which are: habitat relatively not deteriorated, catchment area uninhabited and protected from any urban/industrial activity,and absence or scarcity of adjustments of the river's bed (Gibson *et al.*, 1996;Goaziou, 2004).

Four sampling stations were chosen in the Nga stream (Ng1, Ng2, Ng3 and Ng4). The station Ng1 (03°53'37.16''N; 11°22'4.58''E) is located in the upper stream, at about 1.2 km from the spring. This station has drainage of order 2.The substratum is muddy and sandy, and the riparian vegetation is of secondary dense forest type, composed of trees, shrubs, and dominated by species such as *raphia* spp. And *Sarcophrynium* sp.. The stations Ng2 (03°52'18.41''N; 11°23'10.12''E) and Ng3 (03°52'18.87''N; 11°24'45.69''E) are located in the middle part of the stream, respectively at about 8.5 Km and 12 km from the source. These stations have drainage of order 3 with a primarily sandy substratum at station Ng2, while at station Ng3, the substrate is muddy-sandy and strewed with blocks of stones. Station Ng2 is characterized by the deforestation of a broad corridor of approximately 40 m, due to the passage of the pipeline "Chad-Cameroon", with the riparian vegetation being characterized by the quasi absence of trees and shrubs and the dominance of herbaceous vegetation such *Sida acuta*, *Alchornea cordifolia*, *Acroceras amplectens* and *Aspilia Africana*. At station Ng3 the riparian vegetation is of secondary dense forest type with some opening canopy. Situated at approximately 18.5 km from the spring, the station Ng4 (03°51'43.28''N; 11°26'50.00''E) is located in the downstream closer to the confluence with the Mefou stream. This station has drainage of order 4, with a sandy-muddy substratum and gallery forest-type vegetation dominated by the species such *as Maranthochloa purpureum*, *Costus afer* and *Achornea* ssp.

Three sampling stations were chosen in the Fam stream (Fm1, Fm2 and Fm3).The station Fm1 (03°52'53''N; 11°24'01''E) is situated in the upper stream, at about 1.1 km from the spring. This station has drainage of order 1. The catchment area near this station is marshy and has a degraded forest-type vegetation, dominated by shrubs which alternate with many palm trees and undergrowth dominated by species such as :*Cyclosorus dentatus*, *Coster afer*, *Dioscorea Bulbifera* and *Commelina benghalensis*. The stations Fm2 (03°52'42''N; 11°24'36''E) and Fm3 (03°51'56''N; 11°24'56''E) are located respectively at about 3 and 4.05 km from the spring. These stations have drainage of order 2 and are localized in the middle and down part of the stream respectively. The substrate at station Fm2 is primarily sandy and the riparian vegetation is abundant and dominated by species such as *Cyclosorus dentatus*, *Brillantesia owariense*, *Ipomea alba* and *Raphia* sp..While at station Fm3, the river bed is essentially muddy, with poor riparian vegetation dominated by *Alchornea cordifolia*, *Commelina benghalensis*, *Cyclosorus dentatus* and *Acroceras zyganoides*.

In the Mefou stream, three sampling stations (Mf1, Mf2 and Mf3) were selected in the upper part of the stream.With geographical coordinates of 03°54'4.30''N and 11°23'54.71''E, the station Mf1 is situated at about 4.5km from the spring and has drainage of order 2. The river bed has many microhabitat dominated by mud, and the riparian vegetation is dominated by *Thalia welwischi*, *Cyclosous striatus and Lapportea* sp..The stations Mf2 (03°53'48.56''N; 11°24'22.94''E) and Mf3 (03°52'38.19''N; 11°26'13.82''E) are located respectively at about 5.5 and 18 km from the source. Station Mf2 has drainage of order 3 and a muddy substratum. The riverside vegetation is made up of many trees, shrubs and herbs such as *Chromolaena odorata*, *Impatiens irvingin* and *Pennisetum purpureum*. Locatedat about 2 km down stream from the Mefou Dam, the station Mf3 has drainage of order 4, a high outflow and a highly deteriorated riparian vegetation primarily constituted by herbaceous species such as *Impatiens irvingin*, *Chromolaena odorata*, *Pennisetum purpureum* and*Triumfeta cordifolia*. The substrate at this station consists of a diversity of microhabitats where fine gravels prevail.

In the Abouda stream, two sampling stations were chosen in the middle stream (Ab1) and downstream (Ab2), respectively at 2.45 and 4.5 km from the spring.With geographical coordinates of 03°51'55.42''N and 11°25'7.58''E, the station Ab1has drainage of order 2 and the river bed shows a high diversification of microhabitats, though silt is predominant. The riverbank vegetation is mainly constituted of herbs, with species such as*Chromolaena odorata, Impatiens irvingin* and *Pennisetum purpureum*. At thelevel of station Ab2 (03°52’18.01’’N; 11°25’5.01’’E), the drainage is of order 3 and the riparian vegetation which is profuse and diversified, is made up of many trees, shrubs and herbs such as *Cyclosorus dentatus*, *Impatiens irvingin* and *Pennisetum purpureum*.

Only one sampling station each were selected at the Nkoumou stream (Nko) and the Djobo stream (Djb), each having drainage of order 2. The station Nko (03°52'30.73"N; 11°24'23.62"E) is located in the middle part of the stream, at about 4.75 km from the source. The river side along this station is a marshy zone dominated by macrophytes like *Marantochlora purpureum*, *Costus afer* and *Alchornea* spp. At station Djb (03°51’53.25’’N; 11°22’13.21’’E) which is situated in the upper stream, at 2.5 km from the source, the shrubby riparian vegetation is scattered and one notes the presence of *Thabia welwischii*, *Costus afer* and *Sarcophrynium* spp.

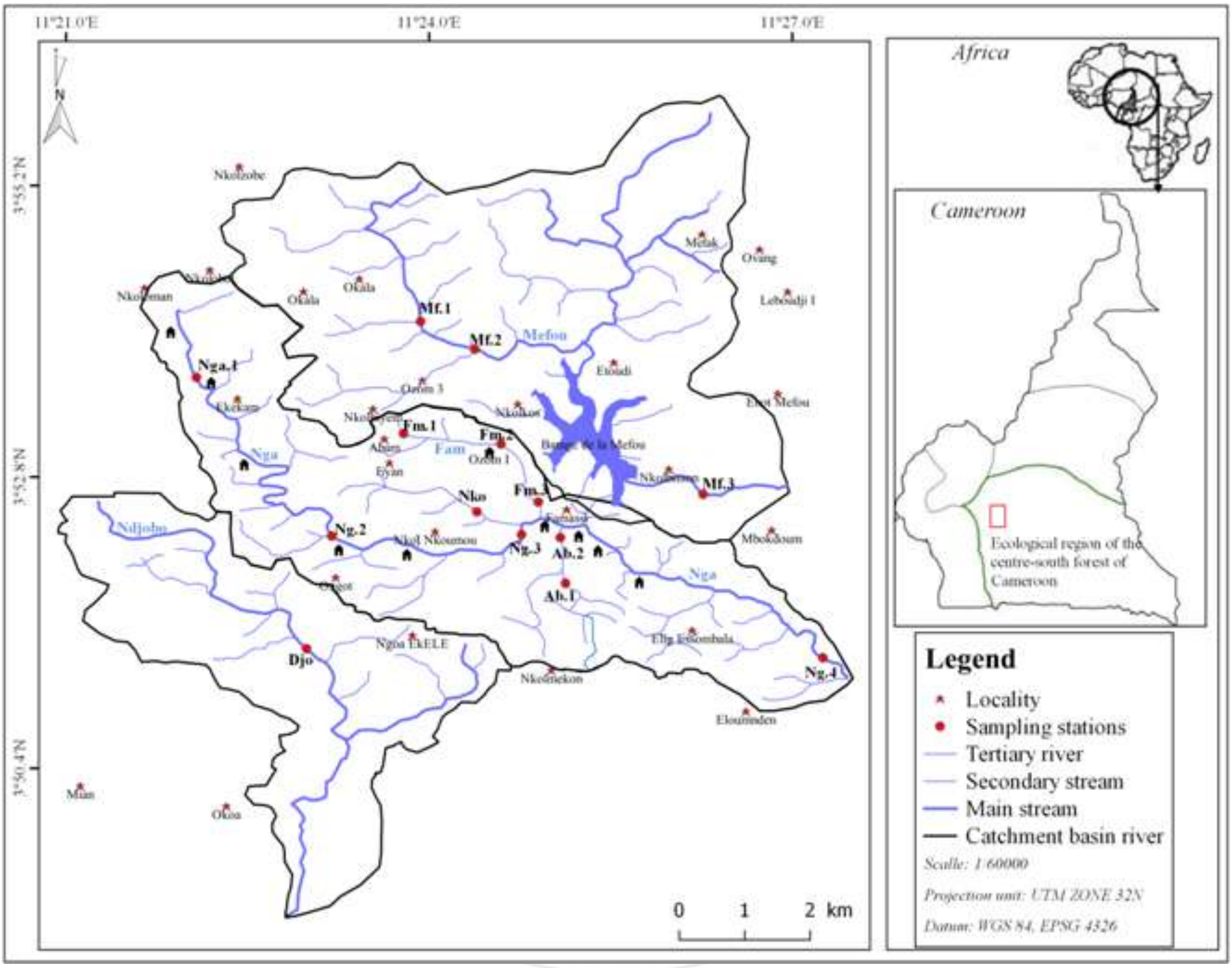

Figure 1: River basins showing studied streams and sampling stations of the Centre-South Ecological Forest Region of Cameroon (Source: INC, 1980, modified).

2.2. Measurement of physicochemical variables

At each sampling station, 14 environmental variables were measured monthly, from January to December 2010. Measurements and analyses of physical and chemical parameters of water were carried out simultaneously in the field and in the laboratory, following APHA (1998) and Rodier *et al*. (2009) standard methods. Water temperature, pH, dissolved oxygen and electrical conductivity were measured *in situ* using an alcohol thermometer and a HACH HQ30d flexi multimeter, respectively. Suspended solids (SS), water color, turbidity, ammonia, nitrites, nitrates, phosphates, and the absorbance of chlorophyll–*a* were analysed in the laboratory using HACH DR/2800 spectrophotometer. Alkalinity and calcic hardness were also anlysed in the laboratory by volumetric method.

2.3. Data analyses

2.3.1. Organic Pollution Index (IPO)

In order to assess the organic pollution level at each sampling station, the Organic Pollution Index (IPO) was calculated according to the protocol described by Leclercq (2001) and Touzin & Roy (2008). IPO is based on three ion concentrations (ammonia, nitrites, and phosphates) resulting from organic pollution. For each parameter, 5 classes of contents having an ecological significance are defined (table 1). The IPO corresponds to the arithmetic mean value of the class number of each parameter and the values obtained are apportioned into 5 levels of pollution (Table 2).

Table 1: Boundaryof the Organic Pollution Index (IPO) classes

Classes	Parameters		
	Ammonia (mg/L)	Nitrites (µg-N/L)	Phosphates (µg-P/L)
5	<0.1	5	15
4	0.1 – 0.9	6 – 10	16 – 75
3	1 – 2.4	11 – 50	76 – 250
2	2.5 – 6	51 – 150	251 – 900
1	> 6	> 150	> 900

Table 2: Classification of the pollution level according to the class values of the IPO

IPO class	5.0–4.6	4.5–4.0	3.9–3.0	2.9–2.0	1.9–1.0
Organic pollution level	Null	Low	Moderate	High	Very high

2.3.2. Application of the SEQ-Eau System to assess water quality

The SEQ-Eau grids were also used to determine the quality of water of the study area for various uses (MEDD and Water Agency, 2003). Also, the classes and indices of biological water quality evaluated on the basis of an index on the quality of water for various uses gives 5 distinct classes (table 3).

Table 3: Classification of the water quality according SEQ-EAU index

SEQ-Eau index	[100 – 80]	[80 – 60]	[60 – 40]	[40 – 20]	[20 – 0]
Characteristic color	Blue	Green	Yellow	Orange	Red
Water quality	Very good	Good	Average	Poor	Very poor

3. Results

3.1. Regional variability of parameters

The mean values along with standard deviation of physico-chemical variables are shown in table 4.

During the study period, the values of water temperature varied from 19°C (station Ab2; December) to 26°C (Mf3; January), with a regional mean value of 21.98 ±1.08 °C and a mean value of 21.80 ± 0.93 °C at the level of the reference stations. An overall assessment of this parameter indicates thermal amplitude of 7°C with June being the warmest month and March the less hot month. Concerning dissolved oxygen, values fluctuated between 3.00 mg/L (Ng2; January) and 24mg/L (Mf3; December)with a mean value of 6.45 ±2.66 mg/L for the region and 6.61±2.73 mg/L at the level of the reference stations.

The values of calcium hardness ranged from 1mg/L $CaCO_3$ and 42 mg/L $CaCO_3$, with a mean value of 5.74 ±6.11 mg/L CaCO3 for the region and 5.27 ± 4.64 mg/L $CaCO_3$ at the level of the reference stations. Waters of the studied region were slightly acidic to neutral with pH values ranging from 4.45 (Djb; March) to 7.38 (Djb; January).The regional mean value was 6.69 ± 0.34 while the mean value at the level of reference sites was 6.73 ± 0.27. Concerning alkalinity, the values varied from 2.30 mg/L CaCO3 (Fm1; December) to 42.00 mg/L CaCO3 (Mf3; November), with mean values of 12.74 ± 5.69 mg/L CaCO3 at the level of the region and 13.15 ± 5.33 mg/L CaCO3 at the level of reference stations.

The electrical conductivity of the waters of the region varied between 6.70 µS/cm (Fm1; December) and 148.00 µS/cm (Ng1; April). Mean values were 33.48 ± 13.96 µS/cm for the region and 34.80 ± 16.50 µS/cm at the level of reference sites.

The concentrations of suspended solids oscillated between 0 mg/L (Fm1; January, November and December and then Ng1 in March) and 65 mg/L (Ab1 and Djb in September), with a regional mean value of12.91 ± 14.74 mg/L while at the level of reference stations, the mean value was 13.20 ± 14.90 mg/L. Regarding water color, values varied from 12.00 Pt.Co (Mf3; October)to 468,00 Pt.Co to (Ng4; February) with a regional mean value of 112,42 ± 65.64 Pt.Co and 110.47 ± 68.49 Pt.Co at the level of the reference sites.Values of turbidity recorded during the study period fluctuated between 2FTU (Ng1 in July and FM1 in January, November and December)and 87 FTU(Ng4; February), with a regional mean value of 21.40± 12.36 FTU, while at the reference stations, a mean value of 21.00 ± 12.78 FTU.

Concerning ions, phosphate concentrations varied from 0 to 3940 µg/L, with mean values of 182.21 ± 381.99 µg/Land 200.84± 449.56 µg/Lat the level of region and reference stations, respectively. Ammonium ions content ranged from 0 to 4mg/L with mean values of 0.21 ± 0.37 mg/L and 0.19 ± 0.24 mg/L at the level of region and reference stations, respectively. As for the nitrite ions, values oscillated between 0and 90 µg/L, with a regional mean value of 7.99 ± 8.53 µg/L while the mean value at the reference sites was 7.71 ± 5.93 µg/L. Regarding nitrate ions, recorded concentration fluctuated between 0 and 3.6 mg/L with mean values of 0.79 ± 0.59 mg/L and 0.79 ± 0.61 mg/L at the level of region and reference stations, respectively.

Table 4: Minimum (Min), maximum (Max), mean and standard deviation (SD) values of physicochemical parameters recorded at the level of the region and reference stations during the study period.

Variables	Region			Reference stations		
	Min	Max	Mean ± SD	Min	Max	Mean ± SD
Temperature (˚C)	19.00	26.00	21.98 ± 1.08	19.00	24.80	21.80 ± 0.93
Dissolved Oxygen (mg/L)	3.00	24.00	6.45 ± 2.66	3.10	22.00	6.61 ± 2.73
Calcic hardness (mg/L $CaCO_3$)	1.00	42.00	5.74 ± 6.11	1.00	32.00	5.27 ± 4.64
Ph	4.45	7.38	6.69 ± 0.34	6.09	7.28	6.73 ± 0.27
Alkalinity (mg/L de $CaCO_3$)	2.30	42.00	12.74 ± 5.69	4.00	34.00	13.15 ± 5.33
Electrical conductivity (µS/cm)	6.70	148.00	33.48 ±13.96	21.24	148.00	34.80 ± 16.50
Suspended solids (mg/L)	0.00	65.00	12.91± 14.74	0.00	65.00	13.20 ± 14.90
Color (Pt.Co)	12.00	468.00	112.42 ± 65.64	15.00	468.00	110.47± 68.50

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Turbidity (FTU)	2.00	87.00	21.40 ± 12.36	2.00	87.00	21 ± 12.78
Phosphates (µg/L of PO_4^{3-})	0.00	3940	182.21±381.99	0.00	3940	200.84±449.56
Ammonium (mg/L of NH_4^+)	0.00	4.00	0.21 ± 0.37	0.00	1.52	0.19 ± 0.24
Nitrites (µg/L of NO_2^-)	0.00	0.09	0.01 ± 0.01	0.00	0.02	0.01 ± 0.01
Nitrates (mg/L of NO_3^-)	0.00	3.60	0.79 ± 0.59	0.00	0.36	0.79 ± 0.61

3.2. Application of the IPO for the water quality assessment of the study region

3.2.1. Spatial variation of the IPO

The application of the IPO indicates that the organic pollution level of waters of the Centre-South Forest Region varied from null (Fm1 in January and November; Fm2 in September and November and then to the station Mf3) to very high (Ng2 in September). Mean values of the IPO showed low organic pollution level at stationsNg1, Fm1, Fm2, Mf1, Mf2 and Mf3, with station Ng1 having the best water quality (IPO = 4.4); whereas in stations Ng2, Ng3, Ng4, Fm3, Ab1, Ab2, Nko and Djb this index revealed a moderate organic pollution level (Table 5).Similarly, beside station Mf3, this index distinctly separates the upstream stations (low organic pollution) from the downstream stations (moderate organic pollution) while the middle stream stations are located in one or other class according to its dynamics and the specific nature of its immediate environment.

Table 5: Mean values of the IPO for each sampling station

Station	Ng4	Nko	Ng2	Ng3	Ab2	Fm3	Ab1	Djb	Fm2	Mf2	Fm1	Mf1	Mf3	Ng1
Mean IPO	3.6	3.7	3.8	3.8	3.8	3.9	3.9	3.9	4	4.1	4.2	4.3	4.3	4.4
Pollution level	Moderate								Low					

3.2.2. Frequency distribution of the IPO classes

The frequency distribution of the IPO classes, showed that during this study period, low organic pollution waters are the most represented 42.85%), followed by moderate organic pollution (39,28%), null organic pollution (17.26%) and high organic pollution (0.59%). The frequency distributionsof the IPO classes showed similar profilesat both regional and reference sites level (Figure 2).

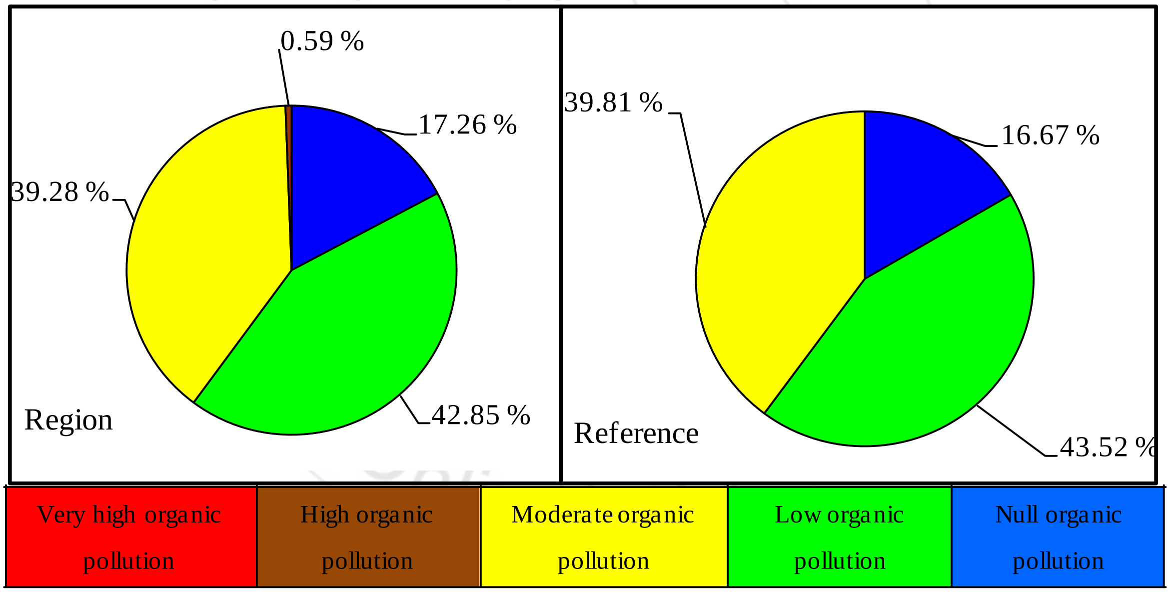

Figure 2: Frequency distribution of the IPO classes at both regional and reference sites level

The frequency distribution of the IPO classes at the level of the impacted sites (Ng2, Nko, Djb, Fm1 and Mf3) revealed some specific characteristics (figure 3).

Stations Ng2 and Nko have not displayed null organic pollution level throughout the study period, reflecting the high input of organic matters, with station Ng2 being the only station where high organic pollution level was observed. Although station Djb, is subjected to physical pollution by rich brick-colored soil containing iron and aluminum, its water quality is similar to that of reference sites. Despite the relative substitution of the native vegetation by the *raffia* at station Fm1, this station presents a better quality of water than the reference sites, reflecting its upstream characteristics. Station Mf3 showed the highest frequency of null organic pollution level of waters, reflecting a significant improvement of the water quality downstream of the Mefou Dam that breaks the longitudinal continuum.

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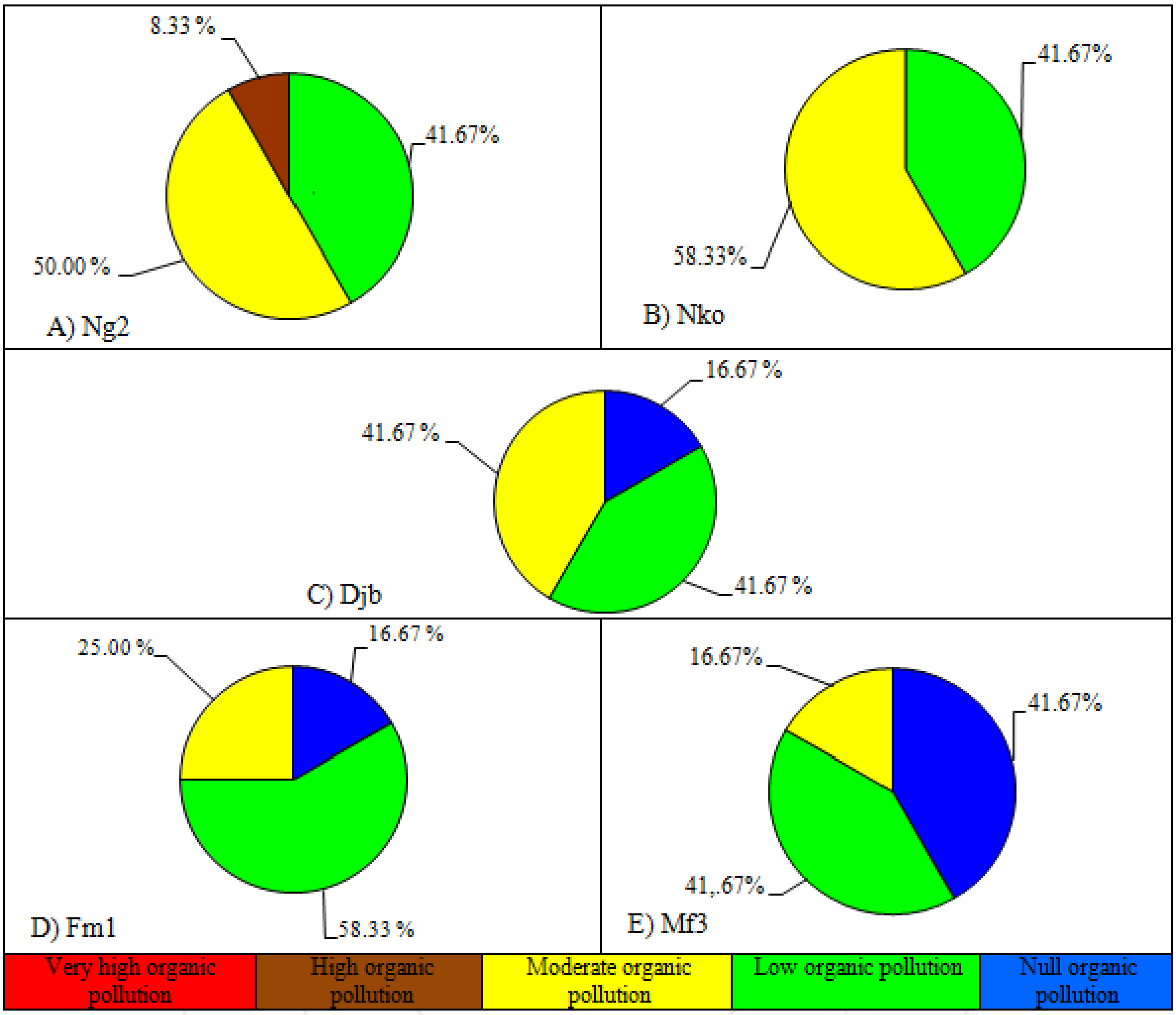

Figure 3: Frequency distribution of the IPO classesat the level of stations Ng2 (A), Nko (B), Djb (C), Fm1 (D) and Mf3 (E)

3.3. Application of the SEQ-EAUindex for the water quality assessment of the study region

3.3.1. Ability of the studysites to drinking water production

The determination of the ability to the production of drinking water on the basis of the index indicates that the studied water systems belong to two quality classes (table 6):

- The green class(stations Ng1, Fm1, Fm2, Fm3, Mf1, Mf2 and Ab1), where water requires a simple physical treatment and disinfection before the distribution;
- The yellow class(Ng2, Ng3, Ng4, Mf3, Ab2, Nko and Djb), with water requiring a classic treatment (physical, chemical and disinfection) before distribution.

Except for station Mf3, the classification by the SEQ-Eau is globally in concordance with the IPO conclusion.

Table 6: Ability classes for drinking water production of each sampling stationin the Centre-South Forest Region of Cameroon

Station	Quality class/measure of the physicochemicalwater quality										Quality class for drinking water production
	O_2	NH_4	NO_3	SS	Turb	pH	Cond	Ca	TAC	Color	
Ng1	5	0.07	0.8	14	15	7.17	143.3	8	12	102	
Ng2	6.7	0.34	2.1	4	38	7.16	36.4	8	14	153	
Ng3	6.8	0.31	1.6	22	37	7.02	33	8	14	213	
Ng4	6.7	0.68	2.5	46	50	6.96	43.7	10	22	270	
Fm1	6.7	0.38	0.8	8	20	6.9	35.8	6.2	14	117	
Fm2	7.7	0.12	0.5	13	21	6.86	36.3	10	16	109	
Fm3	6.7	0.34	1.2	19	35	6.94	45.8	10	22	180	
Mf1	7	0.15	0.7	13	14	6.88	35.3	10	14	80	
Mf2	7.2	0.2	1	14	17	6.92	35.8	8	16	92	
Mf3	6.3	0.27	0.8	42	18	7.22	39.5	20	20	91	
Ab1	7	0.43	1.4	14	31	6.92	39.2	12	16	167	
Ab2	7.1	0.36	1.6	19	40	7	39.1	8	24	203	
Nko	6.4	0.56	1.61	24	49	7.04	44.7	20	20	275	
Djb	6.8	0.44	1.5	14	29	6.82	40.4	18	18	169	

3.3.2. Ability of water to aquaculture

Concerning the determination of the ability to be used in fish farming, the SEQ-Eau index revealed that the studied waters belong to the green water quality class that corresponds to water suitable for the rearing of less sensitive adult fishes (table 7). No station belongs to the blue water quality class, suitable for all rearing, including eggs, fingerlings and adults of sensitive species (Salmonids).

Table 7: Ability of water to aquaculture of each sampling station in the Centre-South Forest Region of Cameroon

Station	Quality class/measure of the Physicochemical water quality								Quality class for aquaculture
	O_2	NH_4	NO_2	NO_3	MES	pH	Ca	TAC	
Ng1	6.7	0.28	0.007	0.8	14	7.17	8	12	
Ng2	6.7	0.34	0.019	2.1	4	7.16	8	14	
Ng3	6.8	0.31	0.022	1.6	22	7.02	8	14	
Ng4	6.7	0.68	0.017	2.5	46	6.96	10	22	
Fm1	6.7	0.38	0.008	0.8	8	6.9	6.2	14	
Fm2	7.7	0.17	0.005	0.5	13	6.86	10	16	
Fm3	6.7	0.34	0.012	1.2	19	6.94	10	22	
Mf1	7	0.15	0.008	0.7	13	6.88	10	14	
Mf2	7.2	0.2	0.013	1	14	6.92	8	16	
Mf3	6.3	0.27	0.007	0.8	42	7.22	20	20	
Ab1	7	0.43	0.022	1.4	14	6.92	12	16	
Ab2	7.1	0.36	0.018	1.6	19	7	8	24	
Nko	6.4	0.56	0.018	1.61	24	7.04	20	20	
Djb	6.8	0.44	0.009	1.5	14	6.82	18	18	

4. Discussion

4.1. Physicochemical composition of natural waters in the Centre-South Forest Region of Cameroon

Although the water temperature is essentially dependent on weather factors and particularly on air temperature at the time of sampling (Liechti *et al.* 2004; IBGE, 2005), we observed some specificities related to the areas shaded by the riparian vegetation and deforestation due to human activities. Favriou (2010) made similar observations on the river Nam Khan in Laos. This temperature remains compatible with the ambient temperature of the region which is approximately 23.5°C (Olivry, 1986). No significant variation of the dissolved oxygen content is observed from one site to the other. Rather, we note a meteorological impact with a long dry season during which the dissolved oxygen levels show little variation. The values of calcic hardness showed no significant difference from one site to another, reaffirming the relative homogeneity of the substrate in the study region. The fluctuations of alkalinity observed from one site to another are in harmony with those of pH (6.69 ± 0.34 UC), which is strongly correlated, and are indicative of the alkaline nature of exogenous inputs. Indeed, the substrate of the Centre South Forest Region of the Cameroon is acid (Yongue-Fouateu, 1986; Nola *et al.*, 1998) and the tendency of water to the neutrality, denotes the alkaline nature of the input matters. The degree of mineralization, turbidity, suspended solids, ion concentrations (phosphates, nitrites, nitrates and ammonium) of the region are similar to those obtained in the previous work carried out onless anthropogenic watershedof the same region [Djeufa Heuchin (2008) and Madonguia (2009) on the Nga stream; Foto Menbohan *et al.* (2012) on the Mefou stream and Dzavi (2014) on the Konglo stream].

For some parameters taken individually, we notice that the reference sites did not present best water quality. This is particularly the case of color, turbidity, calcic hardness and ammonium for which the mean values at the reference sites are high, indicating that some of the pressures on the environment can be translated by a decrease in their measure. This is the case of the waters downstream of the Mefou Dam where temperature and dissolved oxygen content increase while calcic hardness, color and phosphate ions content are low. Campeau (2010) attributed this improvement of the water quality to settling and purification due to the longer residence time of the water. The works carried out by Banas (2001) on ponds; revealed that the input-output balance broadly favours matter retention.

4.2. Relevance of the application of the IPO and SEQ Eau index to the assessment of the water quality of the Centre-South Forest Region of Cameroon

The reliability of the IPO is reinforced in its ability to separate distinctly the waters of the upstream area, weakly loaded in organic matters, from those of the middle and downstream areas, moderately loaded. As per its current use, its application on affected mediums in which modified organic matter load is not transported is inaccurate. In addition, the response of reference sites to its application, marked by the low representation of the null organic pollution level class, allows it to be recalibrated for a better match between the response of the index and the observations made on the field. Indeed, the IPO was calibrated in a temperate ecosystem, and this can explain while its application on reference stations of inter-tropical region has not always led to the expected conclusions due to the profound ecological differences. The rate of production of litter in the tropical forest zones is 3 to 4 times higher than in the temperate region (Dommergues, 1963; Jung, 1969). We can understand that the waters of the Centre-South Forest Region of Cameroon, although not subjected to anthropogenic activities, have a greater organic load and biogenic elements.

Although all the parameters involved in the implementation of the SEQ-Eau have not been measured, it is apparent from his application that no station belongs to the blue class, indicating acceptable waters requiring only a disinfection treatment before distribution in the drinking water supply network (MEDD and Water Agency, 2003). Similarly, most of these waters would not be suitable for all types of rearing, including eggs, fingerlings and adults of sensitive fish species. These findings which breach somewhat with the status of reference site of the 9 sampling stations involved, put to test the reliability of the use in the current state of the SEQ-Eau index designed in the temperate region, for the assessment of water quality of the Centre-South Forest Region of Cameroon. In view of the fact that the criteria for water quality can be improved or modified in the face of new available information (MDDEFP, 2013), it would be necessary that this evaluation system be recalibrated to suit the biogeochemical specificities of the equatorial zone.

5. Conclusion

From the physicochemical analysis, we note that the reference sites have not always presented the best water quality. This is particularly the case of water color, turbidity, calcic hardness and ammonium for which the mean values at the reference sites were high, indicating that some pressures on the environment can be translated by a decrease in their measure.

The IPO appeared to be able to distinctly separate the waters of the upstream area, weakly loaded in organic matters, from those of the middle and down stream areas, moderately loaded. However, a recalibration of this index is necessary for a better match between its result and the observations made on the field.

Similarly, the use in the current state of the SEQ-Eau designed in the temperate region, deeply questioned the reliability of the water quality assessment. It would be necessary that the SEQ-Eau index be recalibrated to suit the biogeochemical idiosyncrasies of the equatorial zone

In summary, the results of this study reinforce the need to complete the physicochemical analyzes and indicators of quality that result from biological analyzes. In addition, the IPO and the SEQ-Eau index which are designed in the light of specific realities to the ecosystems of the temperate regions must be contextualized for optimal use.

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