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Evalua Tion Of The Effect Of The Cameroonian Chemical Complex (CCC) Effluent On The Structure Of The Zooplankton Communities Of The Mgoua Watercourse Tributary (Douala, Cameroon)

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Abstract

Background: *This study carried out in the city of Douala aims to assess the impact of the effluent of the Cameroonian Soap Manufacturing Company (CCC) on the zooplankton communities of the main tributary of the Mgoua watercourse in order to establish strategies for the sustainable management of aquatic ecosystems in Cameroon.*

Materials and Methods: *Sampling for physicochemical and biological analysis was done on monthly basis from March to July 2013 at 2 stations (MG_1 and MG_2) respectively located upstream and downstream of the point of discharge of the effluent into the watercourse. Two samples of the raw effluent were also collected in April and July 2013. All the samples were taken to the Hydrobiology and Environment Laboratory of the University of Yaounde I for analysis.*

Results: *The physicochemical results revealed a poor quality of the water of the Mgoua watercourse tributary, with a deep alteration downstream of the point of discharge of the effluent into the watercourse. In fact, except for dissolved CO_2 (18.48 mg/L and 18.04 mg/L), dissolved O_2 (36.98 % and 20.33 %), BOD_5 (52.38 mg/L and 5 mg/L) and ammonia (4.24 mg/L and 2.85 mg/L) for MG_1 and MG_2 respectively, all the other parameters increased downstream compared to that of the upstream. Zooplankton richness and abundance decreased downstream with 14 species of rotifers, 4 species of Cladocerans and 1 species of copepod identified in MG_1 compared to 7 Rotifers, 1 Copepod and 0 Cladocera in MG_2. The Shannon and Weaver diversity index was low in both stations, and suggested a low diversity of the zooplankton community, which was marked by the predominance of one species Rotaria rotatoria, an indicator of eutrophic waters in the two stations (242 ind/L MG_1 and 196 ind/L MG_2.*

Conclusion: *The results of the analyses carried out during this study revealed that the tributary of Mgoua is highly anthropized and that the CCC effluent has a negative impact on the water quality increasing the physicochemical parameters downstream which has the effect of reducing the richness and specific abundance of zooplankton communities. This observation revealed the relevance of zooplankton in assessing the impact of industrial discharges on the quality of water in lotic environments.*

Key words: *Tributary of MGOUA, zooplankton communities, CCC effluent, physicochemical, Douala.*

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I. Introduction

The rivers of most African cities are subjected to all kinds of water pollution both accidental and intentional, mainly due to rise of urbanization and industrialization. Indeed, aquatic environments have become receptacles for all kinds of waste [1]. These entries of pollutants into aquatic ecosystems lead to the degradation of the quality of environments, a decrease of biological diversity and even the disappearance of water bodies [2]. Over the last few decades, the city of Douala in Cameroon witnessed an accelerated development that inevitably had repercussions on the environment in general and on aquatic ecosystems in particular [3 4 5 6]. It's worth bearing in mind that almost 95% of the industries in Cameroon are located in the coastal city of Douala and most of them are not equipped with waste treatment systems and discharge must effluent directly into the urban aquatic network, which then flows into the Atlantic Ocean [7]. For a better management and preservation of the aquatic ecosystems, an assessment of the impact of the industrial effluents is henceforth imperative. In fact, regular monitoring of the physicochemical quality and the biodiversity of the waterways in the city of Douala, which have become dumping grounds of all kinds, is essential. Thus, in the context of aquatic ecosystem management, it is recommended to use biological communities at the expense of physicochemical variables which give a snapshot of the quality of the environment [8]. Zooplankton communities, because of their short lifespan (a few hours to a few days) and their wide distribution in the aquatic environment offer advantages as indicators of water quality in lakes, rivers and also of pollutants and ecosystem imbalances [9 10 11 12]. The exploration of this vast field of increasing aquatic pollution that constitutes the city of Douala has led to the realisation of numerous scientific studies [6 13 14]. Hydrobiological studies in particular, carried out as part of the assessment of the impact of anthropogenic pollution of the watercourses of the city of Douala have mainly used benthic macroinvertebrates as bioindicators [4 15 16 17 18 19] and very little have used zooplankton [20]. Hence the initiation of this study whose overall objective was to evaluate the effect of the Cameroon Chemical Complex (CCC) effluent on the zooplankton communities of the main tributary of the river Mgoua in the city of Douala. More specifically, it was to characterise the quality of the effluent from this Complex and determine the physicochemical and biological characteristics in upstream and downstream of its point of discharge.

II. Materials and Methods

Study area

Douala, the economic capital of Cameroon, spreads over approximatively 18,000 hectares with an estimated population of 3,9 million inhabitants [21]. With an average altitude of 13 m, this city extends between latitude 04°03' and 04°57' North and between longitude 09°42' and 09°47' East. Its climate of the equatorial of Guinean type and Cameroonian subtype, is characterised by two seasons: a rainy season of 9 months (March - November) and a dry season from December to February. The Mgoua, which is about 7.4 km long has its source at PK5 at the crossroads of the rails and crosses respectively through the Newbell, Nylon, Brazaville, Oyak, Soboum, Bilonguè, Ndokoti, Bassa industrial zone before flowing into the Wouri on the left bank (**Figure 1**). The main tributary of the Mgoua River originates at the entrance of Cameroun's cardboard and school and office supplies company (SOCARTO), at about 34 m of altitude and crosses respectively the Industrial Centre, Madagascar, Nylon, Oyak, Bilongue II and I before flowing into the Mgoua River at the bank in the Bilongue I district. From its source to its mouth, the watershed of this river is strongly anthropized. It receives many effluents from the industrial center, the most important of which is the Cameroonian Chemical Complex (CCC), a company that manufactures soap and detergents, which flows continuously and flows into the river in the CCC district, just behind the private bilingual school, La Lumière CCC.

Sampling points

The sampling was carried out within the period of April to July 2013, at an altitude of 35m above watercourse having the coordinates: 04° 2.022' N and 009° 44.499' E, flowing down slope to the watercourse. The effluent leaving the plant which is located at an altitude of 35 m above the watercourse with the following geographical coordinates: 04° 2.022' N and 009° 44.499' E, flows down a slope in the watercourse. Two samples (in April and July) of the raw effluent were taken directly at the outlet of the plant in order to characterise its quality. Two sampling stations were also selected on the main tributary of the Mgoua watercourse. Station 1 labelled MG_1, with geographical coordinates 04° 2.025' N and 009° 44.549' E, and an altitude of 10m, located nearly 100m upstream from the point of entry of the CCC effluent into the watercourse. This station is close to a spring whose water is used for various purposes by the local residents, on the left bank stands a huge rubbish dump. Station 2 labelled MG_2 with geographic coordinates 04° 1.958' N and 009° 44.520' E and an altitude of 16m located approximately at 150m downstream from the point of entry of the CCC effluent into the watercourse (**Figure 1**).

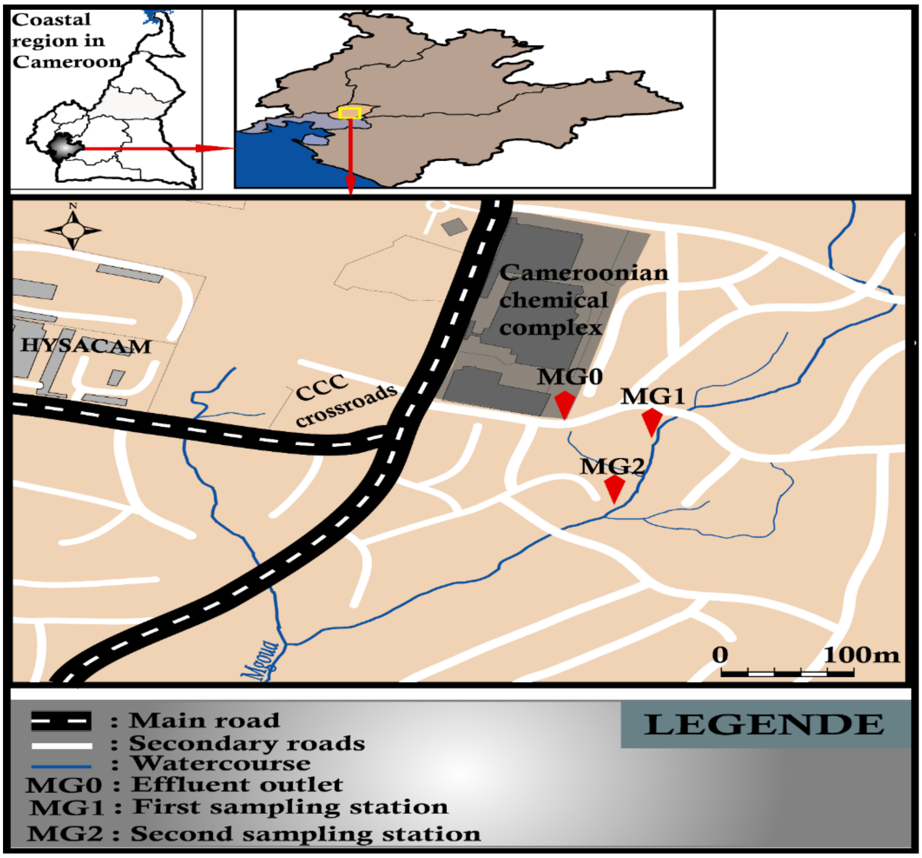

Figure 1: Geographical location of the study site

Physicochemical analyses

Samples for physicochemical analysis were collected at the effluent level and at each stations using 1000 mL double-capped polyethylene bottles and transported to the laboratory in a refrigerated condition. Temperature, electrical conductivity, pH and Dissolved Oxygen and were measured *in situ* using respectively a mercury thermometer, a HANNA HT 8733 series conductivity meter, a HACH HQ14d series multimeter and a HACH HQ 30d flexi multimeter. Back in the laboratory, Suspended Solids (SS), turbidity and colour were evaluated with the spectrophotometer HACH DR/2900 at different wavelengths (810 nm, 455 nm, 450 nm respectively) while Ammonia was measured using a Jenway 6300 colorimeter at wavelengths 655 nm and Sodium using a Buck Scientific Model 210 Absorption Spectrophotometer (SAA) at the wavelength of 589 nm. Measurements of dissolved CO_2, chloride ions and alkalinity were carried out volumetrically. Finally, BOD_5 was evaluated by respirometry using a LIEBHERR BOD analyser.

Sampling and Identification of Zooplankton Communities

Sampling for biological analyses was done on a monthly basis. Thus, 100 L of water was sampled and filtered through a plankton sieve with of 64 µm mesh size. The filtrate obtained was introduced into a 100 mL bottle and fixed in the field with 5% formaldehyde. Back in the laboratory, the analysis of zooplankton was done using a WILD M5 binocular magnifier with 10 x 5 magnification and the Olympus CK2 UL WCD 0.30 microscope. Identifications of zooplankton species were done using the specific keys and guides [9 22 23 24 25 26 27 28]. Counting of zooplankton was done in triplicate by taking 10 mL of sample using a pipette and introducing into a Petri dish 90 mm in diameter which was squared in squares of 3 mm side. The Petri dish thus prepared prevented any repetition in counting.

Data analysis

Microsoft Excel 2016 was used for graphical representations and calculations. The parametric and non-parametric test of Student and Wilcoxon were done with R software, to compare physicochemical parameters between the two stations MG_1 and MG_2. The Spearman correlation coefficient was done with SPSS 20.0 software to determine the link between physicochemical and biological variables. The level of statistical significance was maintained at 95% ($p < 0.05$).

Biological variables were analysed using diversity index of Shannon and Weaver and equitability (evenness) index of Piélou.

The Shannon and Weaver index (H), used to characterise the structure of the zooplankton settlement, was calculated using the following formula:

H'= -∑ (ni/N $\log_2$ ni/N)
Where ni is the number of species i in a sample and N is the total number of individuals in the sample.

The Pielou equitability index (J) was as calculated as follows

J = H'/log2S
Where S = Total number of taxa in the sample. J is equal to 0 when a single taxon dominates and 1 when all taxa have the same abundance.

III. Results

Physicochemical variables at sampling stations and the effluent

Variations in physicochemical parameters recorded at the sampling stations and the effluent during the study are presented in **Table 1**. For all the physicochemical parameters, no significant difference was observed between the two sampling stations. However, an increase in most of the parameters was observed at the MG_2 station located downstream from the point of discharge of the effluent into the watercourse.

Table 1: Mean values ± standard deviations of the physicochemical variables at the various study stations and the effluent (minimum and maximum values in brackets).

Sampling stations	MG_1	MG_2	Effluent	P	Sig
Temperature (°C)	28,63 ± 0,38 ^{a} (28 - 29,5)	28,25 ± 0,48 ^{a} (27 - 29)	30,5 ± 3,5 (27-34)	0,561	NS
pH (CU)	6,72 ± 0,12 ^{a} (6,4 - 6,96)	6,91 ± 0,13^a (6,62 - 7,26)	6,53 ± 0,67 (5,86-7,2)	0,347	NS
Electrical conductivity (µS/cm)	301,25 ± 2,69 ^{a} (295 - 308)	455,75 ± 90,79 ^{a} (294 - 665)	232 ± 49 (183-281)	0,312	NS
Suspended Solids (mg/L)	14 ± 7,44 ^{a} (4 - 36)	21,25 ± 9,57 ^{a} (6 - 49)	61,5± 53,5 (8-115)	0,529	NS
Turbidity (FTU)	21,75 ± 9,79 ^{a} (7 - 49)	30,75 ± 11,52 ^{a} (15 - 65)	73,5 ± 62,5 (11-136)	0,574	NS
Colour (PtCo)	122 ± 53,39 ^{a} (34 - 269)	179,25 ± 65,89 ^{a} (67 - 367)	420 ± 380 (40-800)	0,526	NS
Dissolved CO_2 (mg/L)	18,48 ± 0,88 ^{a} (15,84 - 19,36)	18,04 ± 2,53 ^{a} (10,56 - 21,12)	2,28 ± 0,52 (1,76-2,8)	0,536	NS
Dissolved O_2 (% sat)	36,98 ± 20,45 ^{a} (3,3 - 95)	20,33 ± 13,22 ^{a} (4,8 - 59,9)	45 ± 40,9 (4,1-85,9)	0,538	NS
Alkalinity (mg/L)	89,75 ± 12,33 ^{a} (68 - 125)	96,75 ± 36,62 ^{a} (18 - 195)	221 ± 189 (32-410)	0,866	NS
BOD_5 (mg/L)	52,38 ± 18,52 ^{a} (9,5 - 100)	5 ± 5 ^{a} (0 - 20)	5± 5 (0-10)	0,079	NS
Na+ (mg/L)	14,38 ± 1,75 ^{a} (11,24 - 18,15)	33,40 ± 9,05 ^{a} (16,34 - 54,86)	26,02 ± 9,1 (16,92-35,12)	0,112	NS
Cl- (mg/L)	14,88 ± 6,77 ^{a} (0,6 - 30,5)	46,92 ± 22,33 ^{a} (1,3 - 86,98)	278,1 ± 275,7 (2,4-553,8)	0,326	NS
NH4+ (mg/L)	4,24 ± 0,65 ^{a} (2,72-5,83)	2,85 ± 0,42 ^{a} (2,15-4,05)	0,61 ± 0,32 (0,29-0,92)	0,122	NS

Means in each row with different superscript are significantly different at $p<0.05$. P= probability, Sig= significance, NS= non-significant, *= significant.

Suspended Solids, colour and turbidity were all higher at MG_2 (21.25 mg/L, 179.25 PtCo and 30.75 FTU respectively) when compared to MG_1 (14 mg/L, 122 PtCo and 21.5 MPO respectively). Electrical conductivity, chloride ions, alkalinity and sodium ions were also consistently higher at the MG_2 station with maximum values of 665 µS/cm, 86.98 mg/L, 195 mg/L and 54.86 mg/L respectively compared to station MG_1 with maximum values of 308 µS/cm, 30,5 mg/L, 125 mg/L and 18,15 mg/L respectively. These higher values recorded at the station MG_2 follow the same trend as that of the effluent with average value of 61.5 mg/L Suspended Solids, 420 PtCo for colour and 73.5 FTU for turbidity. The effluent also recorded a higher value for electrical conductivity, chloride ions, alkalinity and sodium ions with maximum values respectively of 281 µS/cm, 553.8 mg/L, 410 mg/L and 35,12 mg/L. Some parameters such as BOD_5, dissolved $O_{2,}$ dissolved CO_2 and ammonia nitrogen were lower at MG_2 than MG_1 with minimum values up to 0 for BOD_5, 4.8% for saturation in oxygen and 2,15 mg/L for ammonia. The effluent also presented the same lower value like the station MG_2 for these parameters with minimum value of 0 mg/L for BOD_5, 4.1% for saturation in oxygen and 0,29 for ammonia nitrogen. In general, although the statistical analysis did not show any difference between results of the two sampling stations, a slight difference in the studied parameters was observed between the MG_1 and MG_2 stations. Nevertheless, MG_2 station and the effluent presented a similar evolution. The Spearman rank correlations made between the physicochemical parameters showed that electrical conductivity was positively and significantly correlated with Suspended solids (r = 0,743*), Sodium (r= 0,881**) and Chloride ions (r= 0,905**). Suspended Solids were also positively and significantly correlated with chloride ions (r= 0,766*) and sodium ions was correlated with chloride ions (r= 0,810*).

Biological variables at sampling stations

Specific composition of the Zooplankton Community

During this study, a total of 17 species of zooplankton consisting of 12 species of rotifers, 4 Cladocerans and 1 Copepods belonging to 12 families were identified and counted in the main tributary of the Mgoua watercourse. At station MG_1 17 species were identified made up of 12 species of Rotifers, 4 Cladocerans and 1 species of copepods. Station MG_2 had 07 species, consisting of 6 species of rotifers, and 1species of Copepods (**Table 2**). The average density of each zooplankton group showed a decrease from upstream to downstream with 258 ind/L rotifers and 15 ind/L copepods counted in MG1 when compared to 205 ind/L and 5 ind/L respectively counted in MG_2. The density of Cladocerans in MG_2 was 0 ind/L compared to 6 ind/L in MG_1 (**Table 2**).

Table 2: Average abundance (ind/L) of the different species identified in the tributary of the Mgoua tributary per station during the study period

			Samples stations	
GROUPS	**FAMILY**	**SPECIES**	MG_1 (ind/L)	MG_2 (ind/L)
ROTIFERS	**Philodinidae**	*Rotaria rotatoria*	242	196
	Euchlanidae	*Euchlanis dilatata*	3	3
	Collurelidae	*Collurella uncinata*	1	0
	Mytilinidae	*Mytilina bisulcata*	1	0
	Epiphanidae	*Epiphane macrourus*	2	2
	Brachionidae	*Brachionus calyciflorus*	2	1
	Lecanidae	*Lecane lecane*	1	0
		Lecane difficilis	1	0
		Lecane papuana	1	0
		Lecane bulla	2	0
		Lecane cornuta	1	1
	Notommatidae	*Cephalodella inquila*	1	2
Average density of Rotifers per station			**258**	**205**
CLADOCERS	**Daphniidae**	*Diaphanosoma volzi*	1	0
	Moinidae	*Moina micura*	2	0
	Chydoridae	*Kurzia longirostris*	1	0
		Alona guttata	2	0
Average density of Cladoceras per station			**6**	**0**
COPEPODS	**Cyclopidae**	*Afrocyclops* sp	5	3
		Copepodite Larvae	5	1
		Nauplii Larvae	5	1
Average density of Copepods per station			**15**	**5**
Total average density of Zooplankton			**279**	**210**

Spatial variation of the abundance of zooplankton

Spatial variation of the zooplankton community of the Mgoua tributary showed that the two stations were mostly made up by Rotifers respectively 92,93 % at station MG_1 and 97,75 % at station MG_2 (Fig 2). This fauna was dominated by the species *Rotaria rotatoria* which makes up the bulk of the Rotifer group at all stations. This species alone represented 93,80% for MG_1 and 95,61% for MG_2 of all the zooplankton collected. The abundance of Cladocerans and copepods constituted respectively 2,25 % and 4,95 % at station MG_1 compared to 0% and 2,12 % at station MG_2 (**Figure 2**).

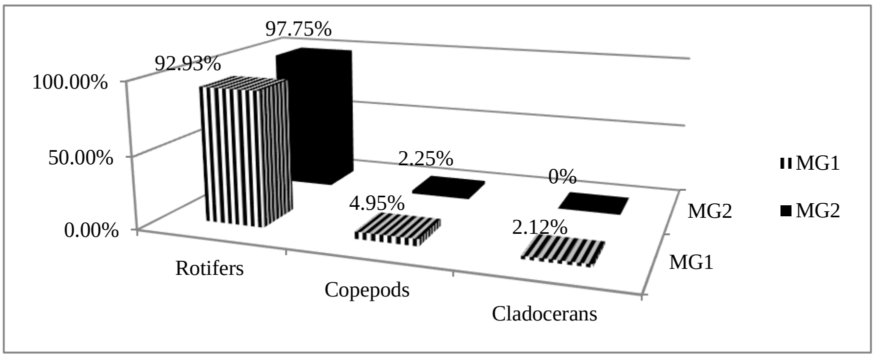

Figure 2: Spatial composition of the zooplankton community in the tributary of the Mgoua during the study period

Community structure

The Shannon and Weaver's diversity index which was 1,18 bit/ind at station MG_1 and 0,69 bit/ind at station MG_2 showed a low specific richness, which reflects a decrease in the number of species downstream. The Piélou index of 0.27 was also higher at MG_1 than MG_2 with 0.21. These values obtained at both stations tend towards 0, indicating that one species largely dominates the community (**Figure 3**).

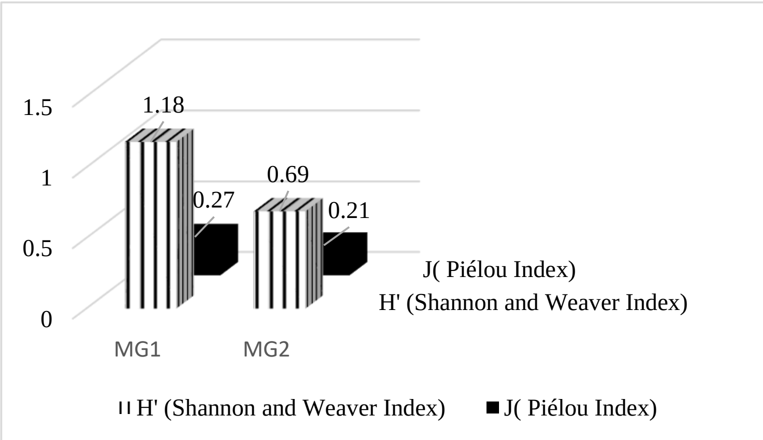

Figure 3: Spatial composition of the zooplankton community in the tributary of the Mgoua during the study period

* = significant (P<0.05) ** = significant (P<0.01)

The Spearman rank correlations done between the physicochemical and biological parameters showed that *Rotaria rotatoria* was negatively and significantly correlated with colour (r = - 0,714*). Copepodite larvae were negatively and significantly correlated with electrical conductivity (r = - 0,845**) and sodium ions (r = - 0,845**).

IV. Discussion

Characterization of effluent

The characterisation of the Cameroonian Chemical Complex effluent showed a fairly strong variation depending on the days of sampling. Indeed, the average values of the results obtained showed a neutral pH (6.53CU), a mineralization between 183 – 281 µS/cm, a turbidity of 11-186 FTU and an alkalinity of 221 mg/ L. These values considerably differed from those recorded in a previous study [3] for which samples of this effluent were taken at different times of the day (2 during the day, 2 at night). These results showed a variation depending on the sampling times with much higher values obtained at night. The authors obtained a basic pH in the range of 9.31 to 11.40, a very high electrical conductivity values between 997 to 5890 µS/cm, turbidity ranging from 324 to 553 FTU and an alkalinity of 40.3 mg/L. Temperature values were more or less the same for the two studies, reaching respective maximums of 34 and 35.2°C, which were well above 30°C, which is the discharge limit for effluents in Cameroon. This significant difference between the results was due to the fact that the studied samples were taken only once a day and in the middle of the day, a period when the discharges seemed to be less concentrated compared to night. The average value of suspended solids recorded (61.5 mg/L) was above the discharge limit authorized by the State for soap effluents (< 10 mg/L). The BOD_5 on the other hand varied between 0 and 10 mg/L, ammonia (NH_4^+) between 0.29 and 0.92 mg/L and chloride ions were strongly elevated, between 2.3 and 553.8 mg/L. These data followed the same trend as those obtained for a soap factory effluent in India, with the respective values of 0 mg/L for BOD_5, 0 mg/L for NH4+ and 148.21 mg/L for chloride ions [29]. The presence of a large quantity of chloride ions exceeding the discharge limit value provided for by the state of Cameroon (50 mg/L) and of sodium ions in this effluent was probably due to the fact that the caustic soda (NaOH) used in the saponification processes is obtained by electrolysis of sodium chloride (NaCl) thus resulting in the release of these ions. The low BOD_5 that was recorded, would have been due to an elimination of the majority of microorganisms that could have consumed oxygen. Indeed, sodium chloride can influence microorganisms either through the toxicity of Na+ ions, or as a substance capable of imposing harmful osmotic pressure on the environment [30].

Effect of the Effluent on the water of the tributary of the Mgoua River

The assessment of the effect of the CCC effluent on the water of this tributary of the Mgoua showed that it had an impact on this water. Indeed, although the statistical analysis did not show any significant difference between the two stations studied, an increase in the majority of the physicochemical parameters was observed downstream of the point of discharge of the effluent into the watercourse. Therefore, the effluent could have been responsible for these increases. Such upstream-downstream evolutions of physico-chemical parameters had been observed in several rivers receiving domestic and industrial effluents in the city of Douala, particularly in Simbi [4], Kondi [6 20] and Tongo'o Bassa [19]. Between March 2013 and March 2014, the Mgoua [15], main watercourse of the studied tributary, presented an average value of pH (7.2CU), electrical conductivity (656.2 µS/cm), suspended solids (100.3 mg/L), turbidity (106.5 mg/L) and colour (586.7 Pt-co) much higher than those of this study obtained in its tributary. This difference was probably due to the fact that the Mgoua is the receptacle of several industrial effluents, which further affects its quality. Since the pH can be influenced by the discharge of domestic and industrial wastewater [31], the slight upstream-downstream increase of 2.75% could have been due to the entry of the38ffluxent into the watercourse. Similar results following the spill of products from a soap factory effluent had been observed at a mouth of the Kinyankonge River in Lake Tanganyika [32] reaching up to 8.09CU. The average electrical conductivity recorded downstream during our study (455.75 µS/cm) was within the interval which corresponded to an accentuated average mineralization while that recorded upstream (301 µS/cm) corresponded to an average mineralization [33]. This increase in electrical conductivity downstream would therefore have been partly a consequence in the increase in chloride ions, the average value of which goes beyond those allowed in running water free of pollution (< 25 mg/L) [33]. Similar studies had shown that, these two parameters are correlated [34 35]. The same observations were made in this study with significant correlations existing between electrical conductivity and chloride ions (r= 0.905**) but also between electrical conductivity and sodium ions (r= 0.881**). The increase in sodium and chloride ions downstream would therefore have been due to the entry of the effluent which contained large quantities released during the electrolysis of NaCl to obtain caustic soda. These observations were corroborated by the positive and significant correlations that existed between sodium and chloride ions. The alkalinity values followed the same trend as the electrical conductivity ones with an increase from upstream to downstream, because the variations in the alkalinity of the wastewater is related to its degree of mineralization [36]. Indeed, high electrical conductivity values recorded also indicated the degree of mineralization of the water [31 37 38]. This mineralization is a function of the solubility of dissolved and dissociated compounds, which therefore predicts a high ion content [32]. The suspended solids (SS) present in industrial discharges is generally of mineral origin [39]. Hence the positive correlations observed between suspended solids and chloride ions (r= 0.766*).

The increase in the SS downstream led to an increase in turbidity and colour since these parameters are linked, thus a decrease in the penetration of light into the water [33] which directly affected photosynthetic organisms by inhibiting photosynthesis.

Physicochemical parameters such as dissolved oxygen, dissolved CO_2 and ammonia followed a contrary trend to the previous parameters because they decreased downstream. Dissolved oxygen in water comes mainly from the atmosphere and from the photosynthesis of algae. Its content depends on factors such as temperature, salinity, light penetration, respiration of aquatic organisms [39]. Thus, a decrease in light penetration and photosynthesis caused by the increase in SS explained the decrease in the oxygen content downstream. This decreasing upstream-downstream variation in the amount of dissolved oxygen had also been observed in the waters of Tongo-Bassa [19], Kondi [6 20], and Simbi [4]. It should also be noted that the solubility of oxygen in water is a function of temperature. It drops at high temperatures, which is why the present results are similar to those observed in several rivers in the city of Douala [15].

The average value of BOD_5 which had been recorded downstream was relatively lower than those recorded in other rivers which are also industrial effluent receptacles in the city of Douala [4 6 19 20]. This is explained by the fact that the soap factory effluents contain elements such as Na + which are toxic for the microorganisms

[30] that would have consumed the oxygen to degrade the organic matter present in the environment. The values of ammonia upstream and downstream showed that the studied environment was polluted due its high concentration which (0.1 - 3ml/L) which characterises a polluted water [40]. However, a decrease in this parameter was observed downstream, which could have been explained by the fact that the effluent had led to a decrease in the density of aquatic organisms for which ammonia is the last major product of protein excretion [41].

Effect of the Effluent on Zooplankton Communities

The zooplankton communities of this tributary of the Mgoua were weakly diversified during this study. Indeed, the values of the Shannon and Weaver diversity index reflected a low specific richness of zooplankton, which was much more marked at station MG_2. The same was true for the values of the relative abundance and specific composition indices, which were all lower downstream of the effluent discharge point. Similar observations of this upstream-downstream evolution of biological variables have been presented for many rivers in the city of Douala that constitute effluent receptacles [4 6 18 19 20 42]. In fact, zooplanktons are considered to be very sensitive to variations in environmental conditions and undergo real changes when in contact with polluting agents [10]. The physicochemical quality of water therefore has an impact on the composition, distribution and abundance of zooplankton communities in the receiving environment [43 44].

Cladocera, in particular the species *Diaphanosoma volzi*, *Moina micrura*, *Kurzia longirostris*, *Alona guttata* found upstream, showed a high sensitivity to this effluent as these species completely disappeared downstream. Increase in chloride ions downstream could be the reason of such disappearance because some zooplankton species are very sensitive to these ions and undergo stress even with a slight increase leading to a slowdown in growth and rise in mortality [45 46].

Rotifers and copepodite larvae also decrease downstream. This decrease could be attributed to an increase in the ionic load from the effluent downstream of its discharge point. It should be noted that freshwater organisms generally maintain an internal concentration of ions greater than that of the surrounding water and achieve this by absorbing ions from the environment and expelling water [47]. Thus, a surrounding concentration of ions higher than their internal concentration can lead to a rapid entry of ions into their body up to toxic levels [45]. In addition, high electrical conductivity does not favour the development and proliferation of zooplankton [44] as negative and very significant correlations were observed between electrical conductivity and copepodite larvae ($r = -0.845$ to $p = 0.01$) as well as between copepodite larvae and sodium content ($r = -0.845$ to $p = 0.01$).

The rotifer species *Rotaria rotaria* was the most represented species at both stations. This was corroborated by a low value of Shannon and Weaver index indicating that a taxon among the others had a high relative abundance 41 and also for Piélou index whose values tended towards 0 with $J= 0.27$ for station MG_1 and $J= 0.21$ for MG_2, which reflected an imbalance in the distribution of species at the two stations with this species largely dominating the population at both stations. Indeed, it is a species typical of eutrophic environments [9] which has already been identified in many eutrophic and hypereutrophic rivers in Cameroon [10 12 20 48]. However, a decline in the abundance of this species had been observed downstream. The increase in colour would have been the cause of this result as a highly significant negative correlation was observed between colour and this species ($r = - 0.714$*).

V. Conclusion

Spatial variations in physicochemical and biological parameters showed that the studied tributary of River Mgoua is of poor quality due to simultaneous inflow of domestic wastewater from local residents and industrial wastewater from the Cameroonian Chemical Complex. However, the MG_2 station located downstream of the CCC discharge point is the most altered compared to the MG_1 station located upstream, thus confirming the harmful effect of this effluent on zooplankton communities of this watercourse. It is therefore necessary to treat these effluents before their discharge into the watercourse.

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