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Level of Bacteriological and Physicochemical Pollution of Surface Waters in Rural Area: The Case of Mbankomo Municipality (Center Region, Cameroon)

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Abstract

A study aimed at evaluating the physicochemical and bacteriological quality of surface water was therefore carried out in a few watercourses in the municipality of Mbankomo, located in the Center Region (Cameroon). The physico-chemical parameters were measured according to the standard method. The organic pollution index (OPI) was determined from the contents of nitrates, phosphates, and ammoniacal nitrogen to characterize the level of organic pollution of the water. The microorganisms sought were total flora, indicators of faecal contamination like total coliforms, faecal coliforms, feacal streptococci and *Escherichia coli*, as well as the species *Clostridium perfringens*. The organic pollution index indicates a high-level organic pollution level during the small rainy season and high to moderate during the small dry season. High concentrations of the total and fecal coliforms, streptococci fecal, *Escherichia coli* and *Clostridium perfringens* respectively of 1712×10^5 CFU/100mL; 82×10^5 CFU/100mL; 10×10^5 CFU/100mL; 27×10^5 and 40×10^3 CFU/100mL, all higher than WHO standards, indicate that the waterways of Mbankomo are subject to feacal pollution and harbor pathogenic microflora. The cell densities of main bacteria were significantly correlated with main abiotic parameters, such as *Escherichia coli*, which was significantly correlated with the pH of the water (r = 0.35; $p < 0.05$). The variation of organic pollution index category means correspond to a high level of organic pollution during the small rainy season and a high to moderate level during the small dry season. The deterioration of the quality of these waters is favored by their proximity to sources of pollution (toilets, plantation), the runoff of the waters contaminated, the use of detergents and wrong maintenance. These waters without any treatment are not recommendable for human consumption according to standards of the World Health Organization.

Keywords

Bacteriological Quality, Physicochemical Parameters, Surface Waters, Organic Pollution Index

1. Introduction

Aquatic environments are among the most studied ecosystems because of their ecological, economic and health interests (Mimouni, 2020). Water is an indispensable element for life and for the real and sustainable socio-economic development of a country (Belghiti et al., 2013). The problem of access to safe drinking water has become an increasingly important issue, due to irrational management, over exploitation and degradation of water quality (Pratap et al., 2020). Studies found that two-thirds of the world's population, or more than 4 billion people, already live under conditions of severe water scarcity for at least one month a year (Mekonnen & Hoekstra, 2016). Due to the amplification of human activities, rivers are seriously threatened in their physical, chemical and biological integrity due to their use in different human activities such as domestic, agricultural and industrial uses, generating waste effluents (Mimouni, 2020). Due to this pollution, it can be a source of diseases when contaminated by potentially pathogenic agents (Hassoune et al., 2010; El Haissoufi et al., 2011). In developing countries in general and in rural areas in particular, where public authorities struggle to meet basic water needs, people resort to using surface and groundwater of dubious bacteriological quality for domestic purposes and sometimes for drinking (OMS & IPCS, 2000; Mehounou et al., 2016). Indeed, freshwater often harbours a diverse microflora, mainly bacteria, which can be pathogenic for humans and cause numerous diseases, including gastro-enteritis, typhoid fever, cholera and chronic diseases due to the use of contaminated surface water, which can lead to serious problems and death (Saab et al., 2007). These diseases are most often transmitted through the faecal-oral route. Water pollution due to micro-organisms of faecal origin appeared very early on when water was used as a vector for waste disposal (George & Servais, 2002). Human beings are thus contaminated either by drinking water, or by eating food contaminated by water, or by bathing or contact with recreational water (George & Servais, 2002). When the aquatic environment receives animal or human waste, the bacteria present are capable of making the water unfit for human use (Hébert & Légaré, 2000). Microbiological indicators are among the most important parameters for monitoring the quality of water for domestic use. Studies conducted on the quality of some watercourses in Cameroon, especially in the Center and Littoral regions, have revealed that these waters are highly contaminated by different bacterial groups and their use by the population is the cause of some waterborne diseases (Azeme et al., 2016) and also the positive impact of physico-chemical parameters on microbial density in some water points in the Nkolo-famba subdivision (Noah Ewoti et al., 2021). Studies showed that isolation of pathogenic bacteria liked Gender *Vibrio* in water can be source of real public health problems for the using populations (Tamsa Arfao et al., 2021a). The municipality of Mbankomo, located in the Center (Cameroon) is a rural area, where the population uses mainly water from rivers, wells, springs and rarely from boreholes. The watercourses are used for household, laundry, cooking, bathing, and sometimes even drinking. It is not immune to water supply problems and the little information available on the physico-chemical and bacteriological quality of these watercourses is of great interest to this study. The main objective of this work is to evaluate the bacteriological and physicochemical quality of some surface rivers water in the municipality of Mbankomo (Center Region) and to determine the level of pollution of these waters.

2. Material and Methods

2.1. Description of Study Area and Sampling Stations

The area chosen for this study is located in the municipality of Mbankomo. It is a municipality of Cameroon located in the Center region, Department of Mefou and Akono, crossed by the National Road 3.22 km from Yaoundé and 28 km from Ngoumou. Covering an area of 1300 Km^2. It lies between 11˚13 and 11˚39 East longitude and between 3˚37'30 and 3˚52 North latitude. The municipality had 56,581 inhabitants, divided into 66 villages, of which 2 are in the urban area (Mbalngong and Mbankomo town) and 64 in the rural area. The hydrographic network is dense and made up of numerous water rivers. Fishing is practised in these rivers, especially during low-water periods, and sand is collected by hand. Fish farming is also practiced.

To evaluate the degree of pollution in the streams of the Mbankomo municipality, through anthropic and domestic activities, seven sampling stations on three different streams were selected according to the accessibility of the site, the proximity to dwellings, toilets, agricultural activities and the presence or absence of anthropic or domestic activities in the stream's sub-watershed. The seven selected stations are coded as Nz_1, Nz_2, Av_1, Av_2, Av_3, Os_1, Os_2. The geographical coordinates and altitude of the various stations were taken in the field using a Garmin GPS map 60CSX (**Table 1**).

Table 1. Characteristics of the study sites associated with their catchment attributes.

Catchment attributes	Sampling stations	Altitude (m)	Latitude N	Longitude E	Main activities
River in Oveng village: Nzolong	Nz_1	694	03˚42'11.3"	011˚22'34.8"	Bathing, laundry, dishwashing, car washing
	Nz_2	690	03˚42'08.7"	11˚22'30.9"	Traditional toilet about 15 m Small agricultural activity (cassava and palm trees)
Bibong Bidoum river	Av_1	717	03˚46'34.9"	11˚25'04.5"	Small agricultural activity
	Av_2	715	03˚46'55.0"	11˚24'54.0"	Bathing, washing and cleaning activities
	Av_3	718	03˚46'34.9"	11˚25'01.5"	Bathing, washing and cleaning activities
Nomayos river 1: Ossongoué	Os_1	690	03˚45'04.9"	011˚24'22.3"	Located behind CIMENCAM in a valley, it is used for cleaning, washing, bathing and swimming
	Os_2	680	03˚47'17.6"	011˚23'53.2"	Located in the forest, it is bordered on the right bank by a cassava field and on the left bank by the remaining vegetation

2.2. Bacteriological Analysis

Bacteriological analysis is used to identify water contamination. It includes a qualitative study, which makes it possible to isolate and identify the main germs present in the water sample, and a quantitative study which aims to evaluate the concentration of bacterial bio-indicators. The water samples for these analyses are taken at the various study sites in sterile 500 mL glass bottles. They were brought back to the laboratory in a refrigerated enclosure. Germ testing was carried out within hours of the samples being taken. The bacteriological variables HAB (Heterotrophic Aerobic Bacteria), total and faecal coliforms, *Escherichia coli*, faecal Streptococci were isolated on their specific culture media by the surface spreading technique. Indeed, 100 µL of the sample was taken with a sterile micropipette and deposited on the surface of the agar cast in Petri dishes. The sample was then spread on the culture medium, using a sterile until drying (Marchal et al., 1991). The culture media used were, the Plate Count Agar (PCA) for HAB. The spread was followed by an incubation at the temperature of the laboratory for 5 days. Endo culture medium was used for the isolation of *Escherichia coli*, total and faecal coliforms, incubated at the temperature of 37˚C and 44˚C respectively for 24 - 48 hours; while faecal streptococci was seeded in Bile Esculin Azide (BEA) Agar at the temperature of 37˚C for 24 hours. About isolation of *Clostridium perfringens*, the culture was done anaerobically. During the culture, 1 mL of sample was first placed in the bottom of an empty sterile petri dish, covered with the medium, mixed and allowed to solidify before adding another layer of the culture medium. The petri dishes are then incubated at the appropriate temperature (46˚C). Strains with multiple cultural traits were counted by the direct counting method (Holt et al., 2000). The count of isolated germs was carried out using an OSI brand colony counter. Bacterial abundances are expressed Colony Forming Units (CFU) per 100 mL of water sample.

2.3. Measurement of Environmental Variables

Samples for physicochemical analysis were collected in 1000 mL clean polyethylene and were transported to the laboratory in a cooler with icepacks (7˚C ± 2˚C) for analysis. The physicochemical parameters considered in this study are temperature, pH, suspended solids, total dissolved solids, water color, electrical conductivity of water, dissolved oxygen, dissolved CO_2, phosphates, ammonium ions, nitrates and nitrites. The analysis of these parameters was carried out according to the recommendations of APHA and Rodier and described by some of the authors (Rodier et al., 2009; APHA, 1998; Tamsa Arfao et al., 2021b).

2.4. Evaluation of Organic Pollution Index

The Organic Pollution Index has been calculated to give a synthetic account of the degree of organic pollution of the water in the different stations during the study period. The calculation of this index is based on three parameters (ammonium ions, nitrites and phosphate) generally resulting from organic pollution and a fourth synthetic parameter biochemical oxygen demand, which that was not used in this case. For each of the parameters, 5 classes of content with ecological significance are defined. Organic Pollution Index corresponds to the average of the class numbers for each parameter and the values obtained are divided into five pollution levels.

2.5. Data Analysis

Data recording and histograms were made using Microsoft Excel 2016. The results of the recorded biological and abiotic parameters were analysed using SPSS 25.0 software. The correlations between the biological and abiotic variables were calculated using Spearman's "r" correlation test. In fact, they will allow us to observe the degree of linkage between the parameters studied. In addition, comparisons between the variables considered were carried out using the Kruskal-Wallis H comparison test, which will be used to evaluate the variation of the variables measured according to the different stations and seasons.

3. Results

3.1. Macroscopic Examination of Isolated Bacteria

Macroscopic examination of the bacterial colonies on the different culture media revealed colonies of various colours and sizes. On ordinary agar medium, the Heterotrophic aerobic bacteria were whitish colonies of various shapes, sizes and appearances. For total coliform colonies, they are pink, small in size and those of faecal coliforms isolated on ENDO medium are dark red and metallic (presumptive *Escherichia coli* colonies). Faecal Streptococci were small translucent black halo colonies Bile esculin azide agar. On Tryptone sulfite cycloserine agar with additional egg yolk emulsion, *Clostridium perfringens* colonies are surrounded by a black halo, due to the reduction of sulphite to an iron sulphide precipitate.

3.2. Quantitative Distribution of Isolated Bacteria

Figure 1 depicts spatiotemporal variations in the abundances of bacterial germs. These are HAB, total and faecal coliforms, faecal streptococci, *Escherichia coli* and *Clostridium perfringens*. The abundances of HAB cells ranged from 100 to 4120 × 10^5 CFU/100mL. The lowest value was observed in July during the small dry season at station Nz_2 and the highest was recorded during the small rainy season at station Nz_1 in March. Cell concentrations of total coliform ranged from 5 to 1712 × 10^5 CFU/100mL. The lowest density was observed in May at station Os_2 during the small rainy season and the highest in March at station Nz_1 during the same period. The density of faecal coliforms varied from 1 to 82 × 10^5 CFU/100mL. The highest value was obtained at station Os_1 in July during the small dry season and the lowest value at the same station in April during the small rainy season. The abundances of faecal streptococci were reached 10 × 10^5 CFU/100mL in July at station Av_2 during the small dry season. The minimum cell concentration was recorded in March at Av_1 and Os_2 stations, in April at Os_2 station, in May at t Av_3 and Os_1 stations and in July at Nz_2, Os_1 and Os_2 stations.

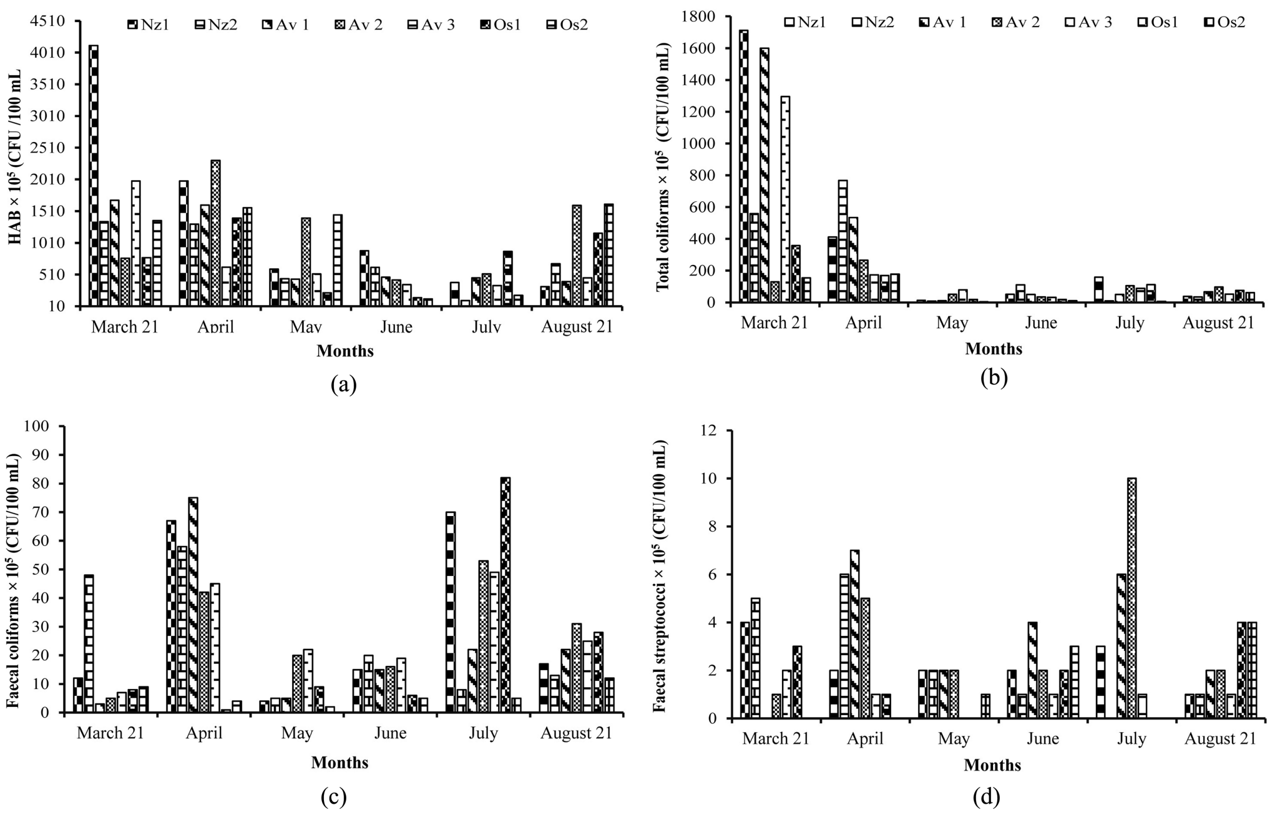

Figure 1. Spatio-temporal variations in cell abundance of Herotrophic Aerobic Bacteria (a), Total Coliforms (b), Faecal Coliformes (c), Faecal Streptococci (d).

The spatiotemporal variations in the abundances of *Escherichia coli* and *Clostridium perfringens* are presented in **Figure 2**. The highest abundance of *Escherichia coli* 27×10^5 CFU/100mL was observed in July at Av_3 station during the small dry season. The lowest value 1×10^5 CFU/100mL was recorded in March at Nz_1, Av_2, Av_3, Os_1 stations and, in April at Os_1 and Os_2 during the small rainy season. About *Clostridium perfringens* cells densities, value of 0 CFU/100mL was recorded during the months of June, July and August of the small dry season. During the small rainy season from March to May, the cells concentration ranged from 1×10^5 CFU/100mL in March and April at Os_2 station to 40×10^2 CFU/100mL at station Nz_1.

3.3. Evaluation of Physicochemical Parameters

The variations of water temperature, pH, dissolved oxygen and TDS are presented in **Figure 3**. During the study, the water temperature varied between 20.5˚C and 27.6˚C. The highest value was recorded in March at Av_3 station during the small rainy season and the lowest value at Nz_1 station in July during the small dry season. Very significant and positive correlations were observed between temperature and *Clostridium perfringens* abundances (**Table 2**). The pH ranged from 5.3 to 7.4 reflecting slightly acidic to neutral water. The highest value was at Av_1 stations. Dissolved oxygen content varied between 0.6 and 2.6 mg/L. The lowest value was obtained at Os_2 in May during the small rainy season. The increase in the values of dissolved oxygen of the medium lead to a significant increase in the abundance of total coliform (r = 0.51; $p < 0.01$) and faecal

Table 2. Correlations between physicochimical and bacteriological parameters.

Physicochimical Parameters	Bacteriological parameters					
	HAB	Total coliforms	Faecal coliforms	*Escherichia coli*	Faecal streptococci	*Clostridium perfringens*
Temperature	0.290	0.273	−0.096	−0.259	−0.106	**0.321***
pH	−0.188	−0.142	0.227	**0.354***	0.194	−0.115
Dissolved oxygen	0.028	**0.512****	**0.372***	0.173	0.060	−0.030
Dissoved CO_2	−0.009	0.271	0.093	−0.033	0.157	−0.131
TDS	0.010	0.182	−0.003	−0.082	−0.149	0.185
Conductivity	0.004	0.158	−0.027	−0.089	−0.200	0.183
Suspended solids	**0.425****	**0.393****	0.048	−0.214	0.122	0.239
Color	0.065	0.014	0.025	0.032	−0.023	0.120
Nitrates	0.037	0.215	0.134	−0.026	0.114	−0.106
Nitrites	**0.445****	**0.311***	**−0.402****	**−0.505****	−0.193	**0.694****
Phosphates	−0.282	−0.019	−0.187	−0.081	0.027	0.034
Ammonium ions	−0.290	**−0.395****	−0.177	−0.006	−0.090	0.049

**Significant correlation at level 0.01, *Significant correlation at level 0.05.

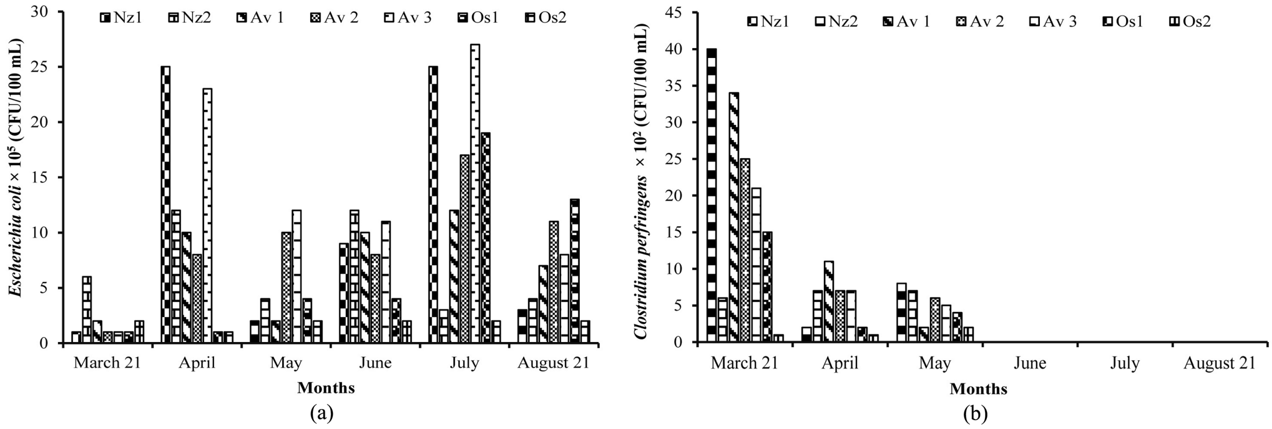

Figure 2. Spatio-temporal variations in cell abundance of *Escherichia coli* (a) and *Clostridium perfringens* (b).

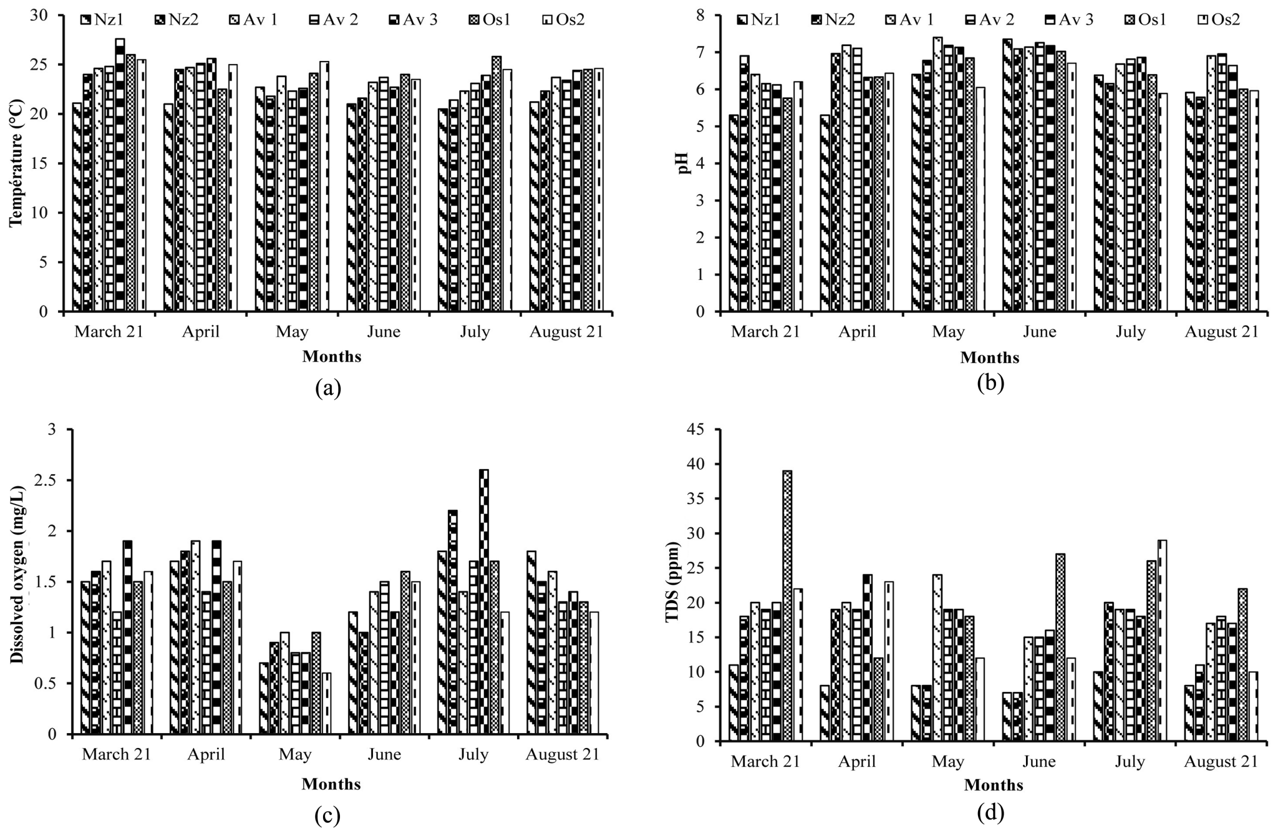

Figure 3. Fluctuation of water temperature (a), pH (b), dissolved oxygen (c) and TDS (d) during the study period.

coliforms (**Table 2**). Total dissolved solids ranged from 7 to 39 mg/L, with the highest value obtained in March at Os_1 and the lowest value in March and June at Nz_1 stations. The temporal variations of electrical conductivity, water color, suspended solids and dissolved CO_2 are presented in **Figure 4**. The electrical conductivity varied from 14 to 78 µS/cm corresponding to the months of March and June for Nz_1 and March for Os_1 stations respectively. The water color values were quite changeable during the sampling period ranging from 21 to 636 Pt/Co. The highest was observed in June at Nz_2 station during the small dry season and

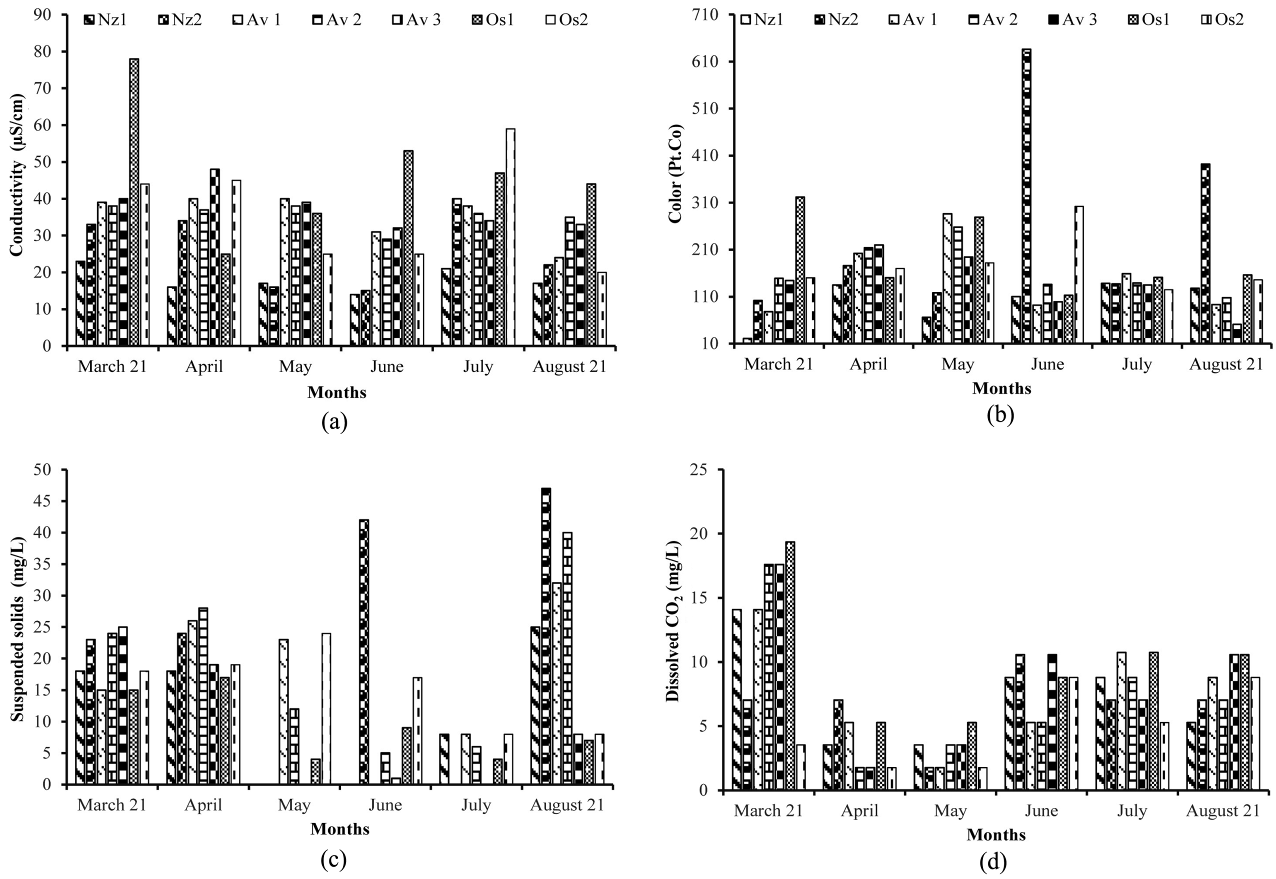

Figure 4. Fluctuation of electrical conductivity (a), water color (b), suspended solid (c) and dissolved CO_2 (d) during study period.

the lowest in March at station Nz_1 during the small rainy season. The suspended solids contents were quite variable during study period (months of May, June and July). The highest value (47 mg/L) was obtained in August at Nz_2 station and the lowest value (0 mg/L) in May, June and July at Nz_1, Av_1 and Av_3 stations respectively. The increase in the values of suspended solids of the medium lead to a significant increase in the abundance of HAB and total coliforms (Table 2). The suspended solids contents were quite variable during study period (months of May, June and July). The highest value (47 mg/L) was obtained in August at Nz_2 station and the lowest value (0 mg/L) in May, June and July at Nz_1, Av_1 and Av_3 stations respectively. The increase in the values of suspended solids of the medium lead to a significant increase in the abundance of HAB and total coliforms (Table 2).

Nitrates values for the whole sampling period fluctuated between 0 and 13.6 mg/L. The highest value was recorded at Os_1 station in March and the lowest value in May at Nz_1 and Av_3 stations and in July at Av_1 station. The nitrite concentrations were decreasing with a considerable difference between the values obtained during the small rainy season and those obtained during the small dry season. The lowest value (0 mg/L) was recorded at Av_3 station in May and Os_1 in June, July and August and the highest value (0.155 mg/L) was recorded in April

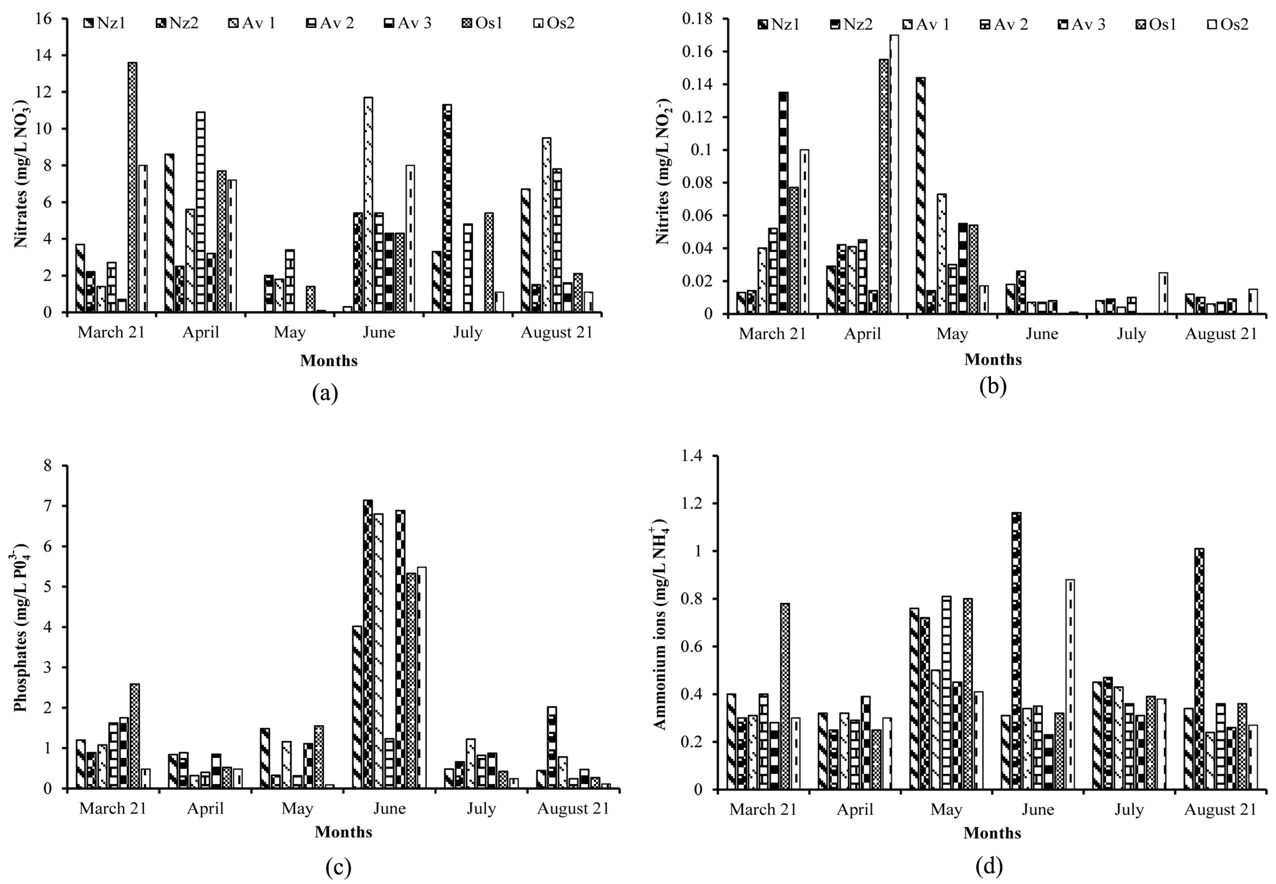

Figure 5. Fluctuation of Nitrates (a), Nitrites (b), Phosphates (c) and Ammonium ions (d) during study period.

at Os_1 station (**Figure 5**). Very significant and positive correlations were observed between nitrites and HAB, total coliforms and *Clostridium perfringens* abundances. A significant and negative correlation between nitrites and *Escherichia coli* densities was noted (**Table 2**). The highest value of phosphates concentration observed was 7.14 mg/L in June at Nz_2 station and the lowest value observed was 0.09 mg/L in May at Os_2 station. Overall, the highest values were observed in June. Ammoniums ions were more or less constant during the study period, although large peaks of variation were observed in March, June and August. The highest value is 1.16 mg/L (Nz_2 station, month of June) and the lowest value is 0.23 mg/L (Av_3 station, month of June) (**Figure 5**). A significant and negative correlation was observed between ammonium ions and total coliform densities (**Table 2**).

3.4. Organic Pollution Index

The Organic Pollution Index differed seasonally, from 2.33 to 2.67 in the small rainy season and from 2.33 to 3.33 in the small dry season (**Table 3**). According to Leclercq (2001), the variation of organic pollution index category means correspond to a high level of organic pollution during the small rainy season and a high to moderate level during the small dry season (**Figure 6**).

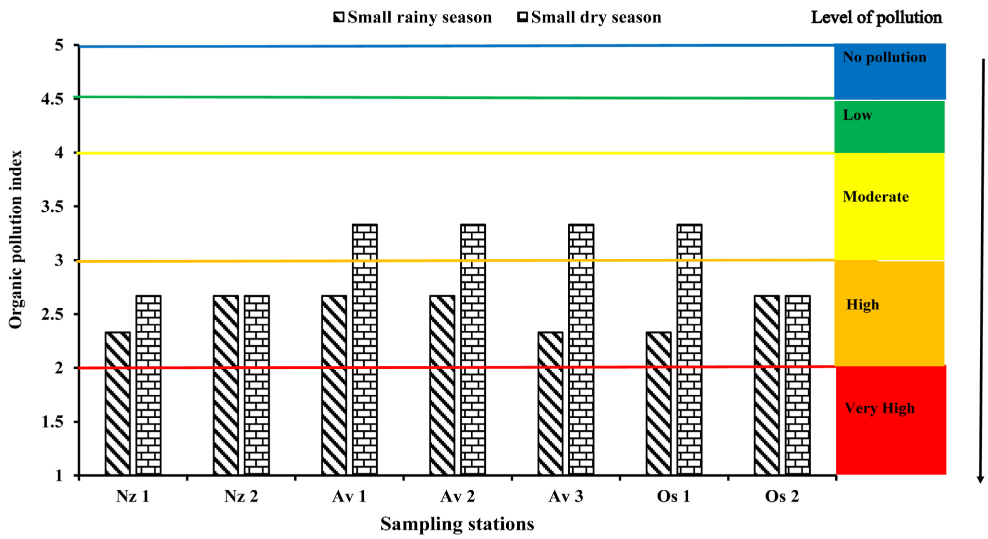

Figure 6. Classification of pollution level according to organic pollution index value category.

Table 3. Variation of organic pollution index.

Stations and seasons		NH_4^+ (mg/L)		NO_2^- (µg/L)		PO_4^{3-} (µg/L)		Mean of category
		Mean	Category	Mean	Category	Mean	Category	
Nz_1	SRS	0.49	4	62	2	1173	1	2.33
	SDS	0.37	4	12.67	3	1647	1	2.67
Nz_2	SRS	0.42	4	23.33	2	697	2	2.67
	SDS	0.88	4	15	3	3273	1	2.67
Av_1	SRS	0.38	4	51.33	2	853	2	2.67
	SDS	0.34	4	5.67	5	2933	1	3.33
Av_2	SRS	0.5	4	42.33	2	777	2	2.67
	SDS	0.36	4	8	4	763	2	3.33
Av_3	SRS	0.37	4	68	2	1237	1	2.33
	SDS	0.27	4	5.67	5	2740	1	3.33
Os_1	SRS	0.61	4	95.33	2	1553	1	2.33
	SDS	0.36	4	0	5	2007	1	3.33
Os_2	SRS	0.34	4	95.67	2	350	2	2.67
	SDS	0.51	4	13.67	3	1943	1	2.67

SRS: Small rainy season, SDS: Small dry season.

4. Discussion

The bacteriological analysis carried out during the study period made it possible to isolate the HAB (Heterotrophic Aerobic Bacteria), representing the total load of bacteria present in the environment. It also showed that these waters contain bacteria that are indicative of faecal contamination. These bacteria are total coliforms, faecal coliforms, faecal streptococci, *Escherichia coli* and *Clostridium* *perfringens*. HABs were present in all the stations during the whole study period, meaning water with high overall microbial pollution. Indeed, the enumeration of the aerobic bacterial flora aims to estimate the density of general bacterial population and is used as an indicator of global pollution (Levallois et al., 2004). Their abundance could be due to the fact that the environment of these stations is favourable to their development. In addition, the high bacterial of HAB recorded could also be due to contaminated runoff. This therefore indicates a deterioration of the bacteriological quality of the water. The cells concentration obtained during this study is well above the WHO standard of 100 CFU/100mL for drinking water (OMS & IPCS, 2000). About indicator bacteria of faecal contamination, notably total coliforms, faecal streptococci, *Escherichia coli* and *Clostridium perfringens*, the abundances of these bacteria varied from one station to another and during the study period. However, for the *Clostridium perfringens* species, low or zero values were recorded during the small dry season, which would indicate a possible absence of the bacteria in water sample. The mean values of concentrations of total coliforms, faecal coliforms including *Escherichia coli*, *faecal streptococci*, *Clostridium perfringens* recorded are 232.7; 23.42; 8.07; 2.28×10^5 CFU/100mL and 5.07×10^3 CFU/100mL respectively. These values are all higher than the standards of World Health Organization which are lower than 100, 50, 10 and 0 CFU/100mL respectively for faecal coliforms, faecal streptococci, *Escherichia coli*, *Clostridium perfringens* and 500 CFU/100mL for total coliforms (OMS & IPCS, 2000). The presence of faecal Streptococci in water reveals faecal contamination as Streptococci are typical of animal and human faeces (Abai et al., 2014). The permanent presence of these pathogenic bacteria and their high abundance reflects the degree of microbiological pollution of these water. Some pathogens grow extremely well at a mesophilic temperature range of 15˚C to 45˚C for most strains. The results of the physicochemical parameters show temporal variations. Temperature and pH varied significantly during the study ($p < 0.05$). Temperature values ranged from 20.5˚C to 27.6˚C. These variations may be due to the climate, characterised by abundant rainfall, which favours the development of dense woody vegetation, particularly around watercourses. These temperatures are compatible with the activity of isolated microorganisms which are all mesophilic and promote the dissolution of gases and salts in water (Tamsa Arfao et al., 2021a). According to Garner et al. (2013), thermal variations in lotic environments follow those of the air. In this regard, the water temperature values obtained would be due to the high vegetation cover. The average water temperature obtained in the Mbankomo streams (23.56˚C ± 0.41˚C) is close to that obtained by some authors and would be in agreement with the climate temperatures of Mbankomo (Djuikom et al., 2009). A significantly positive correlation was therefore observed between temperature and the growth of *Clostridium perfringens*. *Clostridium perfringens* grows in a wide range of temperatures, between 10˚C and 50˚C, which means that this bacterium is resistant to high temperatures.

The pH values recorded during the study ranged from 5.3 to 7.44, of which the average, 6.55 ± 0.75 is close to that obtained by Djuikom et al. (2009) and reveal that the waters are generally weakly acidic to neutral. The pH can be influenced by the environment through which the river flows, including mineral composition, soil type and rock (Korfali & Jurdi, 2011; Mmualefhe & Torto, 2011). These pH values are not in the pH range of natural water (7.2 - 7.6). However, they are favourable for aquatic life (5 - 9). However, the monthly fluctuations in this parameter would probably be due to the influence of precipitation, industrial and urban discharges (Tamsa Arfao et al., 2021b). The increase of the water pH significantly influences the abundance of *Escherichia coli*. Indeed, the increases in pH sometimes favour the development of faecal coliforms and faecal enterococci (Nola et al., 2002). Dissolved oxygen and dissolved CO_2 which are an important parameters in the evaluation of water quality, did not vary significantly during the study ($p > 0.05$). The dissolved oxygen values remained fairly constant, which would indicate poor oxygenation of the waters analysed (Rodier et al., 2009). These values could be due to the consumption of oxygen by aerobic bacteria for their growth. The levels of dissolved CO_2 recorded in this study are influenced by the climate and the seasons, as well as by the nature of the soil and vegetation (Rodier et al., 2009). Electrical conductivity and total dissolved solids varied significantly during the study ($p < 0.05$). Their values varied from 14 to 79 μS/cm and from 7 to 39 mg/l respectively. According to the classification proposed by Rodier et al. (2009), Mbankomo waters are moderate, reflecting low mineralization and low pollution. The results of the parameters nitrates, nitrites, phosphate and ammonium ions show no significant variations during the study. The nitrates variation profile recorded in the Mbankomo watercourses showed a maximum of 13.6 mg/L recorded in March at the Os_1 station and below the OMS & IPCS (2000) standards for drinking water (50 mg/L) (OMS & IPCS, 2000). Although the presence of nitrates in water is mainly attributable to human activities such as the leaching of wastewater into surface waters, the low values of nitrates levels would come from the use of nitrates by plants for their growth. The average nitrite value (0.035 ± 0.021 mg/L), which is close to that obtained by some authors (0.034 ± 0.01 mg/L), suggests significant organic pollution and is the result of incomplete oxidation of ammoniacal nitrogen or partial denitrification of nitrates (Buhungu et al., 2018). Phosphate is present in the water at high levels, with an average of 1.56 ± 0.73 mg/L, which is close to the value (1.24 mg/L) obtained in the peri-urban area of Douala (Tchakonté, 2016). Phosphate is transported in solution in water reservoirs and is fixed to the sediments which then release it. It can also originate from soil leaching through erosion of agricultural land (Hartemann, 2013). Organic pollution is perceptible when the ortho-phosphate content is higher than 0.5 mg/L, thus constituting a pollution index (Rodier et al., 2009). Ammonium ions varied throughout this study from 0.23 to 1.16 mg/L NH_4^+. Some studies have shown that when in a river the concentration of ammonium ions is between 0.1 - 3 mg/L of NH_4^+, the water is polluted (Belhaouari et al., 2017). Some other authors suggest that concentrations ammonium ions above 0.3 mg/L NH_4^+ indicate significant organic pollution (Rodier et al., 2009). Nitrite levels, which partly represent organic matter in the environment, are significantly and positively correlated with HAB, faecal and total coliforms and *Clostridium perfringens*. This result would be related to the fact that organic matter is an important source of nutrients for heterotrophic bacteria in aquatic environments (Kirchman et al., 2004). Similarly, the correlation was significantly positive ($p < 0.01$) between dissolved oxygen and coliforms. This would be due to the fact that these bacteria reduce the nitrates in the water to nitrites by simultaneously producing the dissolved oxygen necessary for their aerobic metabolism (OMS & IPCS, 2000). This study showed, in view of the non-standard concentrations of certain parameters, that these few watercourses in Mbankomo are polluted. This observation was confirmed by the calculation of the organic pollution index. The organic pollution index calculated from the averages of the quality classes of ammonium ions, nitrites and ortho-phosphates is included in a range (2.33 to 3.33) which, according to Leclercq (2001), corresponds to a strong level of organic pollution during the small rainy season (2.33 - 2.67) and strong to moderate during the small dry season (2.33 - 3.33). The organic pollution index data confirms the results obtained with the previous parameters and allows us to conclude that the Mbankomo watercourses are eutrophic, rich in nutrients from organic matter. This index gives a good illustration of the environmental stress that these watercourses undergo.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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