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Conditions to access of Drinking Water, Waterborne Diseases and Link with Socio-Environmental Aspects in Peri-Urban Areas Of Douala Littoral Cameroon, Sub-Saharan Africa

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Abstract – The conditions of access to drinking water and the risk of occurrence of waterborne diseases in the localities of Dibombari, Bonaléa and Mbanga peri-urban area of Douala Littoral Cameroon were studied. Surveys were carried out in health case to identify individuals suffering from waterborne diseases; the water resources consumed by these individuals were examined in their immediate environment and then their in situ physicochemical parameters were measured using a Hanna HI98192 portable multiparameter. The statistical tests of association of Chi-2 and Spearman's Rho associated with binary logistic regression models were used to predict the risks of occurrence of waterborne diseases. It emerged that waterborne diseases were significantly ($P<0.05$ and $P<0.01$) associated with treatment, age, sex, sanitation and proximity to sources of pollution. Individuals over 15 years of age and women were the most affected by waterborne diseases with proportions of 67.71% in Dibombari, 65.38% in Bonaléa and 64.19% in Mbanga. On the pedictive side, the factors associated with an increased risk of waterborne disease were Age (6.39[1.05 ;38.89] in Dibombari; 4.88[1.07 ;30.33] in Bonaléa and 5.79[1.99 ;16.78] in Mbanga) and Distance to sources of pollution (1.13[1.02 ;1.25] in Dibombari; 1.22[1.01 ;1.33] in Bonaléa and 1.17[1.09 ;1.26] in Mbanga). The protective factors were: the type of water (0.80 [0.70 ;0.90] in Dibombi) and the treatment (0.75 [0.65 ;0.86] in Dibombari; 0.76 [0.66 ;0.89] in Bonaléa and 0.05 [0.007 ;0.38] in Mbanga) It is advisable for the development actors in these localities to put an emphasis on the protection of water resources and sanitation because the health of the populations is at stake.

Keywords – Waterborne diseases, drinking water, health risk, Dibombari, Bonaléa, and Mbanga

I. INTRODUCTION

Due to population growth coupled with insufficient financial means, access to safe water for domestic use has become a major challenge for contemporary societies. This situation is exacerbated in less developed countries (Cohen, 2006) and specifically in Sub-Saharan Africa (SSA) due to low resilience to economic crises and poor prioritization of development projects. Access to water resources is very unequal between urban and rural areas, with rural areas suffering from an increased lack of resources due to a low level of decentralization. In rural areas of sub-Saharan Africa, the rate of access to drinking water does not exceed 45% (WHO/UNICEF, 2022); water supply networks to households are almost non-existent; people have to walk 150 to 750 meters to get water from municipal or private boreholes or springs; others, make do with freely accessible wells and rivers. Groundwater exploited in the form of wells, boreholes, or springs is the most used resource in these rural areas due to the availability of reservoirs and the relatively lower cost of collection. Although these water resources meet the population's demand in terms of quantity, the quality remains problematic due to the negative impacts on their health (GWP, 2008). Each year, contaminated drinking water contributes to the deaths of millions of people in sub-Saharan Africa from waterborne diseases (UNESCO, 2013; Yongsi and HBN, 2010). According to the WHO Regional Office for Africa 2022, 500 children in sub-Saharan Africa die every day due to inadequate water, sanitation and hygiene services (Ako *et al*., 2009; McMichael AJ and CD Butler, 2006). More importantly, vulnerable groups, such as children, women and the elderly, are the main victims (Caimcross *et al*., 2010; UN, 2015). Empirical evidence shows the link between sanitation, polluted drinking water and health (WHO, 2008, 2012; Abbu and Yassin, 2008). In particular, one relationship that is often highlighted is contamination with human or animal faeces and the most common health risk associated with this is the resurgence of waterborne diseases such as cholera, typhoid fever, diarrhoea, gastroenteritis, dysentery and other life-threatening diseases (WHO, 2014; Tumwine *et al*., 2002; Chan *et al*., 2007; Nguendo *et al*., 2008). In the context of Cameroon, the proportion of the population with access to drinking water is estimated at 57.8%, with nearly 77% in urban areas and 39% in rural areas; in addition, the proportion with access to basic sanitation is 56% in urban areas compared to 18% in rural areas (INS, 2018). This proportion of access to water is unevenly distributed throughout the country with focused being on the country's two major cities, namely Douala (82.7%) and Yaoundé (80.8%), which constitute the Littoral and Centre regions. Due to the plurality of its natural resources, both hydraulic, mining and forestry, the density of its population, its socio-cultural and ecological diversity, Cameroon is a leading country within the Central African sub-region where access to basic social services, including drinking water, must be controlled (Kouam kemogne et al., 2013). Almost all studies on access to drinking water in Cameroon have focused on its metropolises, namely Yaoundé (Nola *et al*., 2013; Kouam Kemogne *et al*., 2013; Nguendo *et al*., 2008), Douala (Ako *et al*., 2011; Njeuya, 2011; Nouang, 2012), Bafoussam (Mpakam *et al*., 2006) and Garoua (Djouda *et al*., 2013, 2014; Tyler *et al*., 2017). Very little work has focused on the peri-urban and rural areas characterised by high agricultural and artisanal activity requiring available and healthy human resources, high levels of poverty and very poor access to drinking water and health (Tyler *et al*., 2017). This is the case in the Districts of Dibombari, Bonaléa and Mbanga in the Littoral Region. In this regard, by focusing on these study areas, the study aims to be a diagnostic tool of the conditions of access to drinking water and the risks of waterborne diseases in rural domains of Central Africa, in order to propose management options for healthy environments and people.

II. STUDY AREA

II.1 Geographical location

The Dibombari, Bonaléa and Mbanga Districts are located in the Littoral Region of Cameroon (Central Africa) respectively at 22, 31 and 53 km West of the Douala large city. Between the latitudes 4°50'N-4°72'N and 9°36'E-10°16'E of longitudes, the Dibombari district extends over 150 km² and has an altitude that varies between 02 and 92m. With an area of 650 km², the Bonaléa district is located between latitudes 4°12'N -4°32'N and longitudes 9°26'E and 9°66'E, with an altitude ranging from 20 to 98m. The Mbanga district extends over 544 km², between latitudes 4°41'-4°59' and longitudes 9°44'-9°88'E, with an altitude that varies between 35 and 140m (figure 1)

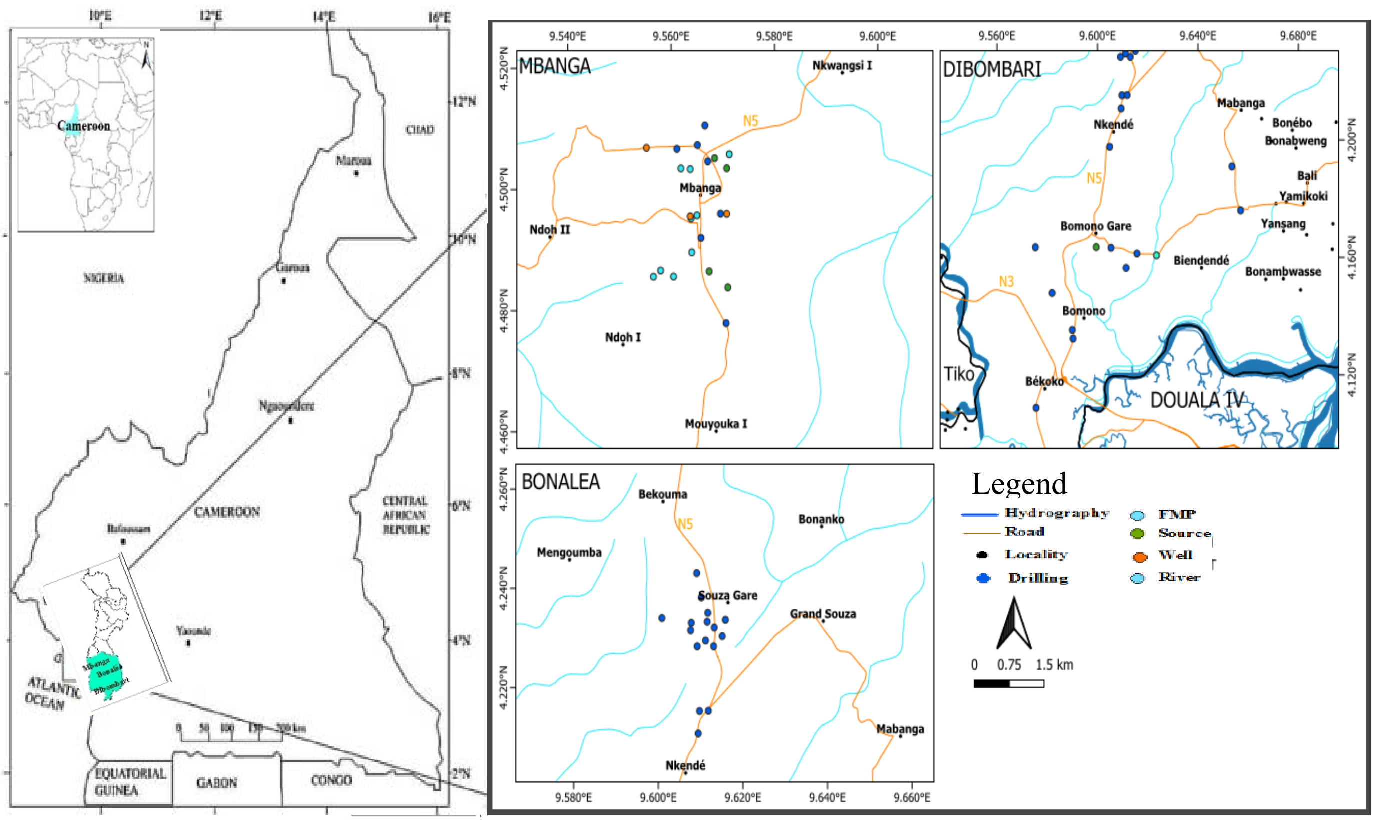

Figure 1 : Study Area

II.2 Climate

The entire study area enjoys a humid Guinean climate, characterized by the alternation of the long rainy season and the short dry season (IUCN, 2013). The rainy season extends from March to mid-November and the dry season from mid-November to March. The average annual rainfall is 2100mm. Temperatures vary between a minimum of 25,4˚C and a maximum of 30,2˚C.

II.3 Geology and hydrogeology

The hydrogeological system of the localities of Dibombari and Bonaléa belong to the Mio-Pliocene aquifer formations (Ketchemen, 2011 in Regnoult, 1986) characterized by a dominant sedimentary rock, formed on materials most often sandy or sandstone from the Cretaceous to the Miocene. The pH is always acidic but increases with depth. At Mbanga, Quaternary basalts have been found there (Dumort 1968; Sieffermann 1973). The main minerals present in these basalts are plagioclase (strong dominance of anorthite over albite) partly made up of volcanic ash favorable to agricultural activities. These quaternary basalts are made up of 3 rock layers (GEOBASE, 2008; WATER SURVEY 2007) namely the upper lateralized rocks (organic matter in decomposition), the intermediate fractured rocks and the lower unaltered rocks.

II.4 Hydrography

The hydrographic network is dendritic with small streams in all three localities (Olivry, 1986). In Dibombari, the network is dotted in its eastern part by the Wouri, Nkam and Fiko rivers, and in its south-western part by the Moungo river. In Bonalea, the Fiko, Mbome and Logmbassi rivers are the main courses of its hydrographic network, framed in the South-East by the Nkam river and in the North-West by the Moungo river. In Mbanga, the Moungo River is the main watercourse to which small rivers with fairly regular flows are grafted (PSU, 2014). Despite this dense hydrographic network, the population only obtains drinking water from wells and boreholes (Eboa, 2018) in the absence of a drinking water supply network.

II.5 Socio-economic aspect

Based on data from the last updated general population and housing census (RGPH) of 2012, the population in the study localities is estimated at 51,977 in Dibombari, 70,000 in Bonaléa (PNDP, 2018) and 140,000 in Mbanga (Ako et al., 2014). The structure of the population by age group reveals that more than half (64.3%) of the population is under 30 years old, with 53.3% of the population in the 15-54 age group. The main economic activities are livestock breeding, trade and above all agriculture. As the agricultural basin of the Moungo, the area is home to many agro-industries that contribute significantly to the country's Gross Domestic Product: the Cameroonian Palmoil Society (SOCAPALM) in Dibombari, the Cameroon Development Cooporation (CDC) and SOCAPALM in Bonaléa, then the Mbanga Plantation Company, a subsidiary of the Haut Penja Plantation (PHP). In addition, the locality of Dibombari is the subject of the extension of the Company for the Development of Industrial Zones (MAGZI) to absorb the strong demand for the installation of industries (agri-food). The growing need for personnel in these agro-industries has led to a migratory flow of people who settle there, with the corollary of the demand for basic infrastructure, including water and sanitation

Access to drinking water is a major problem for the population. In the absence of the water distribution network of the national company in charge of water, CAMWATER, the populations have recourse to other alternatives, mainly groundwater (wells, boreholes and springs), and some rivers. The populations of the study area are mostly middle-income people with little education and do not have sufficient means to acquire a quality water borehole or, better still, to maintain it. Furthermore, due to the precariousness of the population and the limited means, most of the wells built rarely reach the right water table and are limited to the water table subject to variations in environmental conditions, and therefore to the risks of water pollution. In addition, the practice of water treatment (disinfection) before consumption remains occasional. In these localities, the structure of the soil and the lack of developed drains cause a problem of evacuation of run-off water, which sweeps away wastewater, domestic and agro-pastoral waste, and wild refuse dumps, and ends up in the water resources (rivers, undeveloped springs, shallow wells) downstream, with the potential risk of developing water-borne diseases.

III. MATERIAL AND METHOD

III.1 Health survey

The health survey consisted of collecting data on waterborne diseases that had occurred during the last 04 months following the study period (September to December 2021) in each of the three localities of the study area. The survey method was based on consultation of health registers and exchanges with health personnel in order to establish statistics of waterborne diseases encountered and a list of affected patients. The parameters taken into account are the monthly frequency, the vulnerable age group and the breakdown by sex. The data was obtained from 09 health facilities (FOSA) chosen on the basis of their technical platforms likely to detect or not waterborne diseases and the abundance of patients. These are the Dibombari District Hospital, the Nkapa and Bomono Ba Mbengue Integrated Health Centers for the locality of Dibombari; the integrated health Center in Souza Gare, the Philanthropique and Saint-Augustine clinics in Bonaléa; the Mbanga District Hospital, the Salvation Health Center and the Catholic Mission Medical Center in Mbanga. Additional data was obtained from health districts and from the Ministry of Public Health digital database.

III.2 Socio-environmental survey

After an initial survey phase in the hospital, a second phase following a non-probability sampling was carried out in the households of individuals identified in the list of patients retained in the health facilities (FOSA). Based on the patients' addresses, they were geo-located in their homes throughout the commune and then a structured survey form was administered to them. A total of 403 individuals were surveyed, including 97 in Dibombari, 78 in Bonaléa and 229 in Mbanga. The content of the form was based on four modules: (1) the socio-economic characteristics of the patient, (2) hygiene and sanitation methods (liquid and solid waste disposal), (3) water supply methods and (4) methods of preventing waterborne diseases. In addition to the data from the survey form, a direct observation technique was used. This consisted of assessing the distances between water sources and possible pollution points (latrines, rubbish dumps, livestock farms and agricultural areas).

III.3 Water sampling and Physicochemical analysis

A total of Fifty-two (52) water points were sampled throughout the study. It includes: Fifteen (15) in Dibombari, fourteen (14) in Bonaléa and twenty-three (23) in Mbanga. The selected points in line with the socio-environmental and health surveys have been subjected to measurements of in situ physicochemical parameters (pH, Temperature, electrical conductivity, solids total dissolved, resistivity and redox potential) using a Hanna Multi-parameter probe code HI98192.

III.4 Statistical treatment

The statistical analysis involved univariate, bivariate and multivariate using IBM SPSS Statistics 20 software. The univariate analysis was carried out to bring out the descriptive statistics of the physicochemical parameters of the study. The bivariate analysis made it possible to verify the associations between the diagnostic variable and the explanatory variables through the independence tests of Chi-2 and Rho of Sperman. Multivariate analysis was used on the other hand to predict the effect of each explanatory variable on the diagnostic variable, the results of which were expressed in terms of risk ratios from logistic regression models (Duyme, 2001; Van Houwelingen, 1990). The diagnostic or dependent variable is the prevalence of waterborne disease observed in health facilities, comprised of two modalities: typhoid fever and other cases (gastroenteritis and diarrhoea). The explanatory variables are age, sex, type of water resources consumed, treatment applied, a distance of access to the water resource, distance from sources of potential pollution of the resource, and waste disposal methods.

Due to the abnormality of the data according to the Kolmogorov and Smirnov tests, a Mann-Whitney ANOVA (Student) test was carried out in order to compare the physicochemical parameters by locality. Then the bilateral test of equality for proportions with Bonferroni's correction was carried out. In addition, a dendrogram by Ward's agglomeration method (Husson *et al*., 2011) has been associated with it.

IV. Result And Discussion

IV-1 groundwater physicochemical characteristics and threats on population health

All the pH of the water surveyed has average values that are lower than those recommended (6.5-8) by the WHO (2012) and the Cameroonian Standard for Drinking Water (2014). These mean values are 3.7±0.19 in Bonaléa, 4.7±1 in Dibombari, and 5.04±0.5 in Mbanga (Table 1). The acidic pH values would be characteristic of the geological substratum crossed. These values are similar to those obtained by Eboa (2018) with a mean pH of 5.6±0.6 at Dibombari and Ako *et al* (2011) with a mean pH of 5.8±0.9 at Mbanga. According to Ketchemen (2011), the acidity could be attributed to the hydrolysis of humic acid-bound silicates from the decomposition of organic matter in the feeding areas. Acid water has been noted be dangerous to the health of consumers but it can indicate the presence of a pollutant in the water or reflect a strong mineralizing activity of bacteria, near the water table (Matini *et.,al* 2009, Ako *et al*., 2011). According to Magah *et al* (2021) and Dirisu *et al* (2019), the pH of the water affects most biochemical processes in the water such as enzymatic activity, solubilization and absorption of certain ions such as ammonia; which could lead to the proliferation of bacteria that are pathogenic to human health in this water used for drinking. The average temperature values are 28.2±0.71°C in Bonaléa, 26.9±1.19°C in Dibombari, and 27.4±0.7°C in Mbanga. The temperature values are very close to that of the air (28.3°C) indicating an opening of the water table and therefore its vulnerability; according to Nlend *et al* (2019) and Magah *et al* (2021) this refers to the shallow flow path of the water in the study area, and therefore the risk of contamination by pathogens responsible for waterborne diseases. The water is not very mineralized with EC and TDS values below the WHO guideline value of 1500µS and 1000 mg/l respectively. Mbanga is the most mineralized area with a maximum value of 304µS/cm and an average of 129±64µS/cm. A significant difference at the 5% threshold was observed for the pH, EC, and TDS values between the three localities. Although the localities of Dibombari and Bonaléa are part of the Mio-Pliocene aquifer (Ketchemen, 2011 in Martin, 1978) where the natural conductivity of the water is lower than 50µs/cm, 42% and 46% of the samples in the respective localities have EC values higher than 50µS/cm. This indicates an external input of ions linked to anthropogenic activities. Moreso, nitrate and chloride inputs resulting from a leaching process could deteriorate the water quality with the possibility of an upsurge in waterborne diseases among consumers (Robert *et al* 2014).

Table 1: Univariate statistical of physicochemical parameters by locality

Parameters		**pH**	**Temperature (°C)**	**CE (µS/cm)**	**TDS (mg/l)**	**ORP (mV)**
WHO limit values (2017)		6.5-8.5	25	1500	1000	/
Cameroonian standard NC 207 (NC, 2014)		6.5-8	/	/	/	/
Bonalea	Minimum	3,400	27,100	25,480	12,530	129,600
	Maximum	4,230	29,300	187,700	93,570	172,600
	Mean	3,779	28,293	80.051	39,994	152,371
	Median	3,765	28,500	43,335	21,695	154,550
	Standard deviation	.195	.711	59,882	29,818	9,593
Dibombari	Minimum	3,500	25,300	17,530	8,590	26,600
	Maximum	7,260	29,700	245,500	137,400	167,200
	Mean	4,730	26,980	52,394	27,136	118,453
	Median	4,680	27,000	35,060	17,270	126,300
	Standard deviation	1,042	1,191	56,184	31,743	46,570
Mbanga	Minimum	4,280	26,300	32,460	26,620	28,200
	Maximum	6,210	29,500	304,000	151,300	128,500
	Mean	5,043	27,496	129,698	65,771	91,417
	Median	4,890	27,600	124,800	61,640	97,500
	Standard deviation	.523	.793	64,636	30,755	26,894
Z Test Bonaléa and Dibombari		0.000*	0.000*	0.013*	0.010*	0.001*
Z Test Bonalea and Mbanga		0.000*	0.000*	0.002*	0.001*	0.000*
Z Test Dibombari and Mbanga		0.064*	0.204	0.000*	0.000*	0.581

*: significant at P≤ 5% ; Z Test : Student test

Based on the work of Abbu and Yassin (2008), Chan *et al. (* 2007) and Tumwine *et al* . (2002) empirical evidence shows the link between sanitation, polluted drinking water and health. Thus, in order to better appreciate this link, a dendrogram was used.

The method of hierarchical ascending classification through a dendrogram (figure 2) makes a grouping between the variables of sanitation, physicochemical parameters, and the occurrence of waterborne diseases in the three localities

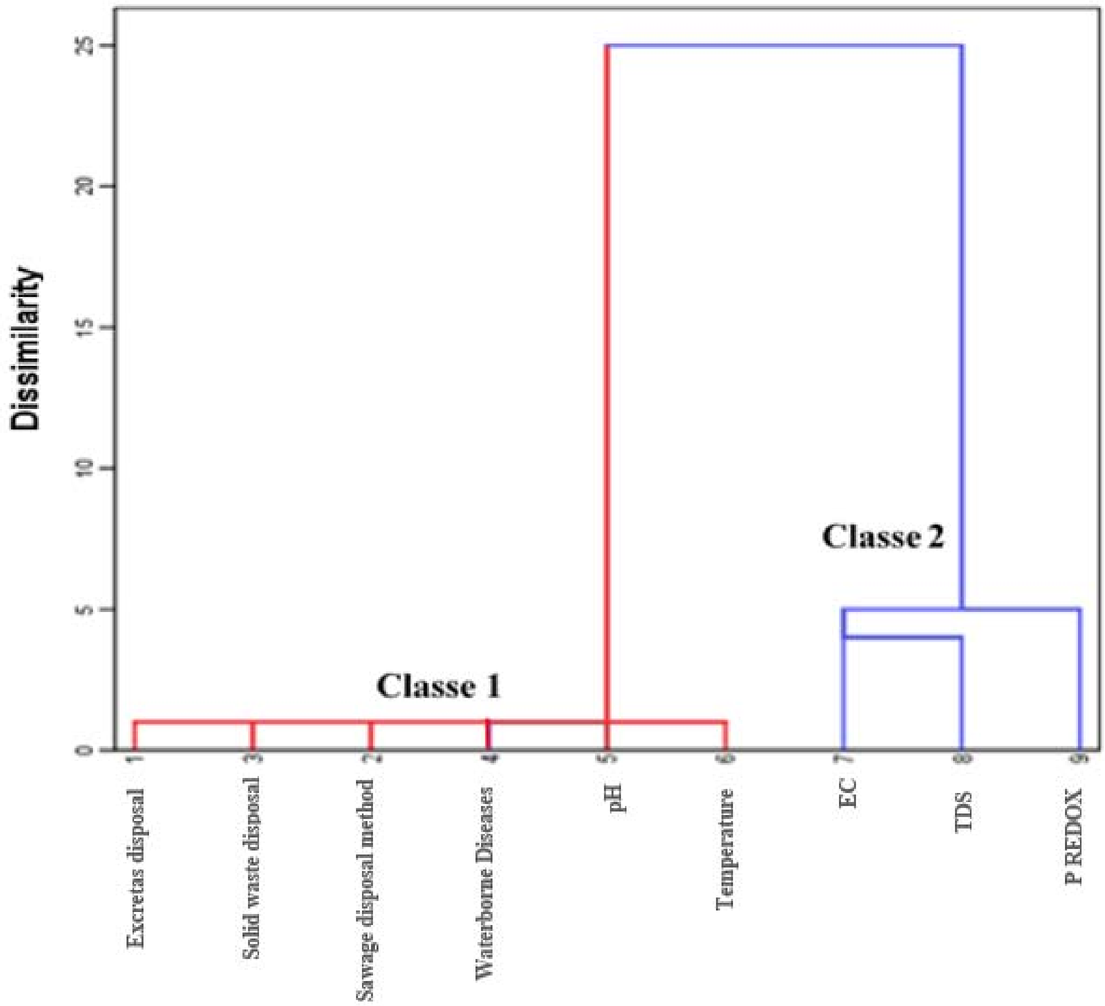

Figure 2: Agglomerative hierarchical clustering dendrogram of Physicochemical parameters, remediation variants, and waterborne diseases.

Two classes emerge from this grouping. Class 1 is related to the recrudescence of waterborne diseases exacerbated by the low level of sanitation. It groups the modalities of sewage disposal, excreta disposal, solid waste disposal, pH, and temperature. As demonstrated by Magah *et al* (2021) and Dirisu *et al* (2019), the pH of water affects most biochemical processes in water such as enzyme activity. Indeed, with the precarious sanitation characteristic of the area and the opening of the water table consumed, runoff water loaded with organic and plant detritus will flow and infiltrate into water reservoirs (wells, rivers, springs, and boreholes) changing the mineral composition of the latter. According to Tala Navab-Daneshmand *et al* (2018), Lanata *et al* (2013), and Kotloff K.L(2013), waters with organic detritus are the development site of enteric pathogenic microorganisms (Escherichia coli, Salmonella Typhi, Shigella Cryptosporidium spp.), which are the main causes of diarrhoea, typhoid fever, and gastroenteritis. Furthermore, Ketchemen *et al* (2017) associate poor water quality with latrine waste and surface discharge. This pollution trend also reflects the vulnerable nature of water resources in localities linked to poor hygiene and sanitation, which is confirmed by the good association (class 1) obtained between sanitation modalities and the occurrence of water-borne diseases; according to the work of Abbu and Yassin (2008), Chan *et al* (2007) and Tumwine *et al* (2002) empirical evidence shows the link between sanitation, polluted drinking water, and health. Class 2 includes TDS, EC, and ORP which refers to the process of mineralization of groundwater. In agreement with Ngo Boum *et al* (2015), this mineralization is the result of processes such as hydrolysis, weathering, dissolution, and diffusion of water-collecting substrates. These processes, generally natural, can be influenced by anthropogenic factors leading to pollution of environmental compartments (soil, air, and water) and thus deteriorating the quality of water resources. Rational management measures should be taken to mitigate the risk of waterborne diseases by acting on the risk factors to maintain the integrity of the water resources and thus preserve the human health of the dependent populations

IV-2 Waterborne diseases and link with socio-environmental conditions

The bivariate analysis of certain socio-environmental factors observed in drinking water supply in the three localities of the study area revealed an influence on the occurrence of waterborne diseases. Except for the type of water resources and their access distance, all the explanatory variables are significantly ($P < 0.05$ and $P < 0.01$) associated with the occurrence of waterborne diseases in all localities (Table 1). The water resource mainly consumed in all three localities is drilling at the rate of 86.46% in Dibombari, 100% in Bonaléa, and 70.30% in Mbanga. In addition, there is a low propensity to treat water before drinking, 16.67% in Dibombari, 15.38% in Bonalé,a and only 12.66% in Mbanga. Individuals over 15 years old were the most affected by waterborne diseases with proportions of 67.71% in Dibombari, 65.38% in Bonaléa and 64.19% in Mbanga. Also, women turn out to be the most affected with 62 (64.58%) of cases in Dibombari, 48 (61.54%) of cases in Bonaléa and 147 (64.19%) of cases in Mbanga. In terms of hygiene and sanitation, wastewater mainly flows into fields and courtyards near homes; solid waste is the subject of household manure (51.16% in Dibombari; 53.85 in Bonaléa and 49.78% in Mbanga); and cannon latrines are the most used for the evacuation of excreta with 33.38% in Dibombari; 35.89% in Bonaléa and 32.75% in Mbanga (Table 2).

Tableau 2: Prevalence of waterborne diseases observed according to various socio-environmental variables

Variables	Prevalence of waterborne diseases					
	Dibombari		Bonalea		M'banga	
	N	%	N	%	N	%
TYPE OF WATER						
Boreholes	83	86.46	78	100	161	70.30
Others	13	13.54	00	00	68	29.70
Total	96	100.0	78	100.0	229	100.0
Chi2	0.007**		-		0.643ns	
TREATMENT						
No	80	83.33	66	84.62	200	87.34
Yes	16	16.67	12	15.38	29	12.66
Total	96	100.0	78	100.0	229	100.0
Chi2	0.02**		0.08**		0.00**	
AGE						
Under 15	31	32.29	27	34.62	82	35.81
More than 15 years	65	67.71	51	65.38	147	64.19
Total	96	100.0	78	100.0	229	100.0
Chi2	0.002**		0.003**		0.000**	
SEX						
Male	34	35.42	30	38.46	82	35.81
Women	62	64.58	48	61.54	147	64.19
Total	96	100.0	78	100.0	229	100.0
Chi2	0.017**		0.097**		0.000**	
WASTE WATER DISCHARGE						
Channels	15	15.63	15	19.25	28	12.22
Course	30	31.25	23	29.48	68	29.69
Toilet	18	18.75	12	15.38	46	20.10
Fields	33	34.37	28	35.89	87	37.99
Total	96	100.0	78	100.0	229	100.0
Chi2	0.000**		0.000**		0.000**	
SOLID WASTE DISPOSAL						
Manure	52	51.16	42	53.85	114	49.78
Laugh	14	14.58	13	16.66	43	18.78
Municipal bins	11	11.47	8	10.26	23	10.04
Dumps	19	19.79	15	19.23	49	21.40

Total	96	100.0	78	100.0	229	100.0
Chi2	0.000**		0.000**		0.000**	
EXCRETA EVACUATIONS						
Improved latrine	26	27.08	21	26.94	48	20.96
Full bleed latrine	19	19.79	17	21.79	59	25.76
cannon latrine	33	34.38	28	35.89	75	32.75
modern toilet	18	18.75	12	15.38	47	20.53
Total	96	100.0	78	100.0	229	100.0
Chi2	0.000**		0.000**		0.000**	
DISTANCE SOURCES OF POLLUTION						
Spearman's Rho	0.000*		0.000*		0.000*	
WATER POINT DISTANCE						
Spearman's Rho	0.167ns*		0.168ns		0.146ns	

N: observed number; %: ratio; ns: not significant at 5%; ns*: not significant at 1%; **: significant at 5%; *: significant at 1%; - : not applicable

The significant association (Chi2 = 0.007; P < 0.05) between the type of water resources and waterborne diseases observed in Dibombari could be explained by the fact that apart from boreholes, the other types of resources found are essentially rivers. The latter are less protected than boreholes and therefore more vulnerable to sources of pollution whose contact by individuals would lead to the occurrence of waterborne diseases. These results are in accordance with Ntouda Julien *et al* (2012) where the type of water consumed by households influences the onset of diseases. related to water. In Mbanga, on the other hand, the independence between the type of water and the waterborne disease reflects the fact that individuals can contract the disease regardless of the type of water they consume. This would account for the vulnerability of all the water resources consumed by the individuals surveyed in the area. This result is important because it provides information on the poor state of hygiene and sanitation in the locality, confirmed by the perfect associations between the occurrence of waterborne diseases and the methods of solid waste disposal (Chi2 = 0.007; P < 0.05), wastewater (Chi2 = 0.007; P < 0.05) and excreta (Chi2 = 0.007; P < 0.05). According to Sorlini *et al* (2013) the poor state of sanitation in the Logone Valley, Far North of Cameroon contributes to the appearance of waterborne disease. Furthermore, a systemic review on the impact of water resources on human health by Pickering AJ *et al* (2012), highlighted the association between waterborne diseases and hygiene. Women and people over the age of 15 are the most affected by waterborne diseases which can be attributed to the general activeness in household work, particularly with the use of water, which is an excellent driver for the transmission of waterborne diseases. These results are in line with the findings of Monica Muti et *al.*,2014 in Harare, Zimbabwe, for whom women were noted to be more likely than men to contract typhoid fever. The precarious hygiene and sanitation methods observed are characteristic of rural areas in sub-Saharan Africa, as noted by Ako *et al* (2010) and the WHO/UNICEF Joint Monitoring Program (2015) estimating the hygiene and sanitation rate in Cameroonian rural areas at 8 %. In fact, households have low incomes, insufficient to afford boreholes and ensure their maintenance, as well as modern toilets.

The prediction of the appearance of waterborne diseases in the study area was made using a binary logistic regression model expressed in terms of relative risk ratio (odd ratio) in a 95% confidence interval (table 3). The factors associated with an increased risk of occurrence of waterborne disease are: age (6.39[1.05;38.89] in Dibombari; 4.88[1.07;30.33] in Bonaléa and 5.79[1.99;16.78] in Mbanga) and the distance to pollution sources (1.13[1.02;1.25] in Dibombari; 1.22[1.01;1.33] in Bonaléa and 1.17 [1.09; 1.26] in Mbanga). The protective factors for their part are: the type of water (0.80 [0.70; 0.90] in Dibombari) and the treatment (0.75 [0.65; 0.86] in Dibombari; 0 .76[0.66;0.89] in Bonaléa and 0.05[0.007;0.38] in Mbanga).

Table 3 : Relative risk of occurrence of waterborne diseases observed in populations according to logistic regression models

Explanatory variables	Prevalence of Waterborne Diseases					
	DIBOMBARI		BONALEA		MBANGA	
TYPE OF WATER	**		-	-	Ns	
Boreholes	0.80*		-	-	0.74ns	
Others	(r)		-	-	(r)	
CI for risk 95%	0.70	0.90	-	-	0.33	1.68
TREATMENT	**		**		**	
Nope	(r)		(r)		(r)	
Yes	0.75**		0.76**		0.05**	
CI for risk 95%	0.65	0.86	0.66	0.89	0.007	0.38
AGE	**		**		**	
Under 15	(r)		(r)		(r)	
More than 15 years	6.39**		4.88**		5.79**	
CI for risk 95%	1.05	38.89	1.07	30.33	1.99	16.78
SEX	**		**		**	
Male	(r)		(r)		(r)	
Women	0.001ns		0.001ns		0.000ns	
CI for risk 95%	0.000	6.01	0.000	18.36	0.000	5.57
DISTANCE SOURCES OF POLLUTION	*		*		*	
Value Risk	1.13**		1.22**		1.17**	
CI for risk 95%	1.02	1.25	1.01	1.33	1.09	1.26
WATER POINT DISTANCE	ns*		ns*		ns*	
Risk value	0.99ns		0.89ns		0.99ns	
CI for risk 95%	0.94	1.04	0.83	1.014	0.97	1.007
Chi2	56.43**		43.83**		135.84**	
Cox & Snell's R²	0.44		0.43		0.44	
Nagelkerke R²	0.62		0.59		0.61	

ns: not significant at 5%; **: significant at 5%; *: significant at 1%; r: reference terms; ns*: not significant at 1%; CI: Confidence interval; -: not applicable

The age and proximity of pollution sources to water resources affect the risk of occurrence of waterborne diseases. Indeed, when an individual in Dibombari, Bonaléa, and Mbanga is over 15 years old, he is 6.39, 4.88, and 5.79 times respectively more likely to contract a waterborne disease than those less than 15 years old. Moreover, this susceptibility within the population varies by a factor ranging from 1.05 to 38.89; 1.07 to 30.33, and 1.99 to 16.78 respectively in Dibombari, Bonaléa, and Mbanga. These results are in agreement with Caimcross *et al*., 2010 and NU (2015) where the elderly are the main victims. On the other hand, according to WHO/UNICEF (2015) and Tyler *et al* (2017), children are the most vulnerable in this case to diarrhoea and gastroenteritis. This difference is explained by the fact that in the regression analysis, typhoid fever was considered a reference condition in relation to other diseases that include diarrhoea and gastroenteritis. Thus, the risk is expressed for the fact of contracting typhoid fever than diarrhoea and gastroenteritis vis-à-vis an age category. Typhoid fever was taken as the reference modality because of its preponderance in all localities compared to other diseases. The proximity of the sources of pollution to water-borne diseases is significantly associated, the closer the sources of pollution (latrine, garbage dump, and wastewater) are to the water resources consumed, the more individuals are likely to have a waterborne disease. This risk is 1.13 in Dibombari, 1.22 in Bonaléa and 1.17 in Mbanga. This result reflects the vulnerability of water resources in the study area related to hygiene and sanitation, is explained by the significant association found between sanitation methods and waterborne diseases. Tyler J *et al* (2017) associated the occurrence of gastrointestinal diseases with microbial pollution of water from poor sanitation of the immediate perimeter of the water resource. The application of treatment consumed in all three localities and the type of water resources in Dibombari are the factors reducing the risk of occurrence of waterborne disease. Indeed, individuals applying a treatment before water consumption are 0.75 (in Dibombari), 0.76 (in Bonaléa) and 0.05 (in Mbanga) times less likely to have waterborne disease than those who do not. applying any treatment. At the population level, this risk can decrease between 14 and 35% in Dibombari, 11 and 34% in Bonaléà, and 62 to 99% in Mbanga. These results reflect the need to raise household awareness for the treatment of drinking water in all localities.

The distribution of diseases by age group was not uniformly distributed in all three study localities. By comparing the rates of waterborne diseases by age group and by locality, a significant difference ($P < 0.05$) was observed between typhoid fever and gastroenteritis in each of the localities for children under 1-year-old (table 4).

Table 4: Incidence of waterborne diseases in the study area by age group.

Localities/years		**waterborne diseases**					
		(n)Typhoid fever (%)		(n) Gastroenteritis (%)		(n) Diarrhoea (%)	
Dibombari	< 1 year	10_a	15.4%	9_b	47.4%	0	0.0%
	1-4 years	3_a	4.6%	0	0.0%	2_a	16.7%
	5-14 years old	5_a	7.7%	2_a	10.5%	0	0.0%
	15-44 years old	33_a	50.8%	8_a	42.1%	10_a	83.3%
	> 44 years old	14_a	21.5%	0	0.0%	0	0.0%
Bonalea	< 1 year	8_a	15.4%	7_b	43.8%	0	0.0%
	1-4 years	3_a	5.8%	0	0.0%	2_a	20.0%
	5-14 years old	4_a	7.7%	3_a	18.8%	0	0.0%
	15-44 years old	24_a	46.2%	6_a	37.5%	8_a	80.0%
	> 44 years old	13_a	25.0%	0	0.0%	0	0.0%
M'banga	< 1 year	14_a	9.6%	19_b	41.3%	0	0.0%
	1-4 years	7_a	4.7%	0	0.0%	27_b	71.9%
	5-14 years old	12_a	8.1%	8_a	17.4%	0	0.0%
	15-44 years old	88_a	60.0%	19_a	41.3%	8_b	28.1%
	> 44 years old	27_a	17.6%	0	0.0%	0	0.0%

Values from the same rows and subarrays that do not share the same index (a, b) differ significantly at $p<0.05$ in the two-tailed test of equality for column proportions.

The incidence of gastroenteritis is much higher (47.4% in Dibombari, 43.8% in Bonaléa and 41.3% in Mbanga) than that of typhoid fever (15.4% in Dibombari, 15.3 % in Bonaléa and 17.6% in Mbanga).

In addition, a significant difference is obtained in Mbanga between typhoid fever and diarrhoea for the age groups 1-4 years and 15-44 years. Indeed, for children from 1 to 4 years old, the incidence of typhoid fever is 4.7% against 71.9% for diarrhoea; Moreover, for the age group of 15-44 years the incidence of typhoid fever is 60.0% against 28.1% for Diarrhoea. In agreement with WHO/UNICEF, 2022 and the work of Tyler *et al.,* 2017, children under 5 are more susceptible to diseases such as diarrhoea and gastroenteritis due, among other things, to their immune systems still poorly adapted to pathogens.

V. CONCLUSION

Due to the lack of access to safe drinking water in rural areas of sub-Saharan Africa, the resident populations are rushing to access sources whose quality remains questionable, with unprecedented consequences for their health. This study highlighted the conditions of access to drinking water and the risks to the health of its consumers in a peri-urban area of the coastal region of Cameroon. It shows that the precarious level of sanitation contributes to the deterioration of available water resources with observable consequences on the health of the population, including the occurrence of waterborne diseases. The occurrence of waterborne diseases is accentuated by risk factors such as the age of the individuals and the proximity of pollution sources to the water resource consumed. Treatment is obviously a protective factor, although its application has been very low. This study is intended as an alarm bell to the actors of sustainable development and mainly to those responsible for land use planning in the peri-urban area of the city of Douala, in this case, the localities of Dibombari, Bonaléa, and Mbanga. Emphasis could be placed on the management of water resources and sanitation because the population's health which are an essential link in development, is at stake.

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CONFLICT OF INTEREST

The authors declare there is no conflict

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