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Research Paper

Ecohydrology of Surface and Underground Water of the Mgoua Drainage Basin in Douala (Cameroon)

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Abstract: *This work investigated the Mgoua catchment in Douala whose water bodies are highly exposed to sources of pollutants and contaminants resulting mainly from anthropogenic activities. The purpose of this work is to evaluate the impact of pollution on the physicochemical quality of waters in the Mgoua catchment in Douala. The parameters were determined using standardized procedures. Results from the different sites investigated reveal the following: pH (5.2 ± 0.9 to 10.2 ± 1.8), conductivity (201.2 ± 77.1 to 2418.4 ± 2202.2 µS/cm), TDS (135.1 ± 89.5 to 2358.5 ± 2189.1 mg/l), turbidity (9.6 ± 8.4 to 333.7 ± 432.5 NTU), colour (33.6 ± 45.3 to 1330 ± 1119.8 Pt.Co), temperature (26.4 ± 1.7 to 27.5 ± 2.6 ^oC), dissolved oxygen (1.5 ± 0.9 to 5.7 ± 1.2 mg/l), fluoride (0.1 ± 0.0 to 34.3 ± 59.7 mg/l), sodium (16.8 ± 1.8 to 13792.3 ± 33350.7 mg/l) which exceed the standards recommended by WHO (2006). On the average, the Axe lourd and the Tergal area recorded a exceptionally high Ca^{2+}, conductivity, Ca^{2+} and Na^{+} concentrations in the water samples. Chlorides on the other hand recorded high average concentrations (17.3±1.6 to 56.0±17.2 mg/l) in some areas. Magnesium and calcium concentrations recoded below the acceptable WHO threshold for drinking water. The Bobongo, Axe lourd, Chococam and CCC areas poses threat of aluminum pollution with concentrations of 0.3 ± 0.5 mg/l, 1.5 ± 1.4 mg/l, 6.4 ± 11.7 mg/l and 1.8 ± 2.1 mg/l respectively. It is evident that the Mgoua water catchment is effected by pollution based on the physico-chemical analyses carried out and is thus not suitable for human consumption. Majority of parameters measured below the permissible limits recommended by WHO for drinking water.*

Key words: Contamination, Douala, pollution, physico-chemical characteristics, Water resource quality.

Introduction

It is often said that water is life, a "universal solvent" and made up of oxygen, hydrogen and carbon which together are indispensable for the formation of cells [1]. Having water in sufficient quantity and high quality is essential in maintaining good health. Though essential to life, water constitute a major agent of diseases transmission both within the industrialized and the less industrialized countries [2]. Water pollution is caused by the rapid increase in population which coupled with high industrialization has rendered potable water a scarce commodity. A lot of health problems have also resulted from the consumption of polluted water especially in the less industrialized countries. Douala with a population density of ≈3 million inhabitants [3] has witnessed a drastic increase in the demand for potable water. This increase has caused shortages in the supply of pipe borne water in most household, thereby compelling the population to depend on poorly/untreated water from wells, streams and springs. Large volumes of industrial effluent discharge into surface waters have been the main cause of pollution and contamination of most water bodies. The industrial city of Douala-Cameroon like most industrial zones is the most vulnerable to the above mentioned environmental problem. This study intends to determine the physico-chemical characteristics of water from the Mgoua drainage basin in Douala which is presently affected by pollution. Furthermore, it intent to evaluate the average spatio-temporal variation of water samples from the different sites.

Material and Methods

Description of study area: The Mgoua catchment is situated within the southwestern part of Douala in the littoral region of Cameroon. It has a surface area of over 8.30 km^2 and lies between latitudes 0^o 04'00"N and 0^o04'02" N, and longitudes 0^o09'41" E and 0^o09'45" E. The catchment rests upon the Douala sedimentary basin.

The climate is of the equatorial humid Cameroon type with two seasons: a long rainy season (March–November) and a short dry season (December–February). for the purpose of this study, sample locations were selected based on organoleptic factors (colour of water and its nauseating odour), streams management, the frequency of water extraction from the wells, accessibility to sampling sites and the nearness to sources of pollution (solid and liquid wastes from industries, agricultural and animal husbandry).

Physicochemical parameters of water in the Mgoua catchment were investigated using samples collected from nine locations (Figure 1) within the study area: two at industrial effluents, four streams and three wells. The two effluents samples came from Chococam and Cameroon Chemical Complex (CCC). The four sample points on streams were from Oyack, Bobongo, Song mahop and Axe lourd. The three wells are located at Oyack, Tergal and Axe lourd (Figure 1).

Sampling and Analyses of Water Samples: Two set of samples were collected from the nine location mentioned earlier that is: one set for physico-chemical parameters. For the physico-chemical sample set, one sample from each location was collected in a monthly interval for a period of two years. The biological samples on the other hand, were obtained by collecting one sample from each location once per semester for a period of two years.

Sampling was done during the rainy season between March and November 2004, (highest water levels); and during the dry season from December 2004 to February 2005 (lowest water levels) All samples were collected in clean (washed and rinsed with distilled water) polyethylene tubes with a capacity of 0.1 L. During manual in situ sampling, the washed bottles were rinsed thrice with the water to be sampled. Stream samples were collected in bottles plunged at 20 cm depth below the water surface with mouth facing the upstream direction following Rodier's technique[4]. The labeled samples were conserved at 4^oC and transported to the laboratory of environmental Geosciences of the University of Toulouse, and that of the Geo-chical Analysis of water of the Institute of Geological and Mining Research of Cameroon within a period of four hours. The following measurements were carried out: pH, electrical conductivity, total dissolved solids, and temperature. pH and temperature were measured with the help of a pH meter of Schott Gaëte mark, while electrical conductivity and total dissolved solids (TDS) were measured using a field conductimeter of WTM LF 91 type.

Turbidity was determined using a HACH DR 2000 Spectrophotometer, Dissolved Oxygen contents using Oxi 196 Oxymeter by directly plunging electrodes in the water sample. Major anions such as Chloride (Cl^-), Nitrate (NO_3^-), Sulfate (SO_4^{2-}), Fluoride (F^-) and Phosphate (PO_4^{3-}) were analyzed through Dionex ICS-2000 ionic chromatography (H.P.L.C High performance liquid chromatography). On the other hand, major cations such as Sodium (Na^+), Potassium (K^+), Aluminium (Al^{3+}), Iron (Fe^{3+}), Calcium (Ca^{2+}), Manganese (Mn^{2+}) and Magnesium (Mg^{2+}) after filtration and addition of 10 % distilled nitric acid were analyzed using Perkin Elmer 5100 ZL model of Inductive Argon Coupled Plasma Atomic Emission Spectrophotometer (ICP-AES). Statistical analysis of the results was done by comparing average measured parameters using SAS software.

Results and Discussion

Water being a vital element is an efficient agent of the transportation and dissemination of pollution and diseases. That is the reason why extreme attention has to be paid on its quality and portability. The quality of potable water (drinkable water) causes a lot of problems to human health in developed and developing countries and should be free of all impurities.

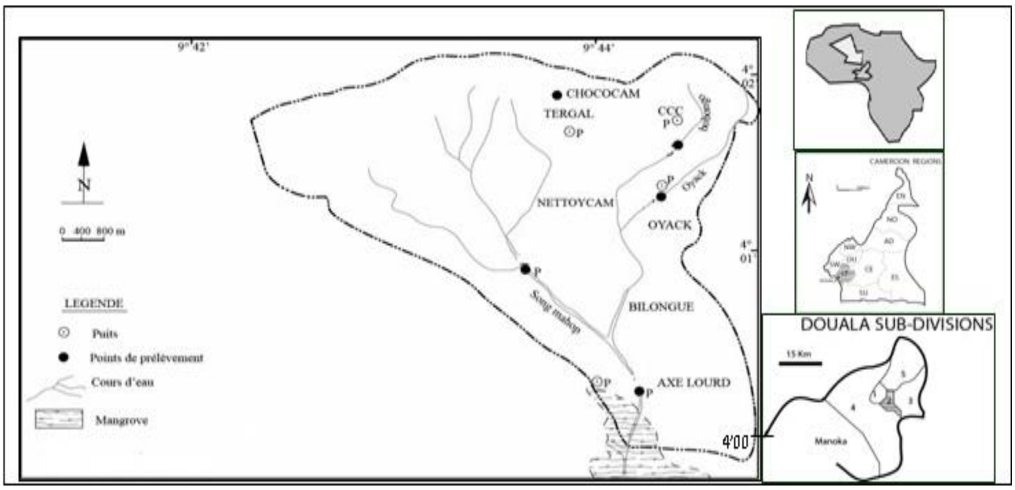

Figure 1: Location map of Mgoua drainage basin in Douala and water sampling sites

The results of the analyses of water samples from the Mgoua drainage basin are presented in Table 1, in the form of average ± standard deviation.

a) Physico-Chemical Parameters: The pH values vary from 6.3±0.7 to 6.9±0.2 for streams samples, 5.1±0.5 to 6.5±0.33 for well samples and 5.2±0.9 to 10.2±1.8 for effluent samples (Table 1). These results indicate a low acidity in the water samples (from streams, wells, effluents) and thus possess less danger to the consumers. On the other hand, water samples with pH values <7 (low pH) are corrosive. The low pH values could be attributed to the discharge of effluents from factories (CCC) and also from the interaction of groundwater with soils of low carbonate content (acid soils). Generally, all samples conform with WHO's standards for waste water except for effluent samples obtained from the CCC production area. These results are similar to those obtained at Benin City of Edo state in Nigeria [5].

The mean measurement of Electrical conductivity of the Mgoua water, ranged from 355.3 ± 111.2 to 2054.2±1428.6 µS/cm in streams, 186.9±103.3 to 2418.4±2202.2 µS/cm in effluents and 201.2±77.1 to 394.2±266.1µS/cm in wells (Table 1). These values fall below WHO's standard (1000 µS/cm) for electrical conductivity of potable water. Meanwhile, samples from stream on Axe lourd (2054.2 ±1428.6 µS/cm) and the CCC effluents (2418.4 ± 2202.2 µS/cm) gave a higher conductivity. Similar values were obtained at Messdour and Wadi Z'Ommor in Algeria [6].

Total dissolved solid mean values were also varied significantly between 343.1±115.3 to 1616.5±1115.9 mg/l in streams, 160.1±68.6 to 2358.5±2189.1 mg/l in effluents and 135.1±89.5 to 311.2 ± 306.7 mg/l in wells. Even though, most of the sites recorded lower values, results from Axe lourd (1616.5±1115.9 mg/l) and CCC factory area (2358.5±2189.1 mg/l) were higher than the WHO's standard of 1000mg/L. Such abnormalities were also observed in parts of Akure, South-Western Nigeria [7].

Measured temperature values of 26.4 ± 1.7 to - 27.5 ± 2.6^{o}C (Table 1), were slightly higher than WHO's standards (25^{o}). High temperatures can also negatively impact water quality by enhancing microorganism growth, and may increase taste, odour, colour and corrosion problems [8].

For the turbidity of the water bodies, slight variation was with season was encountered but never exceeded the WHO's standards. The streams recorded 114.3±60.8 to 174.6±136.8 NTU in streams, 441.5±241.2 to 432.5±333.7 NTU in effluents and 9.6±8.4 to 46.3±39.4 NTU in wells (Table 1). Similar results were reported at the basin Nakambé in Burkina Faso [9].

Colour in this study revealed that the average values for stream samples range between 514.3±351.9 to 640.4±468.8 Pt.Co, for effluents range between 850.4±837.6 to 1330±1119.8 Pt.Co and between 45.3 ± 33.6 to 224.5 ± 184.4 Pt. Co in wells. The mean values obtained from various sites are largely above established standards (15 Pt. Co) by WHO [2]. This is due to the presence of domestic, natural or industrial substances.

Dissolved oxygen content recorded 2.1±1.4 to 3.4±1.8 mg/l for stream samples, 1.5±0.9 to 4.2±2.4 mg/l for effluents and 4.4±1.6 to 5.7±1.2 mg/l for wells. Generally, these values indicate no signs of eutrophication as all measurements fall below WHO'S standard (6 mg/l) for dissolved oxygen in water. Recent works on the water quality of the river Oeud Bouishak-Meknes in Morocco [5] produced similar results thereby implying that the Mgoua surface water are presently under saturated with dissolved oxygen.

Sulfate concentrations in water could be attributed to the dissolution of gypsum, leaching and/or anthropogenic (industrial, domestic, agricultural pollution [11]. On the average, the water samples from wells in the Mgoua catchment gave the highest Sulfate concentrations (4.5±4.3 to 253.8± 81.4 mg/l) followed by effluents (15.6±10.1 to 173.6±54.5 mg/l) while the lowest values were recorded in stream samples (6.1±5.0 to 88.9 ± 40.8 mg/l), (table 1). Meanwhile, it should be noted that in environments where high Sulfate concentrations (>400mg/l) is a problem, consumers suffer from diarrhea and might also harm intestinal flora. Identical results were observed in groundwater of M'nasra in Morocco [12].

Reports have shown that anthropogenic activities contribute enormously to high phosphate concentration in surface water. As observed from this study, average PO^{-}_{4} concentrations recorded the highest (4.1±2.98 to 17.6±11.2 mg/l) probably due to its' high contribution from industrial and anthropogenic activities. The streams and wells recorded 4.1±3.0 mg/l (particularly for Bobongo) and 0.29±0.0 to 0.84 ± 0.6 mg/l respectively. These results are close to those observed in Chilika Lakeafter in India [13] and are higher than the WHO'S standards (0.3mg/l).

The analysis of nitrate concentrations recorded 13.4±10.1 to 29.6±19.5 mg/l, 26.5±19.4 to 34.5±24.2 mg/l in effluents, and–18.7±15.0 to 74.2±70.6 mg/l in wells. Most of the samples were below the 50 mg/l threshold defined by WHO. However, the Tergal well was an exception with a higher concentration of 74.2±70.6 mg/l. Increase in nitrates concentration in drinking water is the most common cause of methaemoglobinaemia, gastric cancer, synopsis, infertility and hypertension. This disease is an infection that is triggered by the lack of oxygen in tissues leading to respiratory difficulties and dizziness [14].

The concentration in chloride in the water samples vary between 31.8±11.8 to 724.2±357.4 mg/l in streams samples; 29.7±25.8 to 579.3±361.1 mg/l in effluents and 17.3 ± 1.6 to 1028.5± 320.9 mg/l in wells. Stream in the Bobongo and Axe lourd area recorded the lowest chloride concentration (56±17.2 mg/l). The wells and the CCC effluents presented considerably moderate to high values of 579.3±361.1 mg/l and 1028.5±320.9 mg/l respectively. In general, all the sites recorded chlorite concentrations above standards (250mg/L) except for samples from the following localities: stream samples from Oyack (34±14.8 mg/l) and Song mahop (31.8±11.8 mg/l), effluents of Chococam (29.7 ± 25.8 mg/l) and the wells of Tergal (17.3 ± 1.6 mg/l) and Oyack (29.4±10.4 mg/l). Such observations have been reported in shallow wells in Kitui town in Kenya [15]. Also, it was reported in Tunisia that salt water is caused by high concentrations of chloride (>250 mg/l). Chlorides concentrations in aquatic environments come from the following sources: natural origin related to marine intrusions or from salty terrain and industrial activities related to agriculture [16].

Significantly high calcium concentrations from this survey were observed in stream samples that measured from 34 mg/l up to 4150 mg/l. The wells and industrial effluents on the other hand measured concentrations below the WHO's standard of 500mg/l. The Axe lourd streams sample in particular recorded the highest values with 4150±322.7mg/l calcium concentration while the Tergal gave the lowest with just 14.5±3.9 mg/l. Very high calcium concentrations can result to calcareous crust formation in water pipes [17]. Additionally, calcium is an alkaline metal that causes hardness in water. These concentrations definitely depend on the geology of the underlying rocks [11]. Some of which included the weathering of calcareous rocks containing calcium and gypsum. However, moderate calcium intake is an essential element in the buildup of skeletal organs and cellular permeability in animal and human systems.

Magnesium is one of the abundant elements in nature and constitutes about 2.1 % of the earth's crust. The dissolution of basaltic rocks, clays, potash and brewery constitute the main sources of magnesium in surface and underground water. However, Mg^{2+} is toxic in the form of chlorides and sulphates. Similar to results from studies in Morocco [12], respectively, the low Mg^{2+} concentration observed within the Mgoua drainage basin varies from 2.7±0.9 to 611.8±324.6 mg/l, 9.5±8.1 to 33.9±22.7 mg/l and 1,4 ± 0.3 to 8.1±6.0 mg/l (Table 1) in streams, effluents and wells with averages lower than WHO's standard of 150mg/L. Excess magnesium could lead to cardio-respiratory disorders [11].

Potassium is an essential nutrient for plant and animal growth. Its concentration in surface waters is generally less than 10 mg/l. Potassium comes essentially from the alteration of feldspars (orthoclase), clays, and micas (muscovite, biotite). Average K^+ concentration in the Mgoua catchment vary from 15.9±5.5 to 306.1±277.9 mg/l, in streams, 20.1±11.1 to 20.2±11.9 mg/l effluents and 7.5±1.2 to 37.1±30.2 mg/l wells (Table 1). Except for the Tergal (7.5±1.2 mg/l) and Oyack (8.4±2.3 mg/l) wells, all analyzed samples gave concentrations higher than WHO's [2] threshold (12 mg/l) for potable water. These values are similar to those recorded in surface water of ouesd Fes in Morocco [18].

In nature, the concentration of sodium in water varies in tens of milligram per litre. Apart from the dissolution of rocks containing halite, sodium can result from the decomposition of mineral salts such as sodium silicates, inputs from marine origin and from the excursion of water from marine aquifers. From table 1, the highest concentrations recorded in effluents ranged from 657.5±464.9 to 33350.7±13792.3 mg/l. Values greater than the recommended WHO standards were observed in the stream sample from Axe lourd (6991.7±3632.5 mg/l). Lower values ≤50 mg/l were recorded in all the wells. Sodium does not present any serious danger to man, but low concentrations can provoke hypertension, renal and vascular problems [19].

Iron is a major constituent of igneous and metamorphic rocks as well as in leachate from landfills reducing sedimentary environments and in metamorphic rocks irons occur in the form of pyrite is associated. It has been reported that high Fe concentrations in water comes from the alteration of olivine-pyroxenes and formation of hematite and goethite minerals. Results for iron concentration in the Mgoua waters vary from 0.7 ±0.4 to 11.2±6.2 mg/l in streams, 9.8±6.9 and 47.4±27.8 mg/l in effluents and 0.0±0.0 to 0.9±0.5 mg/l in wells. The iron content of the Mgoua waters is higher than the 0.3 mg/l threshold set by WHO [2]. These are indications of contamination are exceptions for the Tergal and Oyack wells. There is a slight similarity in the iron concentrations to those reported in Burkina Faso [9]. The abundance of iron could be the cause of primitive hemochromatosis reported in the area.

Manganese occurs in different forms in water: soluble, suspension and as complexes. Airborne manganese is brought in from industrial regions with high metallurgic activities and also from farmlands [4]. The results in Table1 show the average manganese concentrations in the streams samples from Axe lourd (1.4±1.1 mg/l). Effluents from Chococam (2.5±1.4 mg/l) and CCC areas (0.5±1.2 mg/l) are relatively higher than the WHO limit (0.5 mg/l). The manganese concentrations in some of the wells (Tergal, Oyack and Axe lourd) and streams (Bobongo, Oyack and Song mahop) are acceptable according to WHO's standard. Manganese pollution causes dark coloration of water bodies related to the precipitation of hydroxides. Cases of chronic intoxication of water with manganese manifested in the form of Parkinson diseases [20].

Fluorides are found in the soil, air and water as well as in plants and animals. They occur in different forms, fluorine, cryolithe and fluorapatite. Fluoride in water originates either from the weathering of alkaline igneous rocks rich in apatite, topaz and fluorine or discharges from volcanic eruptions. Based on this study, the highest fluoride concentrations were recorded in effluents and wells. Measured values were higher than the 1.5 mg/l recommended by WHO[2]. A similar observation has been reported in surface water samples in Akot City of India [21]. The high fluoride concentrations encountered in effluents was attributed to either the type of industrial raw material used or the interaction of the effluent with the discharged environment. Since the surface waters (streams) have a direct contact with the atmosphere, the low fluoride concentrations recorded gives a direct indication of low atmospheric fluoride content. Practically, humans have been able to used fluoride in toothpaste to combat teeth infection, and the treatment of osteoporosis.

Aluminium is one of the most abundant constituents of the earth's crust and most demanding in the industries. This investigation recorded generally low Al^{3+} concentration as compared to WHO's threshold of 0.2mg/L. These include: 0.1 ± 0.0 to 1.5 ± 1.4 mg/l in streams, 2.1±1.8 to 11.7± 6.4 mg/l in effluents and 0.0 ± 0.0 to 0.1± 0.1 mg/l in wells. The means of concentrations of all streams and well are lower than the limit recommended by WHO, except the mean values from effluents (2.1±1.8 to 11.7±6.4). The presence of aluminium in the study area is indicative of the existence of feldspars, smectites, illites, chlotites and kaolinite. Aluminium is equally present in the form of dust particles precipitated from the air. The aluminium silicates that make up a greater proportion of the dust particles come from the soil. High aluminium concentrations might contribute to psychological disorders, bone diseases and anaemia[20].

Correlation Matrices between the Various Physico-Chemical Parameters of Different Waters of the Mgoua Basin Drain: The correlation co-efficient between the various physicochemical parameters were calculated and presented in the Table 2. These Pearson's correlation matrices (table 2) show no negative correlation between the different parameters analyzed, but several have zero correlation between them. A zero correlation was observed between pH Verses PO_4^{3-}, F^-, K^+, Iron Fe^{3+}, Ca^{2+} and Mg^{2+}; E.C Verses PO_4^{3-}, F^-, SO_4^{2-} and Fe^{3+}; TDS Verses PO_4^{3-}, F^-, SO_4^{2-} and Fe^{3+}; Cl^- verses F^-, Fe^{3+} and Mg^{2+}; NO_3^- verses Na^+, K^+ and Mg^{2+}; PO_4^{3-} verses Na^+, K^+, Ca^{2+}, Mg^{2+}; F^- verses K^+, Ca^{2+} and Mg^{2+}; SO_4^{3-} verses Na^+, K^+ and Fe^{3+}; K^+ verses Na^+, K^+, Fe^{3+} and Mg^{2+}; K^+ versus Fe^{3+} and Fe^{3+} verses Ca^{2+} and Mg^{2+}. The rest of the parameters showed a positive correlation especially between pH verses E.C (0.76), TDS (0.71) and Na^+ (0.78); EC verses TDS (0.99) and Na^+ (0.92); TDS versus Na^+ (0.87); PO_4^{3-} verses F^- (0.82) and Fe^{3+} (0.85); F^- verses Fe^{3+} (0.89); K^+, Ca^{2+} (0.98) and Mg^{2+} (0.98). For the 126 correlations performed, 77 correlated between 0.0 and 0.3, 30 between 0.3 and 0.6, 7 greater than 0.6 while 12 were greater than 0.75. These zero correlations is an indication that the elements do not have a common origin. On the other hand, the high positive correlations indicated a common origin. These parameters are reminiscence of probable Geogenic origin.

Conclusion

This study reveals that the water quality of the Mgoua drainage basin is generally affected with pollutants from anthropogenic activities. The physicochemical properties of the measured parameters clearly reveal that this water catchment is polluted especially the CCC, Axe lourd, Tergal and Chococam localities. Therefore, the discharge of urban wastes and untreated industrial effluents are the principal sources of pollutants in the Mgoua catchment. Thus proper management and treatment is of paramount importance for the inhabitants of this community. It can therefore conclude that the Mgoua Douala water resources are unhealthy for human consumption.

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Table 2: Correlation matrix of Pearson for studied physicochemical parameters, data from whole study

	pH	EC	TDS	Cl^-	NO_3^-	PO_4^{3-}	F^-	SO_4^{2-}	Na^+	K^+	Fe^{3+}	Ca^{2+}	Mn^{2+}	Mg^{2+}
pH	1	0,76	0,71	0,2	0,1	0,0	0,0	0,2	0,78	0,0	0,0	0,0	0,1	0,0
EC		1	0,99	0,6	0,1	0,0	0,0	0,0	0,92	0,1	0,0	0,1	0,3	0,1
TDS			1	0,61	0,1	0,0	0,0	0,0	0,87	0,2	0,0	0,1	0,4	0,2
Cl^-				1	0,1	0,1	0,0	0,2	0,4	0,2	0,0	0,2	0,2	0,0
NO_3^-					1	0,1	0,1	0,1	0,0	0,0	0,1	0,1	0,1	0,0
PO_4^{3-}						1	0,82	0,1	0,0	0,1	0,85	0,0	0,4	0,0
F^-							1	0,1	0,1	0,0	0,89	0,0	0,6	0,0
SO_4^{2-}								1	0,0	0,0	0,0	0,1	0,1	0,1
Na^+									1	0,0	0,0	0,0	0,4	0,0
K^+										1	0,0	0,98	0,2	0,98
Fe^{3+}											1	0,0	0,65	0,0
Ca^{2+}												1	0,2	1,0
Mn^{2+}													1	0,2
Mg^{2+}														1

Significant correlation ($p = 0.05$)

Table1
Variation of different physicochemical parameters of Mgoua catchment water; (CCC= Cameroon Chemical Complex)

S. No.	Parameters	Streams				Effluents		Wells			WHO(2006)
		Oyack	Bobong	Axe lourd	Song mahop	Chococam	CCC	Tergal	Oyack	Axe lourd	
1	pH	6.9±0.2	6.3±0.7	6.7±0.3	6.8±0.2	5.2± 0.9	10.2±1.8	5.7±0.3	6.50±0.33	5.1±0.5	6.5<pH<9.5
2	Conductivity (μS/cm)	355.3±111.2	484.5±204.5	2054.2±1428.6	408.4±166.1	186.9±103.3	2418.4±2202.2	201.2±77.1	375.7±158.5	394.2±266.1	
3	TDS (mg/l)	343.1±115.3	455.7±224.1	1616.5±1113.9	401.2±167.4	160.1± 68.6	2358.5±2189.1	135.1±89.5	254.73±149.3	311.2±306.7	1000
4	T°C	27.3±2.4	26.6±2.6	27.5±2.6	27.1±2.4	27.1±2.4	27.4±2.2	26.6±1.9	26.4±1.7	26.4±1.8	25
5	Turbidity (NTU)	114.3±60.8	174.6±136.8	136.4±95.4	70.6±43.0	441.5±241.2	432.5±333.7	9.6±8.4	31.7±26.5	46.3±39.5	5
6	Colour (Pt.Co)	514.3±351.9	640.4±468.8	498.4±261.9	379.6±303.8	850.4±837.6	1330.0±1119.8	45.3±33.6	185.6±142.4	224.5±184.4	15
7	Dissolved Oxygene (mg/l)	3.4±1.8	2.1±1.4	2.3±1.6	2.3±1.7	1.5± 0.9	4.2± 2.4	5.7±1.2	4.4±1.6	4.7±2.0	>6
8	SO_4^{2-} (mg/l)	10.5±6.0	6.1±5.0	88.9±40.8	9.4±6.1	173.6±54.5	15.6±10.1	4.5±4.3	15.3±8.9	253.8±81.4	150
9	PO_4^{3-} (mg/l)	<0.001	4.1±3.0	<0.001	4.1±3.0	17.6±11.2	4.1±2.98	0.29±0.0	0.7±0.7	0.84±0.6	0.3
10	NO_3^- (mg/l)	28.4±12.39	13.4±10.1	21.5±18.6	29.6±19.5	26.5±19.4	34.5±24.2	74.2±70.6	18.7±15.0	52.7±21.2	50
11	Cl^- (mg/l)	34.0±14.8	56.0±17.2	724.2±357.4	31.8±11.8	29.7±25.8	579.3±361.1	17.3±1.6	29.4±10.4	1028.5±320.9	250
12	Ca^+ (mg/l)	34.9±10.3	48.0±70.0	415.0±322.7	114.4±82.6	75.5±69.4	22.8±18.8	14.5±3.9	116.0±72.6	45.4±30.5	500
13	Mg^{2+} (mg/l)	2.7±0.9	5.0±6.0	611.8±324.6	8.5±6.7	33.9±22.7	9.5±8.1	1.4±0.3	8.1±6.0	4.0±2.1	150
14	K^+ (mg/l)	15.9±5.5	25.2±19.3	306.1±277.9	44.5±38.7	20.2±11.9	20.1±11.1	7.5±1.2	37.1±30.2	8.4±2.3	12
15	Na^+ (mg/l)	31.2±16.2	161.6±146.3	6991.7±3632.5	83.0±73.2	657.5±464.9	33350.7±13792.3	16.8±1.8	76.9±49.3	46.2±10.9	200
16	Fe^{3+} (mg/l)	0.7±0.4	1.8±2.1	11.2±6.2	3.1±1.9	47.4±27.8	9.8±6.9	0.0±0.0	0.2±0.2	0.9±0.5	0.3
17	Mn^{2+} (mg/l)	0.1±0.1	0.3±0.2	1.4±1.1	0.5±0.4	2.5±1.4	1.2±0.5	0.1±0.0	0.1±0.1	0.1±0.1	0.5
18	F^- (mg/l)	0.3±0.2	0.7±0.2	0.8±0.0	0.1±0.1	59.7±34.3	23.7±16.6	0.1±0.0	2.1±0.6	45.0±3.6	1.5
19	Al^{3+} (mg/l)	0.1±0.1	0.5±0.3	1.5±1.4	0.1±0.0	11.7±6.4	2.1±1.8	0.2±0.2	0.1±0.1	0.0±0.0	0.2

References

1 Hertig J.A., Fallot J.M., Etude d'impact sur l'environnement, Polytechnique et universitaires romandes, Presses (ed.) 2nd. **23**, 544 **(2006)**

2. World Health Organization Guidelines for Drinking-Water Quality. First Addedum to (ed.) 3rd Press, Geneva, **515 (2006)**

3. Guévart E., Noeske J., Essomba J.M., Edjenguele M., Bita A., Mouangue A., Manga B., Factors contributing to endemic choera in Douala, Cameroon. *Med. Trop*., **66 (3)**, 283-291 **(2006)**

4. Rodier J., L'analyse de l'eau, eaux naturelles, eaux résiduaires, eau de mer, (ed.) 7ème, Dunod, Paris, 1350 **(1996)**

5. Imoisi O.B., Ayesanmi A.F., Uwumarongie-Ilori E.G., Assessment of groundwater quality in a typical urban settlement of resident close to three dumpsites in South-south, Nigeria, *Journal of Environmental Science and Water Resources,* **1(1)**, 12 – 17 **(2012)**

6. Souiki L., Rouabhi R., Berrebbah H., Djebar M.R., Survey of the physico-chimical quality of the wastewater of Biskra city rejected in Chabat Roba, Messdour and Wadi Z'ommor (Algérie), *African Journal of Environmental Science and Technology*, **2(8)**, 231-238 **(2008)**

7. Nwankwoala H.O. and Nwagbogwu **C.N**., Characteristics and quality assessment of groundwater in parts of Akure, South-Western Nigeria, *Journal of Environmental Science and Water Resources*, **1(4)**, 67–73 **(2012)**

8. Islam M.F. and Johnston R.B., Household Pasteurization of Drinking-water: the Chulli water-treatment System. Journal of Health, Population and Nutrition; 24(3): 356-362, International Centre for Diarrhoeal Disease Research, Bangladesh.www.icddrb.org/images/jhpn243_Household-Pasteurization.pdf **(2006)**

9. Some K., Dembélé Y., Somé L. & Millogo Rasolodimby J., Agricultural water pollution in the basin Nakambé: If tanks Loumbila and Mogtédo, Ouagadougou /Burkina Faso: 2IE, International Institute of Engineering of Water and Environment, 9 **(2008)**

10. El Addouli J., Chahlaoui A., Berrahou A., Chafi A., Ennabili A., Karrouch L., Influence des eaux usées, utilisées en irrigation, sur la qualité des eaux de l'Oeud Bouishak- Région de Meknes (Centre –Sud du Maroc). *Rev. Microbiol. Ind. San. Et Environn*, **3(1),** 56-75 **(2009)**

11. Queneau P. and Hubert J., The role of mineral water in the diet. National Academy of Medicine Report, French Society of Medical Hydrology and Climatology, France, 175-220 **(2009)**

12. Bricha S., Ounine K., Oulkheir S., El Haloui N. and Attarassi B., Study of the physicochemical and bacteriological quality of the M'nasra groundwater (Morocco), *Africa Science* **3(3),** 391-404 **(2007)**

13. Patra A.P., Patra J.K., Mahapatra N.K., Das S. and Swain G.C., Seasonal Variation in Physico-chemical Parameters of Chilika Lakeafter Opening of New Mouth near Gabakunda, Orissa, India, *World Journal of Fish and Marine Sciences* **2(2),** 109-117 **(2010)**

14. Ward M.H., DeKok T.M. and Levallois P., Workgroup report: Drinking-water nitrate and health Recent findings and research needs, *Environ Health Perspect*, **113**, 1607-14 **(2005)**

15. Abila R., Muthangya M., Mutuku E., Mutati K., Munguti M. and Musyoka C.M., Physico-chemical and bacteriological quality assessment of shallow wells in Kitui town, Kenya, *Journal of Environmental Science and Water Resources,* **1(2),** 27 – 33, **(2012)**

16. Trabelsi R., Smida Z.M.H. and Ben Dhia H., Salinization of coastal aquifers: the case of water north of the Sahel of Sfax, Tunisia, *Geosci*., **337**, 515-524 **(2005)**

17. Vierling E., Food and drinks: sector and product. (ed.) 3rd. Doin editor. Regional Centre for Educational Aquitaine documentation, France, 230 **(2008)**

18. Derwich E., Beziane Z., Benaabidate I. and Belghyti D., Evaluation of the quality of surface water ouesd Fes and in Fes and Sébou used for **maraîcher** agriculture in Morocco, *LARHYSS* Journal, *ISSN 1112-3680*, **7**, 59-77 **(2008)**

19. Kourradi R., Evaluation of the degree of anthropogenic pollution of the Bouregreg estuary and impact on the biology and dynamics of Scrobicularia plana (Linnaeus, 1758) and Solen marginatus (Linnaeus, 1767), Ph.D thesis, Mohammed University V-Agdal, 313 **(2005)**

20. Baque D., Anthropogenic interference with the drainage network of the Garonne basin, for metals and nitrates, PhD Thesis, University of Toulouse III - Paul Sabatier, 482 **(2006)**

21. Murheka Gopalkrushna H., Determination of physicochemical parameters of surface water samples in Akot City of India, *Int. J. Res. Chem. Environ.* **1(2),** 183-187 **(2011).**