Research Article

Physico-chemical and bacteriological contamination of water from some supply wells in the Mandjou and Kano neighbourhoods, Djadombè sub-watershed, Bertoua, East Cameroon

Philippe SAMBA ASSOMO [1©]; Sylvain KOUAYEP LAWOU [1]; Lucas BOUBA [2]; Daniel Florent AKONO [3]; Cynthia AZAPMOH [1]; Véronique KAMGANG KABEYENE BEYALA [4]

[1] Higher Teacher Training College Bertoua, PO.Box: 6 52 Bertoua, University of Bertoua, Cameroon

[2] Faculty of Science, University of Maroua, PO. Box: 814 Maroua, Cameroon

[3] Faculty of Science, University of Yaounde I, PO. Box: 812 Yaounde, Cameroon

[4] Faculty of Science, University of Dschang, PO. Box: 110 Dschang, Cameroon

© Corresponding author, Email: sambafilipe@yahoo.fr Phone: +237 677 46 60 34

Abstract

The present research focused on the determination of the physical parameters and the biological contamination of water from four wells (MAP1, MAP2 KAN3, KAN4) at the Djadombè sub-watershed irrigating Mandjou and Kano neighbourhoods in the city of Bertoua. The Physical parameters were assessed at the Institute of Geological and Mining Research (IGMR) of Yaoundé, while the Centre Pasteur (CP) of Yaoundé analyzed the bacteriologic status of various water samples. The results showed that water is acidic. Low alkalinity (HCO-3) and low mineralization $35 \leq EC \leq 197$ were recorded. The values of TDS and TSS did not exceeded WHO (2011) standards (1000 mg/L and 25-40 mg/L). Water is fresh without any salinity. The bacteriological examination revealed a strong bacterial contamination of the water. The microbial contamination concerns both fecal bacteria (E.coli, Intestinal Enterococci) and sufficiently pathogenic germs (vibrio cholerea, Salmonella ssp). The FS/FC > 2 ratios led to the conclusion that the biological contaminations are human origin.

Keywords: biological contamination, wells, human origin, waters.

Résumé

La présente recherche a porté sur la détermination des paramètres physiques et de la contamination biologique de l'eau de quatre puits (MAP1, MAP2, KAN3, KAN4) du sous-bassin versant de Djadombè irriguant les quartiers de Mandjou et de Kano dans la ville de Bertoua. Les paramètres physiques ont été évalués à l'Institut de recherche géologique et minière (IGMR) de Yaoundé, tandis que le Centre Pasteur (CP) de Yaoundé a effectué le statut bactérien de divers échantillons d'eau. Les résultats ont montré que l'eau est acide. Une faible alcalinité (HCO-3) et une faible minéralisation $35 \leq EC \leq 197$ ont été enregistrées. Les valeurs de TDS et TSS n'ont pas dépassé les normes de l'OMS (2011) dont 1000 mg/L et 25-40 mg/L respectivement. L'eau est douce sans aucune salinité. L'examen bactériologique a révélé une forte contamination bactérienne de l'eau. La contamination microbienne concerne à la fois des bactéries fécales (E.coli, entérocoques intestinaux) et des germes suffisamment pathogènes (vibrio cholerea, Salmonella ssp). Les rapports FS/FC > 2 ont permis de conclure que les contaminations biologiques sont d'origine humaine.

Mots clés : contamination biologique, puits, origine humaine, eaux.

Received: 02/01/2024

Accepted:10/03/2024

DOI: https://dx.doi.org/10.4314/jcas.v20i.4

1.0 INTRODUCTION

Water is essential to life, but many people do not have access to clean and safe drinking water and many die of waterborne diseases. According to the WHO(2011), the mortality of water diseases exceeds 5 million people per year. From these, more than 50% are microbial intestinal infections, with cholera standing out in the first place (João, 2010). Developing countries such as Cameroon are experiencing rapid demographic change with the corollary of rapid uncontrolled urbanization. Under these conditions, the availability of quality water resources is becoming a real challenge for the public authorities who are unable to satisfy the population. Less than 40% of the population in Cameroon has access to clean drinking water (Tanawa et al., 2002, Kuitcha et al., 2008, Ndjama et al., 2008). Therefore, they are forced to turn to other sources of water supply such as domestic wells, private boreholes, or natural water points. Unfortunately, water from dubious sources can have a very high level of bacterial contamination (Katte et al., 2003; Tita et al. , 2009; Kuitcha et al., 2010). In the city of Bertoua, the population face this sad reality, which manifests itself in a very limited drinking water supply network coupled with untimely cuts. The Kano and Mandjou neighbourhoods along the Bertoua-Garoua Boulai national highway are characterized by a high human density and a significant presence of supply wells that serve as water points for the resident population and even for those in transit. Water is often consumed directly without further treatment. The purpose of this paper was to assess the biological contamination of water samples from four wells located on either side of the Bertoua- Garoua Boulai road in the Djadombè sub-watershed, covering the Kano and Mandjou.

1.1 Study area

The study area is in East Region from Lom and Djerem Division in the District of Bertoua 2. The area extends between 4°34'30" North latitude and 13°41' 04"East longitude and covers an area of 100 Km^2. It is influenced by both tropical and equatorial climates due to the presence of the Congo Forest. The district of Bertoua 2 has four seasons including two rainy seasons of unequal importance (March to June and September to October) and two dry seasons of unequal duration (July to August and September to October). Rainfall is abundant and humidity is constant (Gazel and Gérard, 1954). The peak of rainfall is usually in October when the rainfall reaches 265mm, the average annual rainfall is 1640mm, and the average temperature is 32°C. The soil cover of the study area is made up of two types ferritic and hydromorphic. Ferritic soils are the most abundant, they are developed on plutono-metamorphic basement (Fig. 1). The soils are characterized by a thick profile formed by three levels from weathering process (Nkoumbou et al. , 2014 ; Ngnotué et al., 2000). In terms of hydrology, the study area belongs to Kadei River basin, 552 km long covering a surface area of 41,000 km^2 (Rakotondrabe et al., 2018).

2.0 METHODS

The work was carried out in two phases including field and laboratory works.

2.1 Field work

The fieldwork involved the identification, description, and collection of water samples (Fig.2). The sampling campaign was carried out during the month of June 2022, which marks the transition from the short to the long rainy seasons. The wells are hand-dug hydraulic structures with piezometric levels ranging from 5m (KAP4) to 9m (MAP1) and are generally protected (Fig.3). Samples were collected using a bucket and string that had been washed three times with clean water. The water samples were collected in washed and labelled polyethylene bottles. The water samples for bacteriological analysis were carried into labelled sample bottles provided by the CP of Yaoundé. All vials were then packed

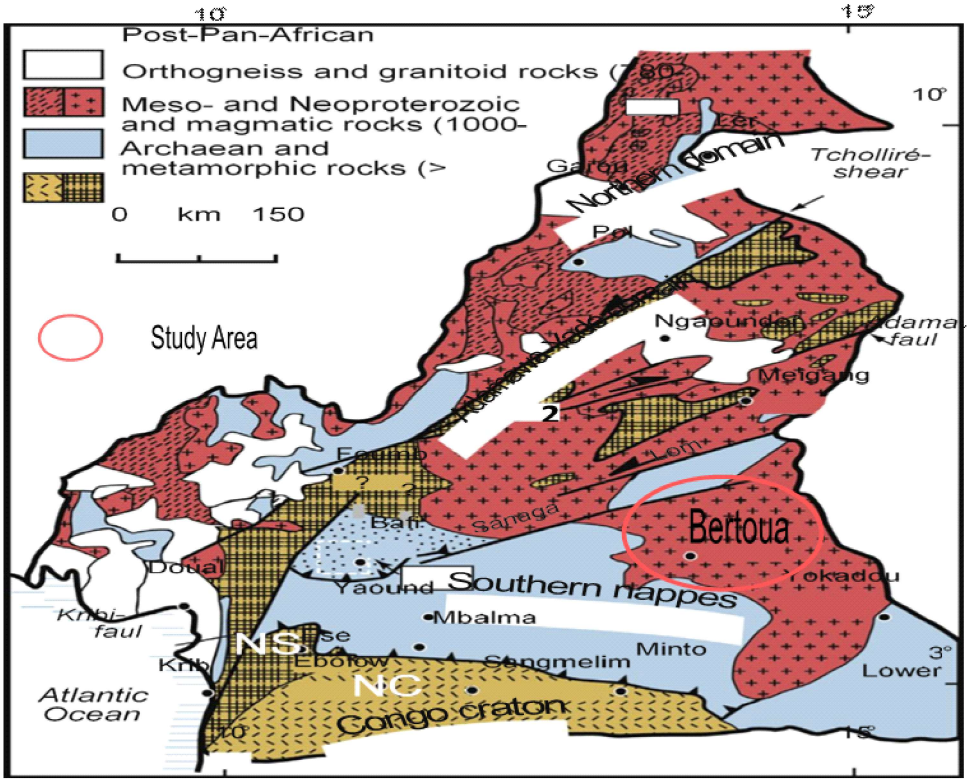

Figure 1 : Geology of the study area

in a cooler refrigerated at 2°C (Fig.4). The sample codes correspond to different names assigned to the sampling wells (MAP1, MAP2, KAPA3 and KAPA4). A total of 12 water samples were collected with a ratio of 3 in each well.

2.2 Laboratory work

The laboratory work aimed to determine the physico-chemical parameters (Hydrogen potential, pH ; Electrical Conductivity, EC ; alkalinity, salinity, Total Dissolved Solid,TDS and Total Suspended Solid, TSS). The physical parameters were assessed by the IGMR of Cameroon. The results of physico-chemical parameters were interpreted based on WHO (2011) standards. The bacteriological analyses were carried out by the CP of Yaoundé. The French standards (Tab.1) were used to interpret all the results.

Table 1: Summary of the microorganisms tested and the French Standards applied

Microorganisms tested	French Standards used
Revivable microoganisms at 36°C	NF EN ISO 622, July 1999
Revivable microoganisms at 22°C	NF EN ISO 622, July 1999
Coliforms	ISO 9308-1, Septembre 2004
EscherichiaColi	ISO 9308-1, Septembre 2004
Intestinal Enterococci	NF EN ISO 7899-2, July 1993
Spore of suphite reducing microorganisms	NF EN 26461-2, July 1993
Pseudomonas Aeruginosa	NF EN 16266, August 2008
Salmonella ssp	NF EN ISO 19250, July 2013
Vibrio Cholerae	CNR, Vibrio institute of Paris , France

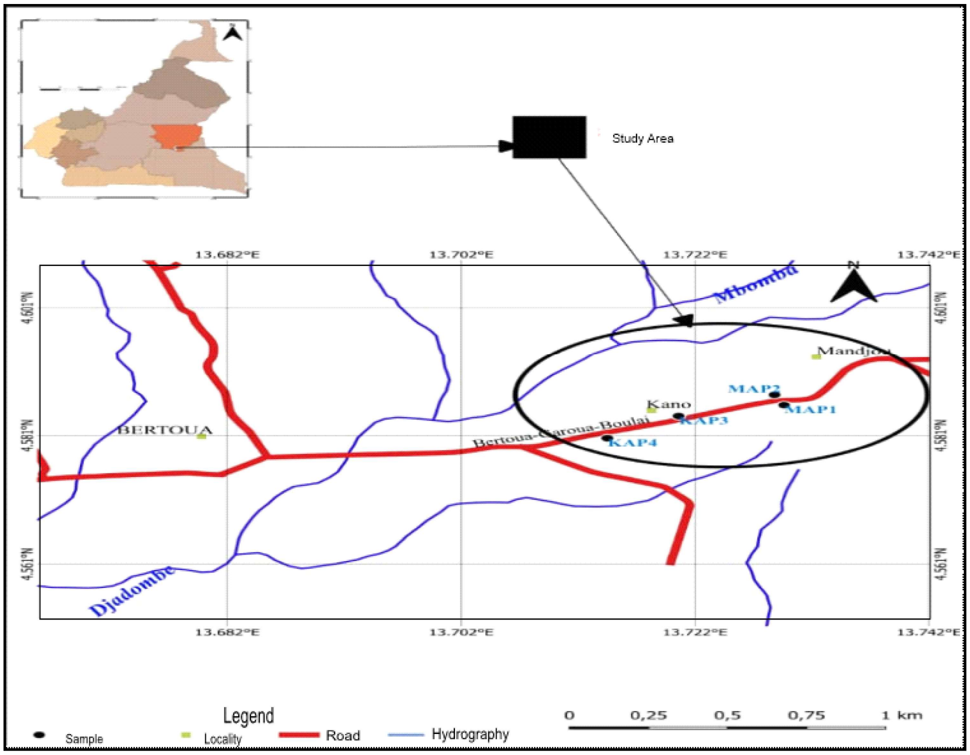

Figure 2 : Sampling map

KAN3

MAP1

KAN4

MAP2

Figures 3: Overview of supply wells

A. biological parameters

B. physico-chemical parameters

Figure 4: Sample conditioning

3.0 RESULTS

3.1 Physico-chemical parameters

The table 2 presents the values of the physico-chemical parameters (pH, EC, Alkalinity, Salinity, TDS, and TSS) in the water samples from the different wells.

Table 2: Values of physical parameters regarding WHO (2011) standards

Samples	pH	EC (µS/cm)	Alkalinity HCO_3^- (mg/L)	Salinity (mg/L)	TDS (mg/L)	TSS (mg/L)
MAP1	4.818	35.3	12.462	0	24.43	1.8
MAP2	6.192	197.1	134.41	0	136.45	2.05
KAP3	4.991	123.8	17.4385	0	85.71	1.95
KAP4	5.395	89.5	38.8693	0	61.96	2.15
Min	4.818	89.5	12.4620	0	24.43	1.8
Max	6.192	197.1	134.41	0	136.45	2.15
Avg	5.349	111.4	49.79	0	77.13	1.98
WHO	6.5-8.5	1500	125-130	NA	1000	25-40

3.1.1 pH

The pH value of the water varies from 4.818 (MAP1) to 6.192 (MAP) with an average of 5.349. This result shows that the water collected is acidic as the values obtained are not in line with standards of permissible pH of water at between 6.5 and 8.5.

3.1.2 Electrical Conductivity

The electrical conductivity of the water ranged from 35.3 (MAP1) to 197.1 (MAP2) with an average of 111.4. This parameter is closely related to the mineralization of the water. All the water samples examined are weakly mineralized, as the values obtained did not exceed the WHO(2011) target value (1500 µS/cm).

3.1.3 Alkalinity

The alkalinity ranges from 12.4620 (MAP1) to 134.41 (MAP2) with an average of 49.79.

This parameter refers to the bicarbonate anions content. The values obtained in the water samples (MAP1, KAP3, KAP4) are low in comparison to WHO(2011) standards except the KAP2 in which the value obtained (134.41mg/L) is in accordance with WHO(2011) standards. .

3.1.4 Salinity

The water samples analyzed were not salty (value equal zero). This can be explained by the fact that the sampling area does not belong the marine environment.

3.1.5 TDS

The TDS of the water samples varied from 24.43 (MAP1) to 136.45 (MAP2) with an average of 77.137. These values agree with the WHO standard (1000mg/L).

3.1.6 TSS

Suspended solids vary from 1.8 (MAP1) to 2.15 (MAP2) with an average of 1.987. This parameter expresses whether the water is turbid or not. As the values obtained are below the range prescribed by the WHO standards (25-40 mg/L), it can be deduced that the water examined are less turbid than those from watercourses.

3.2 Bacteriological parameters

Nine varieties of microorganisms were detected (Revivable microoganisms at 36°C, Revivable microorganisms at 22°C, Coliforms, Escherichia Coli, Intestinal Enterococci, Spore of sulphite reducing microorganisms, Pseudomonas Aeruginosa, Salmonella ssp, Vibrio Cholerae) in water samples collected and examined at the CP in Cameroon. The interpretations were done based on the contextualized French standard JORF N°31 of 09/06 February 2007. The results obtained concern the detection (Tab.3), scanning (Tab. 4) and evolution of the microorganisms (Fig. 4). The results obtained reveal the presence of all the microorganisms sought in the water samples analyzed, with the exception of salmonella ssp, which were not detected in the MAP1, KAP3 and KAP4 wells, and vibrio cholerae, which is totally absent in the water samples (MAP1, MAP2, KAP3 and KAP4). With regard to the number of microorganisms identified in the water samples, it is above the French standards (Tab. 4) for each bacterium. These results show that the water is unfit for human consumption.

Table 3: Detection of the presence of microorganisms in the water samples

Wells	*Revivable microoganisms at 36°C*	*Revivable microoganisms at 22°C*	*Coliforms*	*EscherichiaColi*	*Intestinal Enterococci*	*Spore of suphite reducing microorganisms*	*Pseudomonas Aeruginosa*	*Salmonella ssp*	*Vibrio Cholerae*
MAP1	D	D	D	D	D	D	D	ND	ND
MAP2	D	D	D	D	D	D	D	ND	ND
KAP3	D	D	D	D	D	D	D	D	ND
KAP4	D	D	D	D	D	D	D	ND	ND

Note : D : Detected ; ND : Not Detected

Table 4: Enumeration of microorganisms in the waters samp

Wells	*Revivable microoganisms at 36°C (CFU)*	*Revivable microoganisms at 22°C(CFU)*	*Coliforms (CFU)*	*Escherichia Coli (CFU)*	*Intestinal Enterococci (CFU)*	*Spore of sulphite reducing microorganisms(CFU)*	*Pseudomonas Aeruginosa (CFU)*	*Salmonella ssp (CFU)*	*Vibrio Cholerae (CFU)*
MAP1	> 3000/ml	> 3000/ml	> 800/100 ml	> 8000/100 ml	N20/100ml	<10/100ml	N230/50ml	absence/1000ml	Absence /1000ml
MAP2	> 3000/ml	> 3000/ml	> 800/100 ml	> 8000/100 ml	N180/100 ml	10<N< 100/100ml	N150/50ml	absence/1000ml	Absence /1000ml
KAP3	> 3000/ml	> 3000/ml	> 800/100 ml	1 < N < 10/ 100ml	N20/100ml	N40/100ml	N180/50ml	presence /1000ml	Absence /1000ml
KAP4	> 3000/ml	> 3000/ml	> 800/100 ml	> 800/100ml	N360/100 ml	> 800/100ml	> 800/50ml	absence /1000ml	Absence /1000ml
French Guidelines JORF N° 31of 6th February 2007	**<20/ml**	**<100/ml**	**0/100ml**	**0/100ml**	**0/100ml**	**0/100ml**	**0/50ml**	**absence /1000ml**	**absence /1000ml**

Figure 5: Evolution of physical parameters in the wells

4.0 DISCUSSION

4.1 Physico-chemical parameters

The evolution of the physical parameters is recorded in Figure 5 above. The pH values show that the water is acidic. This acidity could be linked to the geological environment which is made of acidic plutonic and metamorphic rocks. The results obtained are like those reported by several authors who have examined surface waters in forest areas (Braun et al., 1998; Viers et al., 2000; Braun et al., 2012). Therefore, the alkalinity of the water samples is low for all wells except MAP2 (134.4mg/L) this could be linked to the recent input of pollutants that would neutralize the acidity. This is also observed in mining localities such as Bétaré-Oya (East Cameroon) where pH is generally basic. This basicity is due to oil spills or leakages from excavation machinery and transportation vehicles (Ahialy et al., 2000; Ibrahima et al., 2015). The EC shows that the water has low mineralization (Detay, 1993). These results reflect those obtained for water flowing in forest areas over plutonic and metamorphic rocks (Viers et al., 2000; Boeglin et al. , 2003, Braun et al., 2005). However, sample MAP1 shows a very high value of EC (197.1 µS/cm) which could be due to its great depth reaching the geological bedrock (Li et al., 2014; Mfonka et al., 2014). TSS and TDS show very low values because of the wells protection in stonework that avoids collection of various particles from surrounding area. Thus, in watercourses, TSS and TDS values are quite high, especially in forest areas (Sigha, 1994; Olivry, 1997, Braun et al., 2005, Ndam Ngoupayou et al. ,2016). The increase of TDS and TSS in mining areas may be linked to deforestation, dredging of river-beds, dumping of solid and liquid waste resulting from gold washing, high soil leaching and exposure during the raining season (Batancourt et al., 2005). The zero value of salinity is related to the non-marine environment to which belongs the study area.

4.2 Biological parameters

The content of digestible microorganisms in water sample (Revivable microorganisms at 36°C, Revivable microorganisms at 22°C, Coliforms, Escherichia Coli, Intestinal Enterococci, Spore of sulphite reducing microorganisms, Pseudomonas Aeruginosa) shows an overflow for each type of microorganism (Tab.4). Bacteriological examination of water sample which is usually carried out is to estimate the level of faecal pollution and the presence of other pathogenic organisms that could be hazardous to man and animals (Raji et al. , 2015). Bacteria in the intestines of vertebrates have majorly been used as indicators of faecal pollution. Total coliforms, faecal coliforms, and faecal streptococci have all been used as pollution indicators (Isobe et al. , 2002; Park et al. , 2006). The results obtained are like those of many authors who studied the biological contamination of water in Cameroon (Nola et al. , 2006; Djeukom et al. , 2003; Tita et al. , 2009; Kuicha et al. , 2010). Since the routine basic microbiological analysis of drinking water regards the assaying the presence of Escherichia coli and the quantification of enterococci (João, 2010), the FC/FS ratio is used to examine the origin of faecal coliforms and streptococci (Borego and Romeo, 1982). The result of FC/FS ratio (Tab.5) indicates that the contamination is caused by human origin.

Table 5: Origin of bacterial contamination of wells (Borego and Romeo, 1982)

Wells	FC *Escherichia Coli* (CFU/100ml)	FS *Intestinal Enterococci* (CFU/100ml)	FC/FS	Origin of contamination
MAP1	800	20	40	human
MAP2	800	180	4.44	human
KAP3	800	20	40	human
KAP4	800	360	2.22	Mixed with human prevalence

Note : FC/FS < 0.7 : Mainly or entirely animal ; 0.7 < FC/FS < 1 : mixed with animals prevalence ; 1 < FC/FS < 2 : Dubious origin ; 2 < FC/FS < 4 : mixed with human prevalence ; FC/FS > 4 : exclusively human.

5.0 CONCLUSIONS

The physical parameters (pH, EC, TDS, TSS, alkalinity, salinity) indicated that the water samples were acidic trend but not salty. They are weakly mineralized and less turbid. However, the water was highly contaminated with bacteria. The omnipresence of bacteria indicates faecal contamination (E.coli, Intestinal Enterococci) as well as other pathogenic germs (vibrio cholerea, Salmonella ssp). This shows a very high risk of the occurrence of water-borne diseases in these neighborhoods where the populations use the water drawn from the wells for consumption and domestic purposes. The level of bacterial contamination is high, and human has been identified as the main cause for this contamination. A solution to this situation would be for local authorities to organize the population into hygiene committees who are responsible for the protection and maintenance of the wells and their surroundings.

DECLARATIONS

CONFLICTS OF INTEREST

The authors declare no competing interests

FUNDING

No funding was provided for this study.

ACKNOWLEDGEMENT

The authors express their deep gratitude to the technicians of the IITA laboratory in Yaoundé, Cameroon (International Institute of Tropical Agriculture) for carrying out the chemical analyses of the samples.

REFERENCES

Ahialey, E.K., Serfoh-Armah, Y., Kortatsi B K. (2000) : Hydrochemical analisys of groundwaterin the lower Pra basin of Ghana.J.Water Ressou.Prot.2 :864-871. http://dx.doi.org/10.4236/jwarp.2010.210103

Betancourt, O., Narvaez, A., Roulet, M. (2005) : Southern Ecuador: a study of environmental impacts and human exposures. EcoHealth 2:323–332. http://dx.doi.org/10.1007/ s10393-005-8462-4.

Boeglin, J.L., Ndam, J.R., Braun, J.J. (2003) : Composition of the different reservoir waters in a tropical humid area: example of the Nsimi catchment (Southern Cameroon). J. Afr. Earth Sci. 37:103–110. http://dx.doi.org/10.1016/S08995362(03)000411

Borrego, A.F., Romero, P.(1982) : Study of the microbiological pollution of a Malaga littoral area II. Relationship between faecal coliforms and faecal streptococci, VI ème journée Etude, Pollutions Cannes 2(4): 561-569.

Braun, J.J., Dupré, B., Viers, J., Ndam Ngoupayou, J.R., Bedimo Bedimo, J.P., Sigha Nkamdjou, L., Freydier, R., Robain, H., Nyeck, B., Bodin, J., Oliva, P., Boeglin, J.L., Stemmler, S., Bertheli, J. (2002) : Biogeohydrodynamic in the forested humid tropical environment : the case study of the Nsimi small experimental watershed (south Cameroon). Bull. Soc. géol. France 173 (4), 347–357.

Braun, J.J., Marechal, J.C., Riotte, J., Boeglin, J.L., Bedimo Bedimo, J.P. (2012) : Elemental weathering fluxes and saprolite production rate in a Central African lateritic terrain (Nsimi, South Cameroon). Geochim. Cosmochim. Acta 99, 243–270.

Braun, J.J., Ndam Ngoupayou, J.R., Viers, J., Dupre, B., Bedimo Bedimo, J.P., Boeglin, J.L., Robain, H., Nyeck, B., Freydier, R., Sigha Nkamdjou, L., Rouiller, J., Muller, J.P. (2005) :. Present weathering rates in a humid tropical watershed: Nsimi site (South Cameroon). Geochim. Cosmochim. Acta 69, 357–387.

Detay, M. (1993) :. Le forage d'eau, réalisation, entretien, réhabilitation. Masson, Paris (375 pp.)

Djeukom, E., Njiné, T., Nola, M., Sikali, M.V.,Jugnia, L.B. (2003) : Microbiological water quality of the Mfoundi at Yaoundé, Cameroon as inferred from indicator bacteria of faecal contamination. Environ Monitor .assess 122 : 171-183.

Gazel, J et Gérard G. (1954) : Carte géologique de reconnaissance du Cameroun au 1/500000, feuille de Batouri-Est avec notice explicative. Mémoire Direction des Mines et de la Géologie, Yaoundé, Cameroun, 43 p.

Ibrahima, M., Moctar, D., Maguette, D.N., Diakher, M.H., Malick, N.P., Serigne, F. (2015) : Evaluation of water resources quality in Sabodala gold mining region and its surrounding area (Senegal). J. Water Resour. Prot. 7:247–263. http://dx.doi.org/10.4236/jwarp.2015.73020

Isobe, K. O., Tarao. M., Zakaria, M. P., Chiem, N. H., Minh, L. Y., and Takada, H. (2000) : Quantitative application of fecal sterols using gas chromatography-mass spectrometry to investigate fecal pollution in tropical waters: Western Malaysia and Mekong Delta, Vietnam," Environ Sci. Technol., vol. 36, pp. 4497–4507.

João,P. S., Cabral. (2010) :. Water Microbiology. Bacterial Pathogens and Water. Int. J. Environ. Res. Public Health. 7, 3657-3703; doi:10.3390/ijerph7103657

Katte, V.Y., Fonteh, M.F.,Guemuh, G.N. (2003) : Domestic water quality in urban center in Cameroon :a case study of Dschang in the West province. Afr .Water.J. pp. 43-54.

Kuitcha, D., Kamgang, K.B.V., Sigha, N.L., Lienou, G., Ekodeck, G.E. (2010) : Water supply, sanitation and health risks in Yaoundé, Cameroon. Afr. J. Envir. Sc. Technol. 2(11): 379-386.

Li, J., Li, F., Liu, Q., Zhang, Y. (2014) : Trace metal in surface water and groundwater and its transfer in a Yellow River alluvial fan: evidence from isotopes and hydrochemistry. Sci. Total Environ. 472:979–988. http://dx.doi.org/10.1016/j.scitotenv.2013.11.120.

Mfonka, Z., Ndam Ngoupayou, J.R., Ndjigui, P.D., Zammouri, M., Kpoumie, A., Rasolomanana, E. (2014) : Hydrochimie et potabilité des eaux du bassin versant du Nchi dans le plateau Bamoun (Ouest Cameroun). Int. J. Biol. Chem. Sci. 9: 2200–2218. http://dx.doi.org/10.4314/ijbcs.v9i4.39.

Ndam Ngoupayou, J.R., Dzana, J.G., Kpoumie, A., Tanwi Ghogomu, R., Fouepe Takounjou, A., Braun, J.J., Ekodeck, G.E. (2016) : Present-day sediment dynamics of the Sanaga catchment (Cameroon): from the total suspended sediment (TSS) to erosion balance. Hydrol. Sci. J. 61 (6):1080–1093. http://dx.doi.org/10.1080/02626667.2014.968572.

Ndjama, J., Kamgang, K.B.V., Sigha, N.L., Ekodeck, G.E., Tita, M.A. (2008) : Water supply, sanitation and health risks in Douala, Cameroon, Afr. J. Environ. Sc. Technol. 2(12): 422-429.

Ngnotué, T., Nzenti, J P., Barbey, P and Tchoua, F M. (2010): The Ntui-Betamba high-grade gneisses: a Northward extension of the Pan-African Yaoundé gneisses in Cameroon. Journal of African Earth Sciences, 31, 369-381.

Nkoumbou, C., Barbey, P., Yonta-Ngoune, C., Paquette, J.L., Villiéras, D.F. (2014) : Pre-collisional geodynamic context of the southern margin of the Pan-African fold belt of Cameroon. Journal of African Earth Sciences, (99) 245-260.

Nola, M., Njiné, T., Kemka, N., Zébazé, T.S.H., Servais, P., Messouli, M., Boutin, CL., Monkiedje, A., Foto Menboban, A. (2006) : Transfert des bactéries fécales vers une nappe phréatique à travers une colonne de sol en région équatoriale : influence de la charge en eau appliqué en surface », Rev. Sci. Eau. 19(2): 101-112.

Olivry, J.C. (1977) : Transports solides en suspension au Cameroun. In: erosion and solid matter transport in inland water, Paris. IAHS Publ. 122, 134–141

Olivry, J.C. (1997) : Fleuve et rivières du Cameroun. Collection Monographie Hydrologie, MESRE/ORSTOM. 574 Afr. J. Microbiol. Res. Santoir C,

Park, J. E., Ahn,T. S., Lee, H. J and Lee ,Y. O. (2006) : Comparison of total and faecal coliforms as faecal indicator in eutrophicated surface water," Water Sci. Technol., vol. 54, pp. 185 – 190.

Raji, M.I., Ibrahim, Y.K., Tytler, B.A., Ehinmidu, J.O. (2015) : Faecal Coliforms (Fc) And Faecal Streptococci (Fs) Ratio As Tool For Assessment Of Water Contamination: A Case Study Of River Sokoto, Northwestern Nigeria. The Asia Journal of Applied Microbiology ISSN(e): 2313-8157/ ISSN(p): 2409-2177. DOI: 10.18488/journal.33/ 2015.2.3/33.3.27.34

Rakotondrabe, F., Ndam Ngoupayou, J. R., Mfonka, Z., Rasolomanna Harilala, E., Nyagona Abolo, A. J., Ako Ako, A. (2018): Water quality assessment in the Bétaré Oya gold mining area (East Cameroon): Multivariate statistical Analisys approach. Elsevier, Science of the Total Environment, 610-611(2018) 831-844.

Sigha, L. (1994) :. In: ORSTOM, TDM (Ed.), Fonctionnement hydrochimique d'un écosystème forestier de l'Afrique centrale: la Ngoko à Mouloundou (Sud-Est du Cameroun). 111 (378 pp.)

Tanawa, E., Djeuda, T.H.B., Ngnikam, E., Temgoua, E., Siakeu J. (2002) : Habitat and suburban areas in African cities. Bulding Environ. 37: 269-275.

Tita, M.A., Kamgang, K.B.V., Tsala, G.N. (2009) : Microbial pollution of surface water and its health impact in the Nkoup River basin in Foumbot, West Cameroon. Rev. CAMES – Serie A 8: 52-57.

Viers, J., Dupre, B., Braun, J.J., Deberdt, S., Angeletti, B., Ndam Ngoupayou, J.R., Michard, A. (2000) : Major and trace element abundances, and strontium isotopes in the Nyong basin rivers Cameroon constraints on chemical weathering processes and elements transport mechanisms in humid tropical environments. Chem. Geol. 169, 211–241.