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Physico-Chemical And Microbiological Analyses Of Water From Three Springs In The City Of Brazzaville (Congo)

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Abstract
This study assessed the water quality of three springs in the city of Brazzaville (Congo). Water samples were taken from springs in district 8, Madibou. The water samples were analysed for the following physico-chemical parameters: temperature, hydrogen potential (pH), alkalimetric titre (TA), complete alkalimetric titre (TAC), hydrotimetric titre (THT), suspended solids (SS), salts of strong acids (SAF), salts of strong bases (SBF), conductivity, turbidity, colour, potassium permanganate oxidability, Ryznar index (IR), Larson index (IL), general mineralisation, oxidation-reduction power (rH), as well as bicarbonate ion (HCO_3^-), carbonate ion (CO_3^{2-}), nitrate ion (NO_3^-), nitrite ion (NO_2^-) and phosphate ion (PO_4^{3-}) content. The following microbiological parameters were determined: total germs, total and faecal coliforms, Salmonella, Shigella and Staphylococcus. The results of the physico-chemical analyses highlighted the acidic, aggressive and corrosive characteristics of these spring waters. The average pH values were 4.95, 5.07 and 5.37 respectively; the Ryznar index values were 11.41, 11.30 and 11.06; and the Larson index values were 1.48, 1.42 and 5.55 respectively. Microbiological analyses showed, among other things, total germs at average concentrations of 75 CFU/100 mL and 75.5 CFU/100 mL in the Mbouono and Mbemba Landou spring waters. These spring waters, which appear to be palliative solutions for local populations, therefore require prior chemical treatment.

Keywords: *Water, Spring, Analysis, Physico-chemistry, microbiology, Brazzaville.*

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I. Introduction

The Republic of Congo has abundant water resources, consisting of surface water and groundwater (Moukolo et al., 1992; Vennetier, 1966). Surface water is drained by two major river basins: the Congo Basin and the Kouilou-Niari Basin. The Congo basin groups together the main tributaries on the right bank of the Congo river, which is the main collector. It borders the country for more than 6,000 km and has a modulus of 43000 m^3 per second at Brazzaville. The Kouilou-Niari basin, with a surface area of just over 55340 km^2, covers virtually the entire south-west of the country. The main collector is the Kouilou river, also known as the Niari in its middle course and the Ndouo in its upper course. Its modulus reaches 930 m^3 per second in its lower course, more precisely at Kakamoeka (Moukolo et al., 1992; Vennetier, 1966). Groundwater resources can be grouped into four aquifers: aquifers in the coastal sedimentary basin (6000 km^2), aquifers in the continental terrain of the Congolese Cuvette (224000 km^2), aquifers in the ancient sedimentary series (68000 km^2) and aquifers in crystalline and crystallophyllous rocks (44000 km^2) (Moukolo et al., 1992). The country's overall renewable water resources are estimated at 294826 m^3/inhabitant/year (ReFEA, 2001). Despite its abundant water resources, the Republic of Congo is faced with a low production capacity and outdated and poorly maintained production and distribution facilities (GWP, 2010; UNDP, 2010; Ofoueme, 2010). Nearly 40 % of the population in urban areas and 11% in rural areas are supplied with drinking water by the national distribution network. In peri-urban areas, domestic water supply is increasingly provided by the informal sector (GWP, 2010). In Brazzaville, the country's political capital, there have been serious disruptions and breaks in the supply of drinking water in some neighbourhoods. Households are supplied with water from the national water distribution network, wells, rivers, rainfall, boreholes and springs (Nkounkou et al. 2017; IPS, 2007). Groundwater is not always drinkable in its natural state (Blum et al., 2007; El Hammoumi et al. 2012; Ben Abbou et al., 2013; Atteia, 2015; Vauvillep, 2010). Several authors have reported the acidic nature of groundwater in the city of Brazzaville (Ngouloubi, 2013; Moukolo, 1987; Matini et al., 2009; Opo, 2009). Groundwater may require treatment to make it potable before being distributed to the population (Bouchahm et al., 2016; Kateb, 2017). Water intended for human consumption must have adequate characteristics to ensure the health of the population [WHO, 2017; Drobenko, 2007]. The aim of this study is to use physicochemical and microbiological analyses to assess the quality of water samples from three springs in the city of Brazzaville.

II. Materials And Methods

Collection of water samples

Water samples were collected from 3 springs in the Mbemba Landou, Kombé and Mbouono neighbourhoods of arrondissement 8, Madibou in the city of Brazzaville, during the month of March 2017. Four samples were taken from each spring.

Determination of physico-chemical parameters

Measurements and analyses were carried out in the laboratory of the Société Nationale de Distribution d'Eau (SNDE), on raw water samples from the three springs in order to determine the following physico-chemical parameters: temperature, hydrogen potential (pH), alkalimetric titre (TA), complete alkalimetric titre (TAC), hydrotimetric titre (THT), suspended solids (SS), salts of strong acids (SAF), salts of strong bases (SBF), conductivity, turbidity, colour, potassium permanganate oxidability, Ryznar index (IR), Larson index (IL), general mineralisation, oxidation-reduction power (rH), as well as bicarbonate ion (HCO_3-), carbonate ion (CO_3^{2-}), nitrate ion (NO_3^-), nitrite ion (NO_2^-) and phosphate ion (PO_4^{3-}) contents.

Hydrogen potential (pH), temperature, redox potential (rH)

The pH was measured using a HANNA pH meter combined with a reference electrode and temperature measurement, in accordance with standard NF T90-008 (Tardat-Henry et al., 1992; Rodier et al. 2009). The redox potential was determined using the relationship below (Rodier et al. 2009; Lugube, 2015):

$$rH = \frac{Pr + 0{,}250}{0{,}029} + 2 \times pH$$

Pr: potential difference between the platinum electrode and the reference electrode (calomel) in Volt; 0.250: value of the redox potential at the saturated calomel with respect to the hydrogen electrode.

Turbidity, suspended solids, colour

Turbidity was measured using a HACH 2100 N turbidity meter in accordance with standard NF EN ISO 7027. Suspended matter was determined using a HACH DR/890 colorimeter. Colour was determined using the LOVIBOND colour comparator, with reference to standard NF EN ISO 7887 (Tardat-Henry et al., 1992; FUNASA, 2013; Cardot et al, 2013).

Conductivity, General mineralisation

Conductivity was measured using a HACH conductivity meter, with reference to standard NF EN 27888 and general mineralisation was assessed from conductivity with reference to standard NF T 90-111 (Rodier et al. 2009; Lugube, 2015).

Alkalimetric strength, full alkalimetric strength, hydrotimetric strength

Alkalimetric strength and full alkalimetric strength were determined by acid-base assay using a titrated sulphuric acid solution in the presence of phenolphthalein and helianthin respectively, in accordance with standard NF EN ISO 9963. The hydrotimetric titre was determined in accordance with standard NF T90 003 (Rodier et al. 2009).

Bicarbonate ions (HCO_3^-), Carbonate ions (CO_3^{2-})

The bicarbonate and carbonate ion contents were calculated from the complete alkalimetric titre (TAC) and alkalimetric titre (TA) respectively (Tardat-Henry et al., 1992).

Salts of strong acids (SAF), Salts of strong bases (SBF)

The content of salts of strong acids was calculated from the conductivity and the full alkalimetric titre. The content of salts of strong bases was calculated from conductivity and hydrotimetric titre (Tardat-Henry et al., 1992).

Nitrate (NO_3^-), nitrite (NO_2^-) and phosphate (PO_4^{3-}) levels

Nitrate, nitrite and phosphate levels were determined using the DR/890 HACH colorimeter, with NitraVer 5, NitriVer 3 and PhosphoVer reagents respectively (Tardat-Henry et al., 1992).

Oxidability to potassium permanganate

Oxidability to potassium permanganate was determined with reference to standard NF EN ISO 8467 (Cardot et al., 2013; Rejsek, 2002).

Ryznar index, Larson index

The Ryznar index is used to define the aggressive or scaling tendency of water (Lugube, 2015). It is calculated using the relationship:

$IR = 2 \times pHe - pHm$

pHe being the equilibrium pH and pHm the measured pH

The Larson index is used to assess a water's corrosive tendency (Lugube, 2015). It is calculated using the relationship:

$IL = SAF / TAC$

SAF being the content of salts of strong acids in °f and TAC the total alkalimetric titre in mg/L $CaCO_3$.

Determination of microbiological parameters

Microbiological parameters were determined using the methods described by the WHO in 2017 and the standards of the International Organisation for Standardisation (ISO). We identified: total germs, total and faecal coliforms, Salmonella, Shigella and Staphylococci (WHO, 2017).

Statistical analysis

A statistical analysis of the data was performed by standard deviation calculation using Microsoft Excel 2007 software.

III. Results And Discussion

Physico-chemical parameters

The results of the physico-chemical analyses carried out for the three sources are presented in Table 1. This table shows that, of the 21 parameters studied, 18 met WHO recommendations and three did not. These are pH, Ryznar index and Larson index (Figures 1, 2 and 3). The average pH values are 4.95 for the Mbemba Landou spring, 5.07 for the Kombé spring and 5.37 for the Mbouono spring. These values are below the WHO drinking water guidelines, which range from 6.5 to 8.5. The water from the three springs has an acid pH and must be treated to correct this parameter before consumption. (Degremont, 2005; Kettab, 1992). The Ryznar index has average values of: 11.41 for the Mbemba Landou spring, 11.3 for the Kombé spring and 11.06 for the Mbouono spring. These values do not comply with WHO recommendations, which indicate a value of less than 8.5. The mean values of the Larson index are: 1.48 for the Mbemba Landou source; 1.41 for the Kombé source and 5.55 for the Mbouono source. These Larson index values are also higher than the WHO recommendations, which should be less than 1. The high Ryznar and Larson index values indicate that the water from the three springs is corrosive and aggressive. The corrosive and aggressive characteristics of Brazzaville's groundwater were discussed by Makomo et al. in 2020.

Table 1: Physico-chemical parameters of water from the three springs

Parameters	Units	Source 1 (Mbemba Landou)					Source 2 (Kombé)					Source 3 (Mbouono)					WHO standard
		P1	P2	P3	P4	Mean	P1	P2	P3	P4	Mean	P1	P2	P3	P4	Mean	
Hydrogen potential	-	4.96	4.94	4.93	4.98	4.95	5.08	5.05	5.15	5.01	5.07	5.35	5.40	5.38	5.36	5.37	6.5-8.5
Temperature	°C	23.9	21.6	21.3	20.2	21.7	23.7	21.3	21.4	21.4	21.6	23.6	21.9	21.6	20.1	21.8	12-30
Turbidity	NTU	0.3	0.3	1,1	0.3	0.5	2.4	2.3	6.7	2.3	¾	0.8	0.6	4.3	0.6	1.5	5
Colour	mg/L Pt-Co	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15
Conductivity	µs/cm	30.15	22.11	20.1	22.11	23.61	20.1	20.1	18.09	18.09	19.09	58.2	68.3	46.23	66.3	59.7	300
Alkalimetric titre	mg/L $CaCO_3$	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5

Complete alkalimetric titre	**mg/L $CaCO_3$**	8.75	7	5.25	3.5	6.12	9.62	5.25	5.25	3.5	5.9	8.75	7	5.25	3.5	6.12	100
Hydrotimetric titre	**mg/L $CaCO_3$**	6.6	6.6	6.6	13.2	8.25	3.3	6.6	6.6	9.9	6.6	3.3	9.9	9.9	9.9	8.25	150
Suspended solids	**mg/L**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	<1
Salts of strong acids	**°f**	0.93	0.62	0.68	0.97	0.8	0.24	0.68	0.56	1.1	0.64	2.61	3.4	2.24	3.6	2.96	10
Salts of strong bases	**°f**	1.14	0.66	0.54	0.006	0.58	0.87	0.54	0.42	0.21	0.51	0.87	3.11	1.78	2.9	2.16	10
Bicarbonate	**mg/L**	10.6	8.54	6.4	4.27	7.45	11.73	6.4	6.4	4.27	7.2	10.67	8.54	6.4	4.2	7.45	200
Carbonate	**mg/L**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10
Oxidability with $KMnO_4$	**mg/LO_2**	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.19	0.13	0.13	0.14	< 1
Redox capacity	-	21.56	21.51	21.5	21.52	21.52	21.58	21.52	21.55	21.47	21.53	21.59	21.58	21.57	21.5	21.54	20-27
Ryznar Index	-	11.1	11.3	11.49	11.76	11.41	10.86	11.37	11.27	11.7	11.3	11.1	10.8	11.04	11.3	11.06	< 8,5
Larson Index	-	1.06	0.88	1.29	2.71	1.48	0.24	1.2	1.06	3.2	1.42	2.9	4.85	4.26	10.2	5.55	< 1
Nitrate	**mg/L**	10	10.2	10.3	10.5	10.25	8.4	10.1	12.7	14.4	11.4	26.5	24.8	22.5	23.9	24.4	50
Nitrite	**mg/L**	0.004	0.006	0.005	0.002	0.004	0.012	0.01	0.012	0.013	0.011	0.036	0.037	0.039	0.042	0.038	0,1
Phosphate	**mg/L**	0.00	0.09	0.1	0.13	0.08	0	0.05	0.09	0.11	0.062	0.16	0.16	0.18	0.21	0.17	1
General mineralisation	**mg/L**	41.04	30.06	27.3	30.06	32.11	27.33	27.33	24.6	24.05	25.82	79.1	93.21	62.8	90.2	81.32	350

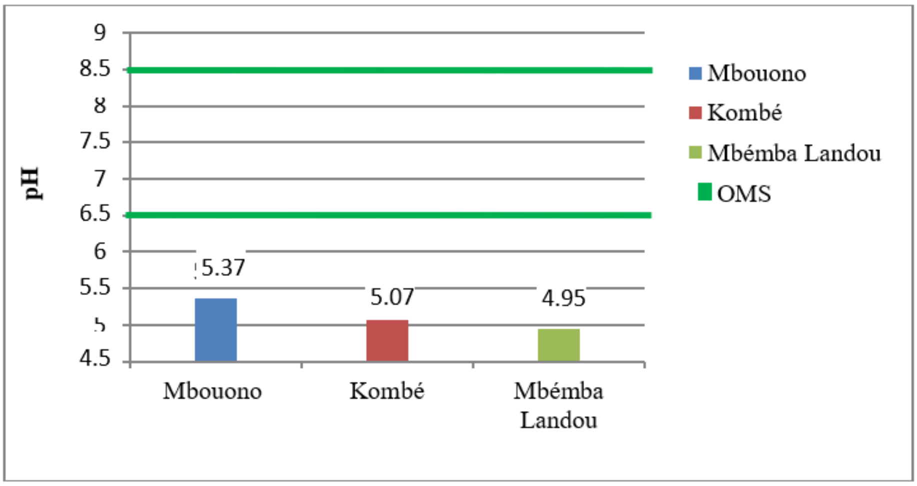

Figure 1: Variation in the pH of water from the three springs

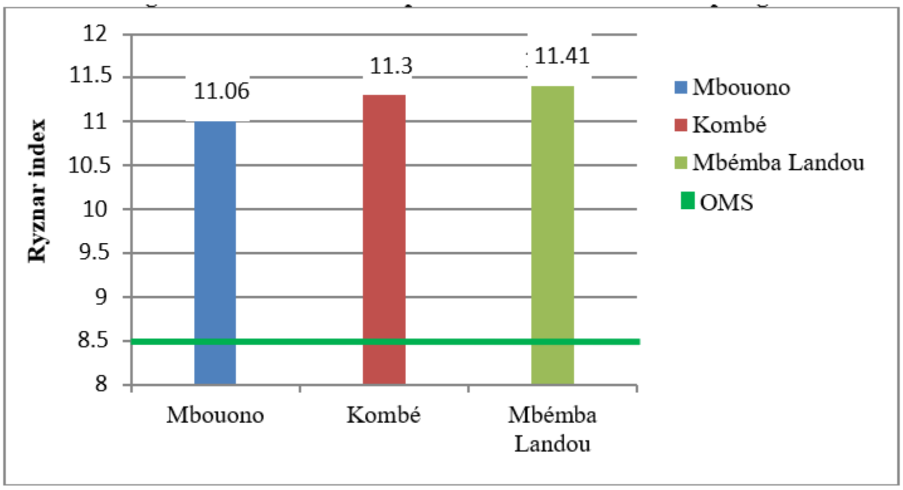

Figure 2: Variation in the Ryznar index of water from the three springs

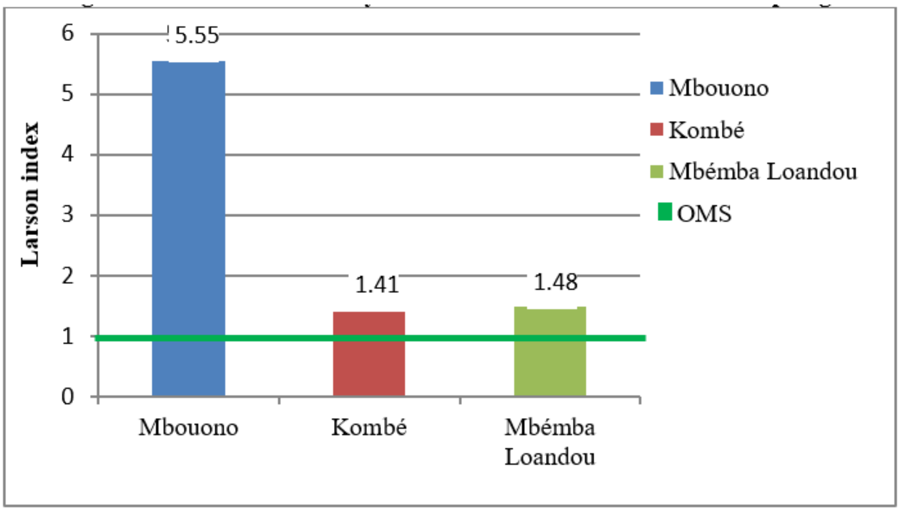

Figure 3: Variation in the Larson index of water from the three springs

Microbiological parameters

The results of microbiological analyses of water from the three springs are presented in tables 2, 3 and 4. Observation of these tables shows that the Mbemba Landou spring water contains total germs, total coliforms and faecal coliforms at average concentrations of: 75.5 CFU/100 mL; 1.5 CFU/100 mL and 0.25 CFU/100 mL. These parameters do not meet WHO drinking water guidelines. Salmonella, shigella and staphylococci were absent from these waters. The Kombé spring water was free of total germs, total and faecal coliforms, salmonella, shigella and staphylococci, which complies with WHO recommendations. In the Mbouono spring water, total germs were present at 75 CFU/100 mL; faecal coliforms at 25.5 CFU/100 mL; and shigella and staphylococci at 50 CFU/100 mL. These values do not comply with the WHO recommendations of 0 CFU/100 mL. Salmonella are not present in these spring waters. Water from the Mbemba Landou and Mbouono springs should be disinfected before consumption.

Table 2: Microbiological analyses of water from the Mbemba Landou spring

Parameters	Units	Source 1				Mean	WHO standard
		P1	P2	P3	P4		
Total germs (24h at 37°C)	UFC	100	100	2	100	75.5	0-30 UFC/100 mL
Total coliforms (24h at 37°C)	UFC	6	0	0	0	1.5	0 UFC/100 mL
Faecal coliforms (24h at 44°C)	UFC	1	0	0	0	0.25	0 UFC/100 mL
Salmonella (24h 37°C)	UFC	0	0	0	0	0	0 UFC/100 mL
Shigella (24h at 37°C)	UFC	0	0	0	0	0	0 UFC/100 mL
Staphylococci (48h at 37°C)	UFC	0	0	0	0	0	0 UFC/100 mL

Table 3: Microbiological analyses of water from the Kombé spring

Parameters	Units	Source 2				Mean	WHO standard
		P1	P2	P3	P4		
Total germs (24h at 37°C)	UFC	0	0	0	0	0	0-30 UFC/100 mL
Total coliforms (24h at 37°C)	UFC	0	0	0	0	0	0 UFC/100 mL
Faecal coliforms (24h at 44°C)	UFC	0	0	0	0	0	0 UFC/100 mL
Salmonella (24h 37°C)	UFC	0	0	0	0	0	0 UFC/100 mL
Shigella (24h at 37°C)	UFC	0	0	0	0	0	0 UFC/100 mL
Staphylococci (48h at 37°C)	UFC	0	0	0	0	0	0 UFC/100 mL

Table 4: Microbiological analyses of water from the Mbouono spring

Parameters	Units	Sources 3				Mean	WHO standard
		P1	P2	P3	P4		
Total germs (24h at 37°C)	UFC	100	100	100	0	75	0-30 UFC/100 mL
Total coliforms (24h at 37°C)	UFC	0	1	0	0	0.25	0 UFC/100 mL
Faecal coliforms (24h at 44°C)	UFC	100	1	0	0	25.5	0 UFC/100 mL
Salmonella (24h 37°C)	UFC	0	0	0	0	0	0 UFC/100 mL
Shigella (24h at 37°C)	UFC	100	0	100	0	50	0 UFC/100 mL
Staphylococci (48h at 37°C)	UFC	100	100	0	0	50	0 UFC/100 mL

Statistical analysis

Statistical analysis of the data from the study on the three springs showed a dispersion of 0.02 to 0.06 for pH; 0.20 to 0.35 for the Ryznar index; 0.83 to 3.20 for the Larson index.

IV. Conclusion

The aim of this work was to carry out quality control of water from three springs in district 8, Madibou, intended for human consumption, in order to check whether their quality is safe. The study highlighted the acidic, aggressive and corrosive nature of the water from three springs in arrondissement 8, Madibou, in the city of Brazzaville. In terms of microbiological analysis, the Kombé spring water is of good quality. The Mbemba Landou and Mbouono spring waters are not of good quality. The results of the physico-chemical and microbiological analyses in this study show that the water from these three springs requires treatment to make it drinkable. As water quality is a public health issue, the results obtained in this study can be used to raise awareness of the need to use spring water.

References

[1] Atteia O. Chimie Et Pollutions Des Eaux Souterraines. Editions Technique & Documentation, Paris, 2015, 448 P.
[2] Ben Abbou M., El Haji M., Zemzami M. Et Fadil F., Détermination De La Qualité Des Eaux Des Nappes De La Province De Taza (Maroc), Larhyss Journal, N°16, 2013, 77 – 90.
[3] Blum A., Chery L. Et Legrand H., L'eau Souterraine Est-Elle Toujours Potable A L'état Naturel ?, Géosciences N°5, 2007, 58 – 67.
[4] Bouchahm N., Hecini L. Et Kherifi W., Adoucissement Des Eaux Souterraines De La Région Orientale Du Sahara Septentrional Algérien : Cas De La Région De Biskra, Revue Des Sciences De L'eau, 29(1), 2016, 37 – 48.
[5] Cardot C. Et Gilles A., Analyse Des Eaux : Réglementation, Analyses Volumétriques Et Spectrophotométriques, Statistiques, Ellipses Edition Marketing S.A, Paris, 2013, 296 P.
[6] Degremont S., Memento Technique De L'eau, Lavoisier SAS, 10e Edition, Tome 1 Et 2, 2005, 785 P., 1718 P.
[7] Drobenko B., Droit De L'eau, Gualino Editeur, Paris, 2007, 330 P.
[8] El Hammoumi N., Sinan M., Lekhli B. Et El Mahjoub L., Évaluation De La Qualité Des Eaux Souterraines Pour L'utilisation Dans L'eau Potable Et L'agriculture : Plaine De Tadla, Maroc, Afrique Sciences, 08 (1), 2012, 54 – 66.
[9] Fondation Nationale De La Santé, Manuel Pratique D'analyse De L'eau, 4ème Edition, FUNASA, Brésil, 2013, 150 P.
[10] Global Water Partnership Central Africa, Développement D'une Stratégie De Financement Du Secteur De L'eau En Afrique Centrale. Etude Nationale Sur Le Financement Du Secteur De L'eau. Rapport Congo, 2010, 112 P Https://Www.Gwp.Org/Globalassets/Global/Gwp-Caf-Files
[11] Inter Press Service. Développement-Congo : Forages Et Châteaux D'eau Pour Contourner Les Pénuries, 2007, 2 P. Https://Www.Ipsinternational.Org.
[12] Kateb S., Déferrisation Des Eaux Souterraines De Sud Algérie: Station De Traitement De L'eau Potable De La Ville d'Illizi, Editions Universitaires Européennes, 2017, 96 P.
[13] Kettab A (1992). Traitement Des Eaux. L'eau Potable. Edition Des Publications Universitaire. Alger, 1992, 118-123
[14] Lugube B., Production D'eau Potable. Filières Et Procédés De Traitement, Dumod, Paris, 2015, 414 P.
[15] Makomo H., Ntalani H., Dissinda M., Bouaka F., Ouamba J-M. Caractérisation Physico-Chimique Et Etude Sur La Mise En Equilibre Calco-Carbonique Des Eaux De Trois Forages De La Ville De Brazzaville, Congo. Afrique Science, 2019, 15(5) : 101-115.
[16] Matini L., Moutou J. M. Et Kongo-Mantono M. S., Evaluation Hydrochimique Des Eaux Souterraines En Milieu Urbain Au Sud-Ouest De Brazzaville, Congo, Afrique Science, 05 (1), 2009, 82 – 98.
[17] Moukolo N., Ressources En Eaux Souterraines Et Approvisionnement : Données Hydrogéologiques De La Région De Brazzaville, ORSTOM, AGECO, 1987, 97 - 109.
[18] Moukolo N., Samba Kimbata M. J., Mpouza M., Nzalabaka J., Maziezoula B. Et Ossete, J. M. Hydrogéologie Du Congo, Edition Du BRGM, Orléans 1992, 121 P.
[19] Ngouloubi Maba P. L., Les Problèmes D'accès A L'eau Potable De La Population De L'arrondissement 4, Moungali A Brazzaville (République Du Congo), Mémoire De Maîtrise, Université Marien NGOUABI, 2013, 139 P.

[20] Nkounkou Loumpangou C., Louzayadio Mvouezolo R.F., Ayessou N., Elouma Ndinga A.M., Ngakegn A.C, Limbili, Mar Diop Codou G. Et Ouamba J.M., Approvisionnement En Eau Dans La Ville De Brazzaville, Congo, European Scientific Journal, Vol.13, N°21, 2017, 474 – 498.
[21] Ofoueme Berton Y., L'approvisionnement En Eau Des Populations Rurales Au Congo Brazzaville, Les Cahiers d'Outre-Mer, N°249, 2010, 7 – 30.
[22] OMS, Directives De Qualité Pour L'eau De Boisson, 4ème Edition 2017, 564 P. Https://Www.Who.Int.
[23] OMS. Directives Sur La Qualité De L'eau De Boisson. 4e Ed. Intégrant Le Premier Additive, 2017, 564 P.
[24] Opo
[25] U. F., Qualité Des Eaux Souterraines Des Quartiers Périphériques De l'Arrondissement I De Brazzaville. Mémoire De DEA. Université Marien NGOUABI, Brazzaville, 2009, 130 P.
[26] Rejsek F., Analyse Des Eaux. Aspects Réglementaires Et Techniques", CRDP Aquitaine, 2002, 361 P.
[27] Réseau Francophone Sur l'Eau Et l'Assainissement. Ressources En Eau 2001, 2 P. Https://Www.Iowater.Org/ Refea
[28] Rodier J., Legube B., Merlet N., Brunet R. Et Coll, L'analyse De L'eau, Dumod, 9e Edition, Paris, 2009, 1526 P.
[29] Tardat-Henry M. Et Beaudry J-P, Chimie Des Eaux, Les Editions Le Griffon D'argile, Québec, 1992, 537 P.
[30] UNDP, Rapport National Des Progrès Vers L'atteinte Des Objectifs Du Millénaire Pour Le Développement-République Du Congo, 2010, 82 P. Htps://Www.Undp.Org
[31] Vauvillep. R, Protection Des Eaux Souterraines, Editions Technique & Documentation, Paris, 2010, 443 P.
[32] Vennetier P., Géographie Du Congo Brazzaville, Gauthier-Villars, Paris, 1966, 174 P.