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Physico-chemical quality of tap water in an urban environment: The case of the Massengo district, arrondissement n°9 Djiri, Brazzaville

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Abstract

The drinking water supply in the Massengo Soprogi district in Brazzaville's Djiri 9 arrondissement is provided by the Djiri river, whose mineralization dictates that of the water in the distribution network. Tap water in this district was analyzed for various parameters in order to understand the acquisition of mineralization. The physico-chemical analysis of these water samples showed that the water has very little mineralization, and is not very hard due to the geological nature of the Djiri riverbed (sandy soil). The pH values in the wet and dry seasons give the water a weakly acidic nature and, taking into account the concentration of bicarbonate ions, a low level of complete alkalinity. The geochemical processes responsible for this mineralization are mainly: water-rock interaction and ion exchange, and silicate dissolution. The geochemical methods used were the Gibbs diagram and the calculation of a few characteristic ionic ratios. Tap water has a strong aggressive and corrosive tendency, as revealed by Langelier's saturation index and Ryznar's stability index.

Keywords: Djiri river; Gibbs diagram; Water aggressiveness; Mineralization; Corrosion.

1. Introduction

Water is a natural resource essential to life. Maintaining its quality is a major concern for a society that has to meet ever-increasing water needs [1,2]. Today, nearly 2.2 billion people do not have access to safe drinking water [3]. Several million people die every year from water-related diseases (diarrhoea, cholera, dysentery), the majority of them children [4]. Water is important from a public health point of view, and determines living standards. In African countries, various policies and strategies have been put in place to provide access to drinking water [5-6]. In the Massengo Soprogi district of arrondissement n°9 Djiri, drinking water is supplied by units known as potablocs. These have a capacity of 480 m of water/day for 18,000 inhabitants. This water is pumped to consumers' taps over a radius of 3,500 meters. Drinking water must comply with O.M.S. potability standards or those of the various national organizations accredited in this field. Several studies have shown the importance of determining the physico-chemical characteristics of water for various uses [7,8]. The chemical composition of water is nothing other than the result of geochemical processes that take place in the water resource (Rivière Djiri). These geochemical processes, which control the mineralization of water from potablocks, are the result of water-rock interaction and ion exchange in the water resource, as shown by several studies [9]. Thus, in our study we set ourselves the general objective of assessing the potability of tap water in the Massengo Soprogi district.

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2. Material and methods

2.1. Description of study environment

Brazzaville is located on the right bank of the Congo River, downstream of Stanley Pool, in the line historically located at the outlet of the Stanley Pool. Its natural limits were the Djoué River to the south and the Djiri River to the north, but these limits are now largely exceeded by new extensions. Its surface area was 100 km, with a population of 1,482,225 in 2010 and a density of 1,822 inhabitants per km [10].

2.2. Location of water taps

Water taps were located using a Garmin E-Trex GPS. The positions are given in UTM coordinates. Table I gives the geo-referenced coordinates of each water tap.

Table 1 Georeferenced coordinates of water taps

Faucet	X	Y	Z
R1	528848	9538948	437
R2	528868	9538980	438
R3	528881	9538982	440
R4	528914	9538928	441
R5	528945	9538900	442
R6	528968	9539004	445
R7	529045	9539026	449
R8	529056	9539120	452
R9	529059	9539168	457
R10	529028	9539216	458
R11	529043	9539322	456
R12	529076	9539508	474
R13	529029	9539554	478
R14	528983	9539566	471
R15	528994	9539641	472
R16	528952	9539650	469
R17	528927	9539696	470
R18	528882	9539724	466
R19	528878	9539666	468
R20	528891	9539510	466

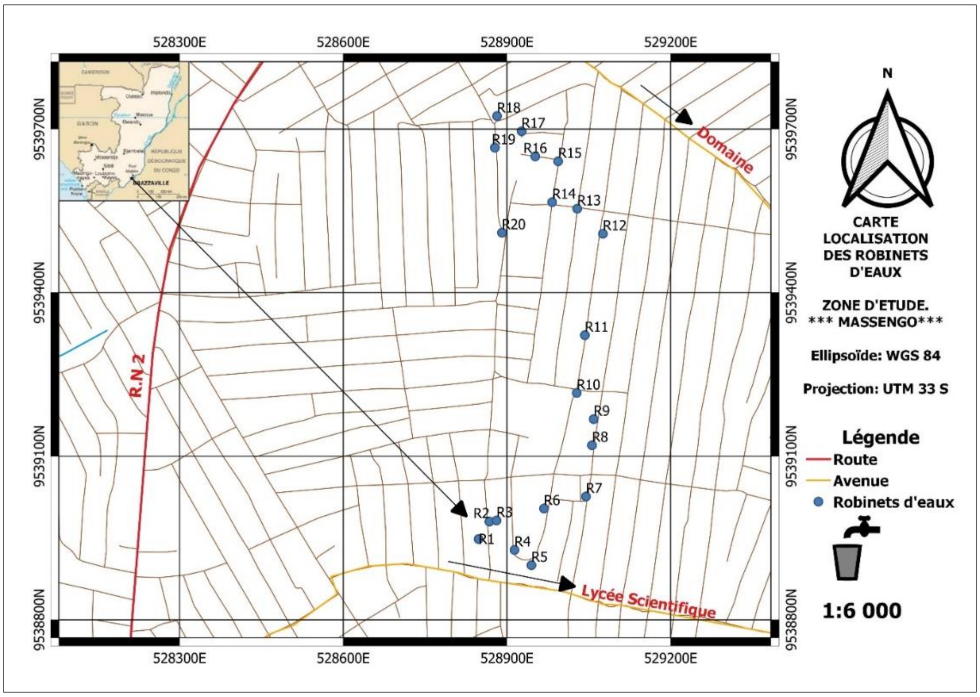

Figure 1 Location of water taps in the study area

2.3. Water tap sampling and analysis

To determine the chemical composition of water in the study area, two separate sampling campaigns were carried out in the rainy season (April 2022) and the dry season (August 2022). Twenty taps were selected in the study area. Before filling the 1.5L polyethylene bottles, which had been washed with the water to be analyzed, each sample was taken after running the tap water for at least five minutes [11]. The bottles are hermetically sealed to prevent any exchange with air. The Consort C6030 multiparameter analyzer was used to determine pH, temperature, electrical conductivity, total dissolved solids and chemical elements were determined using a PC 7000 photometer.

2.4. Calculation of Langelier index and Ryznar stability index

These two indices were determined using a free calculator on the lenntech website [12]. Input parameters are: pH, TDS (mg/L), Ca^{2+} and HCO_3^- concentration expressed in mg/L and water temperature (T°C). Interpretation criteria are given directly by the calculation program. The Langelier index is a water saturation index, noted LSI. Ryznar's index is used to assess the tendency of water to corrode, and is rated RSI.

3. Results and discussion

The values of the parameters taken into account are given in Tables II and III below, for the rainy and dry seasons respectively. With the exception of temperature (°C), pH and electrical conductivity (µS/cm), all other parameters are expressed in mg/L. Tables II and III give their elemental statistics, for the rainy and dry seasons respectively.

Table 2 Elementary statistics for rainy-season parameters (April 2021)

Parameters	Minimum	Maximum	average	Median	variance	S.D
T	25.000	29.800	29.032	29.090	0.971	0.985
pH	5.070	6.560	5.828	5.880	0.185	0.430
CE	29.600	32.900	31.040	30.800	1.109	1.053
TDS	15.500	17.500	16.435	16.300	0.342	0.585
TAC	2.500	15.000	8.411	9.000	13.262	3.641

THt	0.150	17.300	3.035	1.460	14.911	3.861
Ca^{2+}	0.080	4.010	1.501	1.430	0.849	0.921
Mg^{2+}	0.020	6.000	0.839	0.375	1.728	1.314
Na^{+}	0.100	1.290	0.540	0.440	0.105	0.323
K^{+}	0.050	2.200	1.020	0.785	0.491	0.700
HCO_3^{-}	3.050	18.300	10.257	10.980	19.703	4.438
SO_4^{2-}	1.300	16.000	5.975	5.000	13.734	3.705
Cl^{-}	0.170	1.310	0.601	0.695	0.075	0.274
NO_3^{-}	0.050	3.970	1.067	0.995	0.820	0.905
NO_2^{-}	0.010	0.070	0.022	0.020	0.003	0.016
F^{-}	0.010	0.090	0.048	0.055	0.001	0.028
PO_4^{3-}	0.010	0.100	0.039	0.020	0.001	0.034
Fe^{2+}	0.005	0.060	0.018	0.010	0.0004	0.018
Fe^{3+}	0.005	0.030	0.009	0.005	0.001	0.008
Mn^{2+}	0.010	0.090	0.056	0.060	0.001	0.023
Crtot	0.005	0.060	0.022	0.020	0.0003	0.016
Cr(VI)	0.005	0.020	0.010	0.010	0.00003	0.005
Pb^{2+}	0.005	0.010	0.006	0.005	0.000005	0.002
Cd^{2+}	0.001	0.001	0.001	0.001	0.000	0.000
Al^{3+}	0.004	0.030	0.010	0.005	0.000	0.0079

Table 3 Elementary statistics for dry-season parameters (August 2021)

Parameters	**Minimum**	**Maximum**	**average**	**Median**	**variance**	**S.D**
T	27.000	27.800	27.455	27.550	0.074	0.272
pH	5.290	6.130	5.769	5.800	0.063	0.251
CE	22.400	37.800	31.865	31.450	12.725	3.567
TDS	14.000	20.000	16.865	16.550	2.126	1.458
TAC	2.800	20.000	10.435	8.175	36.298	6.025
THt	3.000	15.000	7.443	7.320	9.464	3.076
Ca^{2+}	1.260	9.200	3.759	3.095	5.603	2.367
Mg^{2+}	0.230	8.000	1.225	0.645	2.956	1.719
Na^{+}	0.170	4.500	1.651	1.440	1.839	1.356
K^{+}	0.325	0.565	0.100	4.400	0.854	0.924
HCO_3^{-}	3.410	24.400	12.658	9.975	55.806	7.470
SO_4^{2-}	0.000	7.000	1.444	0.805	3.399	1.844
Cl^{-}	0.050	7.300	2.600	2.380	4.675	2.162
NO_3^{-}	0.050	2.650	0.927	0.640	0.613	0.783

NO_2^-	0.004	0.053	0.020	0.014	0.000	0.015
F^-	0.120	0.200	0.158	0.160	0.000	0.022
PO_4^{3-}	0.000	1.230	0.167	0.030	0.127	0.356
Fe^{2+}	0.000	0.080	0.039	0.035	0.001	0.002
Fe^{3+}	0.000	0.040	0.017	0.015	0.000	0.016
Mn^{2+}	0.000	0.090	0.036	0.035	0.001	0.032
Crtot	0.000	0.040	0.077	0.040	0.009	0.097
Cr(VI)	0.000	0.070	0.024	0.015	0.000	0.021
Pb^{2+}	0.001	0.001	0.001	0.001	0.000	0.000
Cd^{2+}	0.001	0.001	0.001	0.001	0.000	0.000
Al^{3+}	0.000	0.090	0.029	0.020	0.001	0.028

3.1. Distribution of physico-chemical parameters in the study area

In the dry season, the acidity of the tap water analyzed is a little more pronounced than in the rainy season; overall, tap water samples in the study area have a low acidity. pH values ranged from 5.29 to 6.1, with an average of 5.77. All samples have a pH below 6.5, which is the lower limit acceptable for drinking water. In the rainy season, the pH ranges from 5.07 to 6.56, with an average of 5.82. Of these twenty tap water samples, 19 have a pH value below 6.5, which is the lower limit for drinking water according to the W.H.O. This gives the tap water analyzed during this period a weakly acidic character. It should be noted that, according to the W.H.O., the pH value must fall within the range 6.5 - 8.5. Thus, 95% of tap water samples were weakly acidic (pH < 6.5), indicating low alkalinity. Figure 2 shows the distribution of pH values in the study area.

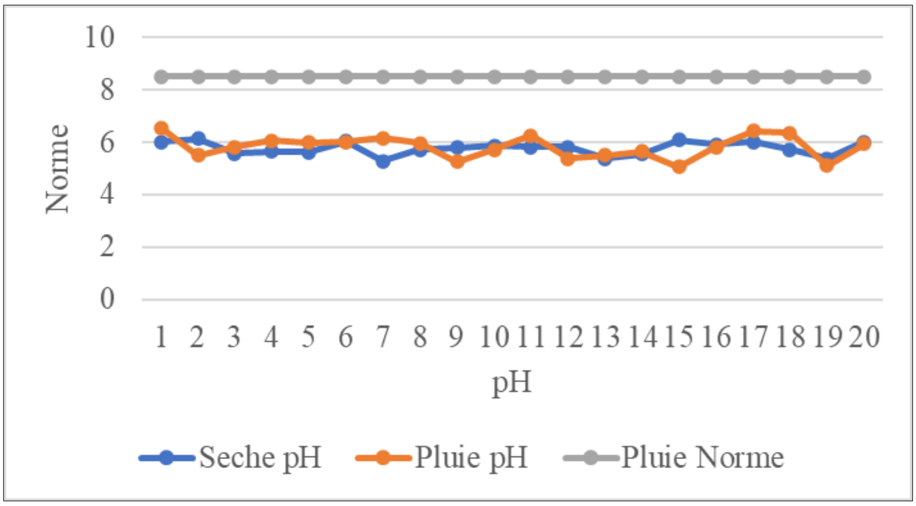

Figure 2 Distribution of pH values in the study area

Electrical conductivity varies between (29.6 - 32.90 µS/cm) and in the dry season between (22.4- 37.8 µS/cm). In view of these values, mineralization is low in both seasons. Figure 3 shows the distribution of conductivity values in the study area.

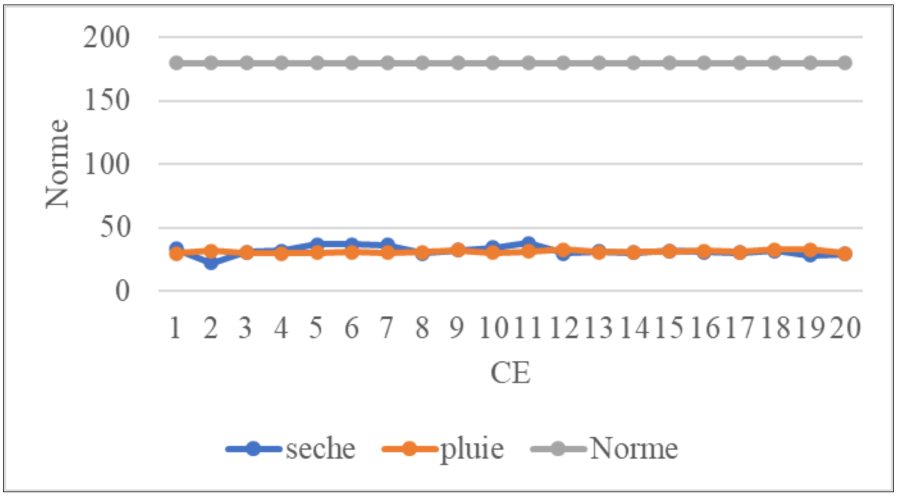

Figure 3 Distribution of electrical conductivity values in the study area

Total dissolved solids vary in the wet season between (15.5 - 17.5 mg/L) and in the dry season between (14 - 20 mg/L). Very low variability for these two parameters is observed in both seasons. Figure 4 shows the distribution of TDS values in the study area.

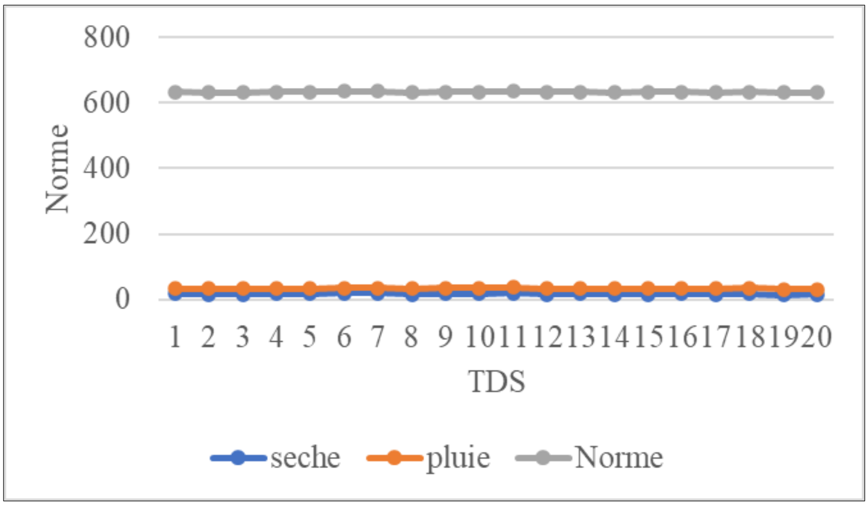

Figure 4 Distribution of TDS values in the study area

Inorganic nitrogen (NO_3^-) concentration varies between 0.05 and 2.65 mg/L in the rainy season and 0.05 - 2.65 mg/L in the dry season. Figure 5 shows the distribution of $N0_3^-$ values in the study area.

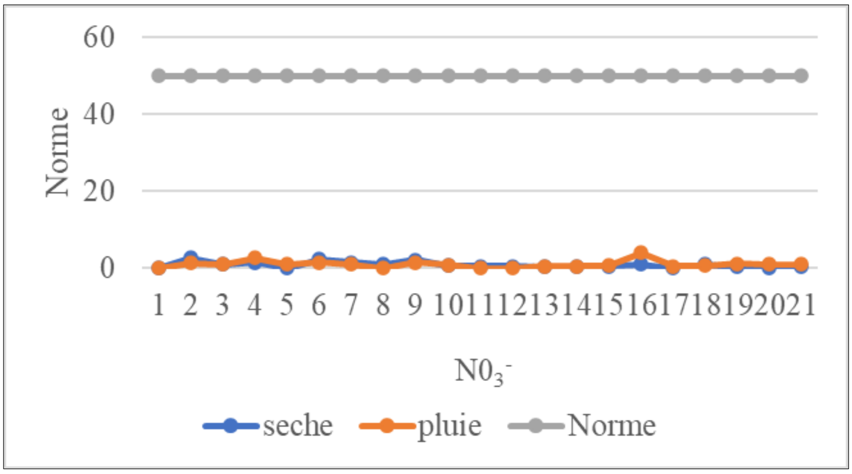

Figure 5 Distribution of N0$_3^-$ values in the study area

The concentration of inorganic nitrogen N0$_2^-$ in the rainy season varies between 0.004 and 0.053 mg/L and in the dry season between 0.06 - 0.053 mg/L. Figure 6 shows the distribution of N0$_2^-$ values in the study area.

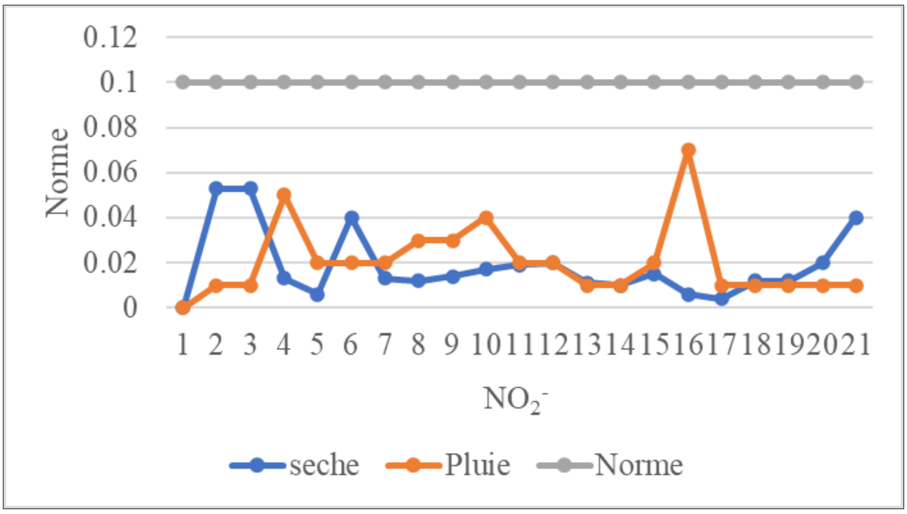

Figure 6 Distribution of N0$_2^-$ values in the study area

For chromium (VI), two tap water samples exceeded the 50 µg/L limit: R3 and R4, with a chromium VI concentration of 70 µg/L. In drinking water, Cr(VI) is present in the form of oxyanions: hydrogen chromate ($HCrO_4^-$) and chromate (CrO_4^{2-}). In drinking water, Cr(VI) is present in the form of oxyanions: hydrogen chromate ($HCrO_4^-$) and chromate (CrO_4^{2-}). These anions are considered highly soluble in water, and their concentration depends on pH. As chromium III is naturally present in the water distribution system, it can be oxidized to Cr(VI) if oxidizers such as chlorine and chloramines come into contact with soluble Cr(III) or plumbing surfaces containing chromium [13]. A recent study showed the presence of chloramines in mains water in Brazzaville [14].

3.2. Distribution of major ion proportions and chemical facies

The average percentage of each cation for all tap water samples is shown in Figure 10 during the rainy season. The order of average cation distribution is as follows: Ca^{2+} (49.95%) > Mg^{2+} (27.12%) > Na^+ (19.08%) > K^+ (3.85%). In the case of anions, the distribution is as follows: HCO_3^- (66.76%) > Cl^- (23.56%) > SO_4^{2-} (9.68%) As shown in figure 10, none of the cations is predominant, i.e. has a percentage greater than or equal to 50%. In the dry season, figure 11 shows the average percentage of cations. The order of cation distribution is as follows: Ca^{2+} (56.03%) > Na^+ (21.40%) > Mg^{2+} (18.25%) > K^+ (4.32%). The average anion distribution is as follows: HCO_3^- (67%) > Cl^- (23%) > SO_4^{2-} (10%). Figures 7 and 8 show the percentages of rainy-season and dry-season ions respectively.

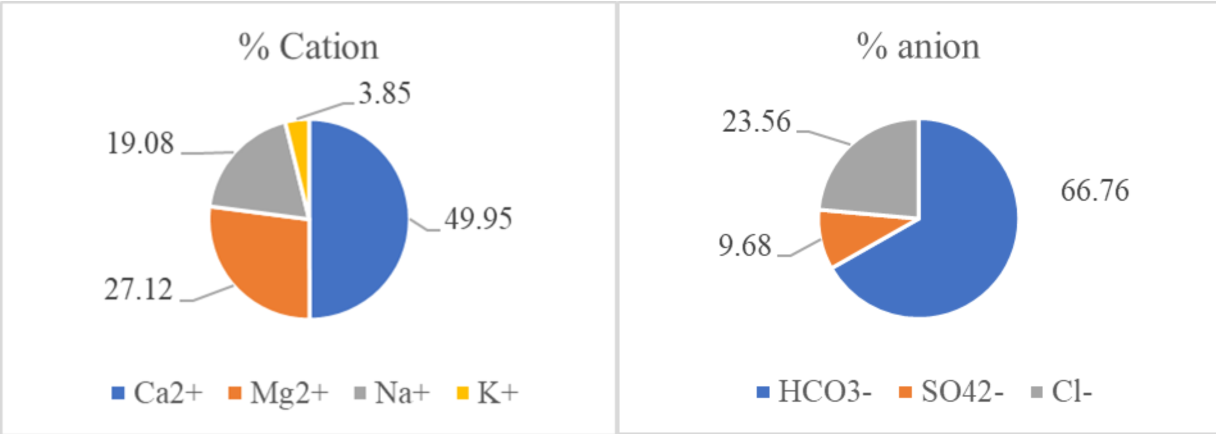

Figure 7 Ion percentages (rainy season)

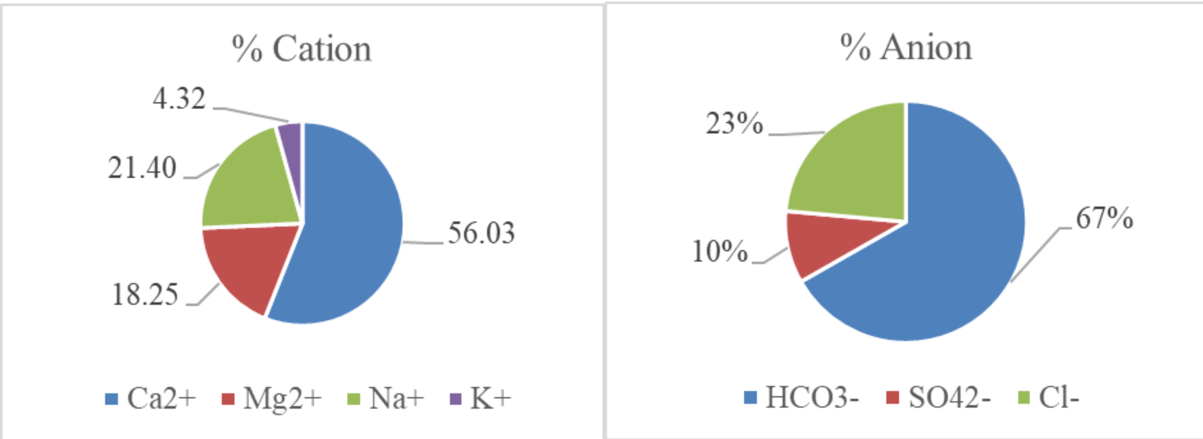

Figure 8 Ion percentages (dry season)

3.2.1. Chemical facies

The chemical facies of these tap water samples was determined from the Schoeller diagram. The Schoeller diagram shown in figure 9 below gives an average chemical facies for these tap water samples of the Ca-Mg-HCO_3 type for cations, while bicarbonate anions predominate in the rainy season. In the dry season, the Schoeller diagram presented in figure 10 shows a chemical facies of the Ca-HCO_3 type, with calcium ions Ca^{2+} as the dominant cation and bicarbonate ions as the HCO_3^- dominant anion. Figures 9 and 10 show the Schoeller diagram for tap water samples taken during the wet and dry seasons.

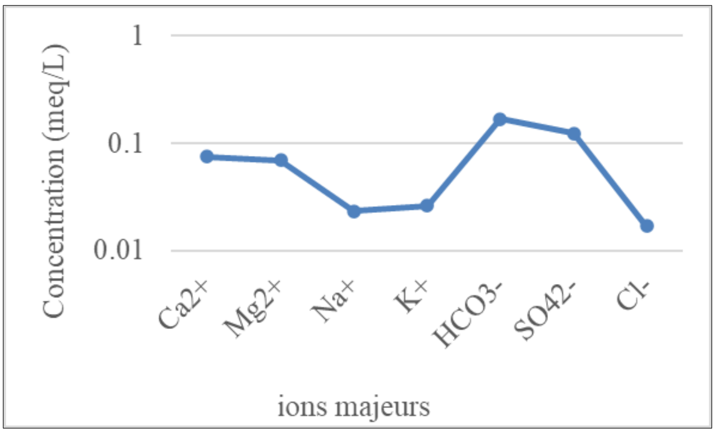

Figure 9 Schoeller diagram of rainy-season water samples

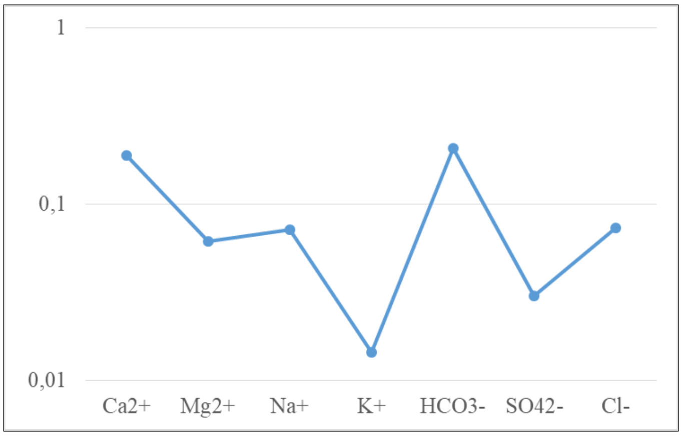

Figure 10 Schoeller diagram of dry-season water samples

3.3. Geochemical processes

The geochemical factors influencing the chemical composition of these waters have been determined from standard graphs and ion ratios, which highlight various geochemical processes such as water-rock interaction and basic ion exchange [15, 16,17]. In the rainy and dry seasons, the Gibbs diagrams shown in figures 11, 12 and 13, 14 respectively, demonstrate that water-rock interaction is one of the geochemical processes influencing the chemical composition of tap water obtained from the water resource (Djiri River). The figures below show the Gibbs diagrams for the rainy and dry seasons respectively, taking cations into account.

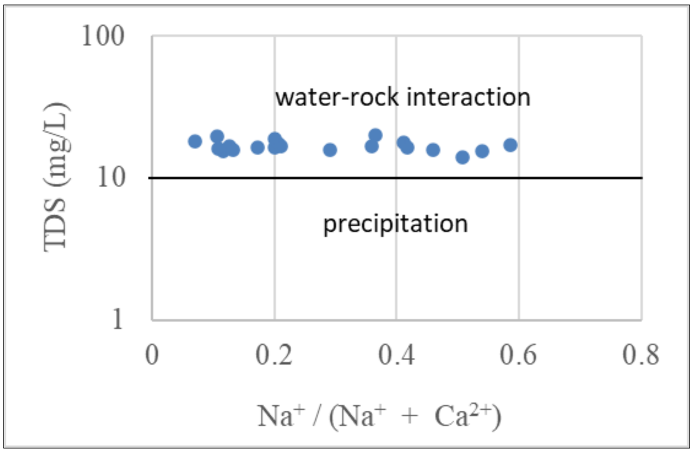

Figure 11 Rainy season Gibbs diagram taking cations into account

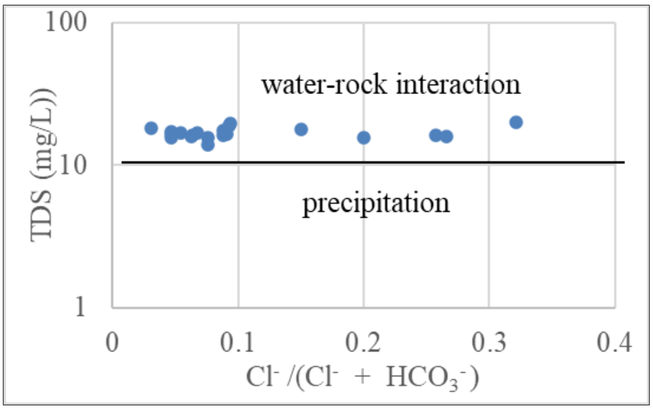

Figure 12 Rainy season Gibbs diagram taking anions into account

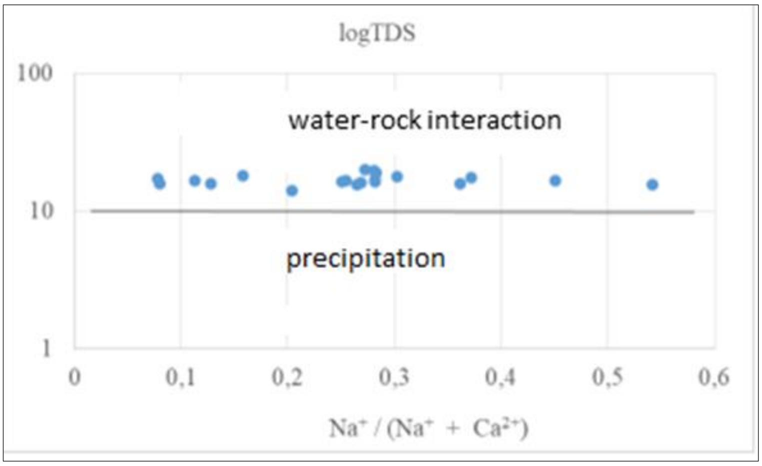

Figure 13 Dry-season Gibbs diagram taking cations into account

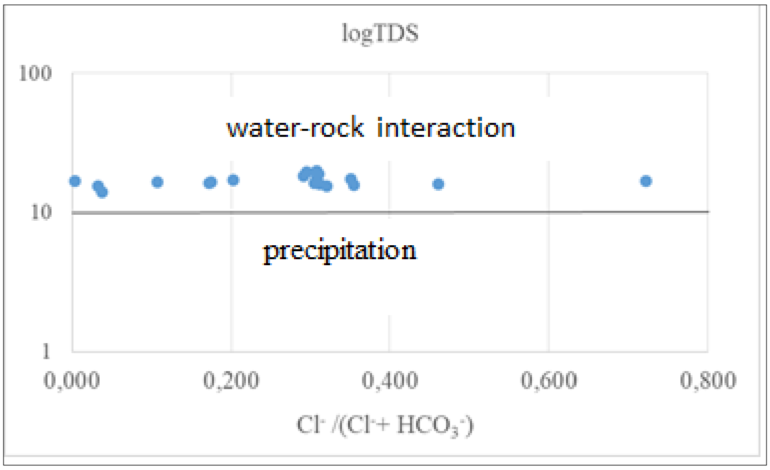

Figure 14 Dry-season Gibbs diagram taking anions into account

3.4. Water aggressiveness and corrosion

The aggressive and corrosive properties of tap water were determined by calculating the Langelier saturation index and the Ryznar stability index in the wet and dry seasons respectively [18]. The results obtained using the lenntech calculator are shown in Table IV.

Table 4 Saturation pH values (pHs) and Langelier and Ryznar indices

	Saison pluie				**Saison seche**		
Code	pH	pHs	LSI	RSI	pHs	LSI	RSI
R1	6.56	10	-3.7	14	10	-4.1	14
R2	5.5	10	-5	15	9.8	-3.7	14
R3	5.83	10	-4.6	15	9.5	-3.9	13
R4	6.06	10	-4.3	15	9.2	-3.6	13
R5	5.98	10	-4.1	14	9.9	-4.2	13
R6	6.01	10	-4.2	14	9.6	-3.5	13
R7	6.16	10	-4.2	15	9.9	-4.6	14
R8	5.97	11	-4.2	14	9.8	-4	14

R9	5.27	11	-6.1	17	10	-4.6	15
R10	5.71	10	-4.6	15	10	-4.6	15
R11	6.27	11	-4.3	15	10	-4.4	15
R12	5.38	9.8	-4.4	14	10	-4.6	14
R13	5.5	10	-4.6	15	10	-4.9	15
R14	5.65	10	-4.5	15	10	-4.7	15
R15	5.07	10	-5.1	15	9.9	-3.8	14
R16	5.82	9.7	-3.9	14	9	-3.1	12
R17	6.44	10	-4	14	9.9	-3.2	12
R18	6.35	10	-4	14	9.9	-4.2	14
R19	5.11	11	-5.5	16	9.9	-4.3	14
R20	5.93	11	-4.8	15	10	-4	14

In both wet and dry seasons, the various pH values are in the basic range. LSI (Langelier saturation index) values in the wet season are such that -6.1 < LSI < -3.7 and in the dry season -4.9 < LSI < -3.1, with an average of -4.5 in the wet season and -4.1 in the dry season respectively. Negative LSI values reflect acidic, aggressive water, undersaturated with calcium carbonate (CaCO3), which dissolves limestone under the action of aggressive :

$$CO_2 + H_2O + CaCO_3 \rightleftharpoons Ca^{2+} + 2HCO_3^-$$

Aggressive water is also prone to corrosion. The RSI (Ryznar Stability Index) values used to assess the corrosion tendency of tap water are such that 14 < RSI < 17 in the rainy season, with an average of 14.75. In the dry season, RSI values are such that 12 < RSI < 15 with an average of 13.9. For the aggressive tendency of tap water, it is established that for RSI > 8.5 the water is very aggressive. At RSI > 9, tap water has a very strong tendency to corrode.

4. Conclusion

The main aim of this study was to assess the quality of tap water in the Massengo Soprogi district in arrondissement 9 of Djiri, Brazzaville. The factors on which this quality depends are expressed in terms of tap water mineralization, in other words, the mineralization of the water resource (Djiri River). The physico-chemical analysis of these water samples showed that the water has very little mineralization, and is not very hard due to the geological nature of the Djiri riverbed (sandy soil). The pH values in the wet and dry seasons give the water a weakly acidic nature and, taking into account the concentration of bicarbonate ions, a low level of complete alkalinity. The geochemical processes responsible for this mineralization of the water were determined using the Gibbs diagram. The chemical facies presented by these waters are, on average, calcic and magnesian bicarbonate ($Ca\text{-}Mg\text{-}HCO_3$) in the rainy season and calcic bicarbonate in the dry season. Chromium VI is the undesirable metal to be regularly monitored, as its dry-season concentration of 0.07 mg/L exceeds the limit value for drinking water in two samples. The aggressive and corrosive tendencies of these waters, determined by calculating Langelier's saturation index and Ryznar's stability index, showed that the water is undersaturated in calcium carbonate, with a strong aggressive and corrosive tendency.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to disclosed.

References

[1] Haouchine S. (2011). Research on the faunistic quality and ecology of benthic macroinvertebrates in Kabylie streams, mem. Magister sciences bio.

[2] Foto MS, Zebaze, TSH, Nyamsi, TNL, Ajeagah, GA and Njiné, T. (2011) Spatial Evolution of the Diversity of Benthic Macroinvertebrate Populations in an Anthropized Stream in a Tropical Environment (Cameroon). European Journal of Scientific Research, 55, 291-300.

[3] Report of the Joint Monitoring Program 2021, WHO/UNICEF, 85 p.

[4] Olivaux Y. (2007). The nature of water. Ed. Marco Pietteur. France. 563p.

[5] John P. and Donald, A. (2010): Microbiology, 3rd Edition, p1216.

[6] Baron C. & Tidjani-Alou Mahaman, "Access to water in sub-Saharan Africa: beyond models, a plurality of local innovations", Mondes en développement, n° 155, 2011, p. 7-22.

[7] Bousquet Anne, Access to water for poor city dwellers: between market regulations and community regulations (Kenya, Tanzania, Zambia), Doctoral thesis in geography, University of Paris 1, 2006.

[8] Moïssou LAGNIKA, Moudachirou IBIKOUNLE, Jean-Pierre C. MONTCHO, Valentin D. WOTTO, Nestor G. SAKITI. (2014). Physico-chemical characteristics of well water in the municipality of Pobè (Benin, West Africa). J. Appl. Biosci., 79:6887 – 6897.

[9] Malcuit Eline. Origin of water mineralization in a deep multilayer aquifer: example of the "mineralized zone of Entre-Deux-Mers" (Aquitain Basin, France). Earth Science. Thesis from the University Michel de Montaigne-Bordeaux III, 2012. France. 457 p.

[10] PNUD (2006). Human Development Report. Beyond scarcity: power, poverty and the global water crisis. Economica, New York, USA. 422 p. ».

[11] Rodier J.(1996), Water analysis (natural water ,Ground water, seawater) 8th Paris 1996,1260p.

[12] WWW.lenntech.com/calculators/ryznar/index/ryznar.htm.

[13] Brandhuber P., Frey, M., McGuire, M., Chao, P.F., Seidel, C., Amy, G., Yoon, J., McNeill, L. et Banerjee, K. (2004). Low-level hexavalent chromium treatment options: bench-scale evaluation. American Water Works Association Research Foundation, Denver, Colorado.

[14] NDOKI Bernard, Matini Laurent, Moutou Joseph Marie, Ifo Grace. Modeling of trihalomethanes in the water distribution network of Brazzaville, Congo. Research Journal of Recent Sciences Vol. 7(8), 1-10, August (2018).

[15] [15] Gouaidia L, MS Laouar, N. Défaflia and N. Zenati, (2018). Origin of groundwater mineralization of an aquifer in a semi-arid zone, case of the Merida aquifer, northeastern Algeria.

[16] ESSOULI Olivier Florent, Timothée MIYOUNA, Primaèle ESSOULI KESSIMPOU, Florent BOUDZOUMOU, Laurent MATINI, Serigne FAYE (2020). Hydrochemistry of surface and underground waters of the northern part of Brazzaville: Origin and process of mineralization. RAMReS Journal – Sci. Appl. & Ing., Vol. 2(1), p. 1-15. ISSN 2630-1164.

[17] HAMZAOUI AZAZA F, BOUHLILA R & GUEDDARI M. (2012). Characterization of the mineralization of the waters of the Triassic sandstone aquifer (South-East Tunisia) by geochemical and statistical methods. Geo-Eco-Trop., 36: 49-62

[18] Rodier J., Bernard L., Nicole M. et al. (2009). Water analysis 967th edition, Dunod, Paris 151p