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Hydrogeological and Physico-Chemical Study of the Groundwater of Mitendi South-East in the Commune of Mont-Ngafula around the Kimwenza Quarry (Province of Kinshasa, DR Congo)

Jonathan Mayi Nkolomonyi[1,2], Ivon Ndala Tshiwisa[1,2], Hervé Khonde Mbumba[1], Samuel Ingila Asanga[1], Clement N'zau Umba-Di-Mbudi[1,2,3]

[1]Geo-Hydro-Energy-Research Group, Geosciences Department, Faculty of Sciences and Technologies, University of Kinshasa, Kinshasa, Democratic Republic of Congo
[2]Geosciences Department, Faculty of Sciences and Technologies, University of Kinshasa, Kinshasa, Democratic Republic of Congo
[3]Polytechnic Faculty, President Joseph Kasa-Vubu University, Boma, Democratic Republic of Congo
Email: mayinkolomonyi@gamail.com, ivonndala@unikin.cd

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Abstract

The exploitation of groundwater by drilling in the Mitendi South-East district constitutes a solution to the water shortage in this peripheral part of the Mont-Ngafula township in Kinshasa, the capital of the DR Congo. Individuals exploit groundwater in boreholes to serve the population without taking into account certain necessary aspects such as the origin of the groundwater table and the quality which constitute the major problems of this work such as: What is the quantity of water from the recharge of our aquifer? What is the state of the Mitendi South-East aquifer water in relation to some physico-chemical parameters? The cardinal objective of this work is to provide chemical data and trace elements in each analyzed borehole and determine the type of recharge of the underground aquifer. The specific objectives are as follows: analyze the potability of groundwater on a physico-chemical level and their chemical facies, take the geographical coordinates of water samples from the aquifer in each targeted borehole in order to develop the sampling map of the area under study; also check each parameter analyzed in relation to WHO standards. We carried out a general investigation of the study area by carrying out observations, sampling and *in-situ* measurements of each borehole, as well as the good conservation of the samples taken in a cooler. The various measurements that we took *in-situ*: pH, electrical conductivity, turbidity, salinity, temperature, and TDS were carried out by using a multi-parameter probe in the laboratory of appropriate methods such as titled-sorting, spectrophotometry, atomic absorption spectrometry, ArcGise and Excel software. With regard to the results from laboratory analysis (physical and chemical analysis), the parameters showed that the standards recommended by the WHO were not respected. We affirm that the water consumed in the Mitendi South-East district in Mont-Ngafula town ship is not drinkable. Since, it can cause several water-borne diseases. It would be better to treat that water before being drunk.

Keywords

Groundwater, Aquifer, Physicochemical Parameters, Mitendi, Kimwenza Quarry

1. Introduction

Water is essential for good health, which ensures the cleanliness of the body, and good growth and guarantees their vital role (food and respiration). When it is in insufficient quantity and of poor quality, it is dangerous for health. Water, as we know, occupies approximately 70% of the earth. Three quarters of fresh water is blocked in the surface far from any human habitation (AQUATER, 1987). And only 1% available is found in rivers… renewed by rainfall and others. It is these groundwater and surface waters that we use (Ndembo, 2009; Makoko & Ndembo, 1987).

Indeed, the Democratic Republic of Congo (DRC) is a country which alone has 40% of the 70% of fresh water in Africa and 50% of forests in Africa constitute a real receptacle for regulating the hydrological cycle (Berger, 1994). However, less than 50% of the Congolese population has access to drinking water (CNAEA, 2003).

Despite the liberalization of the water sector by our leaders in the DRC, the exploitation of groundwater by private individuals constitutes a more profitable means of resource in the city of Kinshasa, particularly in the Mitendi South-East district of the commune of Mont-Ngafula (REGIDESO, 2001). The exploitation of groundwater in the Mitendi Sud-Est district constitutes a solution to the water shortage in this corner of the commune of Mont-Ngafula in Kinshasa because it is a peripheral entity of the capital of the DRC that REGIDESO has not yet been used.

The correct regulatory provisions are not taken into account by our leaders to unanimously control what is exploited inside the capital of the DRC and put on sale to the population, finally to protect it. Individuals exploit groundwater by drilling to serve the population without taking into account certain necessary aspects such as the origin of the groundwater table and the quality which constitute the major problems of this work such as: What is the quantity of water from the recharge of our aquifer? What is the state of the Mitendi South-East aquifer water in relation to some physico-chemical parameters?

The cardinal objective of this work is to provide chemical data, metallic trace elements in each analyzed borehole and determine the type of recharge of the underground aquifer. The specific objectives are as follows: calculate the recharge of the aquifer; analyze the potability of groundwater on a physico-chemical level and their chemical facies, take the geographical coordinates of each point of water samples from the aquifer in each targeted borehole in order to develop the sampling map of the area under study, but also verify each parameter analyzed against WHO standards.

We carried out a general investigation campaign in the study area by carrying out observations, sampling and *in-situ* measurements of each borehole, as well as the good conservation of the samples taken in a cooler. The different measurements that we took in situ: pH, electrical conductivity, turbidity, salinity, temperature, and TDS were carried out using appropriate methods (titrimetry, spectrophotometry, atomic absorption spectrometry, ArcGis and Excel software).

It is with this in mind that we found ourselves obliged to better collect water samples from different boreholes in Mitendi South-East and the various rainfall data as well as temperature measurements from June 2012 to May 2020.

2. Study Area

The Mitendi district which is the study area has been created since 1987. It is limited to the North by the Nkayi locality and the Lutendele district, to the South by the Mbuki district and the Kasangulu locality, to the East by the Musangu district, Kimwenza from which it separates by the Lukaya and Mambidisi rivers, and finally to the West, it is the locality of Kimvulu which delimits it and which forms its border with the KongoCentral province (Kasangulu Territory).

3. Methodology

Apart from the documentation stage, the methodology used in the development of this work consisted of the selectivity of drilling water with a high customer base in the purchase of water in the Mitendi South-East district, sampling of drilling water which leaves directly into the aquifer to avoid contamination of our sample by the tank or the modification of the chemical elements following the reactions due to failure to keep the temperature at four degrees Celsius and the coupling of three stages below.

3.1. Field Stage

We carried out a general investigation campaign in the study area by carrying out observations, sampling and *in-situ* measurements at each drilling, as well as the good conservation of the samples taken in a cooler.

The different measurements that we took in situ: pH, electrical conductivity, turbidity, salinity, temperature, TDS. Our field work was obviously oriented towards contributing to the knowledge of the hydrogeology and hydrogeochemistry of the site's aquifer.

In short, this step consists first of all in the use of bottles for taking samples of aquifer water. The different field instruments are: an *in-situ* measuring probe, a Garmin brand GPS, field minute, gloves, markers, cooler, tape, field notebook, phone camera, pens and pencils, bottles suitable for water sampling, and other accessories.

The water sampling points from the boreholes represented by the green and red dotted lines represent National Road No. 01, the location of which is shown in Figure 1.

In front of a borehole or in front of a place where water came out of the aquifer after pumping into a tank, in order to avoid the rest time which modifies the physico-chemical parameters, the different operations below were carried out: taking geographic coordinates; taking the photo; taking a representative sample of the water; and a brief description of the location. To do this, the following equipment was used for collecting and storing the samples: a multi-parameter

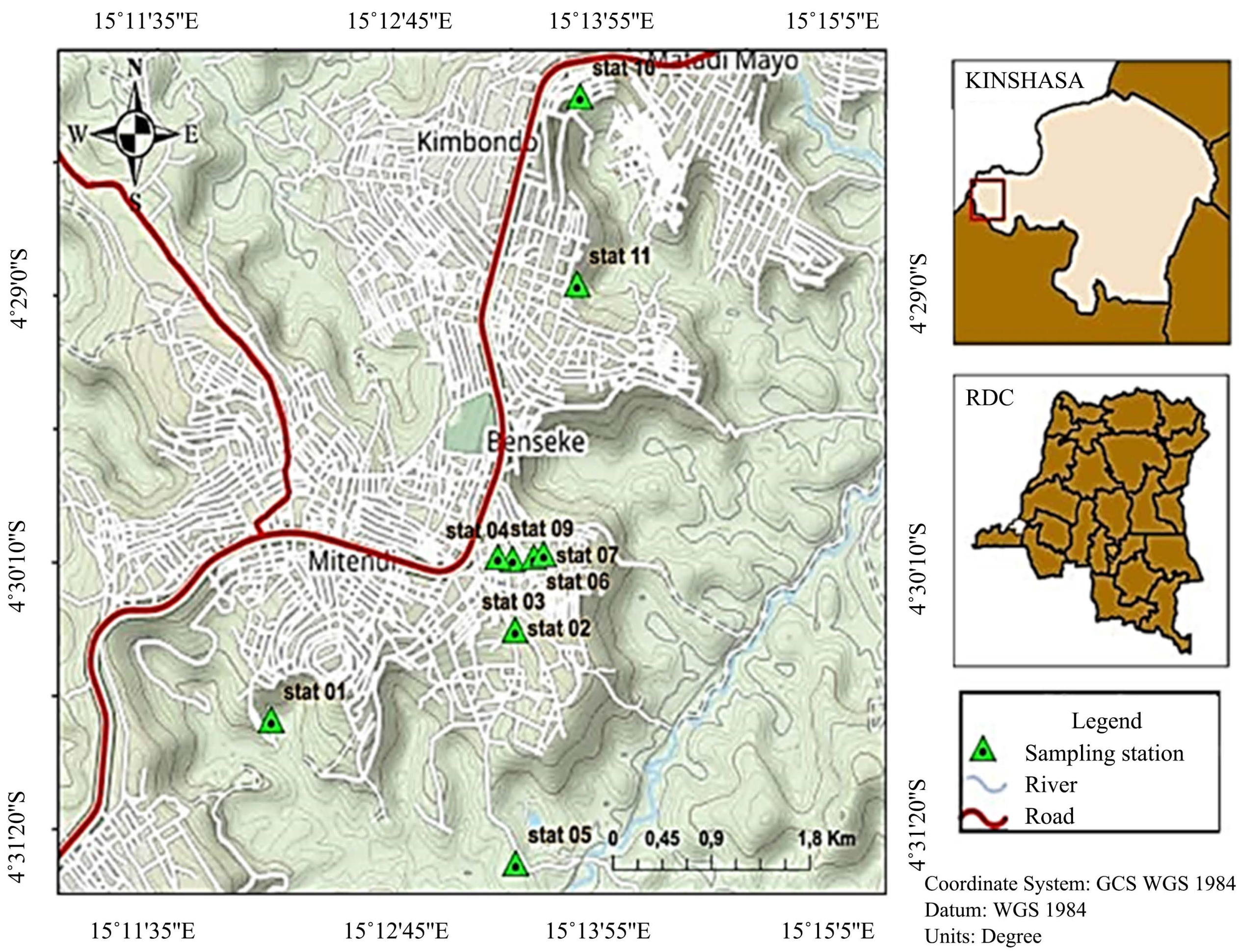

Figure 1. Map of the location of the boreholes sampled in the study area.

probe, a Garmin type GPS for taking the geographic coordinates used in the location; bottles for storing samples taken; gloves; a cooler for good storage of samples; notebooks for taking notes; and a phone camera for taking photos (Figure 2). These devices allowed us to obtain the results of the physical parameters of the water. The different samples were subsequently used in the laboratory to determine the physicochemical parameters and trace elements.

3.2. Laboratory Stage

This stage concerns the different analyzes and treatments carried out on the water samples collected in the field in order to arrive at the results on which the interpretations are based, thus making it possible to make a hydrogeochemical contribution to the area under study.

We used the materials according to the chosen method; for the Titrimetry method where we used the following equipment: OHAUS stirrer, Beaker, Graduated burette, Graduated foot, Pi-pette, Wash bottle, Spatula, Pear, Stand, Erlenmeyer, OHAUS balance, Volumetric flask, Tweezers.

Figure 2. (a): *In-situ* sampling of pH, T˚, TDS, Salinity, electrical conductivity with the multi-parameter probe; (b): Equipment used to collect and preserve samples: a GPS (1), multi-parameter probe (2), a cooler (3), bottle (4); (c): Sampling of the water which leaves the aquifer after pumping before reaching the cistern at the borehole flange level (5); (d): Sampling of water leaving the aquifer after pumping.

Other than these elements, we used the Spectrophotometric method where there is the Spectrophotometer with the reagents that we added and stirred according to the timer indicated by the device for each chemical compound. Without forgetting the method known as Atomic Absorption Spectrometry (AAS).

The analysis and processing of data collected in the field was carried out using software such as ArcGIS (sampling map), Excel (graphs and piper diagrams).

3.3. Interpretation and Discussion Stage

After analyzes and processing of collected data, we moved to the stage of interpretation and discussion to give a hydrogeochemical meaning to all the results obtained. Based on the rigorously processed data, it was a question of expressing our point of view here according to the standards required in all the approaches addressed in this work.

4. Results

4.1. Contribution to the Hydrogeology of the Mitendi South-East Site

Knowing that groundwater mainly originates from precipitation, we begin by quantifying the rainwater that falls in the area under study. The rainfall data from the Mbinza station allowed us to know the ETPa and bring out the runoff value, the humidity gradient as well as the effective infiltration (aquifer recharge) Table 1 and Table 2 below:

$$\text{EPTm} = 16\left(\frac{10 \times \text{T}^{\circ}\text{moy}}{\text{I}}\right)^{a} \quad \text{For} \quad \text{T}^{\circ}\text{moy} \leq 26^{\circ}\text{C}$$

$\text{I} = \sum_{i=1}^{12} i$ Heat index worth the sum of the values for 12 months of the year. According to Pereira and Pruitt (2004),

Table 1. Rainfall data from June 2012 to May 2020 (Mbinza weather, 2020).

Years	January	February	March	April	May	June	July	August	September	October	November	December	Tot. years
2012	9.6	114.2	101.7	119.4	184	0	0	4.2	54.6	229.1	274	292.8	1383.6
2013	204.1	212	216.7	385.5	249.2	0	0	0	25.8	180.7	260.4	339	2075.4
2024	197.8	33.8	182.4	196.8	214.6	0	1.2	6.8	20.9	172.8	245.4	118.4	1390.9
2015	48.8	87.0	189.9	192.7	97.7	0	0	0	13.2	74.4	389.3	351.1	1390.9
2016	100.2	251.6	419.0	198.1	204.6	2.8	0.0	63.6	15.8	107.4	311.6	220.1	1444.1
2017	153.2	237.5	55.7	167.0	226.8	21.2	0	0	56.6	103.4	148.5	382.8	1894.8
2018	253.9	180.3	79.0	180.0	191.7	5.9	0	0	2.0	139.1	250.0	510.5	1552.5
2019	181.1	218.8	214	102.8	109.4	0.0	0.0	0.0	47.6	450.5	267.4	348.8	1940.0
2020	269.4	165.4	15.8	380.5	177.2	0.0	3.2	0.0	11.5	187.0	261.5	261.5	1831.1

Table 2. Temperature measurement from June 2012 to May 2020 (Mbinza weather, 2020).

Years	January	February	March	April	May	June	July	August	September	October	November	December	Tot. years
2012	25.9	26.1	27.4	25.8	25.8	0	22.1	22.1	25.1	25.2	255.2	25.3	25.2
2013	26.1	26.4	26.7	26.6	25.8	0	22.4	22.4	23	25.5	25.5	25	25.1
2024	25.4	26.3	26	26.4	26	0	21.6	21.6	23.4	25.2	25.2	25.5	25
2015	25.5	25.9	25.8	26.1	25.8	0	23.7	22.8	23.0	25.7	25.0	25.5	24.9
2016	25.9	26.1	26.6	25.9	25.4	2.8	23.4	22.3	23.5	25.0	25.4	25.5	25.0
2017	24.6	26.0	26.6	26.4	25.5	21.2	23.4	22.2	23.0	24.8	25.0	24.8	24.7
2018	25.9	26.5	26.0	26.7	25.0	5.9	24.2	23.0	24.4	26.2	26.0	25.0	25.3
2019	25.9	26.3	27.4	26.7	25.7	0.0	23.9	22.0	23.0	25.2	25.0	25.5	25.0
2020	25.1	26.3	26.8	26.9	26.2	0.0	23.3	22.8	23.6	24.4	25.4	26.3	25.1

Maximum monthly temperature: 30˚C; Minimum monthly temperature: 22˚C; Average monthly temperature: 25˚C.

$$i = \left(\frac{Te}{5}\right)^{1.514}$$

where Te is monthly average temperature corrected in terms of effective temperature.

$$Te = K\left(T^{\circ}max + T^{\circ}avg - T^{\circ}min\right)$$

where K = 0.69 (K is a constant given by Pereira and Pruitt (2004).

It was reduced to 0.69 for one generation in all climates.

$$a = 675 \times 10^{-9} I^3 - 771 \times 10^{-7} \times I^2 + 0.01792 \times I + 0.49239$$

In the case of Mitendi Sud-Est, for the period from June 2019 to May 2020 with T˚max = 30˚C, T˚min = 22˚C, T˚avg = 25˚C.

We find: Te = 0.69 (T˚max + T˚avg − T˚min) = 0.69 (30 + 25 − 22) = 22.77˚C.

$$i = \left(\frac{Te}{5}\right)^{1.514} = \left(\frac{22.77}{5}\right)^{1.514} = 9.9267$$

$$I = i \times 12 = 9.9267 \times 12 = 119.1209$$

$$\begin{aligned} a &= 675 \times 10^{-9} I^3 - 771 \times 10^{-7} \times I^2 + 0.01792 \times I + 0.49239 \\ &= 675 \times 10^{-9} \times 119.1209^3 - 771 \times 10^{-7} \times 119.1209^2 \\ &\quad + 0.01792 \times 119.1209 + 0.49239 \\ &= 1.140952205214780 - 1.09403235040722624 + 2.13464616 + 0.49239 \end{aligned}$$

$$a = 2.67395$$

$$EPTm = 16\left(\frac{10 \times T^{\circ}moy}{I}\right)^{a} = 16\left(\frac{10 \times 25}{119.1209}\right)^{2.67395} = 116.14448 \text{ mm}$$

The annual potential evapotranspiration is:

$$EPTa = 116.14448 \times 12 = 1393.73376 \text{ mm}$$

Characteristic of the aquifer

The capacity of the Mitendi South-East soil:

Total D = 1785.125 mm

$$Hs = \frac{10}{100} \times 1785.125 \text{ mm} = 178.5125 \text{ mm}$$

The soil is much more sandy, so the soil capacity (Hs) is 10% of P, i.e. Hs = 178.51 mm.

Hr = retention in the root zone considered at 1000 mm in savannah, therefore,

Hr = 10/100 × 1000 mm = 100 mm for the savannah;

Hs = Soil moisture gradient.

Runoff is 5% P: R = 5/100 × 1785.125 = 89.25 mm.

Recharge of the South-East Mitendi aquifer:

$$Ie = P - (R + ETPa + \Delta hs) \Rightarrow 1785.125 - (89.25 + 1393.73376 + 78.51)$$

$$Ie = 1785.12 - 1561.49 = 223.63 \text{ mm}$$

$$\text{Total ne} = \frac{Ie \times 100}{P}$$

$$ne = \frac{223.63 \text{ mm} \times 100}{1785.125 \text{ mm}} = 12.5\% \quad \text{(Porosity)}$$

The effective porosity, which is equal to 12.5%, corresponds to moderately permeable soil having varied grain sizes, ranging from fine sands to silts. Our aquifer is granular.

4.2. Physico-Chemical Analysis of Mitendi South-East Aquifer Waters

In order to make a qualitative approach to the results of the analyzes carried out, classification standards were carried out for each of the following parameters: chlorides, magnesium, calcium, electrical conductivity.

Table 3 below determines the parameters taken in situ. These are: temperature, pH, electrical conductivity, salinity, turbidity and dissolved solids rate. Indeed, these parameters are very sensitive to environmental conditions and likely to vary significantly if they are not measured on site.

Table 3. Summary table of pH and T˚ values, salinity, TDS, turbidity, conductivity taken in situ.

Stations	Hydrogen potential (pH)	Temperature	Sainity Concentration (s/L)	TDS Correction (ppm)	Turbidy (in NTU)	Electrical Conductivity
1	5.8	27.3˚C	0.02	13.2	0.55	26.1
2	5.0	27.3˚C	0.01	14.1	1.86	11.5
3	4.55	27.8˚C	0.01	7.7	0.49	9.8
4	5.2	27.5˚C	0.01	25.3	0.69	12.7
5	5.0	27.3˚C	0.01	14.7	1.32	12.5
6	4.1	27.4˚C	0.03	41.5	0.56	48.2
7	4.6	27.7˚C	0.01	14.0	0.56	16.7
8	4.0	25.6˚C	0.01	14.3	0.91	15.5
9	4.7	27.5˚C	0.02	15.3	0.57	16.8
Average	4.7	27.2˚C	0.01	17.1	0.83	18.8

Table 4 below presents the elements analyzed by method.

Atomic absorption spectroscopy is a chemical analysis technique that makes it possible to determine the concentration of trace elements present in a sample. It is based on the phenomenon of absorption of light by the atoms present in the sample.

Atomic absorption spectroscopy is widely used in many fields such as water analysis, metal analysis in materials, environmental analysis, food analysis, etc. It is appreciated for its high sensitivity, its specificity and its ability to measure several elements simultaneously (Table 5).

To clearly visualize the results of chemical analyzes carried out on groundwater, it is useful to make the representation according to Piper.

The Piper diagram (Figure 3) is well suited for the comparative study of a large number of samples. In addition, the diagram highlights the evolution and change of the chemical facies.

However, it presents a risk of error which lies in the comparison of samples, due to the fact that the representation of the analyzes on this diagram is made in percentages (%). In Figure 1 representing the Piper diagram, we see the 3 boreholes are hyper-calcium chloride and the 6 others are chloride, calcium sulfate and magnesium.

The chemical facies of groundwater was determined using this Piper diagram. It shows that the waters of the study area have a dominant chemical facies which is the calcium hyper-chloride and calcium and magnesium sulfate facies.

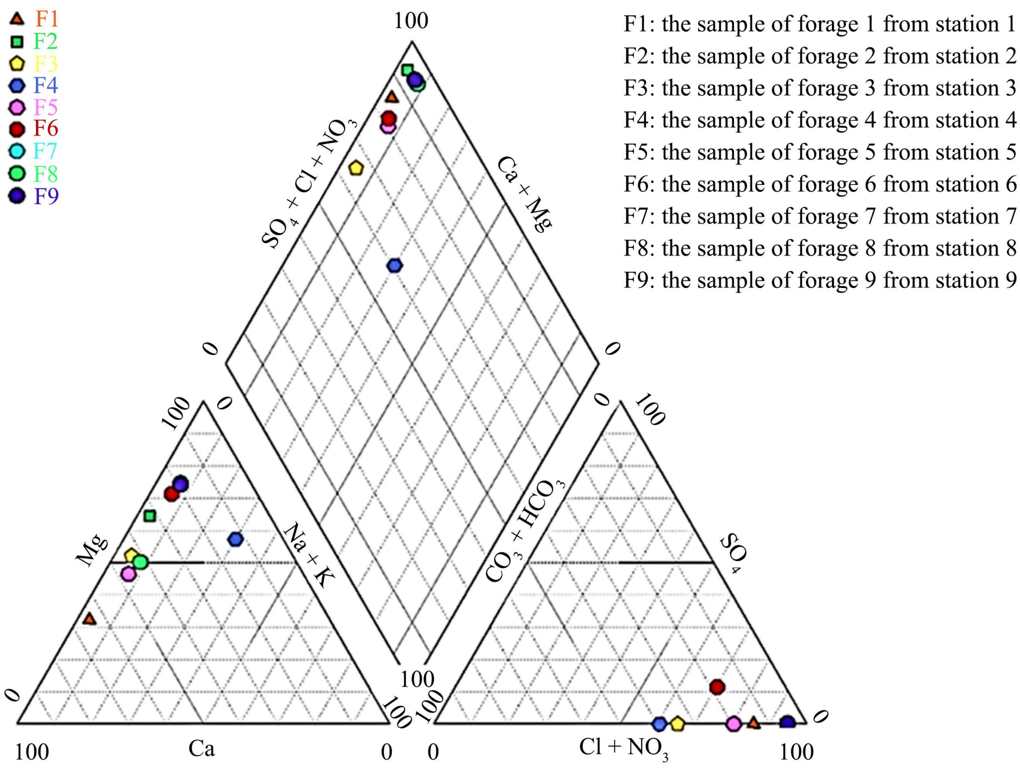

Figure 3. Representation of chemical facies on the Piper diagram.

Table 4. Summary of elements analyzed by method.

Stations	Calcium Concentration (mg/L)	WHO standards Between 60 to 270 mg/L	Appreciation
1	16.03	60 - 270 mg/L	Bad
2	6.01	60 - 270 mg/L	Bad
3	12.02	60 - 270 mg/L	Bad
4	3.20	60 - 270 mg/L	Bad
5	8.01	60 - 270 mg/L	Bad
6	6.41	60 - 270 mg/L	Bad
7	4.00	60 - 270 mg/L	Bad
8	8.01	60 - 270 mg/L	Bad
9	4.1	60 - 270 mg/L	Bad
Average	7.53		Bad
Stations	**Magnesium Concentration (mg/L)**	**WHO standard is ≤10 µg/L**	**Appréciation**
1	4. 86	10 mµg/L	Good
2	7.29	10 mµg/L	Good
3	8.75	10 mµg/L	Good
4	8.75	10 mµg/L	Good
5	4.86	10 mµg/L	Good
6	12.15	10 mµg/L	Bad
7	9.72	10 mµg/L	Good
8	5.83	10 mµg/L	Good
9	9.73	10 mµg/L	Good
Average	7.99		Good
Stations	**Alkalinity concentration (mg/L)**	**WHO standard Between 80 and 140 mg/L**	**Appreciation**
1	3.05	80 - 140 mg/L	Bad
2	0.61	80 - 140 mg/L	Bad
3	18.30	80 - 140 mg/L	Bad
4	12.20	80 - 140 mg/L	Bad
5	3.05	80 - 140 mg/L	Bad
6	6.10	80 - 140 mg/L	Bad
7	0.61	80 - 140 mg/L	Bad
8	0.61	80 - 140 mg/L	Bad
9	0.62	80 - 140 mg/L	Bad
Average	5.01		Bad

Continued

Stations	Chloride concentration (mg/L)	WHO standard is 250 mg/L	Appreciation
1	9.926	250 mg/L	Bad
2	5.672	250 mg/L	Bad
3	19.852	250 mg/L	Bad
4	10.635	250 mg/L	Bad
5	7.09	250 mg/L	Bad
6	10.635	250 mg/L	Bad
7	6.0265	250 mg/L	Bad
8	6.0265	250 mg/L	Bad
9	6.0266	250 mg/L	Bad
Average	9.09		Bad

Stations	Nitrate concentration (mg/L)	WHO standard is 50 mg/L	Appreciation
1	1.3	50 mg/L	Bad
2	0.5	50 mg/L	Bad
3	0.3	50 mg/L	Bad
4	0.4	50 mg/L	Bad
5	0.3	50 mg/L	Bad
6	5.4	50 mg/L	Bad
7	1	50 mg/L	Bad
8	0.9	50 mg/L	Bad
9	1.1	50 mg/L	Bad
Average	2.35		Bad

Stations	Sulfate Concentration (mg/L)	WHO Standard: 250 - 500 mg/L	Appreciation
1	0.0	200 mg/L	Bad
2	0	200 mg/L	Bad
3	0.0	200 mg/L	Bad
4	0	200 mg/L	Bad
5	0.0	200 mg/L	Bad
6	3	200 mg/L	Bad
7	0.0	200 mg/L	Bad
8	0.0	250 mg/L	Bad
9	0.01	250 mg/L	Bad
Average	0.33		Bad

Continued

Stations	Nitrite concentration (mg/L)	WHO standard 3 mg/L	Appreciation
1	0.009	3 mg/L	Bad
2	0.015	3 mg/L	Bad
3	0.007	3 mg/L	Bad
4	0.015	3 mg/L	Bad
5	0.005	3 mg/L	Bad
6	0.009	3 mg/L	Bad
7	0.005	3 mg/L	Bad
8	0.004	3 mg/L	Bad
9	0.006	3 mg/L	Bad
Average	0.008		Bad
Stations	**Iron concentration (mg/L)**	**WHO standards 0.3 mg/L**	**Appreciation**
1	0.04	0.3 mg/L	Bad
2	0.08	0.3 mg/L	Bad
3	0.06	0.3 mg/L	Bad
4	0.056	0.3 mg/L	Bad
5	0.02	0.3 mg/L	Bad
6	0.03	0.3 mg/L	Bad
7	1.33	0.3 mg/L	Bad
8	0.31	0.3 mg/L	Bad
9	1.34	0.3 mg/L	Bad
Average	0.36	0.3 mg/L	Bad

The most weighty cations in water are magnesium while the dominant anion is chloride…

The interception of the two triangles made it possible to find that F2, F8 and F9 are calcium hyper-chloride and F1, F3, F4, F5 and F6 are chloride, calcium and magnesium sulfate, F7 does not appear in the facies. Indeed, the presence of elements such as nitrates, chlorides, sodium, potassium and sulfates can be the consequence of anthropogenic activities, and is linked to the discharge of waste of all kinds into nature, to the use of fertilizers. And the presence of septic tanks or soakaway wells in the absence of a collective sanitation network, which is the case for our study area. We can already think of pollution coming from the surface and which is linked to anthropogenic activities.

Table 5. Concentration of AI, As, B, Ba, Cd, Co, Cu, Hg, K, Mn, Na, Ni, P, Pb, S, U, V, Zn compared to WHO standards.

Stations	Aluminium (Al)	Arsenic (As)	Baryum (Ba)	Cadmium (Cd)	Cobalt (Co)	Chrome (Cr)
Unit	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
F6	0.033	0.007	0.004	0.007	0.001	0.001
F1	0.024	0.017	0.001	0.007	0.005	0.003
F2	0.006	0.001	0.001	0.01	0.001	0.001
F3	1.036	0.01	0.018	0.011	0.005	0.003
F4	0.055	0.015	0.005	0.012	0.001	0.001
F5	0.027	0.01	0.002	0.013	0.01	0.002
Average	0.19	0.01	0.0	0.01	0.0	0.0
WHO Standards and Appreciation	0.2 mg/L Bad	0.01 mg/L Bad without F3 and F5	0.3 m/L Bad	0.003 mg/L Bad	bad	0.05 mg/L Bad
Stations	**Copper (Cu)**	**Mercury (Hg)**	**Potassium (K)**	**Manganèse (Mn)**	**Sodium (Na)**	**Nickel (Ni)**
Unit	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
F6	0.001	0.001	0.406	0.008	1.634	0.003
F1	0.001	0.001	0.295	0.001	0.756	0.002
F2	0.001	0.001	0.073	0.001	0.663	0.012
F3	0.01	0.001	0.645	0.051	1.131	0.005
F4	0.054	0.001	0.509	0.014	8.422	0.001
F5	0.001	0.001	0.287	0.001	1.175	0.01
Average	0.01	0.0	0.36	0.0	2.39	0.0
WHO Standards and Appreciation	2 mg/L Good	0.001 Good	≤12 mg/L Good	0.5 mg/L Bad	200 mg/L Bad	0.02 mg/L Bad
Stations	**Phosphorus (P)**	**lead (P)**	**Suffer (S)**	**Uranium (U)**	**Vanadium (V)**	**Zinc (Zn)**
Unit	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
F6	0.017	0.02	0.142	0.006	0.001	0.006
F1	0.01	0.021	0.227	0.005	0.001	0.004
F2	0.001	0.034	0.273	0.006	0.001	0.003
F3	0.001	0.031	0.129	0.006	0.001	0.011
F4	0.001	0.034	0.144	0.004	0.001	0.054
F5	0.001	0.035	0.218	0.004	0.001	0.005
Average	0.0	0.02	0.12	0.0	0.0	0.0
WHO Standards and Appreciation	bad	0.01 mg/L Bad	bad	0.015 mg/L Bad	bad	3 mg/L Bad

5. Discussions

Precipitation data (Table 6) is essential for understanding the recharge regime of aquifers, assessing groundwater resources and making informed decisions in water resources management to avoid the drying up of certain exploited boreholes. We consider the period from June 2012 to May 2020, the total rainfall is 1785.125 mm for all hydrological years. The temperature data served us to have the true value of evapotranspiration and the idea of the maximum precipitation of a year and led us to have the runoff, the soil humidity gradient and also the recharge (Infiltration effective) (Devred, 1959).

✓ Maximum monthly temperature: 30˚C;

✓ Minimum monthly temperature: 22˚C;

✓ Average monthly temperature: 25˚C.

After analysis, we notice the months of October, November, December, March, April with more rain and the months of February with less rain; moreover, the months of June, July, August and September are almost dry.

Table 6 below shows the physical parameters of the *in-situ* measurement data.

Station 1 has the high pH of 5.8 and station 8 has the low pH of 4.0. Following WHO standards, we observe that all the pH values taken from the waters exploited by drilling in our study area are acidic.

The pH of water presents its acidity when it is less than 6.5 but greater than 8.5 the water is called basic, when the pH = 7 the water is called Neutral (good quality). It is impossible for pH to be a contraindication to the potability of water; it is one of the most important parameters of water quality. It must be closely monitored during all processing operations.

Table 6. pH and T˚ compared to WHO standards.

Stations	pH	Standards between 6.5 and 8.5	Appreciation	T˚C	WHO standards between 25˚C - 30˚C
1	5.8	[6.5 - 8.5]	Acid	27.3˚C	Good
2	5.0	[6.5 - 8.5]	Acid	27.2˚C	Good
3	4.55	[6.5 - 8.5]	Acid	27.8˚C	Good
4	5.2	[6.5 - 8.5]	Acid	27.5˚C	Good
5	5.0	[6.5 - 8.5]	Acid	27.3˚C	Good
6	4.1	[6.5 - 8.5]	Acid	27.4˚C	Good
7	4.6	[6.5 - 8.5]	Acid	27.7˚C	Good
8	4.0	[6.5 - 8.5]	Acid	25.6˚C	Good
9	4.7	[6.5 - 8.5]	Acid	27.5˚C	Good
Average	4.7		Acid	27.2˚C	Good

The acidity of water is also linked to the dissociation of carbonic acid from atmospheric CO_2 dissolved in water, and to that of humic and fulvic acids released during the degradation of organic matter. In addition to the latter, we will present the parameters of salinity, TDS, turbidity, electrical conductivity compared to the WHO (Table 7). We will represents the physical multi-parameters in the graph (Figure 4).

- ✓ Station 6 has the high salinity of 0.03 g/L. For the rest, the salinity rate is almost constant in all stations.
- ✓ Station 6 of solids has the high rate of dissolved solids which is 41.5 ppm and station 3 the rate is low which is 7.7 ppm.
- ✓ Station 2 has high turbidity which is 1.86 NTU and station 3 the turbidity is low 0.49 NTU. Furthermore, the WHO (World Health Organization) guidelines specify that the median turbidity of disinfected water should not be greater than 1 NTU, the maximum value tolerated in a single sample being 5 NTU (OMS, 2000).
- ✓ Station 6 has the high conductivity which is 48.2 $\mu S \cdot cm^{-1}$ and station 3 has the low conductivity which is 9.8 $\mu S \cdot cm^{-1}$.
- ✓ Station 6 has the high salinity of 0.03 g/L. For the rest, the salinity rate is almost constant in all stations.

Figure 4 below represents the physical multi-parameters.

The graph shows us: physical parameters such as TDS and conductivity which have different values in each sampling point not exceeding the acceptable range by WHO standards. In the same graph we observe parameters such as turbidity which has values not having a big deviation in all our samples anddoes not meet WHO standards. PH: Is acidic in all our samples because the soil of Mitendi is acidic, there has been an exchange of acidity from lithology and groundwater. Does not meet WHO standards.

Temperature: The temperature of our samples is almost the same. The exploited aquifers have the same temperature.

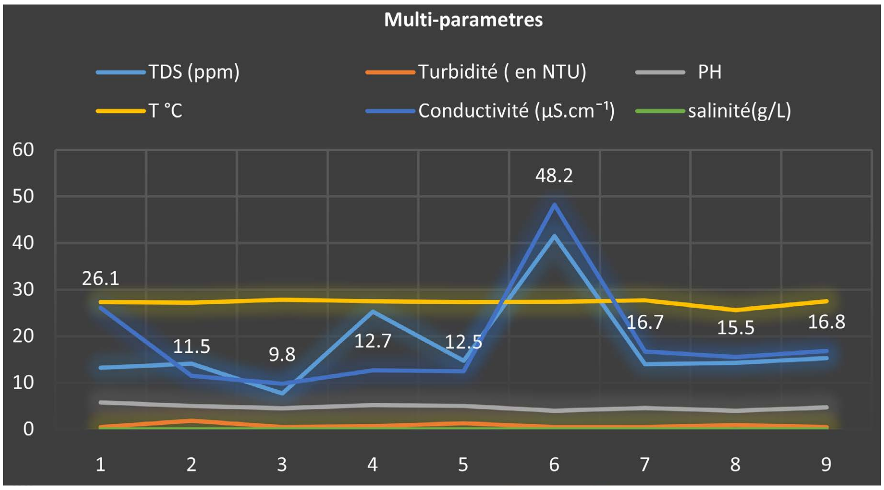

Figure 4. Representation of physical parameters.

Table 7. Salinity, TDS, Turbidity, electrical conductivity values compared to WHO.

Stations	Salinity concentration (g/L)	WHO standards Including 1 and 10 g/L	Appreciation
1	0.02	1 à 10 g/L	Bad
2	0.01	1 à 10 g/L	Bad
3	0.01	1 à 10 g/L	Bad
4	0.01	1 à 10 g/L	Bad
5	0.01	1 à 10 g/L	Bad
6	0.03	1 à 10 g/L	Bad
7	0.01	1 à 10 g/L	Bad
8	0.01	1 à 10 g/L	Bad
9	0.02	1 à 10 g/L	Bad
Average	0.01		Bad
Stations	**TDS concentration (ppm)**	**WHO standards is 1000 ppm**	**Appreciation**
1	13.2	1000 ppm	Bad
2	14.1	1000 ppm	Bad
3	7.7	1000 ppm	Bad
4	25.3	1000 ppm	Bad
5	14.7	1000 ppm	Bad
6	41.5	1000 ppm	Bad
7	14.0	1000 ppm	Bad
8	14.3	1000 ppm	Bad
9	15.3	1000 ppm	Bad
Average	17.7		Bad
Stations	**Turbidity (in NTU)**	**WHO standards ≤ 5 NTU**	**Appreciation**
1	0.55	≤5 NTU	Bad
2	1.86	≤5 NTU	Bad
3	0.49	≤5 NTU	Bad
4	0.69	≤5 NTU	Bad
5	1.32	≤5 NTU	Bad
6	0.56	≤5 NTU	Bad
7	0.56	≤5 NTU	Bad
8	0.91	≤5 NTU	Bad
9	0.57	≤5 NTU	Bad
Average	0.83		Bad

Continued

Stations	Electrical condutivity ($\mu S \cdot cm^{-1}$)	WHO standards is 250 µS·cm	Appreciation
1	26.1	250 µS·cm	Bad
2	11.5	250 µS·cm	Bad
3	9.8	250 µS·cm	Bad
4	12.7	250 µS·cm	Bad
5	12.5	250 µS·cm	Bad
6	48.2	250 µS·cm	Bad
7	16.7	250 µS·cm	Bad
8	15.5	250 µS·cm	Bad
9	16.8	250 µS·cm	Bad
Average	18.8		Bad

NB: the Multi-parameter Diagram is a summary of the physical measurements taken in situ during the sampling campaign.

6. Conclusion

We must remember several points as follows:

1) Although the geology of Kinshasa is known from the work of Eggoford and having not witnessed certain executions of the drillings sampled during our fieldwork, the pre-occupation of the type of aquifers was for us an important element which allowed us to confirm the presence of fine sands (our aquifer is of the granular type) (Egoroff, 1955, 1947). Thanks to the results of ETPa1393.73376 mm, precipitation 1785.125 mm, soil capacity 178.51 mm, runoff 89.25 mm, moisture gradient 78.51 mm and effective infiltration 223.63 mm which we used to find the recharge of the aquifer with a porosity of 12.5%.

2) Based on the physical analyzes carried out in situ, the parameters not meeting WHO standards are: pH, conductivity, salinity and TDS on the other hand, T° and turbidity meet WHO standards, the non-compliant according to WHO standards are the consequences of the following: Digestive problems, skin irritation, dehydration, gastrointestinal disorders, kidney problems, cardiovascular problems (Attei, 2005), etc.

3) For the Chemical parameters which do not correspond to the WHO standards are the following: Nitrate, Iron, Calcium, Alkalinity, Chlorine, Sulfate, Nitrite on the other hand only magnesium corresponds to the standards, the consequences are as follows: weak immune system, high blood pressure, inadequate hydration, metabolic imbalances, gastrointestinal disorders, etc.

4) Considering the results of laboratory analyzes in comparison with the standards recommended by the WHO, we would like to affirm that the water consumed in the Mitendi Sud-Est district in the Municipality of Mont-Ngafula is

not drinkable and likely to cause several of the aforementioned water-borne diseases. Before drinking, this underground water from Mitendi SOUTH-EAST must be treated.

7. Recommendation

Suggestions to Governments and Public Decision-makers:

- ✓ To create a database on groundwater drilling containing information in particular on location, depth and litho-stratigraphy (Corin & Huge, 1948);
- ✓ Beyond the control of the import and export of bottled water from drilling sold by companies which process and submit the samples for analysis to the Congolese control office, they must see the individuals who sell without a company, without analysis and processing before making their markets without taxes or fees. This constitutes a loss of income and a danger to public health. To provide a framework composed of objectives, standards and regulations allowing and requiring water suppliers to fulfill the obligations defined with regard to drinking water (Loi portant fonctionnement de l'office de controle congolais, 1974);
- ✓ Invest sufficiently in drinking water supply projects;
- ✓ To regulate the water sector, while ensuring through permanent monitoring strict compliance with the standards in force by the company, the NGO and individuals working in the sector; Support material and financial study work and research on water quality (Berger, 1994);
- ✓ Allow close and effective synergy between governments and scientists.

Suggestions for Scientists:

- ✓ To organize studies and research on the quality of our fresh water resources;
- ✓ To participate in the preservation of the quality of fresh water resources through raising awareness among the general public by organizing forums and themes centered on the methods, behavior and techniques to be internalized to mitigate the nuisances linked to the water quality.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

AQUATER (1987). *Etude Hydrogéologique et de Recherche des Eaux Souterraines dans la partie Est de Kinshasa*. Régie de Distribution d'Eau. Kinshasa. Rapport inédit.

Attei, O. (2005). *Chimie et pollution des eaux souterraines*. Lavoisier, 398 p.

Berger, L. (1994). *Etude national du plan du développement secteur de l'eau et de l'assainissementdu Zaïre1991-2015*. Rapport n°9, Plan Directeur National. Comité National d'Action de l'eau et de l'assainissement (CNAEA). Kinshasa. Rapport inédit, 194 p.

CNAEA (2003). *Réforme du secteur de l'eau et de l'assainissement en République Démocratique duCongo*. Rapport du Séminaire National.

Corin, F., & Huge, J. (1948). *Bulletin du Service Géologique*. Bureau de Léopoldville et Bureau de Costemansville, Service Géologique du Congo belge, Léopoldville, 38 p.

Devred, R. (1959). *Carte de la végétation du Congo-Belge et du Rwanda-Urundi*. Soc. Roy. Forest.

Egoroff, A. (1947). *Bulletins du service géologique de Léopoldville de la Direction Générale des Affaires Economiques*. Service géologique du Congobelge.

Egoroff, A. (1955). *Esquisse géologique provisoire du sous-solde Léopoldville d'après les données de sondage*. Service Géologique du Congo Belge et du Rwanda Urundi. Léopoldville. Bulletin, n˚6, 3-7.

La Loi Portant Fonctionnement de L'Office de Controle Congolais (RDC), pour La loi numéro 74 du 10 janvier 1974, OCC Statuts Décret Numéro 0944 DU O3.12.2009.SS.

Makoko, M. L., & Ndembo, L. J. (1987). Caractérisation hydrodynamique des sols du Mont-Ambaparlaméthode de drainage interne. *Revue Congolaise des Sciences Nucléaires, 8,* 3957.

Ndembo, L. J. (2009). *Apport des outils hydrogéochimiques et isotopiques a la gestion de l'aquifère du mont Amba*. Thèse de Doctorat, Université d'Avignon, 203 p.

OMS (2000). *Directive de qualité pour l'eau de boisson; Documentation à l'appui* (2ieme ed.). Vol. 2, Masson, 85 p.

Pereira, A. R., & Pruitt, W. O. (2004). Adaptation of the Thornthwaite Scheme for Estimating Daily Reference Evapotranspiration. *Agricultural Water Management, 66,* 251-257. https://doi.org/10.1016/j.agwat.2003.11.003

REGIDESO (2001). *Rapport de Findes Travaux de Forage. Projet* AHI2. REGIDESO-OXFAM-QUEBEC. Kinshasa. Inédit.