Open Journal of Applied Sciences, 2023, 13, 976-986
https://www.scirp.org/journal/ojapps
ISSN Online: 2165-3925
ISSN Print: 2165-3917

Comparative Study of the Physicochemical and Microbiological Quality of Water from Wells, Boreholes and Springs Consumed in the Massissia District in Brazzaville, Republic of the Congo

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How to cite this paper: Tchoumou, M., Mvouezolo, R.F.L., Obami-Ondon, H., Makaya, L.C.B. and Kombo, A.M.M. (2023) Comparative Study of the Physicochemical and Microbiological Quality of Water from Wells, Boreholes and Springs Consumed in the Massissia District in Brazzaville, Republic of the Congo. *Open Journal of Applied Sciences*, **13**, 976-986.
https://doi.org/10.4236/ojapps.2023.137078

Received: May 30, 2023
Accepted: July 9, 2023
Published: July 12, 2023

Abstract

The Republic of Congo in the course of the last two decades has been marked by a strong demographic explosion. The increase of its population has been accompanied by a significant demand for drinking water. The Congolese populations in order to meet their water needs, have recourse to rainwater, surface water and groundwater, because it is easy to access. The city of Brazzaville, political capital of the Republic of Congo, is also affected by this problem. The study carried out here aimed to assess the physicochemical and microbiological parameters of groundwater (wells, boreholes and springs) consumed by the populations of the Massissia district. In this work the physicochemical parameters below were evaluated: the pH, the conductivity, the hardness, the major ions, the undesirable substances as well as some toxic elements (Lead, Cadmium, Iron and Zinc) thanks to techniques of colorimetry, potentiometry and spectrophotometry. The main microbiological parameters determined are E. Coli, Staphylococcus, Total Germs, Total Coliforms, Yeasts and Molds. The physicochemical analyzes revealed that these waters are acidic with pH values between 5 and 6.5, the nitrate concentration evaluated between 50 mg/L and 60 mg/L, and a presence of the element Cadmium at values variants between 0.01 and 0.5 mg/L, values greater than the standard required by the WHO. Microbiological analyzes revealed bacteriological contamination by presence of E. coli in wells and boreholes whose origin is faecal contamination, the presence of yeasts and molds, staphylococcus, Total germs and Total coliforms and Ps Aeuginosis in all water points, making these waters a real danger for consumers.

Keywords

Water Quality, Comparative Study, Consumption, Brazzaville

1. Introduction

Water plays an extremely important role for living beings, particularly in socio-economic development and ecosystems.

The Republic of CONGO is under the influence of an equatorial type climate characterized by the presence of two major seasons: a dry season (from 3 to 4 months) and a rainy season (from 8 to 9 months) according to the regions of the country [1].

The Republic of Congo is a country abundantly watered; However, like other developing countries, the entire Congolese population does not have access to drinking water. This crisis is characterized by a lack of drinking water supply the same national company of water distribution which is experiencing difficulties in supplying the population with sufficient quality water on a daily basis [2].

This deficit in drinking water caused by untimely cuts and the low purchasing power which does not allow all Congolese to connect to the drinking water supply network, leads a large number of the population to use rainwater and the aquifer water (wells, boreholes and springs) whose physicochemical and microbiological qualities are not well known [3].

In the Republic of Congo, a few institutions such as the Congolese water and the national hygiene service are concerned about water quality and undertake spot checks as part of their routine activities. However, this control only concerns major groundwater distribution networks intended for small communities [4]. Consequently, the analyzes carried out within the framework of these periodic checks do not make it possible to apprehend either the evolution of the quality of groundwater, or the events likely to modify it. Thus, populations who do not have easy access to mains water are moving without restriction towards daily use of groundwater.

In order to answer this question, we will in this work carry out physicochemical and microbiological analyzes of groundwater from wells, springs or boreholes in the MASSISSIA district located south of Brazzaville and we will compare the results with the standards required by WHO for drinking water [5].

The study of the quality of groundwater resources exploited for consumption and watering is mainly based on two main types of effects related to human and animal health, crops and soils. These types of effects are toxicity and can influence various water parameters [6].

Three types of groundwater are concerned by this study: the well water, the spring water and the borehole water.

A water source whose highest free surface level may be very close to the ground surface is therefore exposed to faecal pollution when there are sources of such pollution in the immediate vicinity. Pollution can still reach groundwater far from sources of contamination when the ground is formed of fissured rocks. In this case, it is impossible to predict how far the flow of water can carry the germs of pollution, both horizontally and in depth. The propagation of bacteria in the soil is essentially linked to the movement of water serving as a vehicle [7].

The objective of this work is to determine the physicochemical and microbiological parameters of spring, well and borehole water consumed by the inhabitants of the MASSISSIA district, in order to verify their compliance with the standards of the World Health Organization on drinking water.

2. Materials and Methods

2.1. Presentation of the Study Area

This study was carried out in the Massissia district, located south of the city of Brazzaville. This district covers an area of 80.45 km^2. It is bounded to the north by the district of Goma Tsé-Tsé, to the south by the Makélékélé district, to the west by the Djoué and to the east by the Congo River. In order to solve their water problem, these populations use water from springs, boreholes and wells for their daily tasks.

Figure 1 illustrates the study area (Massissia district).

The sites that were selected for this study are located in highly populated areas, and are therefore very popular. Some information on the sampling point are given in **Table 1**.

Figure 2 represents the images of differents sampling points.

Figure 1. Presentation of the study area (Massissia district).

Table 1. Sampling point information.

Origin of water	Code	Use	Depth
Spring 1	MS1	Drinking and other household chores	/
Spring 2	MS2	Drinking and other household chores	/
well 1	MP1	Drinking and other household chores	8 m
well 2	MP2	Drinking and other household chores	9 m
Borehole 1	MF1	Drinking and other household chores	115 m
Borehole 2	MF2	Drinking and other household chores	105 m

Borehole MF1 water sampling location
Borehole MF2 water sampling location
Spring MS1 water sampling location
Spring MS2 water sampling location
Borehole MF1 water sampling location
Borehole MF2 water sampling location

Figure 2. Water sampling location.

2.2. Water Sampling and Analyzes

This study was carried out in the period from January to July 2021 on six sampling points including two wells, two springs and two boreholes and all the water samples were taken respectively in January, April and July. The following parameters were measured in situ: pH, temperature, conductivity.

The well water was sampled using a container used by the users, the water in the container was then put back into a 1.5 L bottle then placed in a bag and then transported to the laboratory for analyzes [8].

All the selected springs being equipped; the sample was taken after sterilization of the water outlet tap with alcohol. Water flowing from the tap was then placed in 1.5 L bottles.

At the boreholes, water was taken from the tap after letting the water run for a five minutes and then placed in 1.5 L bottles.

The water samples intended for the microbiological analyzes were placed in sterilized jars then kept in a cooler containing ice.

Color and turbidity were provided using the Lamotte spectrophotometer. The pH of the waters was determined using a HANNA HI 83141 pH meter, the total hardness by titration using EDTA, the determination of conductivity and TDS was made at using an ADWA AD31/8000 conductivity meter, bicarbonate, alkalinity, nitrate, magnesium, chloride, calcium, phosphate, sulphate, potassium, manganese, nickel, zinc, lead, and chromium ions using a Lamotte spectrophotometer [9] [10].

For the microbiological analyzes, the prepared media were stored between 2 and 8˚C and using 0.45 μm filter membranes. The two procedures used to detect yeasts and molds are M-Green Agar and Mannitol Salt Agar [11].

After preparation of the culture media, inoculation and reading made it possible to count the colonies of bacteria.

3. Results and Discussion

3.1. Results of Physicochemical Analyzes

Three water samples were taken at each location (spring, well and borehole) to carry out physicochemical and microbiological analyzes. **Figures 3-10** give in the form of histogram the average of the parameters determined for each type of water.

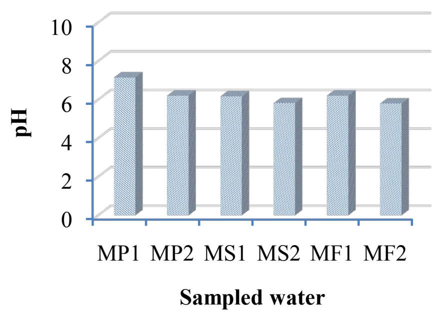

Figure 3. pH of water samples.

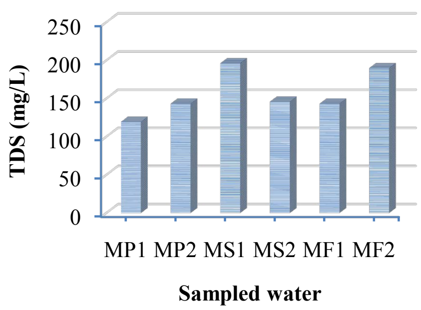

Figure 4. TDS of water samples.

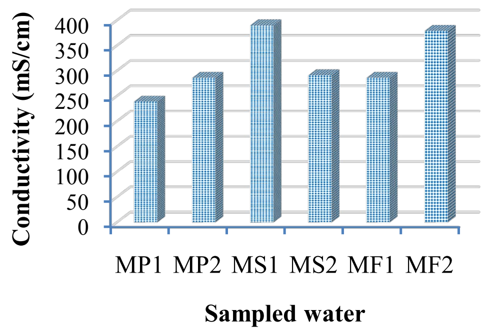

Figure 5. Conductivity of water samples.

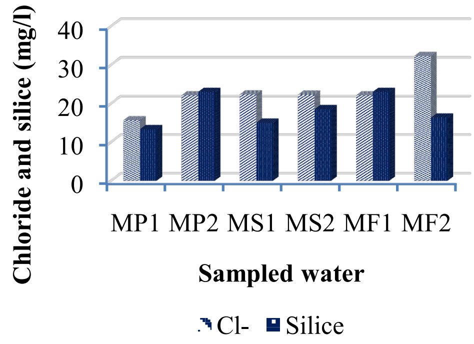

Figure 6. Chloride and silica of water samples.

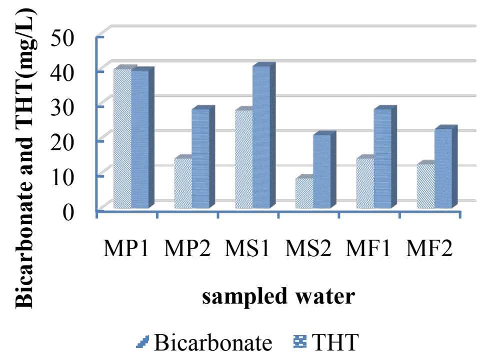

Figure 7. Bicarbonate and THT of water samples.

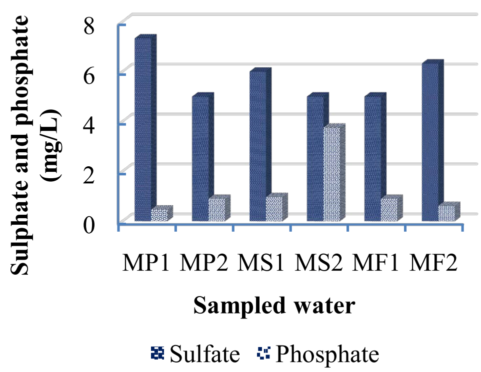

Figure 8. Sulphate et phosphate of water samples.

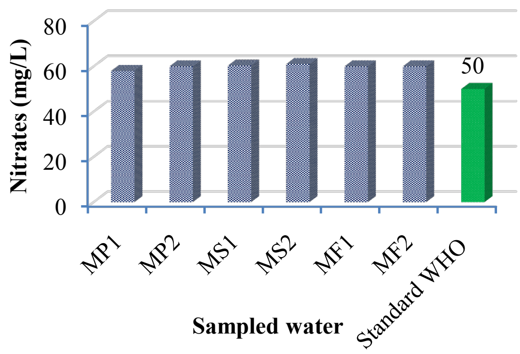

Figure 9. Nitrate of water samples.

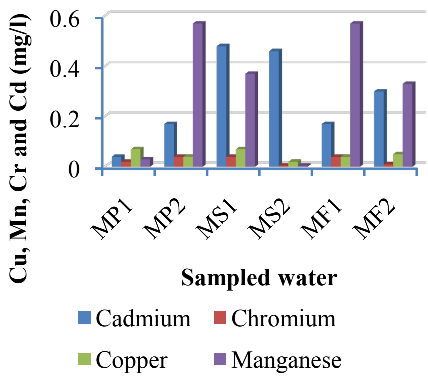

Figure 10. Cd, Cu, Mn and Cr of water samples.

The groundwater in the present study is around acidity. Average pH values below 7 are observed in all the water points except in point MP1.

The pH values of the samplings points MP2, MF1, MF2, MS1 and MS2 are between 5.80 and 6.21, these results are in line with those of ZOULGAMI [12] who found pH values between 5.7 and 7.87 for groundwater in TOGO. The distribution of the pH in the waters of the Massissia sector would come from the decomposition of plant organic matter, with the production of CO_2 in the first layers of the soil, which corroborates with the work of MBILOU *et al.* [13].

The average conductivity values vary between 200 µS/cm and 300 µS/cm at the wells and boreholes, while they are above 300 µS/cm at the springs. The conductivity being proportional to the quantity of mineral salts, it can be deduced that the springs MS1 and MS2 have an accentuated mineralization and that the rest of the water points have a moderately accentuated mineralization. These results are different from those observed by NGOUALA [14], the latter observed relatively lower values which oscillate between 16.33 and 47.17 µS/cm.

The high conductivities obtained during this study may be linked to anthropogenic activities which are diversified and intensified in the study area, and cause water mineralization by surface inputs.

Silica levels are high in water points and are generally higher than the WHO standard (12 mg/L). These results are consistent with those obtained by MBILOU *et al.* [15], who worked on the physicochemical characterization of groundwater in the southern zone of Brazzaville. The silica concentrations revealed by the work of the latter in the part of Massissia presented values higher than the WHO standard, he indicates that this fact would probably be linked to the presence of silicate minerals constituting the groundwater.

The TDS values varying from 119 to 197 mg/L. The high concentration of TDS in all the sampling points indicates a mineralization which is still within the standard. These values are in agreement with the WHO standard and in disagreement with the results observed by MUSUMBA *et al.* [16], who found values include between 88 and 160 mg/L in groundwater of Wakiso district, Uganda.

The very low values of turbidity in all the samples demonstrated that, although having taken the samples in the rainy season, there was no infiltration or percolation and therefore, that the soils probably have a permeability quite important.

Iron and zinc are absent in all samples. Potassium and calcium are present at levels adapted to the WHO standard at all the sampling points. However, we note a Cadmium content that exceeds the standard with average values of 0.21 mg/L in the wells water, 0.47 mg/L in the springs water and 0.24 mg/L in the borehole water. The presence of nigh concentration of Cadmium constitutes a risk for consumption.

3.2. Results of Microbiological Analyzes

The results of the microbiological analyses are given in **Table 2**.

The microbiological analyzes revealed:

- The presence of yeasts and molds in all samples. These elements not being naturally present in the water, would suggest contamination of anthropogenic origin. These results are consistent with those obtained by KANOHIN *et al.* [17] and who claim that their presence is an essential and undeniable indicator of significant water contamination.
- The presence of total coliforms, in a content greater than the 0 CFU/100 mL standard, indicator of faecal contamination; these results corroborate those observed by El Ouali Lalami *et al.* [18] and is based on the hypothesis that total coliform contamination is probably linked to multiple discharges of wastewater loaded with abiotic pollutants;

Table 2. Results of microbiological analyzes.

Parameter	E. coli	Salmonella Shigella	Total Coliforms	Pseudomonas aeruginosa	Total Germs	Staphylococci	yeasts/molds
MS1	0	>100	>100	>100	>100	3	Presence
MS2	0	>100	>100	>100	>100	0	Presence
MP1	>100	>100	>100	>100	>100	63	Presence
MP2	>100	>100	>100	>100	>100	9	Presence
MF1	>100	>100	>100	>100	>100	26	Presence
MF2	>100	>100	>100	>100	>100	5	Presence
Standard WHO	0 CFU/100mL	0 CFU/100mL	0 CFU/100mL	0 CFU/100mL	0 CFU/100mL	0 CFU/100mL	

- The presence of staphylococci; the same observation was made by Palamuleni *et al.* [19] starting from a standard of 0 CFU/100 mL. Its presence relates to contamination linked to anthropogenic activities (discharge of waste water);
- The presence of E. Coli only suggests contamination when they are present in a quantity greater than the standard used. Springs MS1 and MS2 do not reveal any presence of E. Coli, which does not mean that they are not contaminated.
- The presence of Salmonella and Shigella once again confirms that these waters are unfit for consumption; this observation is consistent with that of NOLA *et al.* [20], with a percentage of Salmonella evaluated at 17% in the rainy season and 8% in the dry season on groundwater.

4. Conclusions

This study focused on the comparison of the physicochemical and microbiological quality of water from wells, boreholes and springs consumed in the Massissia district located in the south of Brazzaville. Physicochemical analyzes revealed that spring water has a more acidic pH than well and borehole water, and all these values are lower than the WHO guideline value which is between 6.5 and 8.5. Water from wells and boreholes is more turbid than spring water with an average turbidity of 1.33 NTU at the level of wells and boreholes, while spring water has zero turbidity. Nitrate ions are present at concentrations above the WHO standard at all sampling points. Cadmium and Silica have levels above the WHO standard on all samples. The average concentrations of cadmium are 0.47 mg/L for springs, 0.21 mg/L for wells and 0.24 mg/L for boreholes, while those of silica are 19.66 mg/L for boreholes, 16.75 mg/L for springs and 18.17 mg/L for well.

Microbiological analyzes revealed the presence of Salmonella, Shigella, total coliforms, total germs, staphylococci, molds and yeasts in all samples. The presence of these different bacteria makes these waters an important source of waterborne diseases. Spring water does not contain E. Coli, unlike well and borehole water, which contains more than the WHO standard. Water from wells and boreholes has higher average Staphylococci levels than spring water, with respective average values of 1.5 CFU/100mL at springs, 36 CFU/100mL at wells and 15.5 CFU/100mL at the boreholes.

The results obtained after physicochemical and microbiological analyzes show that all waters studied are contaminated and are therefore unfit for consumption.

Acknowledgements

The authors would like to thank the National Institute for Research in Exact and Natural Sciences for having provided them with the equipment and chemicals reagents necessary for the analyzes of the water samples.

Conflicts of Interest

The authors declare no conflict of interest.

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