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Effect of water salinity and hydrotimetric titer of water sources used for consumption in the commune of Ouinhi in Benin (West Africa)

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ABSTRACT

Despite the availability of Improved Water Sources (IWS), the population of Ouinhi in Benin still consumes surface water. Which is a major public health problem. The present study aims to identify the physicochemical and microbiological parameters, the cause of the population's rejection of the consumption of water from boreholes and other water supply works. To do this, a simple random selection of twenty water sources was made for microbiological and physico-chemical analysis. The results showed that the salinity (1 mg/L) of IWS was found to be 2.5 times higher than that of Unimproved Water Sources (UWS). Similarly, Total Dissolved Solids (173.4 and 218.4 ppm), calcium content (2.753 and 2.007 mg/L) and magnesium hardness (2.4 and 1.253 mg/L) were on average 1.6 times higher in improved than in UWS. Analysis also show that all water sources were contaminated with total coliforms, thermotolerant coliforms, fecal *enterococci*, *E. coli* and *S. aureus* in all samples from the two districts of Dasso and Tohouè. This situation contributes to the frequency of hydro-fecal diseases, and is a factor to be considered in awareness campaigns.

Keywords: Water, Physico-chemical and microbiological parameters, Contamination, Benin.

INTRODUCTION

Safe drinking water is one of the essential elements for health, survival, growth and development. Unfortunately, this basic need is still a luxury for many poor people around the world (Packer et al., 2012). Potable water consumption, the adoption of good hygiene practices and living in a healthy environment constitute real obstacles to numerous infectious diseases, particularly of fecal-oral origin, promoting the health and well-being of populations (WHO, 2019). Furthermore, when the water supply is insufficient, health suffers considerably. No other determining environmental factor has such weakening and profound effects (WHO, 2015).

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Although the Millennium Development Goals (MDGs) have made it possible to achieve drinking water coverage, 2.1 billion people or 30% of the world's population, still do not have access to drinking water services. domestic drinking water (Kouakou, 2009). Communities, especially those living in rural areas, continue to consume water from unprotected sources (Musembi and Musyoki, 2016). In endemic areas, poor conditions relating to Water, Hygiene and Sanitation (WASH) promote the proliferation of germs responsible for parasitosis (UNICEF, 2012). This situation is catastrophic for young children and represents a major cause of mortality for children under five years old.

In Benin, the problem of drinking water supply is more relevant than ever, both in rural and urban areas. Nevertheless, remarkable progress has been recorded in terms of access to drinking water, with coverage now reaching 77% in urban areas and 66% in rural areas (WHO, 2021). In the department of Zou in general and in the Commune of Ouinhi in particular, unsanitary conditions and non-observance of basic rules of hygiene and sanitation are observed in schools and certain households. Populations are therefore forced to rush to runoff water, rivers or lowlands or travel long distances in search of drinking water (Mairie de Ouinhi, 2013). Faced with this situation, construction of drinking water points has been carried out to facilitate the supply of populations but it is clear that despite this, populations continue to consume surface water that is often very contaminated. It is in right that the present study aimed to identify the physicochemical and microbiological parameters, the cause of the population's rejection of the consumption of water from boreholes and other water supply works.

MATERIALS AND METHODS

Study framework

The study covered the peri-urban and rural areas of the Commune of Ouinhi. Located in the south of Benin (Figure 1) and in the Zou department between 6°57 and 7°11 north latitude and 2°23 and 2°33 east longitude, it is limited to the north and west by the Municipality of Zagnanado; to the South-West by the Municipalities of Zogbodomey and Zè, to the South by the Municipality of Bonou and to the East by the Municipality of Adja-Ouèrè. The Municipality of Ouinhi has forty (40) villages subdivided into four (04) districts which are: Dasso, Ouinhi-Centre, Sagon and Tohouè (Mairie de Ouinhi, 2013). Two districts including Tohouè and Dasso were targeted for this study. Hence the present study was a cross-sectional and analytical study which made it possible to assess the quality of improved and unimproved water source consumed by the population in the Commune of Ouinhi.

Water samples taken in these districts are sent to the Hygiene-Sanitation, Eco-Toxicology, Environment and Health Laboratory (HECOTES) of the Interfaculty Center for Environmental Training and Research for Sustainable Development (CIFRED) of the University of Abomey-Calavi (UAC) in Benin for pysico-chemical and microbiological analysis.

Microbiological and physicochemical analyzes of water

Sampling

Twenty (20) samples, ten per source, were taken by simple random sampling in the districts of Tohouè and Dasso in the Municipality of Ouinhi. These water samples were collected in sterile 500 mL bottles three-quarters filled for microbiological analyses. As for the water samples intended for physicochemical analyses, the samples were collected to totally fill 1500 mL plastic bottles of mineral water.

Transport and storage

The vials were carefully labeled once collection was done. Transport from the sampling point to the laboratory was done in an insulated cooler at 4°C, within three hours after collection. Once in the laboratory, the samples were stored in the refrigerator. The analysis was carried out within 12 hours following the sampling. Samples were retained until all results were obtained.

Physicochemical and microbiological analyzes

Microbiological analyses

The microbiological analysis was carried out in two stages.

Cellulosic membrane filtration

This technique consists of passing 20 to 100 mL of water through a cellulose membrane with pores of diameter 0.45 µm. After filtration, each membrane was removed and inoculated on to Petri dish containing previously poured agar.

Incubation

Different incubation conditions (time and temperature) were used depending on the germs sought (*E. coli*, thermotolerant coliforms, total coliforms, fecal *Enterococci*, and *S. aureus*). After incubation, the results obtained are expressed in Colony Forming Units (CFU) per unit of volume.

Identification of germs according to environments

Total coliforms were identified on OXOID *E. coli* coliform shine agar (ISO 9001: 2000; ISO 13485: 2003 NF EN ISO 13485: 2004 Certified, REF: AM50252) after incubation of the Petri dishes at 37°C for 24 hours; fecal coliforms and *E. coli* were identified on OXOID *E. coli* coliform brilliance agar (ISO 9001: 2000; ISO 13485: 2003 NF EN ISO 13485: 2004 Certified, REF: AM50252) after incubation of Petri dishes at 44°C for 24 hours; Faecal *Enterococci* were identified on OXOID Slanetz/Bartley agar (ISO 7899-2: 2000, REF CM0377) after incubation of the Petri dishes at 37°C for 48 hours and *Staphylococcus aureus* was identified on OXOID agar (REF CM0085) after incubation of the Petri dishes at 37°C for 24 hours.

Physico-chemical analyzes

pH, conductivity and dissolved oxygen were measured "in situ" using a portable multimeter (HANNA, HI 991300). Total Dissolved Solids (TDS), salinity, total nitrogen, ammonium, ortho-phosphate, nitrates, nitrites, total phosphorus, calcium, magnesium and total hardness were determined by a DR 6000 type spectrophotometer in accordance with to the analysis methods described by the French Association for Standardization (Rodier et al., 2009).

Data analysis

Once processed, the data were analyzed with SPSS 25 software. Analysis consisted of generating results in the form of tables and graphs followed by their analytical interpretation. In addition, the physicochemical variables being measured in three repetitions, mean values were calculated using a one-way analysis of variance with standard deviation.

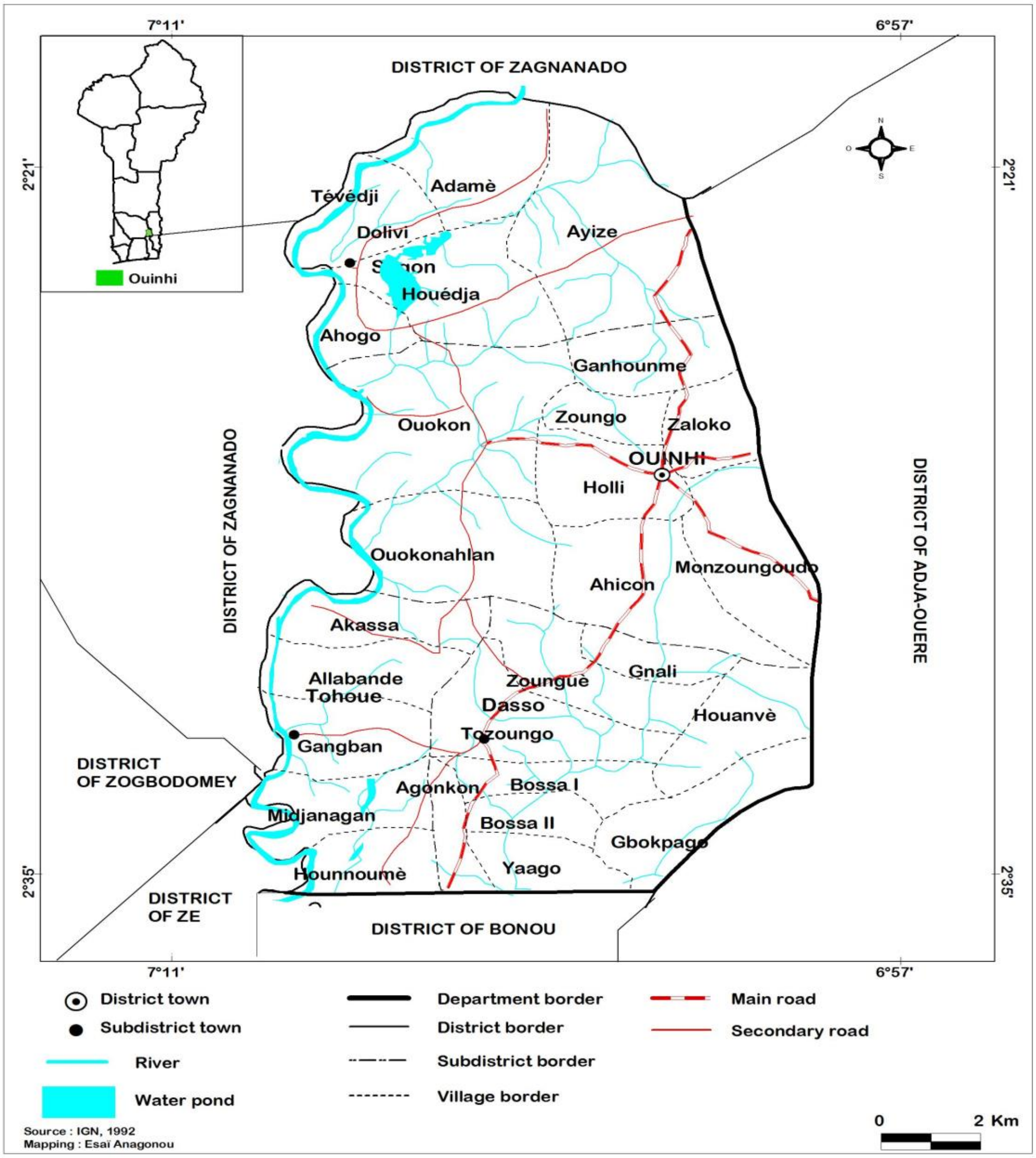


Figure 1: Geographical location of the commune of Ouinhi.

RESULTS

Microbiological parameters

The results of the microbiological analyzes obtained are presented by locality. The germs sought are those involved in fecal contamination. These are total coliforms (CT), thermotolerant coliforms (CTh), fecal Enterococci (FE), *Escherichia coli* and *Staphylococcus aureus*. Figure 2 shows the distribution of germs identified in improved and unimproved water sources consumed in the districts of Tohouè and Dasso. From Figure 2, a respectively very high contamination in total coliforms (243 CFU/mL), *S. aureus* (138 CFU/mL), fecal Enterococci (26 CFU/mL), thermotolerant coliforms (20 CFU/mL) and *E. coli* (16 CFU/mL) in unimproved water source than in improved water in Dasso can be seen. As for the Tohouè water samples collected for microbiological analyses, a high contamination rate in the unimproved source water in *S. aureus* (193 CFU/mL) and total coliforms (13

CFU/mL) was noted. Regarding improved water source, fecal Enterococci (52 CFU/mL) predominated. The results of the bacteriological analysis of the water revealed that all of the water samples collected were contaminated. The bacteriological pollution indicator germs identified during the analysis were total coliforms, thermotolerant coliforms, fecal Enterococci, *Escherichia coli* and *Staphylococcus aureus*.

Physico-chemical parameters

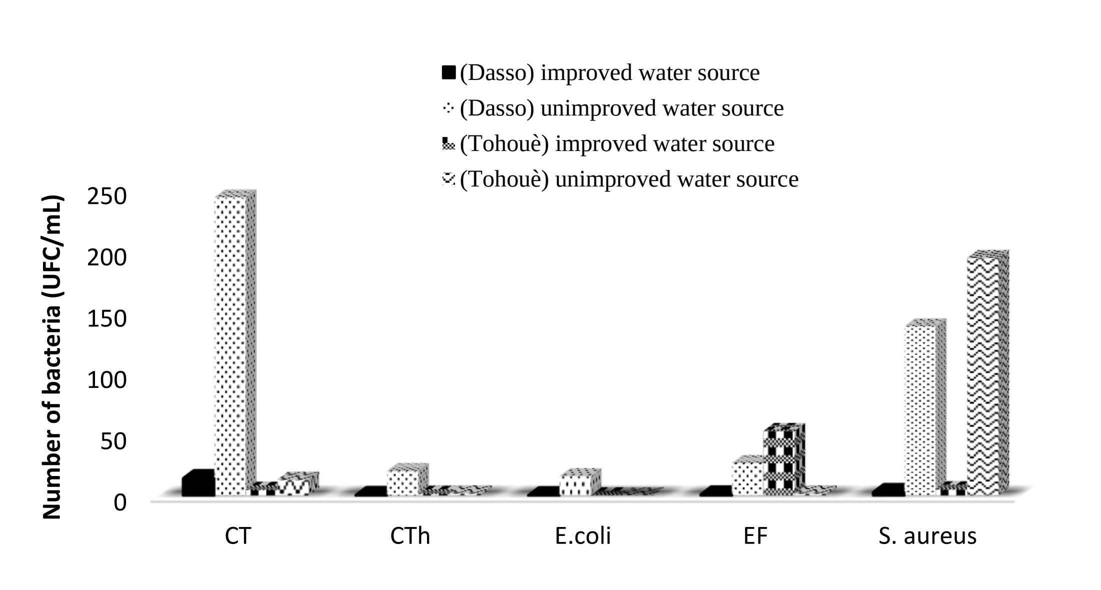
Table 1 presents the nutrient salts contained in drinking water in each district. The results of the various analyzes carried out in relation to the chemical parameters measured (Table 1) show the presence of nitrates, nitrites, total phosphorus, ammonium, total nitrogen, orthophosphates in drinking water in the Municipality of Ouinhi. The other physicochemical parameters measured are also in acceptable proportions (Table 2). The salinity value is high with a rate of 1 mg/L for improved waters source while it is 0.4 mg/L in unimproved water source. Salinity is therefore 2.5 times higher in water from improved sources than from unimproved sources. This situation may be one of the causes of rejection of the consumption of improved sources by the population even though they are of better quality.

The pH of improved or unimproved water source is between 6.5 and 7.6 in the districts of Dasso and Tohouè. The results comply with the quality standards for drinking water in the Republic of Benin according to Decree No. 2001-094 of February 20, 2001 setting the pH between 6.5 and 8.5. The water from the improved sources of Dasso and Tohouè have respectively higher Total Dissolved Solids (TDS) rates of 173.4 and 218.4 ppm than the water from unimproved sources with a rate of 131.5 ppm for Dasso and 162.1 ppm for that of Tohouè. The high level of TDS in improved water source could explain the population's preference for unimproved water source, the taste of which could be unpleasant. Regarding the percentage of O_2 saturation in improved waters source, it is slightly higher (5.8% and 6.3%) than in unimproved waters source (5.4% and 5.8 %).

The conductivity values obtained for both improved and unimproved waters source are below the maximum standard (2000 µS/cm). In Dasso the conductivity obtained in improved water source was 1.02 higher than that obtained in unimproved water source. In the district of Dasso, improved water source is 1.64 times higher than the value of unimproved water source. However, in Tohouè, improved water source is 2.04 times higher than the value obtained from unimproved water source. It should be remembered that although low in the different water sources by Beninese standards, improved sources from groundwater are relatively harsh compared to surface water sources. The magnesium concentrations obtained vary between 0.7 and 2.4 mg/L.

In Dasso, improved water source is 1.49 times higher than unimproved water source. Similarly, in Tohouè improved water source is 1.67 times higher than unimproved water source. Although low in different water sources by Beninese standards, improved sources from groundwater are harsher compared to surface water sources. As for the total hydrometric titer in the districts of Dasso and Tohouè, values were respectively 3.2 mg/L and 1.7 mg/L for unimproved water source. These values were lower compared to those of improved sources (5.1 mg/L and 3.2 mg/L).

In Dasso, improved water source is 1.57 times higher than unimproved water source. Similarly, in Tohouè, improved water source is also 1.88 times higher than unimproved water source. From the results of the physicochemical analyzes on the drinking water of Dasso and Tohouè, it appears that the parameters evaluated were in high proportion in the improved waters source more than those in the unimproved waters source. This situation would explain the less foaming character and dull taste often noted in improved water source compared to unimproved water source. These improved waters source come from underground reserves which, in contact with limestone and magnesium rocks, undergo dissolution to increase the hydrometric titer of the water.



NB: total coliforms (CT), thermotolerant coliforms (CTh), fecal Enterococci (EF), *Escherichia coli* (*E. coli*) and *Staphylococcus aureus (S. aureus)*

Figure 2: Number and type of bacteria identified according to the sources of water consumed and by locality.

Table 1: Nutrient salts contained in drinking water in each district.

Parameters	Sources	Methods used	Values - Dasso	Values – Tohouè	Beninese Standards
NH_4^+	Improved	USEPA Nessler	0,020 ± 0,005	0,013 ± 0,003	0,5 mg/L
	Unimproved		0,023 ± 0,008	0,020 ± 0,005	
NO_3^-	Improved	Cadmium Reduction	0,167 ± 0,033	0,200 ± 0,057	45 mg/L
	Unimproved		0,300 ± 0,057	0,267 ± 0,067	
NO_2^-	Improved	Iron sulfate	0,001 ± 0,00	0,008 ± 0,005	3,2 mg/L
	Unimproved		0,030 ± 0,011	0,026 ± 0,012	
N total	Improved		0,233 ± 0,044	0,300 ± 0,057	
	Unimproved		0,360 ± 0,086	0,467 ± 0,017	
PO_4^{3-}	Improved	Ascorbic acid	0,140 ± 0,043	0,120 ± 0,056	5 mg/L
	Unimproved		0,167 ± 0,067	0,250 ± 0,028	5 mg/L
P total	Improved	Vanadomolybdic with acid persulfate digestion	0,183 ± 0,038	0,167 ± 0,067	
	Unimproved		0,207 ± 0,072	0,320 ± 0,056	

Table 2: Physico-chemical parameters of drinking water sources.

Parameters	Units	Dasso		Tohouè		Beninese Standards
		Improved	Unimproved	Improved	Unimproved	
Salinity	mg/L	1 ± 0,01	0,4 ± 0,030	1 ± 0,01	0,4 ± 0,030	-
pH	-	6,637 ± 0,188	7,637 ± 0,188	6,507 ± 0,288	7,333 ± 0,409	6,5<pH<8,5
TDS (Total Dissolved Solids)	ppm	173,43 ± 20,622	131,5 ± 16,353	218,403 ± 17,921	162,11 ± 36,010	-
O_2	mg/L	5,843 ± 0,418	5,45 ± 0,376	6,313 ± 0,094	5,817 ± 0,299	-
Conductivité	µS/cm	197,15 ± 13,216	191,903 ± 24,767	135,367 ± 41,596	136,937 ± 24,527	-
Ca^{2+}	mg/L	2,753 ± 0,200	1,677 ± 0,364	2,007 ± 0,265	0,983 ± 0,127	100
Mg^{2+}	mg/L	2,4 ± 0,251	1,603 ± 0,213	1,253 ± 0,120	0,747 ± 0,128	50
TH	mg/L	5,153 ± 0,451	3,28 ± 0,577	3,26 ± 0,385	1,73 ± 0,255	200

DISCUSSION

Microbiological parameters

Microbiological analysis show that improved and unimproved water source used as drinking water by the populations of Ouinhi are contaminated by total coliforms, thermotolerant coliforms, fecal Enterococci, *Escherichia coli* and *S. aureus*. This shows that the waters are subject to recent and/or old bacteriological pollution. These results show similarity (total coliforms vary from 200 CFU/100 mL to 39,600 CFU/100 mL; thermotolerant coliforms vary from 0 to 16,000 CFU/100 mL) with the work of Kanohin et al. (2017) on the physicochemical and bacteriological characterization of Bingerville groundwater. This result could be explained by the fact that these districts do not have an adequate sanitation system. The presence of these bacteria could be due to poor protection of wells (open wells), nearby pollution (livestock breeding, existence of septic tanks and latrines) and the absence of a sanitation network (Yapo et al., 2010).

The presence of *Escherichia coli* indicates a recent fecal contamination. The presence of thermotolerant coliforms in these waters or other pathogens linked to fecal pollution or from other origins is dangerous for health (Emile, 2011). Consumption of these waters exposes the population of this locality to many water-borne diseases such as typhoid, dysentery and diarrhea, since these waters contain high levels of *Escherichia coli* and *streptococci* (WHO, 2017). Wirmvem et al. (2013a) also reported a high presence (23 to 1100 CFU/100 mL) of total coliforms in shallow groundwater in the Ndop plain. The poor quality of this water could be explained not only by the lack of sanitation, but also by the unsanitary environment due to the lack of hygiene around these water sources (Nanfack et al., 2014).

Physico-chemical parameters

The pH values are higher than those obtained (5.17 to 6.88) by Lagnika et al. (2014) in the Municipality of Pobè from well water. Likewise, these pH values are higher than those of Tampo et al. (2014) who obtained values lower than 6.5 (5.1 to 6.4) in the water from wells in the peri-urban districts of Lomé but compliant with the quality standards of drinking water in the Republic of Benin according to the decree n°2001-094 of February 20, 2001 setting the pH between 6.5 and 8.5. Electrical conductivity reflects the degree of overall mineralization, it provides information on the salinity level (Cheikh, 2011). The conductivity results are close to those obtained by Adejuwon and Mbuk (2011) on well water from Lagos in Nigeria with conductivity values between 22 and 315 µS/cm.

The contents of mineral compounds such as nitrogen, ammonium, phosphorus, orthophosphate, nitrate and nitrite are all below the limit values recommended by Beninese standards. NO_3^- concentrations vary between 0.1 and 0.2 mg/L for improved waters source. These low concentrations recorded compared to the standard of 45 mg/L recommended in Benin suggest the sorption of NO_3^- by organic matter in the undersaturated zone (Wirmvem et al., 2013b). These low concentrations could also be due to the growth of algae in sewage (Orjiekwe et al., 2013). NO_3^- comes naturally from the soil, but it is also provided synthetically by fertilizers.

From a health perspective, the major risk associated with NO_3^- is methemoglobinemia, also called blue baby disease, resulting from poor transfer of oxygen by the blood caused by nitrites originating from the transformation of nitrates by the body (Ghazali and Zaid, 2013). Indeed, the ingestion of nitrates is a proven potential risk factor for health. They are reduced to nitrites, which attach to hemoglobin barring attached of oxygen and causing breathing difficulties (asphyxia). In adults, nitrates are transformed into nitrites in the oral cavity, then into nitrosamines and other nitrosated compounds in the stomach (Shuval and Gruener, 2013). The NH_4^+ ion concentrations are very low compared to 0.5 mg/L established by the Beninese standard. Ammonium constitutes the product of the final reduction of organic nitrogenous substances and inorganic matter in water and soil. It also comes from the excretion of living organisms, the reduction and biodegradation of waste, without neglecting contributions of domestic, agricultural and industrial origin (Akil et al., 2014). Its presence in water is an indicator of possible bacterial pollution, sewage and animal waste (WHO, 2017). In this study, the PO_4^{3-} contents vary between 0.1 and 0.2 mg/L, which is lower than the Beninese standard which is 5 mg/L. At too high levels, PO_4^{3-} ions are likely to promote the multiplication of algae in reservoirs, large diameter pipes, lake and river water, thus contributing to the eutrophication of the environment (Bouchelaghem et al., 2014). The results obtained in the present work on nitrogen and phosphate mineral compounds are similar to those of Tampo et al. (2014) found on well water (NO_2^-: 0-1.97 mg/L; NH_4^+: 0-3.40 mg/L; PO_4^{3-}: 0-1.3 mg/L).

As for magnesium contents values obtained are almost similar to those obtained by Gbohaida et al. (2016) in Dassa in their investigations on the impact of fluoride in groundwater. The calcium quantification rates are higher than those (0.012 - 0.32 mg/L) of Barhé and Bouaka (2013) who worked on the physicochemical characterization of well water consumed in Congo Brazzaville. Furthermore, these results are different from those (9.89-74.29 mg/L) of Lagnika et al. (2014) whose work focused on well water in the areas of Pobè and Kétou in Benin. The total hardness of water is linked to its content of calcium and magnesium salts. Water hardness mainly influences the condition of pipes, heating appliances and washing clothes (Mahamane and Guel, 2015).

In view of the total hardness results obtained, it should be noted that improved water source is harder than unimproved water source. This is in perfect correlation with the slightly higher magnesium and calcium contents obtained in samples of improved water source.

Conclusion

Research on the microbiological and physical-chemical quality of drinking water has revealed that it is contaminated by germs that are indicators of fecal contamination. Thus, the water sampled is mainly contaminated by total coliforms and *S. aureus*. This may be due to breaches of hygiene rules. Furthermore, the contamination of this water by these bacteria constitutes a major risk of gastroenteritis for consumers. In general, well water is more contaminated than borehole water. Respect for hygiene rules and treatment of water by populations should be encouraged to avoid the occurrence of water-borne diseases. As for the physicochemical analysis, the presence of ammonium, nitrate and phosphorus ions, even in small quantities, can be a source of illness for the population as well as rejection of the use of improved water source. In total, it is the total hydrometric titer and the salinity which are at the origin of the abandonment of the consumption of drilled borehole water which is nevertheless less polluted.

COMPETING INTERESTS

The authors declare that they have no competing interests.

AUTHORS' CONTRIBUTIONS

All authors contributed equally to this study. They participated in all stages of the study.

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