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Physico-Chemical Characterizations of the Water from Three Boreholes in the Town of Massakory (Chad)

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ABSTRACT

The main objective of this study is the physicochemical study of borehole water in the Massakory region in Chad. Water samples were taken from three of the busiest boreholes in the Massakory region: Seitchiri (FS), Wandallah (FW) and Abori (FA). The pH measurement of these boreholes is in accordance with the standard between 6.5-8.5. The electrical conductivity of these three boreholes is respectively: FS (4919.01 ± 41a) FW (8180.50 ± 0.71ᵇ) FA (2899.50 ± 0.71ᶜ), therefore much greater than the limit value (300 µs / Cm). The temperature of the three boreholes is around 25 ° C and the turbidity of these boreholes is: FS (10.50 ± 0.71a) FW (10.39 ± 0.55a) FA (9.77 ± 0.33a), value greater than 5 NUT. The Na+ contents of these three boreholes are respectively: FS (39.80 ± 0.28ᵃ) FW (66.20 ± 0.31b) FA (29.85 ± 0.28 c); the Fe2+ contents: FS (0.51 ± 0.04a) FW (0.82 ± 0.10b) FA (0.27 ± 0.07c) and the Mn2+ contents: FS (0.26 ± 0.04 a) FW (0.74 ± 0.04b) FA (0.08 ± 0.02ᶜ). These values are well above the limit value admissible by the EEC and WHO (20 mg / L for Na+; 0.3 mg / L for Fe^{2+} and 0.4 mg / L for Mn2+). The K+ contents of these three boreholes are respectively: FS (13.021 ± 0.01a) FW (27.86 ± 0.66b) FA (37.75 ± 0.83c); the total chromium content FS: (0, 12 ± 0, 014a) FW (0.17 ± 0.04a) FA (0.17 ± 0, 01a) and the Cu^{2+} contents: FS (0.041 ± 0.01a) FW (0.02 ± 0.01a) FA (0.241 ± 0.03b). These values are much higher than the limit value given by the EEC and the WHO except for the contents of K+ and Cu2+ (200 mg / L for K+; 0.05 mg / L for total Cr and 2 mg / L for Cu^{2+}). The NO3- and PO43- contents of the three boreholes are both lower than the standard 50 mg / L for N03- and 5 mg / L for P043- respectively.

Keywords: *Boreholes, Chad, Drilling, Massakory, Physico-chemical.*

INTRODUCTION

Water is a precious commodity that must be protected. It is a sensitive service, essential for public health and the comfort of the local population. Water resources, threatened by human, industrial and agricultural activities, and by climate change, have become a major issue, to which the whole world, at any stage of development that it is attached today, of great importance.

The end of the 20th century was marked by a significant reduction in water resources. This reduction is attributed either to natural phenomena such as drought or water pollution [1]. Water pollution is very often dependent on human activities, which use surface water as spillways for pollutants. But it can also be of natural origin. Natural water can contain three main types of pollutants: chemical, microbial and physical pollutants. These three types of pollutants are at the origin of three types of pollution. Chemical pollution can be of natural or anthropogenic origin. Microbial pollution is the leading cause of waterborne diseases. Physical pollution does not necessarily have direct effects on health, but its presence can lead to the rejection of water by consumers [1, 2, 3]. In water pollution, several classes of pollutants can be found and have adverse effects for human consumption.

According to WHO/UNICEF [4], since 1990, drinking water coverage in developing countries has increased by 17%, which means that 89% of the world's population had access to safe drinking water in 2012. About 56% (4 billion) of the world's population had the privilege of taking advantage of this resource. Despite this percentage, 748 million people still have no access to safe drinking water and 173 million of them rely on untreated surface water, particularly in rural areas where centralized drinking water systems are not available [1, 5,6,7,8,16]. This situation is more pronounced in sub-Saharan Africa [9].

In Chad despite the efforts of the Drinking Water Supply and Sanitation Program in Semi-urban and rural areas (SUMR), in order to assist member countries which have failed to achieve the Millennium Development Goals for Development (MDG) in the Water and Sanitation sector. Indeed, by the 2015 deadline, it appears that most of the targets of the Millennium Development Goals (MDGs) have not been reached for Chad. The rate of access to drinking water rose from 21% in 2000 to 53% in 2015, that of sanitation rose from 3% in 2000 to 16% in 2015; while the MDGs provided for the rate of access to drinking water at 60% and the rate of access to sanitation services at 35% in 2015. This difficulty of access to drinking water has deepened in the time and space huge gaps in access to education, employment and political life between men and women, to the detriment of women. The prevalence rate of water-borne diseases, especially for children under 5, was 23.6% in 2017. The prevalence rate of acute malnutrition at the national level was 13%, and the prevalence rate of chronic malnutrition was 39.9% among children under 5 in 2014-2015. As a result, around 19,000 people die each year from water-borne diseases, lack of hygiene and sanitation and the country would lose nearly 79 billion FCA each year due to poor hygiene, sanitation and access to drinking water, according to WSP studies, updated in 2016.

We are interested in the physico-chemical analysis of drinking water in the department of Dagana located 150km from N'Djaména. In the north of the country (Chad), theTibesti massif rises (a mountainous region of the Sahara Desert) from the east and extends to the Ennedi and Ouaddai plateaus. The desert climate of the northern regions and the Sahelian influence in the center make access to water difficult. This is why irrigation systems and wells have been put in place, so that agriculture can be developed.

Geographically, the Hadjer-Lamise region is bounded to the north by the Bahr-ghazel region, to the northwest by the Lake region, to the south by the Mongo region and to the southwest by the Chari Baguirmi region. This study area has easy access, being close to the capital. The city of Massakory has more than 121,342 active inhabitants, most of whom are farmers, herders and traders.

In view of all this, we carry our study to the physico-chemical analysis of drinking water in the region of Hadjer-Lamise, in the department of Dagana more precisely in Massakory (Chad) to assess the impact of chemical pollution in three boreholes the most frequented by the population in this locality.

Materials and Methods

Presentation of the Study Area

The study area is located in the Hadjer-Lamise region, Dagana department, Massakory sub-prefecture. It is about 150 km from the capital N'Djaména on the N'Djaména-Mao and N' Djaména-Moussoro axis.

Geographically, the Hadjer-Lamise region is bounded to the north by the Bahr-ghazel region, to the northwest by the Lake region, to the south by the Mongo region and to the southwest by the Chari Baguirmi region. This study area has easy access, being close to the capital. The town ofMassakory (figure 1) has more than 121,342 active inhabitants (SUMR), most of whom are farmers, breeders and traders.

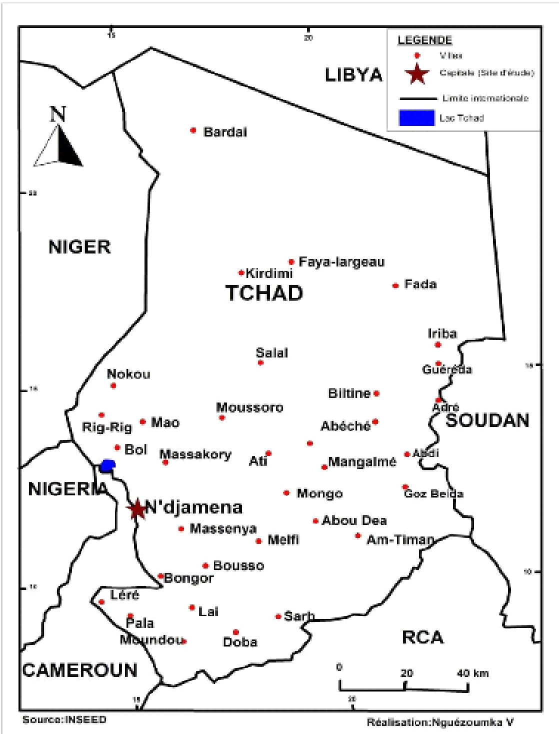

Figure1: *The town of Massakory (Chad)*

The region is characterized by a long dry season from October to May and a rainy season from June to September. The water supply is done through boreholes and wells. The study area is relatively wooded with many gardens and cultivation areas where the inhabitants practice off-season crops. These practices are made possible by a water dam and the many wells and boreholes located in Massakory.

Collection and Storage of Samples

Taking a water sample is quite a delicate operation and the greatest care must be taken. It conditions the analytical results and the interpretation that will be given. The sample must be homogeneous, representative and obtained without modifying the physico-chemical characteristics of the water [10]. It is therefore necessary to develop a methodology adapted to each case and to use the appropriate material. A single sampling session was carried out from November to April.

Samples were taken from three boreholes throughout the region. Most of these water points were created by Non-Governmental Organizations (NGOs), through foreign cooperation or by the State within the framework of village water supplies. To facilitate data manipulation, a sample number has been assigned to each sampling point.

Particular attention was paid to the collection equipment. Thus, we used new polyethylene bottles. Before going to the field, the vials were first washed with plenty of water, then with 10% nitric acid and finally rinsed thoroughly with distilled water. In the field before filling the bottles, as a safety measure, they were washed three (03) times with the water to be analyzed, and then filled to the brim. For each sampling point, five vials were required.

The first vial is acidified with nitric acid (1 mL / L) and will be used for the analysis of metallic trace elements. The second non- acidified flask was to be used for the analysis of physico-chemical parameters in the laboratory in the hours following the sample. The collected samples, carefully labeled and stored at 4 ° C in coolers, were transported to the laboratory.

Materials and Methods used for the Assays

Three physico-chemical parameters (pH, temperature and electrical conductivity) were measured in-situ, immediately after sample collection. The pH is measured in the field using a portable Radiometer Analytical pHM201 brand pH meter and in the laboratory with a Hanna pH 209 laboratory pH meter. The temperature was taken at using a digital thermometer. The conductivity measurement is made in the field using a portable conductivity meter from Hanna. Turbidity is measured using a turbidity meter, turbidity meterWAg-WT 3020. Its unit is the NTU (Nephelometric Turbidity Unit). Sodium and potassium ions are determined by flame atomic absorption spectrometry (SAAF). The apparatus used is a Varian AA 240FS brand atomic absorption spectrometer. Phosphate and nitrate ions are determined by spectrophoto-metry or colorimetry using a Hach Lange DR 3800 brand spectrophotometer. The determination of the Metal Trace Elements (MTEs) iron (II), manganese (II), total chromium and copper (II) was produced by complexing agents also on spectrophotometry. Calcium and magnesium ions are determined by complexometry using EDTA. The Complete Alkalimetric Title (TAC) is determined by volumetry.

Statistical Analyzes

The raw data from the laboratory were first processed (average standard deviations) using the Microsoft office Excel 2007 spreadsheet. The analyzes of variances (ANOVA) were finally carried out using the software of stratum-graph statistical analysis plus 5.0.

Results and Discussion

Physico-Chemical Parameters

Temperature

We noted (Table 1) temperature values relatively around 25°C during the sampling session which took place in December, a period corresponding to the start of the drain season in Chad and these temperatures do not show large variations from one point to another.

It plays an important role in increasing chemical and bacterial reactivity and water evaporation. It varies according to the outside temperature (air), the seasons, the geological nature and the depth of the water level in relation to the ground surface[11]. The observed temperature values are summarized in Table 1. We had three (3) boreholes: Seitchiri borehole (FS), Wandallah borehole (FW), Abori borehole (FA). We found out that the temperature of each analysis made from one borehole to another does not vary significantly. This temperature is substantially equal to the standard.

The temperature values recorded are in agreement with what is reported in the literature: groundwater is less sensitive to temperature variations than surface water [10].

Hydrogen Potential

All these values converge towards a neutral pH. This neutral character reflects the geological nature of our study area, the sandy or clayey cover that rissoles our study air and the significant use of detergents [12]. Table 1 shows that all the water points are within the range of the potability standard. The pH values comply with the WHO standard. In general, the pH values obtained for these groundwater are in accordance with the results obtained by other studies published in the literature because in most groundwater, the pH is between 6 and 8.5[13,14,15,16].

Electrical Conductivity

It is linked to the presence of ionic species in solution. The measured values have been corrected with respect to a standard temperature of 25°C. The results obtained are summarized in Table 1. The measurement ofthe electrical conductivity makes it possible to quickly assess, but very approximately, the overall mineralization of the water and to follow its evolution. The values of electrical conductivity obtained vary are greater than 300 µS / cm (table 1). This water is weakly mineralized. These results vary from one borehole to another this can be justified by the absence of cultivation practices in this season and also the influence of the distance of this borehole in relation to the points closest to the agricultural plots, the electrical conductivity varies mainly with the chemical composition of the organic matter which constitutes it and with that of the water in question [17], therefore the water remains mobile hence the instability of the inputs used by the farmers . These values show that the water points, in particular the FS and FW boreholes, exceed the recommended standard for drinking water supply (DWS). The observed high values of the electrical conductivity of these boreholes are due to the infiltration of water into the water table [18]. The waters of Massakory are weakly mineralized. These very weakly mineralized waters are not suitable for consumption.

Turbidity

This is an essential parameter because it gives an idea of the suspended solids content and generally provides information on the more or less cloudy appearance of the water. The results presented in Table 1 do not reveal a significant variation between the grades of these boreholes, on the other hand the three boreholes are slightly cloudy with values exceeding the WHO standard which is 5 NTU. The waters may have a very cloudy appearance from shallow wells, which explains their high turbidity.

Hardness

The total hardness of water is produced by the calcium and magnesium salts it contains. The hardness of the water mainly influences the condition of pipes and heating devices, and the washing of laundry.

Calcium

Calcium is an alkaline earth metal extremely widespread in nature and in particular in limestone rocks in the form of carbonates. It is the major component of water hardness. In our water samples, the calcium contents vary from 60.50 mg / L to 69.50 mg / L (Table 1). None of these waters therefore has a concentration greater than the WHO standard which is 100 mg / L. The presence of Ca^{2+} ions in water is mainly linked to two natural origins: the dissolution of the formation of carbonates ($CaCO_3$) and the dissolution of the formation of gypsum ($CaSO4$). Calcium ion analysis was carried out and the results obtained are presented in Table 1. This table shows calcium concentrations which vary from one borehole to another. The values found indicate that these boreholes are less influenced by the dissolution of the carbonate and gypsum; this could also be due to the strong dilution of the ions. The calcium contents in the department ofDagana are low compared to the norm because the sites are not favorable for the dissolution of carbonate elements.

Magnesium

Magnesium is the second most significant component of water hardness after calcium. It is present in the waters of this region at levels ranging from 101.45 to 208.45 mg / L (Table 1). These grades are lower than the WHO accepted standard for magnesium, which is 150 mg / L for the Seitchiri (FS), Wandallah (FW) wells and higher for the Abori (FA) well. The origins of magnesium are comparable to that of calcium, because it comes from the dissolution of carbonates with high levels of magnesium (magnesite and dolomite). The analysis of the magnesium ions was carried out and the concentrations observed at the level of the boreholes are presented in Table 1. The evolution of the magnesium contents is much greater than that of the calcium. The comparison of these concentrations with the potability standards shows that the Wandallah (FW) borehole has grades above the potability limit, which is explained by the strong dissolution of the carbonate with high magnesium content. The low hardness values of the water recorded do not allow the development of a carbonate layer that can participate in the protection of pipes against certain risks of corrosion [10]. As a result, water that is too soft is aggressive towards the pipes; in particular, the corrosion of lead pipes becomes dangerous for the health of the consumer [19]. On the other hand, these carbonate deposits have a beneficial effect by protecting the pipes from corrosion.

Table1. *The physical parameters of borehole water (A)*

Parameters	Borehole			Admissible values
	FS	FW	FA	
Temperature	$25{,}01 \pm 0{,}01^a$	$25{,}02 \pm 0{,}03^a$	$25{,}01 \pm 0{,}01^a$	25°c
pH	$7{,}41 \pm 0{,}02^a$	$7{,}44 \pm 0{,}19^a$	$7{,}55 \pm 0{,}24^a$	$6{,}5 - 8{,}5$
Conductivity	$4919{,}00 \pm 1{,}41^a$	$8180{,}50 \pm 0{,}71^b$	$2899{,}50 \pm 0{,}71^c$	300 µS/cm
Turbidity	$10{,}50 \pm 0{,}71^a$	$10{,}39 \pm 0{,}55^a$	$9{,}77 \pm 0{,}33^a$	5 NUT
Ca^{2+}	$60{,}50 \pm 0{,}71^a$	$10{,}50 \pm 0{,}71^b$	$69{,}50 \pm 0{,}71^c$	100 mg/L
Mg^{2+}	$101{,}45 \pm 0{,}78^a$	$105{,}40 \pm 0{,}85^b$	$208{,}45 \pm 0{,}64^c$	150 mg/L

a, b, c for the same row, the values assigned the same letter are not significantly different at the probability threshold p <0.05.

Sodium

The sodium ion analysis of the water samples from all 3 boreholes gives us levels ranging from 29.85 to 66.22 mg / L (Table 2), which is harmless to health, WHO recommended limit being 200 mg / L. The origin of this element is linked mainly to the dissolution of salt deposits and the effect of marine salinity. The concentrations are shown in Table 2.

Iron and Manganese

The iron (II) concentrations as can be seen in Table 2, vary from 0.27 to 0.82 mg / L. Almost all of the boreholes have contents exceeding the WHO standard which is 0.3 mg / L.

Manganese generally accompanies iron in rocks and in water. Naturally, the manganese concentrations in groundwater are on average 10 times lower than the iron concentrations. The manganese contents of the analyzed water vary from 0.08 to 0.74 mg / L as can be seen in Table 2. These contents vary from one water point to another and also according to the sampling period. Waters with concentrations greater than the WHO standard (0.4 mg / L).

These two chemical elements are often found together in nature. Their presence in water can have various origins: natural or industrial. The concentrations observed for these two elements in the three boreholes are given in Table 2. The highest concentrations are observed at the level of the FW borehole with concentrations reaching 0.82 mg / L for iron and 0.74 mg / L for manganese. The presence of these elements is linked to the nature of the metallic product which is used as a cover for these boreholes and to the reduced nature of the water, in the case of the existence of a clay cover [17]. The results obtained show a significant variation in iron and manganese from these three boreholes. The iron and manganese contents of these boreholes vary from one bore hole to another. This may be due to drainage and leaching of soils with dissolution of rocks and ores, corrosion of metal pipes, and the use of ferric salts as coagulants [18].

Iron is essential for the human body, but very high concentrations affect the organoleptic characteristics of water and stain laundry. The presence of iron in the water can promote the proliferation of certain strains of bacteria which precipitate the iron where the pipes corrode. The presence of manganese in water first of all represents an organoleptic (metallic taste) and aesthetic (black color) nuisance. This nuisance can be felt by consumers at a concentration of 0.03 mg / L [20]. Overloading the human body with iron can lead to primary hemochromatosis (poor regulation of iron absorption from the intestine) and even liver cancer (risk of liver cancer). Manganese can also cause irreversible neurological damage due to its antagonism to calcium. These disorders generally occur when the iron and manganese concentrations are respectively greater than 10 mg / L and 2 mg / L [21]. The iron (II) and manganese (II) contents exceed WHO standards, this justifies the complaints of the populations about the organoleptic quality of these waters.

Potassium

The potassium values that we measured by flame atomic absorption spectrometry (Table 2) vary from 13.02 to 37.75 mg / L. They are well below the WHO standard (200 mg / L). Potassium comes from the alteration of silicate formations (gneiss, shale), potassium clays and the dissolution of chemical fertilizers (NPK). Table 2 shows the concentrations observed in the boreholes. The highest values are observed at the FA borehole with a grade of 37.75 mg / L. The presence ofthis element in these boreholes is linked to urban waste, to the use of chemical fertilizers or to clay formations rich in potassium. The values observed in Table 2 show that most of the boreholes have concentrations below the potable limit. The presence of agricultural practices in the region has certainly favored the infiltration and leaching of chemical fertilizers rich in potassium.

Total Chrome

All the borehole waters analyzed (Table 2) have high total chromium contents varying from 0.12 to 0.17 mg / L, values higher than the WHO standard which is 0.05 mg / L. In water, chromium occurs in two chemical forms: the Hexavalent form (Cr VI) and the trivalent form (Cr III). The results obtained are presented in Table 2. From this table, it emerges that the concentrations observed in the three boreholes are greater than 0.05 mg / L. At the level of these boreholes we observe an increase in the concentrations which vary from 0.12 mg / L to 0.17 mg / L, this is surely due to the rejections of the electroplating and the tannery. The concentrations observed are higher than the standards for drinking water. The results observed show that there is not a significant difference between the three boreholes. The concentrations of these boreholes can also be partly justified by the presence of fields, dwellings, the practice of animal husbandry and the nature of the Massakory soil. These factors greatly influence the evolution and contamination of the region's waters.

Copper

All the borehole waters analyzed (Table 2) have low copper contents below the WHO standard which is 2 mg / L. Depending on the concentrations observed in three of the holes (Table 6), the concentrations vary from one hole to another. From Table 2, it emerges that there is a significant difference in the copper content between the three boreholes, these results can be explained by the degree of pollution of our water samples as well as in the agricultural treatments.

Nitrates

In the region studied, the nitrate contents varied during the study period (Table 2) from 2.95 mg / L to 4.93 mg / L. These values remain lower than the value admissible by the WHO standard which is 50 mg / L.

It is one of the three chemical forms of nitrogen. Table 2 gives the analysis results for the three boreholes. The maximum grades are observed at the level of the FA borehole but are still lower than the standard. Its presence in drilling water is linked to the intensive use of chemical fertilizers. The concentrations observed are lower than the standard for drinking water. Analysis of the results shows a slight variation in the nitrate content of the three boreholes. This is due to the different types of fertilizer used in the surrounding area for agriculture. Overall, the three boreholes do not constitute a danger for the consumption of water by the populations in nitrate because all these values are below the standard set by the WHO which is of the order of 50 mg / L. The low nitrate values obtained indicate that the water studied is not subject to a risk of pollution by nitrates, but these values indicate wastewater discharges and especially an excessive use of agricultural fertilizers.

Phosphate

The phosphate contents varied during the study period (Table 2) from 2.75 mg / L to 4.57 mg / L. These values remain lower than the value admissible by the WHO standard which is 5 mg / L. The results observed show a slight variation between the three holes. In these three boreholes, it is observed that the contents exceeded the standards because the maximum value of the content of phosphate concentrations must not exceed 5 mg / L according to the standards of the European Economic Community (EEC). They are due to the strong infiltration of water into the water table [11], because they are easily fixed in the soil and their presence in the water is linked to the nature of the land crossed. Agriculture makes extensive use of phosphate fertilizers and adjuvant detergents can also be the cause of increased phosphate concentration.

Table2. *The physical parameters of borehole water (B).*

Parameters	Forages			Admissible values
	FS	FW	FA	
Na^+	$39,80 \pm 0,28^a$	$66,22 \pm 0,31^b$	$29,85 \pm 0,28^c$	20 mg/L
Fe^{2+}	$0,51 \pm 0,04^a$	$0,82 \pm 0,10^b$	$0,27 \pm 0,07^c$	0, 3 mg/L

Mn^{2+}	$0,26 \pm 0,04^a$	$0,74 \pm 0,04^b$	$0,08 \pm 0,02^c$	0,4 mg/L
K^+	$13,02 \pm 0,01^a$	$27,86 \pm 0,66^b$	$37,75 \pm 0,83^c$	200 mg/L
Cr total	$0,12 \pm 0,014^a$	$0,17 \pm 0,04^a$	$0,17 \pm 0,01^a$	0,05 mg/L
Cu^{2+}	*$0,04 \pm 0,01^a$*	*$0,02 \pm 0,01^a$*	*$0,24 \pm 0,03^b$*	2 mg/L
NO_3^-	*$2,95 \pm 0,1^a$*	*$3,25 \pm 0,21^a$*	*$4,93 \pm 0,11^b$*	50 mg/L
PO_4^{3-}	*$2,75 \pm 0,10^a$*	*$4,57 \pm 0,21^a$*	*$3,33 \pm 0,23^b$*	5 mg/L

a, b, c for the same row, the values assigned the same letter are not significantly different at the probability threshold $p < 0.05$.

CONCLUSION

In this work, we analyzed the physico-chemical parameters of the water from three boreholes used as a source of drinking water by the populations of the region of Hadjer-Lamise, the department of Dagana, sub-prefecture of Massakory in order to assess the quality of these waters. This study has shown that these borehole waters are not recommended for consumption as drinking water. The parameters which downgrade this drilling water as drinking water are iron, manganese and total chromium for certain boreholes in the town of Massakory. It is therefore necessary to purify this water in order to eliminate certain metallic pollutants such as Fe^{2+}, Mn^{2+} and total Cr. The water from the Massakory boreholes has electrical conductivities and turbidity above the standard set by the WHO, justifying their very low mineralization and their very cloudy appearance. The major cations have an order of abundance of the type: $Mg^{2+} > Ca^{2+} > Na^+ > K^+$. The major anions occur in the following order: $NO_3^- > PO_4^{3-}$

It emerges from this work that it would be necessary to pay special attention to the water consumed in the Hadjer-Lamise region in general and in Dagana Massakory locality of Chad in particular. We offer a control of the bacteriological quality of the water from this borehole, monitoring this work in the dry season and in the rainy season. It is desirable that such analyzes be extended to all drinking water from all towns and villages in Chad to establish their degree of how potable they are.

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