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Evaluation of the physicochemical and bacteriological quality of drilling water in the Commune of the 7th District in N'Djamena city

Théophile Maoudombaye [1,*], Djibrillah ADAM [2] and Albert NGAKOU [2]

[1] Department of Life and Earth Sciences, Faculty of Exact and Applied Sciences, University of Moundou, B p. 206, Chad.
[2] Department of Biological Sciences, Faculty of Sciences, University of Ngaoundéré, B p. 454, Cameroon.

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Abstract

This study was carried out in the commune of the 7th District of the city of N'Djamena on the physicochemical and bacteriological quality of water from manual drilling. In total, ten boreholes were taken in ten districts of the said District. On each sample of drilling water taken, seven physicochemical parameters were analyzed, namely temperature, pH, conductivity, turbidity, Nitrates, Ammonium and Iron and four bacteriological parameters in occurrence, *E. Coli*, fecal coliforms, fecal enterococci and total aerobic mesophilic flora. It appears from these analyzes that on the physicochemical level, very high values were recorded for turbidity (9.33±0.15 NTU, 25.2±0.1 NTU and 34.63±0.49 NTU), on iron (1.16±0.005 and 5.41±0.25 mg/L) and on ammonium ions (0.6±0.15 mg/L and 0.7±0.057 mg/L). On the other hand, on a bacteriological level, most of the water was contaminated with *E. Coli*, fecal coliforms and total aerobic mesophilic flora. In view of these results, the consumption of this drilling water without prior treatment would expose the population of the 7th District of the commune of Ndjamena to contamination of bacteriological origin. To do this, awareness-raising work among the owners of these boreholes is necessary to warn them of the health risk they run because these borehole waters do not comply with the directives of the texts in force.

Keywords: Quality; Water; Manual forges; N'Djamena

1. Introduction

Better water quality is essential because it improves health. A decline in water quality threatens the progress made over the past 20 years in improving access to drinking water [1]. Between 1990 and 2011, global efforts helped 2.1 billion people gain access to improved drinking water, but not all of these new sources are necessarily safe [2]. The countries with the least access to drinking water are located in Africa and South Asia [3]. 319 million people in Sub-Saharan Africa still did not have access to drinking water in 2014, three out of four households fetch water outside their home [4].

The drinking water supply in the city of N'Djamena is covered by the Chadian Water Company (STE) but this distribution network only covers part of the city, five districts including the 7th are not served by the STE [5]. The 7th Arrondissement is the largest (with 18 districts) and is the most populated in the city demographically [6]. Failing to be covered by the STE, the population carries out private manual drilling to obtain water supplies. However, the water from these boreholes is not subject to quality and hygiene control. To this end, this study aims to evaluate the physicochemical and bacteriological parameters of manual drilling water consumed by the population of the 7th District of the city of N'Djamena.

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[*] Corresponding author: Maoudombaye Théophile; E-mail: theomaoudombaye@gmail.com

2. Material and method

2.1. Study site

The locality of N'Djamena retained for the purposes of this study is the political capital of the Republic of Chad. Crossed by the Chari River, the city of N'Djamena sits on clay soil. The city of N'Djamena is located between 12°06' N and 12°07' N, and between 15°03'' E and 15°04' E, with an area of 395 km^2 (fig. 1). It is located in west-central Chad, at the confluence of the Chari and the Logone. It contains more than 65 neighborhoods which are distributed across the 10 districts. Like many other African cities, Ndjamena suffers from a lack of hygiene and sanitation. N'Djamena enjoys a Sahelian climate. The rainy season really begins in June and ends in October, of which the months of July and August are well rained with an average of 144 mm and 175 mm/year respectively. The average temperature is around 28 °C [7].

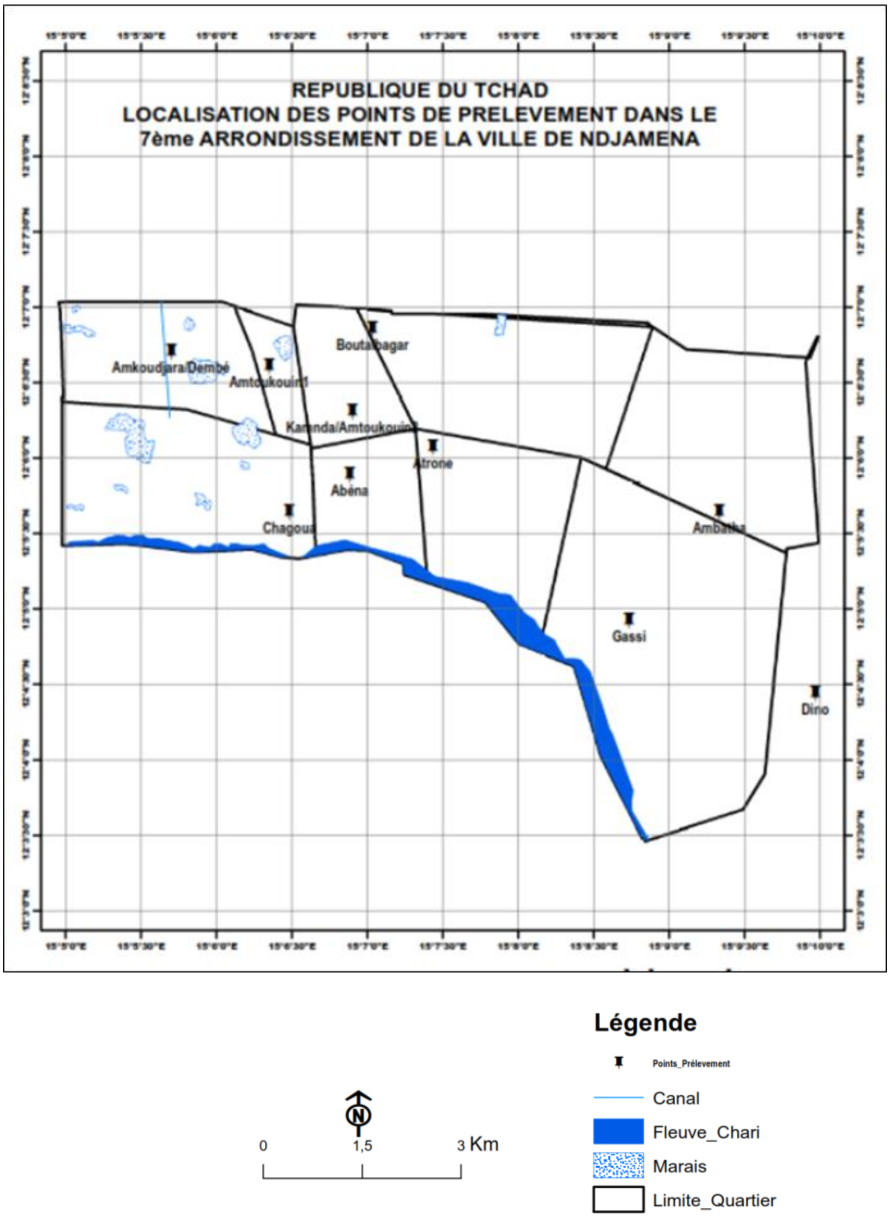

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Figure 1 Geographic location of sampling points

2.2. Sampling points and their surroundings

The sampling points were chosen following a field survey. Information relating to these points concerned risk factors such as the existence of latrines in households, their proximity to water points, the state of health of the environment of water points. Thus, the inventory around water points took into account the distances between latrines and water points, the presence of stagnant water around these points, the management of solid and liquid household waste in households. The distances between water points and latrines were measured using a tape. Indications of unsanitary conditions were also noted.

2.3. Sample collection

The sampling was carried out randomly in the ten (10) neighborhoods of the 7th Arrondissement of the Municipality of N'Djamena. This gave a total of ten (10) samples of borehole water taken. To avoid contamination of the sampling equipment, disposable gloves and disinfection liquids were used during sampling. All water outlet points from the boreholes were sterilized by flame using a blowtorch and cotton soaked in alcohol before any sample collection. The sample was taken after pumping water from the borehole for 4 to 5 minutes in order to derust the pipes.

The sample was taken in 500 mL High Density Polyethylene (HDPE) bottles, previously washed and sterilized in an oven at 80 °C. The previously labeled vials were rinsed two to three times with the sample water before sampling. The samples were labeled and transported to the laboratory in isothermal coolers at 4 °C to block any microbiological activity [8].

2.4. Analyzes of physicochemical parameters

Temperature, pH, conductivity and turbidity were measured in situ. Temperature, pH, conductivity were evaluated using a WTW Hi 9829 brand multi-parameter. While turbidity was measured using a WAGTECH brand turbidimeter.

Iron (Fe), nitrate (NO_3^-) and ammonium (NH_4^+) ions were measured spectrophotometrically using a HACH model DR2800 electrophotometer. This method consists of measuring the optical density of chemical substances according to their absorption wavelength. It is a method that is simple, precise and rapid, which helps reduce errors that could be due to manipulation [8].

2.5. Analysis of bacteriological parameters

Escherichia coli, total coliforms, fecal enterococci and total mesophilic aerobic flora were the bacteriological parameters sought. These bacterial germs were chosen because of their importance in the evaluation of the microbiological quality of drinking water, especially groundwater which is the most consumed water resource in many regions of the world ([9], [10]). These germs were determined by the membrane filtration method as described by [8]. This method is widely used for the enumeration of microorganism germs in water intended for human consumption.

3. Results and discussion

3.1. Environment of the boreholes sampled

Observation of the immediate environment was carried out around human-powered drilling. Latrines and septic tanks (sumps) are located within a maximum radius of 20 m from the boreholes. Most of these boreholes have stagnant water around the edge, often intentionally retained by the owners to water animals or for other uses. These boreholes are not surrounded by protective walls. A few rare boreholes are located on a slab of approximately 40 cm. Roaming domestic animals have been observed around certain boreholes.

Borehole water is intended for all domestic uses. Wastewater is poured into household yards. While solid waste is stored either in the yard or in the streets in front of the houses.

3.2. Sources of pollution from sampled boreholes

The information collected and observations made in the field during the data collection campaign made it possible to understand that human activities, low accessibility to basic sanitation services and the deficit in public hygiene could be the cause of the bacteriological pollution encountered in drilling waters in the municipality of the 7th Arrondissement. Various reasons can explain the pollution of these waters:

- Contamination by surface water loaded with human or animal faeces or wastewater by infiltration: from surface runoff, microorganisms penetrate the soil and increase the activity of their vital functions, allowing good migration towards groundwater;

- Poor drilling equipment: when equipping the drilling, the seal must be placed just at the level of the bedrock in order to prevent any kind of surface pollution;
- The distance separating the borehole from latrines or septic tanks (sumps): a well must be located at least 15 m from any source of contamination if the casing is watertight to a depth of 6 m; otherwise, the separation distance must be at least 30 m [11]. If this distance is not large enough, the effluents from these infrastructures can migrate towards the water table and cause its pollution.

The distances recorded between the sampled water points and sources of contamination such as latrines and septic tanks are recorded in Table I.

Table 1 Distance between sampled boreholes and latrines

Distance in (m)	N	Percentage
0-5	3	30%
5-10	3	30%
10-15	1	10%
>15	3	30%

The 0-5, 5-10, 10-15 and >15 are distances that separate a water point from a source of pollution.

The analysis of Table I shows that 30% of the sampled boreholes are located at a distance between 0 and 5 m, 30% at a distance between 5 and 10 m, 10% at a distance between 10 and 15 m and 30 % at a distance greater than 15 m from the latrines. This analysis shows overall that 70% of the water points sampled are located near latrines (0 to 15 m) which are potential sources of fecal contamination. Only 30% are located at a distance greater than 15 m. In addition to this proximity to latrines, the presence of household waste and/or stagnant water should be noted. The most common sources of contamination are the infiltration of effluent from a septic system, manure, pet excrement, road products as well as dissolved chemical substances naturally present in the water table, such as calcium, sulfur, chlorides or iron [11]. Sewage systems, septic tanks, factory wastewater and solid waste are the main sources of groundwater pollution in the urban sector [12].

3.3. Physico-chemical parameters

Table 2 Physicochemical parameters

parameters	Temperature (°C)	pH	Conductivity (µS/cm)	Turbidity (NTU)	NO_3^- (mg/L)	NH_4^+ (mg/L)	Fer (mg/L)
Dino	30.5±0.5	7.56±0.6	262.5±0.5	0.07±0.11	0.3±0.01	0.,1±0.10	0.28±0.026
Gass	31.8±0.28	7.54±0.05	189.6±0.6	0.15±0.02	1.1±0.63	0.21±0.04	0.14±0.01
Abasha	31.3±0.35	6.25±0.05	282.53±2.82	0.13±0.15	2.16±1.12	0.53±0.05	0.26±0.015
Dembé	32±0.7	5.6±0.1	111.87±1.3	9.33±0.15	3.1±0.75	0.6±0.15	0.28±0.015
Chagoua	31.5±0.07	6,15±0,07	119,57±2,9	34,63±0,49	1,5±0.08	0,22±0,005	5,41±0,25
Abena	31,6±0,4	7±0.1	247.4±3.32	25.2±0.1	1.8±0.03	0.25±0.26	1.16±0.005
Atrone	32.05±0.07	7.11±0.08	208.87±1.64	1±0.98	1.16±0.07	0.3±0.049	0.15±0.005
Kamnda	30.8±0.35	7.19±0.01	227.13±1.26	0.06±0.11	2.1±1.21	0.7±0.057	0.33±0.49
Amtoukouin	31.05±0.07	6.67±0.06	114.4±3.2	1.18±0.02	0.8±0.46	0.13±0.005	0.13±0.15
Boutalbagar	32.1±0.14	6.74±0.05	256.2±0.81	0.14±0.025	1.2±0.69	0.28±0.043	0.4±0.26
WHO guidelines	25	6.5-8.5	400	5	50	0.5	0,3

Gassi, Ambatha, Dembé, Chagoua, Abena, Atrone, Kamnda, Amtoukouin and Boutalbagar are the districts from which the samples were taken.

3.3.1. Temperature

Water temperature is an ecological factor that causes significant ecological repercussions [13]. It acts on the density, viscosity, solubility of gases in water, the dissociation of salts, chemical and biochemical reactions, the development and growth of living organisms in water and particularly microorganisms [14]. The grid established by the WHO for the quality of water intended for consumption is 25 °C.

For all samples analyzed, the temperature is above 25 °C. It is between 30.5±0.5 °C (Dino) and 32.1±0.14 °C (Boudalbangar). According to [15], the ideal temperature of drinking water is between 6 and 12 °C. The high temperatures could be explained by the influence of ambient heat on the water collected and also by the geothermal gradient of the area [16]. The temperatures of the city of Ndjamena which vary between 24.5 and 44.8 °C could explain these values obtained in Table II. These results corroborate those of [17] who also found an average temperature of 31.95±2.24 °C in the Doba oil basin in southern Chad. Also, [18] obtained an average of 30.6±2.78 °C in Cotonou, Benin. [19] also obtained temperatures between 25.6 and 32.2 °C in Tijikja in Mauritania.

3.3.2. pH

pH represents the concentration of hydrogen ions in a solution. The pH of natural waters is linked to the nature of the terrain crossed. In natural waters, pH values are between 6 and 8.5 [20]. Likewise, the WHO assigns a value ranging from 6.5 to 8.5 for quality drinking water.

The water from boreholes in the Dembé, Chagoua and Ambatha districts have respectively pH values of 5.6±0.1, 6.15±0.07 and 6.25±0.05. These are below the WHO limit value of 6.5. Overall, the waters analyzed have pH ranging from 5.6±0.1 (min) in Dembé to 7.56±0.6 (max) in Dino. These results are lower than those obtained by [21] who found an average pH of 7.26 ±0.43 in the Municipality of Ndjamena. They are similar to those of [22] who reported the means of 6.53±0.51. According to [5], the highest pH recorded was that of a borehole in the Atrone district (7.37) and the lowest that of the Dembé district (6.65).

3.3.3. Conductivity

The conductivity of natural water is between 50 and 1500 µS/cm [23]. The conductivity contrasts measured on a medium make it possible to highlight pollution, mixing or infiltration zones [24]. It also makes it possible to assess the quantity of salts dissolved in water ([25], [26]). However, the WHO recommends a value of 400 µS/cm for drinking water.

The conductivity values of the different samples analyzed are between 111.87±1.3 µS/cm in Dembé to 282.53 µS/cm in Ambatha. These results corroborate those reported by [27] which range from the order of 137.25 µS/cm to 261.55 µS/cm in groundwater in Yaoundé II in Cameroon. However, [28] obtained values of electrical conductivities in the groundwater of the town of Moundou varying between 59.7 (Kou-P1) to 1999 µS/Cm (Mbo-P7) with an average of 775.6 µS/ cm. According to [12], the geomorphological context, the depth of the boreholes taken and the geological nature of the soil formations are all factors which influence variations in conductivity.

3.3.4. Turbidity

The turbidity of water is linked to its transparency. It gives an idea of the content of very small suspended matter (silica grains, organic matter, silt, etc.), arouses distrust and repugnance in the consumer [29]. The WHO recommends a value of less than 5 NTU for drinking water. Consumption of very cloudy water can constitute a health risk because excessive turbidity can protect against pathogenic microorganisms or stimulate the growth of bacteria in the networks. For this reason, reducing turbidity is one of the primary treatment factors [30].

The different samples analyzed show a turbidity of between 0.06±0.11 NTU in Kamnda and 34.63±0.49 NTU in Chagoua. To this end, four (4) samples out of the ten analyzed have values consistent with WHO guidelines. [31] obtained average turbidity values between 4.3 and 28.2 NTU in well water in Brazzaville, Congo. Turbidity is caused by materials such as clay, silt, fine organic and inorganic matter, plankton and other microscopic organisms suspended in water [21].

3.3.5. Nitrates

The presence of NO_3^- in certain samples could be explained by the nature of the soil. According to [20], nitrates are present naturally in the soil; they can penetrate and reach groundwater by infiltration. The aging of certain structures leads us to believe that the equipment installed to protect them against pollution of anthropogenic origin is no longer effective [19]. Consequently, borehole water becomes vulnerable to organic pollutants from domestic activities: latrines, garbage deposits, infiltration of dirty water, etc. [32].

The value of 50 mg/L is indicated by the WHO for drinking water. Nitrates are reduced to nitrites, which bind to hemoglobin instead of oxygen and cause breathing difficulties (asphyxia): It is methemoglobinemia (cyanosis) which mainly affects infants (born or pregnant) and presents a short-term risk [33]. The nitrate concentrations of the water analyzed vary from 0.3±0.01 mg/L (Dino) to 3.1±0.75 mg/L in Dembé. These values are very low compared to that recommended by the WHO for NO_3^- concentrations in drinking water (50 mg/L). On the other hand, these values are much lower than those obtained in Ivory Coast by [34] which are on average 14.9±22.4 mg/L and those of [19] in Mauritania which range from 1.97 mg/L to 43.5 mg/L.

3.3.6. Iron

The maximum acceptable concentration in drinking water has been established at 0.3 mg/L to preserve its aesthetic qualities [35]. Table II shows that the iron concentrations of the different samples oscillate between 0.13±0.15 mg/L in Amtoukouin and 5.41±0.25 mg/L in Chagoua. Two samples show a high concentration of total iron, notably the samples from the Chagoua and Abena districts whose iron levels are respectively 5.41 mg/L and 1.16 mg/L. The values of water samples taken in Chagoua (5.41±0.25A mg/L), Abena (1.16±0.005 mg/L), Kamnda (0.33±0.49 mg/L) and Boutalbagar (0.4±0.26 mg/L) are higher than that of the WHO. These results are similar to those of [36] who obtained values between 0.40 and 3.60 mg/L in Abidjan in Ivory Coast. [28] reported iron values ranging between 0.02 (Bel-F3) and 1.1 mg/L (Mbo-P7), with an average value of 0.14 mg/L in the city's groundwater from Moundou. They do not corroborate those of [5] whose iron concentration obtained in the water in Chagoua is 0.5 mg/L and 0.4 mg/L in Dembé. This difference would be due to the variation in the depth of the wells sampled. The high iron concentrations in the waters of certain neighborhoods can be explained by the nature of the different layers passed through by the water to reach the water table. This presence can also be explained by the drilling equipment materials and by the corrosion of metal pipes. Iron comes from the hydrolysis of iron-rich minerals such as biotites, pyroxenes or olivines contained in different sediments [37].

3.4. Bacteriological parameters

Table 3 Bacteriological parameters

samples	*Escherichia coli*	Total coliforms	Faecal enterococci	Total mesophilic aerobic flora
Dino	3	100	0	87
Gassi	6	100	0	95
Ambatha	3	77	0	100
Dembé	4	100	0	100
Chagoua	11	100	0	99
Abena	9	100	0	100
Atrone	5	99	0	91
Kamnda	0	100	0	90
Amtoukouin	4	96	0	100
Boutalbagar	95	98	0	96
WHO guidelines	0	0	0	10 UFC/mL to 37°C and 100 UFC/mL to 22°C (Desjardin, 1990)

Gassi, Ambatha, Dembé, Chagoua, Abena, Atrone, Kamnda, Amtoukouin and Boutalbagar are the districts from which the samples were taken.

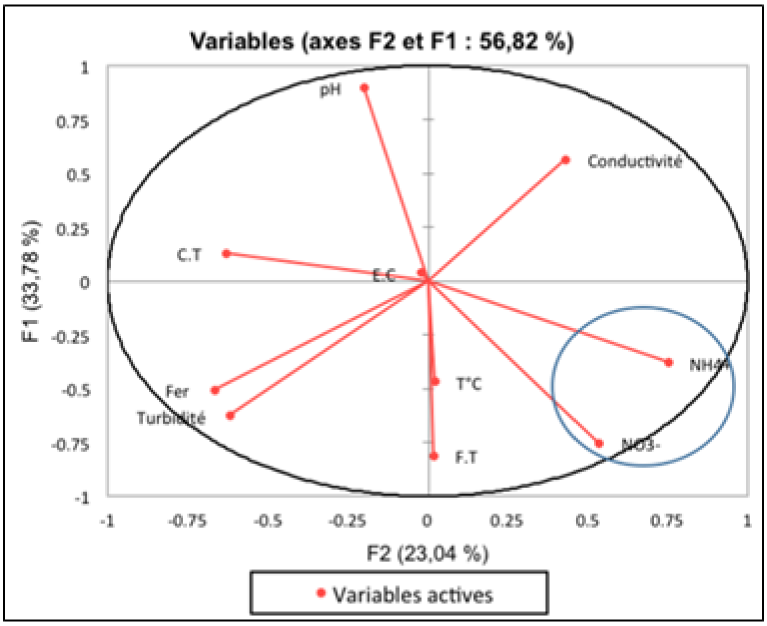
According to the WHO guidelines for safe drinking water, for *E coli*, total coliforms and faecal enterococci tested for, no colonies should be found in a 100 mL water sample. On the other hand, for total mesophilic aerobic flora, Health Canada recommends values of 10 CFU/mL at 37°C and 100 CFU/mL at 22°C for drinking water [38].

The results of the microbiological analyzes show that the samples from the nine (9) districts, Dino, Gassi, Ambatha, Dembé, Abena, Atrone, Amtoukouin, and Boutalbagar, are contaminated with *E. coli* ranging from 3 to 95 CFU/100 mL. Only the water from the Kamnda district which does not contain any. The presence of *E. coli*, found in 99% of the water analyzed, is an indication of contamination of water from fecal origin. According to the WHO, the most accurate indicator for estimating fecal pollution is in fact *E. coli*, a member of the thermotolerant coliform group. [39] found similar results in Lomé, Togo. In Abengourou in Ivory Coast, [40] also counted strains of *E. coli* in 28% of the well water analyzed. The bacteriological quality of well water highlights the contamination of the water table of fecal origin, especially by *E. coli* [16].

The presence of total coliforms is noted in all samples analyzed. The count shows that there are between 77 and more than 100 CFU/100mL per water source. These results do not meet the WHO drinking water criteria for this parameter. [41] also found excessive contamination of Niamey well water with total coliforms and fecal streptococci. Faecal enterococci were not detected in any sample. On the other hand, all the drill water samples analyzed contain values ranging from 87 CFU/100mL to more than 100 CFU/100mL for total mesophilic aerobic flora. According to [42], sewer networks, septic tanks, factory wastewater and solid waste are the main sources of groundwater pollution in the urban sector and in peri-urban areas. [43] and [44] explain the presence of fecal coliforms and fecal streptococci in well water by contamination of fecal origin. Fecal streptococci and coliforms are indicators of fecal pollution and are largely of human origin [36]. In addition, contamination of the well water table depends on the permeability of the soil, the depth of the water table, the absence or unsuitability of sanitation works, poor waste management and the drawing method. ([16], [45]).

3.5. Principal component analysis (PCA) of physicochemical and bacteriological parameters

The analysis of the distribution of samples in the factorial designs makes it possible to highlight the similarities and dissimilarities existing between the samples according to their elementary composition. Thus, the two axes hold 56.82% of the total information with respectively 33.78% for axis 1 and 23.04% for axis 2. This energy is low compared to that reported by [46]. which is 72.69% of the total information with respectively 48.15% for axis 1 and 24.53% for axis 2.



E. c = *Escherichia coli*, CT = total coliforms, total mesophilic aerobic flora.

Figure 2 Circles of correlations of physicochemical and bacteriological parameters

3.6. Matrix of correlations of physicochemical and bacteriological parameters

The correlation matrix (Table IV) took into account seven (7) physicochemical variables (conductivity, pH, temperature, turbidity, NH_4^+, NO_3^- and Iron) and three microbiological variables (E. coli, total coliforms and total mesophilic aerobic flora). The higher the correlation, the more the variable is related to the component. Conversely, the closer the r^2 is to 0 (zero), the less the variable is linked to this component [47].

Highly positive correlations are recorded between NH_4^+ and NO_3^- ions (r = 0.848), between turbidity and iron (r = 0.863). Other weakly positive correlations occurred between conductivity and pH (r = 0.484), between temperature and E. coli (r = 0.445), between temperature and total mesophilic aerobic flora (0.407) and between nitrate ions and total mesophilic aerobic flora (r = 0.477).

Table 4 Correlation matrix (Pearson) between physicochemical and bacteriological parameters

Variables	**Cond.**	**pH**	**T°C**	**Turb.**	**NH_4^+**	**NO_3^-**	**Fer**	**E.C**	**C.T**	**F.T**
Cond.	1									
pH	0.484*	1								
T°C	-0.193	-0.352	1							
Turb.	-0.357	-0.361	0.152	1						
NH_4^+	0.072	-0.419*	0.065	-0.161	1					
NO_3^-	-0.186	-0.710*	0.331	0.219	0.848*	1				
Fer	-0.378	-0.314	0.032	0.863*	-0.195	0.028	1			
E.C	0.256	-0.045	0.445*	-0.104	-0.144	-0.151	-0.016	1		
C.T	-0.384	0.313	0.106	0.256	-0.273	-0.210	0.173	0.076	1	
F.T	-0.406*	-0.725*	0.407*	0.465*	0.061	0.477*	0.277	0.066	-0.346	1

Star (*) values are significantly different from 0 at alpha = 0.05 significance level; E. c = *Escherichia coli*, CT = total coliforms, total mesophilic aerobic flora.

4. Conclusion

The study of the physicochemical and bacteriological quality of water from manual drilling in the 7th district of the city of Ndjamena highlights the contamination of this water by bacterial germs. The main causes of this contamination are latrines and septic tanks (sumps), the presence of stagnant water often voluntarily retained by owners to water animals or for other uses around the edges of boreholes, absence of protective walls, poor drilling equipment, wandering domestic animals, management of solid and liquid household waste. Concerning latrines or septic tanks, 30% of the sampled boreholes are located at a distance between 0 and 5 m, 30% at a distance between 5 and 10 m, 10% at a distance between 10 and 15 m and 30 % at a distance greater than 15 m from the latrines. Overall, 70% of the water points sampled are located near latrines (0 to 15 m) and only 30% are located at a distance greater than 15 m which is a distance recommended by international texts between a water source, drinking water and a latrine. The lack of these hygienic conditions around water points thus reduces the health benefit expected from manual drilling.

Compliance with ethical standards

Disclosure of conflict of interest

The authors declare no conflict of interest.

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