

# Impact of Autonomous Sanitation Practices on Groundwater Quality: Case of Peripheral Neighborhoods of the 7th Arrondissement of the City of N'Djamena, Chad

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**Abstract:** This study assesses the impact of on-site sanitation practices on the bacteriological quality of borehole water in the outlying neighborhoods of the 7th arrondissement of N'Djamena. To this end, sixteen (16) water samples were collected from 16 boreholes for physical and microbiological analyses, combined with piezometric sampling. The results show the presence of *Escherichia coli* in five of the 16 boreholes. Total coliforms and total aerobic bacteria were detected in all sampled boreholes. Fecal enterococci were found in only one borehole. The presence of these microorganisms, indicators of fecal contamination, in the samples reveals the link between the sampled water points and the wastewater treatment facilities. The piezometric map identified three areas of depression, two areas of high groundwater, and several low piezometric levels.

**Key words:** Impact, sanitation, contamination, drinking water, bacteriological.

## 1. Introduction

On-site sanitation is defined as a wastewater treatment system implemented at the household or community level, outside of any collective sewer system. It encompasses a range of storage infrastructures such as septic tanks, traditional latrines, soakaways, and infiltration systems, used primarily in areas where collective sanitation infrastructure is absent or insufficient [1]. This sanitation method, often implemented individually or in communities, constitutes an essential supplementary solution for rural and peri-urban populations, but it raises significant environmental and health challenges when poorly designed or managed. Access to safe drinking water is a major challenge for public health and sustainable development, particularly in developing countries like Chad. The capital, N'Djamena, is experiencing rapid population growth, which is placing considerable pressure on water resources and sanitation

infrastructure [2]. In the 7th arrondissement, where there is no centralized sewage system, households rely on on-site sanitation systems such as septic tanks and traditional latrines. However, these systems, often poorly maintained, outdated, or unsuitable for local hydrogeological conditions, pose a significant risk to groundwater quality, which is the primary source of drinking water for the majority of the population [3]. Indeed, numerous studies conducted in sub-Saharan Africa have highlighted the contamination of groundwater by pollutants from domestic sources, including nitrates, fecal bacteria, and certain heavy metals [4]. In the context of the 7th arrondissement of N'Djamena, the proximity of drinking water sources to substandard sanitation facilities significantly increases the risk of microbiological and chemical pollution of groundwater. According to Belghiti [5], this situation promotes the spread of waterborne diseases such as diarrhea, cholera,

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and intestinal infections. For Ali [6], soil permeability and shallow groundwater levels facilitate the rapid infiltration of contaminants, thus exacerbating the vulnerability of water resources. Added to this are the absence of rigorous regulations, the lack of institutional oversight, and low public awareness of good sanitation practices. Ultimately, autonomous sanitation infrastructure consists of storage facilities accompanied by a sludge treatment plant. However, in the study area, there is no sludge treatment plant; consequently, wastewater is discharged untreated into quarries, retention basins, and public spaces, with the resulting impact on human health. The overall objective of this study is to analyze the impact of on-site sanitation practices on groundwater quality in the outlying neighborhoods of the 7th arrondissement of N'Djamena.

Specifically, the objectives are to:

- Conduct a survey of current wastewater treatment

practices in the study area.

- Analyze the physical and bacteriological quality of groundwater from boreholes tapping the aquifers in the study area;

- Perform piezometric measurements to determine the depths of the boreholes.

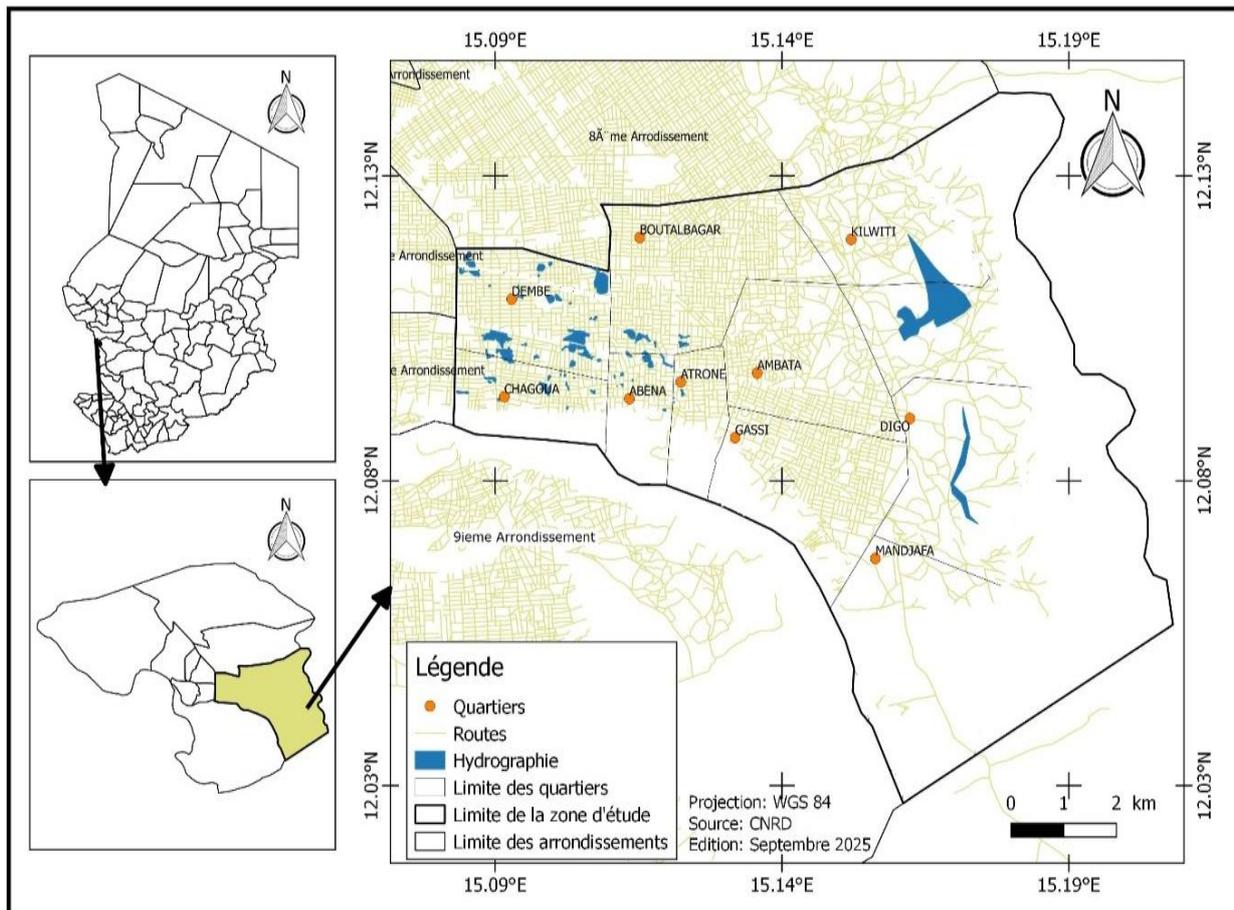
## 2. Materials and Methods

### 2.1 Material

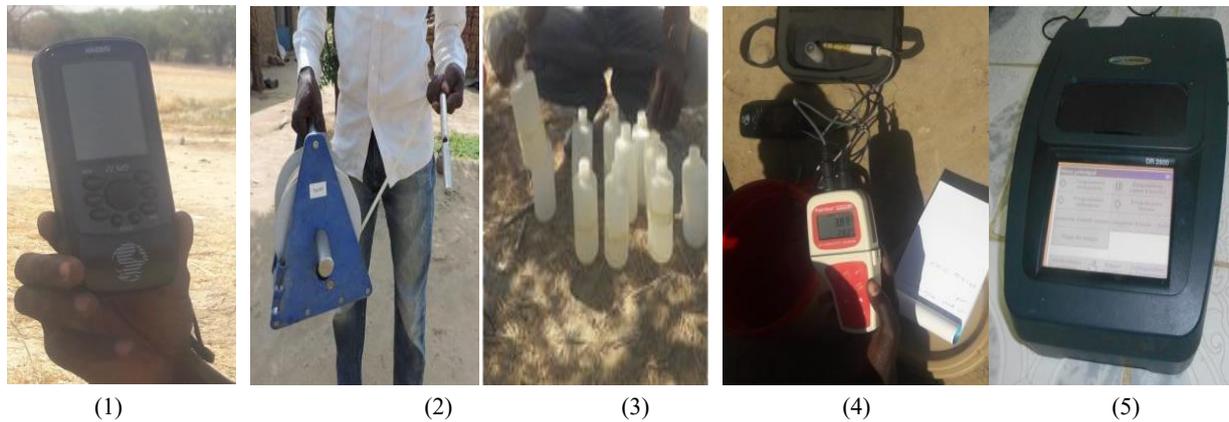
- Location of the study area

The study area covers part of the municipality of N'Djamena, specifically certain outlying neighborhoods of the 7th arrondissement located along the Chari River. Geographically, it extends between 12°03' and 12°10' North latitude and between 15°02' and 15°07' East longitude, with an average altitude of 287.3 m.

The material in box 1 is that which was used for the study.



**Fig. 1** Location map of the study area.



**Fig. 2 Study materials: (1) global positioning system (GPS) records the geographic coordinates of the points. (2) a 100 m piezometric probe to measure piezometric levels. (3) 500 ml polyethylene sampling bottles. (4) a WTW field multimeter for in-situ measurement of physical parameters. (5) DR800 spectrophotometer.**

### 2.1.1 Data Processing and Analysis

For data entry and coding, Excel spreadsheets were used. QGIS 2.16 software was used for positioning sampling points and determining the geographic location of water points in our study.

## 2.2 Methods

Three methods were selected:

- Assessment of existing on-site and water-based sanitation infrastructure;
- Piezometric measurements;
- Bacteriological analysis.

These methods are grouped into fieldwork and laboratory work.

### 2.2.1 Fieldwork

#### (1) Inventory of On-Site Sanitation and Water Infrastructure

The work consisted of conducting field observations, including taking photographs and engaging in discussions with local communities. These observations concerned the construction and use of water infrastructure (hand-pumped boreholes), the types of sanitation facilities (latrines, soakaways, septic tanks), and sludge management practices.

#### (2) Piezometry

Piezometry refers to the set of measurements of piezometric levels: static level and dynamic level of hydraulic structures, wells, and boreholes in the area.

The method used a piezometric probe to perform the various measurements. The campaign lasted 5 days and covered 16 boreholes, whose coordinates were recorded and their positioning on the map of the study area was carried out as illustrated in Fig. 3. Technical data sheets for several hydraulic structures were collected from the provincial hydraulics delegation. This data allows for the visualization of the hydrodynamic parameters of these structures (static level, total depth, test flow rate). The piezometric level is obtained by subtracting the static water level in the structure from the altitude of the point relative to sea level, obtained by GPS, using the following equation:

$N_s = N_m - M$ , with  $N_s$ ; the static level,  $N_m$ ; the measured water level and  $M$  the coping.

**Piezometric level calculation:** This is a mathematical operation based on parameters measured in the field and is calculated by the difference between the ground level (the structure's reference point or altitude) and the water depth. It is therefore obtained using the following formula:  $N_p = Z - N_d$

Where:  $N_d = N_m - M$ ;  $N_m$ : Piezometric level in meters (m);  $N_d$ : Dynamic level in meters;  $N_d$ : Altitude of the topographic surface in meters (m).

#### (3) Water Sampling and Storage

Sixteen water samples were collected from sixteen boreholes, one per borehole, distributed across the four

districts. Their geographic coordinates are shown in Table 1. These boreholes are shown in Fig. 3.

The parameters (pH, temperature, conductivity) were measured in situ. The samples were kept in a cooler and transported on the same day as collection to the National Water Laboratory, N'Djamena branch.

### 2.2.2 Laboratory Work

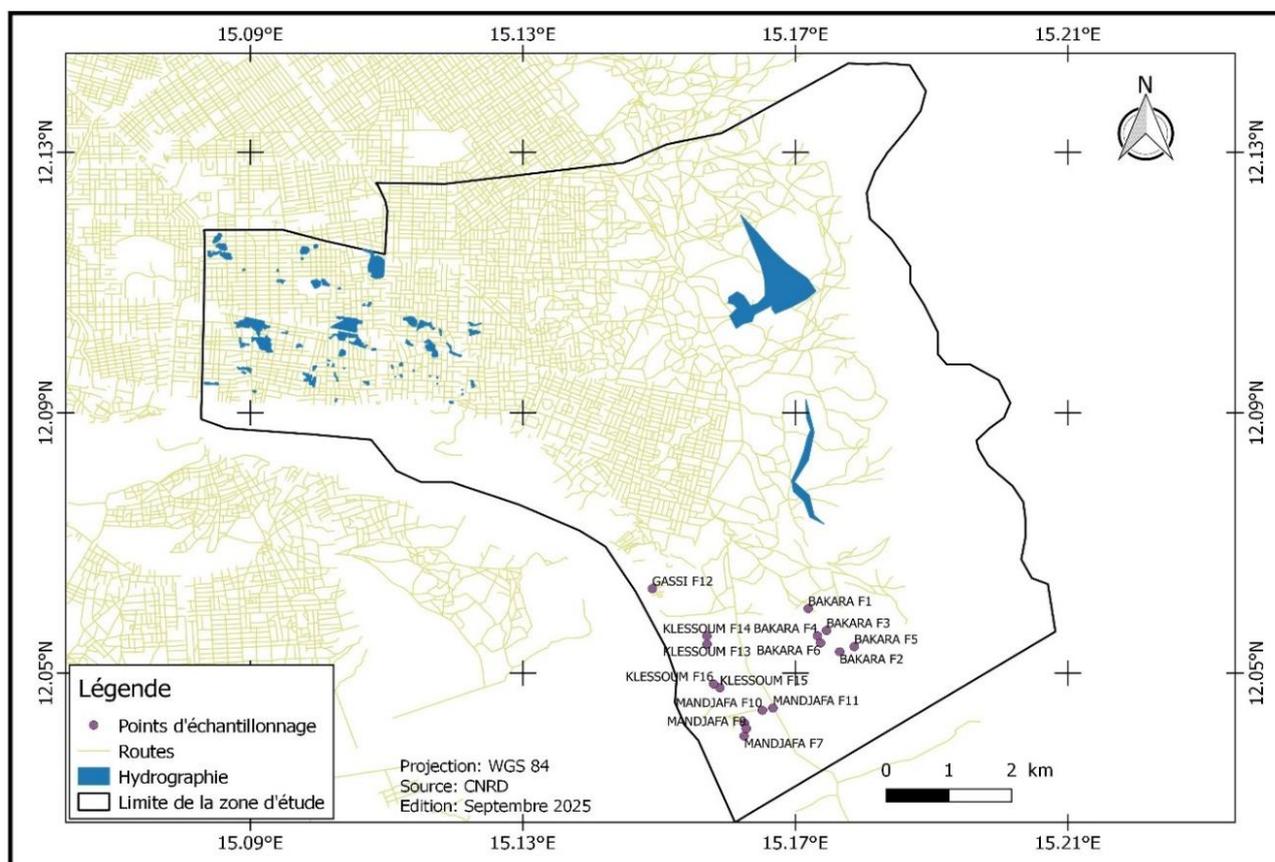
The samples were analyzed at the National Water Laboratory (LNE). The analyses focused on physical and bacteriological parameters.

### (1) Physical Parameters

Table 1 summarizes the methods used to analyze the physicochemical parameters.

### (2) Protocol and Methods for Analyzing Bacteriological Parameters

Bacteriological parameters are analyzed according to the protocol in effect at the water laboratory (LNE). This protocol uses solid and/or liquid media for enumerating microorganisms. Table 2 describes the procedure for this analysis.



**Fig. 3** Map of sampled boreholes.

**Table 1** Methods for analyzing physical parameters and principles.

Physical parameters	Methods used	Principles
Temperature (T °C); Electrical conductivity (CEC); Hydrogen potential (pH)	Multi-paramètres	Physicochemical parameters such as electrical conductivity ( $\mu\text{S}/\text{cm}$ ), temperature ( $T^{\circ}\text{C}$ ), and potential of hydrogen (pH) were measured in situ immediately after water sample collection, using a multi-parameter kit. The procedure involves rinsing the tip of the kit's electrode with distilled water by immersing it in a beaker containing approximately 100 ml of the sampled water. The results are then displayed directly on the digital screen by selecting the desired parameter using a button.

**Table 2 Methods for analyzing bacteriological parameters.**

Méthods	unit	Targeted organisms	principle
Stanetz & Bartley culture medium(membrane filtration method)	UFC/ml	Fecal enterococci	In 100 ml of sample detected, indicates the presence or absence of targeted colonies
Chromocult coliform agar (membrane filtration method) / (24h at 36 ± 1 °C)	UFC/ml	Total coliforms (Escherichia coli)	In 100 ml of sample detected, indicates the presence or absence of targeted colonies
Chromocult coliform agar (membrane filtration method) / (24h at 36 ± 1 °C)	UFC/ml	Coliforme totaux Total coliforms	In 100 ml of sample detected, indicates the presence or absence of targeted colonies

The enumeration results are expressed in colony-forming units (CFU) per 100 ml of sample according to the following equation:

$$N = \frac{n * V}{T_x}$$

N: Colony Forming Unit (CFU); n: average number of colonies counted per petri dish; V: sample volume (100 ml); Tx: dilution rate corresponding to the dilution of the sample (10-4).

### 3. Results and Discussion

#### 3.1 Results of the Assessment of On-Site Wastewater Treatment and Water Infrastructure

This assessment aims to evaluate the operation of existing and planned on-site wastewater treatment systems, as well as groundwater extraction points used as alternatives for drinking water supply in the absence of a public service providing a continuous and high-quality drinking water supply.

##### 3.1.1 Results Related to the Assessment of Water Infrastructure: Boreholes and Wells

Field observations reveal that the majority of the population in the outlying neighborhoods of the 7th arrondissement (study area) obtains their water from manual boreholes drilled by unqualified individuals. These boreholes do not meet technical construction standards, notably the absence of a bottom plug, filter bed, packer, or swelling clay, etc. Furthermore, the water sources primarily draw from the shallow water table, which is highly vulnerable to contamination from human activity and wastewater infiltration. The borehole superstructure is also deficient: the wellheads are too small, and there is no anti-mud slab or

functional soakaway.

##### 3.1.2 Result Related to the State of the Infrastructure for Storing Sludge From Septic Tanks and Their Distances From Boreholes

No city is equipped with a collective sanitation network, and the disposal of sewage sludge, as well as wastewater, occurs uncontrolled and without treatment in the natural environment. Urban drainage networks, where they exist, are underdeveloped and poorly maintained. The health consequences are particularly concerning during floods, which are frequent in the rainy season and affect the capital and outlying neighborhoods lacking basic services, notably the 7th arrondissement, the study area of this article. Insufficient household access to improved sanitation, combined with the lack of adequate excreta and wastewater disposal and inadequate drainage, generates significant economic costs that disproportionately affect the poorest segments of the population. The economic losses related to sanitation due to excess infant mortality, healthcare costs associated with morbidity, and increased time spent accessing a safe defecation site were estimated by the Water and Sanitation Programme at 2.1% of GDP [2]. The distances between latrines and water points often do not comply with WHO guidelines [7] (see photo 2), which recommend that latrines be located 15 meters from water points and at least 30 meters from classrooms to minimize odors. The management of fecal sludge is carried out manually and unhygienically: sludge is often dumped into retention basins, public spaces, or even buried on private property without prior treatment, thus increasing the risk of groundwater contamination.

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**Photo 1** Operating status of boreholes and wells, Epolyste.A October 2025.



**Photo 2** Illustration of distances between borehole and toilet, latrines and their emptying methods; Epolyste.A, October 2025. The majority of households have no access to basic sanitation infrastructure and the prevalence of open defecation (67% nationally, 82% in rural areas) is much higher than the regional average [2]. Nearly 80% of primary schools are not equipped with sanitation facilities and barely 6% of the population has a basic handwashing facility with soap and water.

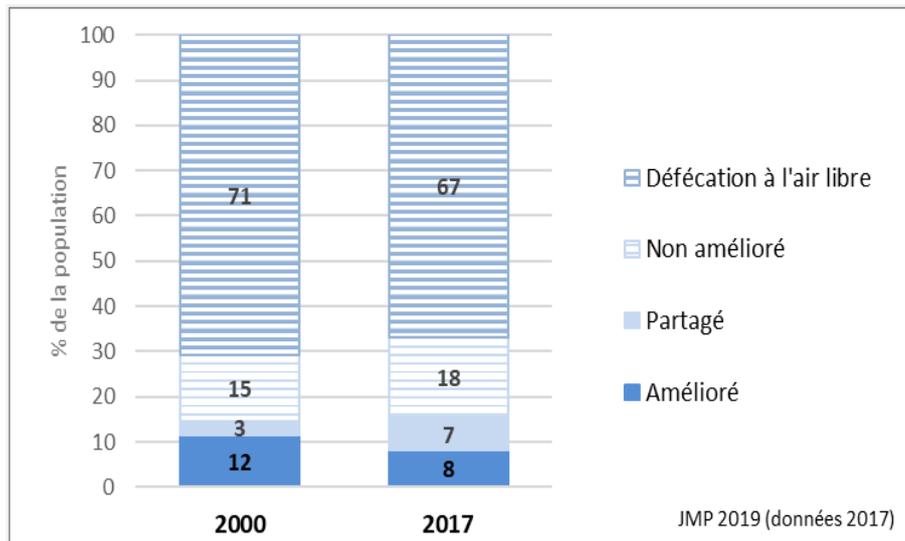


Fig. 4 Access to sanitation in Chad (2000-2017).

### 3.2 Piezometry Results

The piezometric surveys supplemented by field observations are illustrated by Fig. 5.

Static levels vary between 14 and 42 m with an average of 27 m; piezometric levels vary between 249 m (Bakara F2) and 292 m (Mandjafa F7) see Table 3.

The piezometric map shows highly variable elevations along isopiestic lines (Fig. 6). The orientation of the flow lines provides an overall view of the groundwater flow direction and the aquifer recharge zone. This map shows three (3) depression zones at Bakara F2, Gassi F7, and Klessoum F15, and two (2) dome zones at Mandjafa F7 and Klessoum F14, which could contribute to aquifer recharge. These domes are therefore watershed zones. According to Castany [8], zones with centripetal flow axes constitute the aquifer

recharge areas, while zones with centrifugal flow axes are the drainage or discharge zones.



Fig. 5 Piezometric level measurements.

Table 3 Results of hydrodynamic parameters.

	X	Y	Altitude(m)	Water point code	NS(m)	NP(m)
Bakara F1	15.2833338	12.8666668	288	FOR	14.85	273.15
Bakara F2	15.3013887	12.6444445	289	FOR	39.65	249.34
Bakara PUI	15.8983335	12.5472221	295	PUI	40.05	254.95
Bakara F4	15.7513885	12.4944448	295	FOR	40	255
Bakara F5	15.4388885	12.4777775	293	FOR	42.60	250.40
Bakara F6	14.9972219	12.4666662	292	FOR	27.65	264.35
Mandjafa F7	14.9499998	12.5722218	293	FOR	0.04	292.96
Mandjafa F8	14.9583333	12.6888885	290	FOR	22.10	267.870
Mandjafa F9	15.1166668	12.5333338	292	FOR	32.70	259.279

(Table 3 to be continued)



This difference can be explained by the high mineralization of the water at the study site, compounded by evaporation due to the borehole's position relative to the piezometric depression.

### 3.4 Results of Bacteriological Parameter Analyses

The bacteriological parameters were analyzed at the National Water Laboratory. The results are recorded in Table 5.

Escherichia coli: Out of 16 boreholes, it was present in 5 (Bakara F4, Mandjafa F11, Klessoum F13, Klessoum F15, and Klessoum F16). E. coli is very abundant in the human and animal intestinal flora. Its presence in water indicates fecal contamination and can indicate the presence of pathogens (viruses, bacteria, and parasites) responsible for waterborne diseases [9].

Furthermore, field observations show that some boreholes drilled in the study area do not meet the minimum distance of 15 meters from latrines. Total coliforms were detected in almost all 16 sampled boreholes. Like Escherichia coli, total coliforms serve as indicators to measure the degree of pollution and the quality of borehole water. The consequences of exposure to these pathogenic microorganisms present in water can vary. The most common symptoms are nausea, vomiting, and diarrhea. Young children, the elderly, and people with weakened immune systems may experience more severe symptoms. In extreme cases, some pathogens can infect the lungs, skin, eyes, nervous system, kidneys, or liver, and the effects can be more serious, chronic, or even fatal. This finding is similar to that of Yapo [10] in four disadvantaged

**Table 4 Results of physical parameters.**

Sample name	Bakara F1	Bakara F2	Bakara F3	Bakara F4	Bakara F5	Bakara F6	Mndjafa F7	Mndjafa F8	Mndjafa F9	Gassi F10	Klessoum F11	Klessoum F12	Klessoum F13	Klessoum F14	Klessoum F15	Klessoum F16	Normes nationales
T °C	30.3	29.7	31.1	33.1	30.8	29.9	31	32	29.4	30.7	29.4	28.9	31.2	30.9	30.8	30.5	
pH	6.71	6.67	6.79	6.64	6.74	6.94	6.77	6.59	6.35	6.74	6.73	7.06	6.79	6.66	7.95	7.80	6.5-8.5
Conductivity	616.0	555.0	400.0	223.0	270.0	617.0	529.0	410.0	411.0	721	225.0	253.0	552.0	465	543	550	2500µs/cm

T: temperature; pH: potential of hydrogen; °C: degrees Celsius. µs/cm: microns (seisms per centimeter). Groundwater temperatures at the study site range from 33.1 °C (Bakara F4) to 29.4 °C (Mandjafa F10 and Klessoum F11), with an average of 30.61 °C. These temperatures are consistent with the average monthly air temperatures measured at the Ndjama station (31 to 41 °C).

**Table 5 Results of bacteriological parameter analysis.**

Sample name	unit	Escherichia Coli	Fecal enterococci	Total aerobic flora	Total coliforms
Bakara F1	UFC/100 ml	0	0	224	148
Bakara F2	UFC/100 ml	0	0	264	57
Bakara F3	UFC/100 ml	0	0	284	96
Bakara F4	UFC/100 ml	2	0	174	97
Bakara F5	UFC/100 ml	0	0	232	124
Bakara F6	UFC/100 ml	0	0	204	78
Mandjafa F7	UFC/100 ml	0	0	356	164
Madjafa F8	UFC/100 ml	0	0	336	128
Mandajafa F9	UFC/100 ml	0	0	372	244
Mandajafa, F10	UFC/100 ml	0	0	404	376
Mandjafa F11	UFC/100 ml	5	0	376	188
Gassi F12	UFC/100 ml	0	0	212	103
Klessoum F13	UFC/100 ml	4	0	244	118
Klessoum F14	UFC/100 ml	0	0	122	74
Klessoum F15	UFC/100 ml	2	0	336	94
Klessoum F16	UFC/100 ml	187	101	296	244
WHO standard	UFC/100 ml	They must not be found in a 100 ml test portion of the analyzed sample	They must not be found in a 100 ml test portion of the analyzed sample	Not available for drinking water	They must not be found in a 100 ml test portion of the analyzed sample

communes of Abidjan. It could be explained by the lack of adequate sanitation services, often characterized by septic tanks and the discharge of wastewater into the environment without prior treatment, the leaching of animal excrement, and runoff. During and after rainfall, bacteria and other harmful microorganisms can enter poorly constructed or poorly maintained water infrastructure and increase the risk of contamination.

Fecal enterococci are present in the Klessoum F16 borehole, and total aerobic flora is detected in all boreholes sampled and analyzed. These bacteria are indicators of past pollution. Their presence in the water indicates that the contamination is due to enteropathogenic microorganisms, specifically *Salmonella*, which is responsible for typhoid fever. Aerobic flora are globular bacteria that grow in the presence of oxygen at a temperature between 25 and 30°C. The presence of

these bacteria is likely due to the infiltration of water laden with organic matter into the water table. According to Ledeur [11] and Kientga [12], poor water quality, inadequate hygiene, and insufficient sanitation are the root causes of waterborne diseases, particularly waterborne illnesses. Each year, nearly 8 million people, half of whom are children, die from diseases due to poor or inadequate water quality, hygiene or sanitation [13].

### *3.4 Results Related to the Analysis of the Environmental Impact Statement*

The study used the Fectau matrix to assess the environmental impact of on-site wastewater treatment practices on groundwater quality at the study site. Three evaluation criteria were used: intensity, scope, and duration (see Table 6).

**Table 6 Environmental impact statement.**

Components of the environment		Impacts	Intensity	Scope	Duration	Importance
Landscape	Landscape alteration		High	Punctual	Long	Major
water	Groundwater contamination by fecal-oral bacteria		Medium	Local	Medium	Major
Soil	Soil contamination		High	Punctual	Medium	Moderate
Population health	Increased incidence of waterborne and infectious diseases		Medium	Punctual	Short	Major

Based on the report, it is clear that sewage sludge discharges have an impact on the water table and other environmental components. Indeed, the presence of *E. coli*, total coliforms, and fecal enterococci in boreholes reflects fecal contamination. These germs can cause waterborne diseases such as gastroenteritis and typhoid fever. According to Kombasséré [14], 80% of illnesses and more than a third of deaths in developing countries are due to the consumption of poor-quality water. Located in the 7th arrondissement of N'Djamena, the study site encompasses Gassi, Klessoum, Mandjaffa, and Bakara, peripheral neighborhoods of N'Djamena that experience significant health and basic sanitation problems [15].

## **4. Conclusion**

The objective of this study is to assess the impact of

on-site sanitation practices on groundwater quality in the 7th arrondissement of N'Djamena. The results reveal that boreholes drilled by non-professionals in the area do not comply with the technical and environmental standards set by the Ministry of Water. In particular, boreholes are often shallow and draw directly from the water table. Furthermore, the required distance (15 meters) between water points and latrines is not observed, thus increasing the risk of groundwater contamination. Sanitation infrastructure is of the traditional type. The pits, often leaky, allow liquid effluents to infiltrate and directly contaminate the water table, compromising groundwater quality. This situation is exacerbated by the lack of systems for collecting and treating sludge from the cesspools. Indeed, sludge is emptied using manual methods and discharged uncontrolled into public spaces and

retention basins due to the lack of a sludge treatment plant. Looking ahead, it is essential to strengthen regulations and technical monitoring of water and sanitation infrastructure, and above all, to establish sludge treatment plants.

### References cited

- [1] UNICEF 2011. Eau, Assainissement et Hygiène (WASH) dans les écoles. Manuel pour écoles amis des enfants, p.50.
- [2] JMP 2017. *Etude de la filière des boues de vidange: Volume 1: Diagnostic et caractérisation de la filière.* novembre 2017.
- [3] [3]. Kahoul M., & Touhami M. (2014). Évaluation de la qualité physico-chimique des eaux de consommation de la ville d'Annaba (Algérie). *Larhyss Journal*, ISSN. 15:1112-3680, p. 129-138.
- [4] Dossa, B. 2002. Caractérisation physico-chimique des eaux souterraines dans les départements du Zou et des Collines. Mémoire de formation au. E.S.S. Université d'Abomey-Calavi, 72p.
- [5] Belghiti M. L., Chahlaoui A., Bengoumi D., & El Moustaine R. 2013. "Étude de la qualité physico-chimique et bactériologique des eaux souterraines de la nappe plio-quaternaire dans la région de Meknès (Maroc)." *Larhyss Journal* 14: 1112-3680, pp. 21-36.
- [6] Ali. A. 2012. "Étude Hydrodynamique et Hydro chimique de la nappe de Mao et ses environnants (Sud Kanem, Tchad)." mémoire de Master. Université Cheik Anta Diop, p. 33.
- [7] OMS 2010. *Nitrate and Nitrite in Drinking-Water — Background Document for Development of WHO Guidelines for Drinking-water Quality* (3rd ed.). [http://www.who.int/water\\_sanitation\\_health/dwq/chemicals/en/index.html](http://www.who.int/water_sanitation_health/dwq/chemicals/en/index.html).
- [8] Castany, G. 1982. *Principes et méthodes de l'hydrogéologie*. Dunod, Ed. Bordas, Paris, p. 236.
- [9] Scott, T. M., Rose, J. B., Jenkins, T. M., Farrah, S. R., and Lukasik, J. 2002. *Microbial Source Tracking: Current Methodology and Future Directions Applied and Environmental Microbiology*, Vol. 6, pp. 5796-803.
- [10] Yapou, O., Mambo V., and Seka Ohou M. 2010. "Évaluation de la qualité des eaux de puits à usage domestique dans les dans les quartiers défavorisés de quatre communes d'Abidjan en Côte d'Ivoire." *Int. J. Biol. Chem. Sci.* 4 (2): 289-307.
- [11] Ledeur, S. 2004. "Utilisation d'un système d'information géographique comme outil de compréhension des épidémies d'origines hydrique et comme outil d'aide à la décision: étude dans un contexte urbain (Ouagadougou, Burkina Faso)." Mémoire d'ingénieur du Génie sanitaire, Ecole nationale de santé publique (ENSP) Rennes, p. 65.
- [12] Kientga, S. 2008. Contribution du SIG à l'analyse des leishmanioses déchets-santé en milieu.
- [13] Camdessus, M, Badré, B, Chéret, I., and Ténrière Buchot P. F. 2004. *Eau*. Edition Robert Laffont: Paris. *Jeune Afrique Economie* Cas des deux secteurs de la ville de Ouagadougou, Bukina Faso. Thèse de Doctorat, Ecole polytechnique fédérale de Lausanne, p. 241.
- [14] Kombasséré, W. K. 2007. "L'accès à l'eau potable et les risques diarrhéiques dans les zones irrégulières de Ouagadougou: les cas de Yamtenga." Mémoire de Maîtrise de Géographie, Université de Ouagadougou, Ouagadougou, p. 67.
- [15] MEA. 2017. Politique et Stratégie Nationale de l'Assainissement au Tchad (PSNA): Contexte et situation du secteur (juillet 2017).