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Preliminary Study on the Groundwater Resources of the Korama Sub-Catchment in the Commune of Gouchi/Zinder Region: Hydrogeological Characterization and Groundwater Quality

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Abstract The commune of Gouchi is located in the extreme south of the Zinder Region, resting on a sub-watershed of the Korama, and lies between 13°08' and 13°37' North latitude and 09°26' and 09°47' East longitude (Figure 1). From a hydrogeological point of view, this zone is essentially underlain by Malawa sandstone and recent sand aquifers. This area, characterized by a high potential groundwater resource and an abundant ecosystem, has been subjected for many years to the phenomena of climate change, land use dynamics and galloping demography. This has resulted in changes to the quantity and quality of the commune's water resources. However, it seems necessary to undertake quantitative and qualitative studies of these groundwater resources, which are the main source of supply for the population, livestock and irrigation. The main objective of the present study is the hydrogeological and qualitative characterization of groundwater in the commune of Gouchi. The methodology adopted can be summed up in three stages: collection and campaign of measurements and samples; laboratory analysis of samples and, finally, processing and statistical analysis of hydrogeological, chemical and bacteriological data, and production of a piezometric map and hydrogeological cross-section. This led to the following results: From a hydrogeological point of view, the depths of the structures, taking into account all the water tables, vary from 2.70 to 49.93 m, with an average of 20.10 m, giving an average depth of 12.85 m. Static levels range from 0.52 m to 28.58 m, with an average of 4.86 m. Water flow rates are highly disparate, ranging from 0.2 to 30 m3/h, with an average of 5.46 m3/h. Furthermore, the piezometric map shows that the direction of groundwater flow is generally from north-west to south-east. This general trend follows the direction of flow of surface water, whose hydrographic network is more or less fossilized (Korama). This suggests that there may be a groundwater-river relationship. As for the chemical results of the 151 water samples, two (02), one hundred and twenty-one (121) and twenty-three (23) were characterized respectively by fluoride, arsenic and nitrate levels exceeding the WHO drinking water standard. Finally, from a bacteriological point of view, of the 151 samples, 56 and 42 showed respectively Total Coliforms (TC) and Escherichia. Coli in groundwater. This could be explained by the lack of hygiene around water points, combined with the shallow depths of the water in places. All these aspects can compromise the population's drinking water supply

Keywords: *Arsenic, Bacteries, Gouchi, Malawa, Bassin Korama*

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1. Introduction

Groundwater is one of the main sources of drinking water for the population of Niger. It must be managed sustainably, consistently and rationally, as it is threatened by various sources of geogenic and anthropogenic pollution [1,2,3]. Indeed, groundwater mainly acquires its chemical composition according to the geological nature of the soils it flows through, the residence time in the reservoir and the reactive substances it may encounter during flow [1,2]. Faced with galloping demographics and the intensification of irrigated agriculture, groundwater resources in certain regions of the world are confronted with problems of quality and quantity. The chemical and bacteriological composition of groundwater can be altered by undesirable or even toxic substances originating from livestock farming, agricultural activities, human activities and the surrounding rock, which can render groundwater unfit for consumption. The commune of Gouchi, the study area, located in the extreme south of the Zinder/Niger Region in the Korama, is no exception. Indeed, in this area, there are also the potential effects of land use change [4]. The combination of these different phenomena could have repercussions on the quantity and quality of an area's groundwater resources [5]. It is therefore necessary to undertake a study on the quantity and quality of this resource in the commune of Gouchi, where the state of knowledge on the latter remains mediocre. The main objective of this study is to improve knowledge of the commune's groundwater resources.

Specific objectives of these studies are:

- Process and analyze hydrogeological parameters (operating flow rate, depth of water table, thickness of wells tapped, equipped depths);
- Draw up a piezometric water map and a hydrogeological cross-section of the commune;
- Process and analyze physico-chemical and bacteriological water parameters.

2. Materials and Methods

2.1. Presentation of the Study Area

The rural commune of Gouchi is located in the south-western part of the Dungas department, in the Zinder region. It lies precisely between 13°8' and 13°37' north latitude and 9°26' and 9°47' east longitude (Figure 1). The commune of Gouchi is bordered to the north by the communes of Guidimouni and Hamdara, to the south by the commune of Malawa, to the west by the communes of Wacha and Dungas, and to the east by the communes of Guidiguir and Bouné. It covers an area of 488 km^2, with an estimated population of 86418 hbts [6], representing a density of 95 hbts/km^2. The commune of Gouchi is bordered to the north by the communes of Guidimouni and Hamdara, to the south by the commune of Malawa, to the west by the communes of Wacha and Dungas, and to the east by the communes of Guidiguir and Bouné. It covers an area of 488 km^2, with an estimated population of 86418 hbts [6] (INS, 2012), representing a density of 95 hbts/km^2. Applying an annual growth rate of 5.6%, the population in 2023 is estimated at 139,651. Agriculture is the main activity, followed by livestock breeding.

The climate in Gouchi is North Sahelian, characterized by two seasons: a rainy season from June to September and a dry season from October to May. The inter-annual rainfall modulus is characterized by significant spatio-temporal variation (Figure 2). From 1998 to 2015, mean annual rainfall values recorded at the Dungas station ranged from 404 mm (1999) to 803 mm (2000 and 2003), with an interannual mean of 562 mm over the 18-year period (Figure 2).

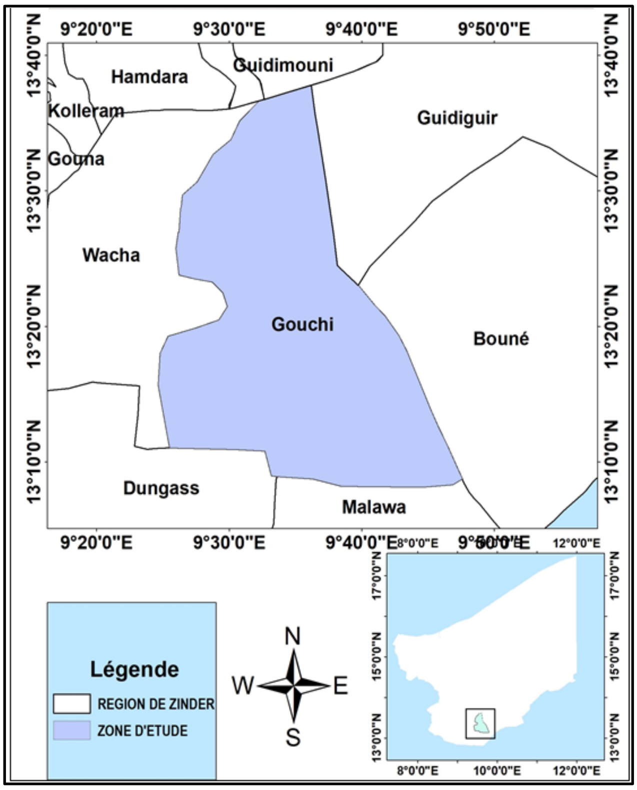

Figure 1. Commune location Map

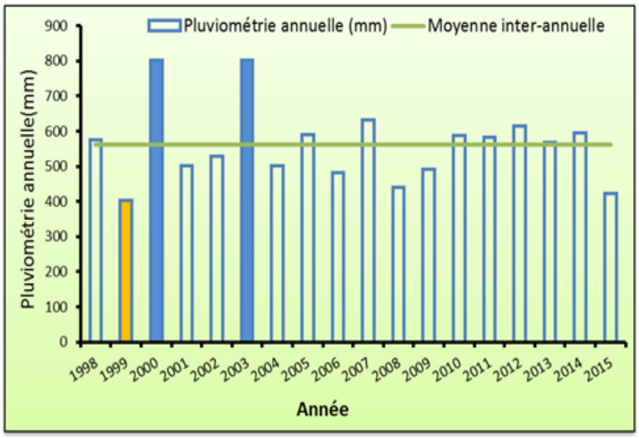

Figure 2. Interannual variation in rainfall at Dungas

2.1.1. Hydrological Context

There are no permanent watercourses in the commune of Gouchi. Its well-structured hydrographic network is partly fossilized and is essentially made up of temporary watercourses (Koris) that feed ponds and lakes (Figure 3). The two main Koris, which cross the commune, are sub-branches of the Korama. There are five managed ponds linked to runoff: Gouchi, Jalkassa, Dossono, Babouje and Moni (Table 1). The latter has a permanent regime, while the others have a water retention period varying from 3 to 5 months. As part of the development of these ponds, several agricultural boreholes, ranging from a few metres to 20 m in depth, have been drilled (Table 1). There are also several ponds associated with major water tables (Génie Rural Zinder), including the Matarawa, Rigal Keya, Ali Isbori and Garin Elhadj Malé ponds. The main activities carried out in all these ponds are irrigation and fishing.

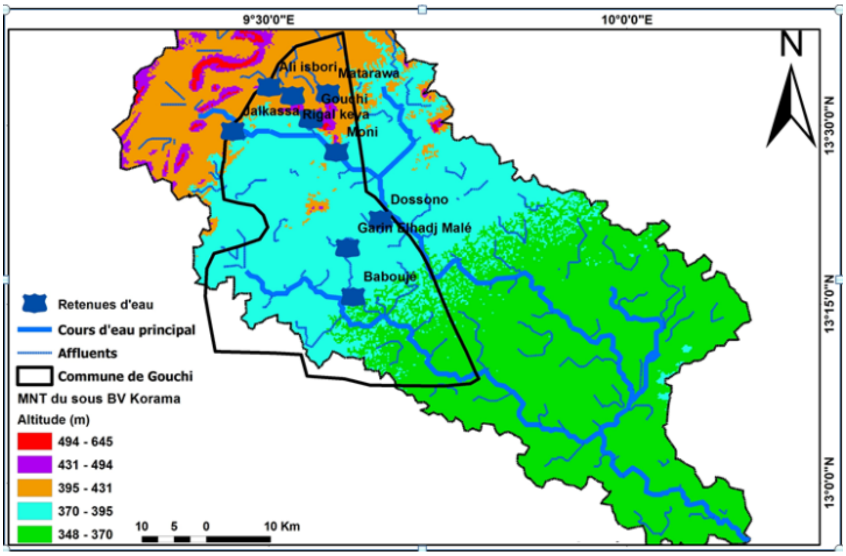

Figure 3. Hydrology of the commune of Gouchi

Table 1. Characteristics of ponds in the commune of Gouchi (source: Génie Rural Zinder)

Ponds names	Agricultural boreholes number	Water retention period
Gouchi		3 to 5 mois
Dossono	150	
Baboujé	20	
Jalkassa	20	
Moni	20	12 mois

2.1.2. Geology and Hydrogeology

In the extreme north, the commune of Gouchi is marked by basement peaks of the Damagaram massif, of Precambrian age. In the north and center, the commune is underlain by sedimentary formations of recent Quaternary age; while the other parts of the commune are represented by the ancient Quaternary formations of the Lake Chad sedimentary basin. The geological formations encountered (Figure 4) range from the oldest to the most recent [7-9]:

- √ The Precambrian-age formations of the Damagaram basement are represented in the commune of Gouchi, by metamorphic formations consisting essentially of quartzites that outcrop in the form of more marked relief (elongated hills). They are characterized by their light-gray color, very similar to the gneisses where they outcrop in the Gouchi area. With their fractured, fissured and/or altered horizons, these quartzites constitute discontinuous aquifers. They are tapped mainly by boreholes, which have very high failure rates, sometimes exceeding 50% [8];
- √ The ancient Quaternary or Malawa sandstone formations consist of fine to medium-grained sand or clay, often indurated and yellowish in color. These sandstones are the result of ancient alluvial sands of the Chad series, and are located in the southern part of the commune. The Malawa sandstones, which are very powerful, do not outcrop, as they are always covered by a thin layer of dune sand. These formations constitute a good aquifer in the area.
- √ Recent Quaternary formations, mainly aeolian and fluvial in origin, reveal only a few quartzite basement outcrops in the area. This recent deposit consists of fluvial and eolian sands with gravel levels and well-rounded pebbles becoming increasingly clayey towards the bottom. The recent fine to medium sands are highly permeable, and their thickness can reach several dozen meters in the center of the basin [10]. These formations form the Korama recent sand aquifer.

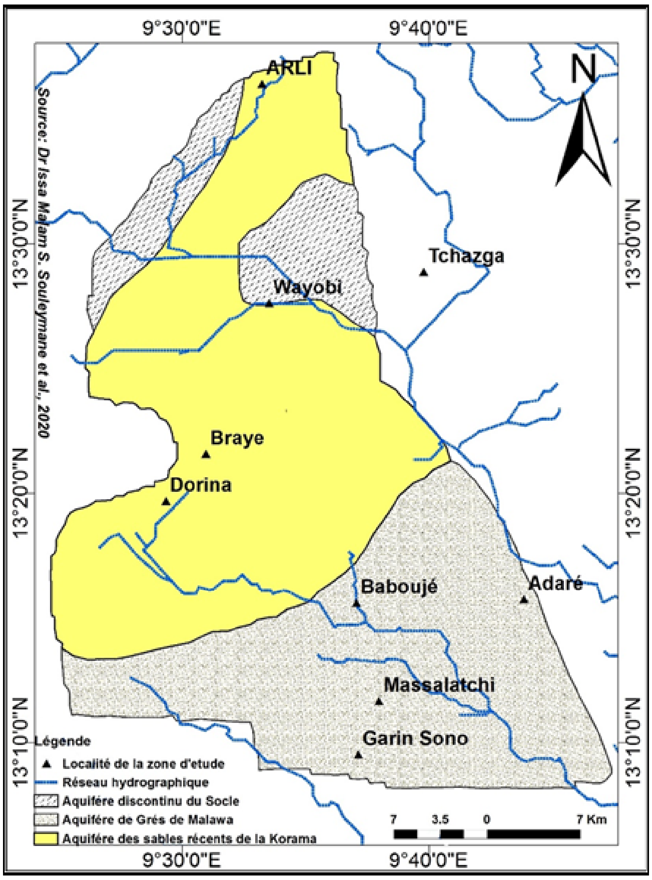

Figure 4. Principal Aquifers Map for Gouchi Commune

2.2. Hardware

2.2.1. Data and Tools

- The data used in this study are:
  - Hydrogeological parameter data (borehole logs; operating flow rate; aquifer thickness tapped; static level; depth drilled)
  - Chemical parameter data (Arsenic; Nitrate and Fluoride)
- The tools used include
  - Hydraulic structures (Wells, PMH, Mini-AEP and PEA);
  - Small hydrogeological equipment: Electric probe, pH meter, Conductivimeter for in situ parameter measurements;
  - Tablet for taking geographic coordinates and photos;
  - Bottles, pill boxes, coolers, samplers, sterile bags, torch, adhesive tape, markers for water sampling;
  - Mobile laboratory including two POTALAB kits (Wagtech/Palintest)
  - Various software packages comprising: Arc Gis, Surfer, Excel, Forage and Paint.

2.2.2. Data Collection

Data on hydrogeological and hydrodynamic parameters of the boreholes were collected from the Direction Régionale de l'Hydraulique et de l'Assainissement de Zinder (DRHA/Z). It should be noted that only boreholes with reliable data were included in this study. In addition, a piezometric campaign was carried out in February 2020.

○ Sampling

Physical water parameters (pH, EC, TDS and T°) were measured in situ at all functional wells and boreholes in the commune (279 water points). They were carried out on water drawn from a well or from the taps of standpipes. The residual water was then used to fill 500 ml polyethylene plastic bottles and plastics after rinsing. These bottles and plastics were labelled, sealed and placed in a cooler for transport to the laboratory for chemical analysis (which included nitrate, nitrite, fluoride and arsenic) and bacteriological analysis (Escherichia coli and total coliforms) respectively. Sampling was carried out at 164 of 279 sites, to give a clear picture of the chemical and bacteriological quality of the groundwater. GPS coordinates are also recorded for each water point.

2.2.3. Data Processing

○ Hydrogeological characterization

Borehole logs were used to produce a hydrogeological cross-section of the study area. The operating flow rate (Q) is determined from the interpretation of short and/or long-term pumping tests using the semi-logarithmic method of Jacob and/or Theis.

Statistical calculations of hydrogeological and hydrodynamic parameters included determination of statistical parameters (means, extremes, standard deviations and coefficients of variation).

Static level readings taken during the piezometric campaign and borehole dimensions determined by DTM were used to calculate the piezometric levels of the various structures. The absolute Z coordinates obtained by DTM were compared with the coordinates of certain water points levelled during previous work [11] using a WM102 GPS. This comparison showed a good correlation between these data. In addition, this method has been used by some authors [4,12,13]. The piezometric map was then produced using Arc Gis software. The IDW interpolation method was selected as it offers the lowest average error.

○ Chemical and bacteriological water analysis

The laboratory has 02 POTALAB analysis kits from Waghtech/palintest for physico-chemical and bacteriological analysis. Waghtech is an international company with over 20 years' expertise in water quality control. The chemistry kit includes: spectrophotometer, digital multi-parameter, turbidimeter and accessories.

The Potalab microbiology kit includes a filtration, incubation and colony-reading device.

Together, these kits enable analysis of major, minor and even trace elements in water.

Several calibration tests were carried out on the various measuring devices mentioned above, to ensure the reliability of the analysis results: reliability criteria include method fidelity, accuracy and sensitivity. Several calibrations and blank tests were repeated to ensure the functionality of the equipment and analysis methods.

In this work, the spectrophotometric method was used to determine nitrate (NO_3^-), nitrite (NO_2^-) and fluoride (F-) ions. The instrument used is the DR 2800 spectrophotometer, and the various reagents are nitraver5, nitriver3 and SPDNS respectively.R.

3. Results

3.1. Hydrodynamic Parameters

Water table depths in the commune of Gouchi ranged from 2.70 to 49.93 m, with an average of 20.10 m for the 68 structures studied (wells and boreholes) (Table 2). Thus, more than 50% of the structures tap the water table at depths of between 15 and 25 m (Table 3a). It should be noted that the shallowest depths are characteristic of the recent alluvium nappe, while the deepest depths are found in the Malawa sandstone and discontinuous nappes. Moreover, the shallow depths of the piezometric levels highlight the susceptibility of these aquifers to anthropogenic pollution. This remains to be confirmed by the results of chemical and, above all, bacteriological analyses carried out on these waters.

As for the thicknesses tapped, they vary from 3 to 27.80 m, with an average of 12.85 m and a standard deviation of 4.99 (Table 2). Spatially, they vary from north to south, with the highest values observed in the southern and central parts, where the Malawa sandstone nappe is essentially located (Figure 5).

Water level depths during February 2020 ranged from 0.52 m to 28.58 m, with an average of 4.86 m. In general, these water levels are very shallow, as over 70% of the structures have depths of just over 6 m (Table 3b). These low piezometric levels highlight the high vulnerability of these waters to pollution. (Table 3b).

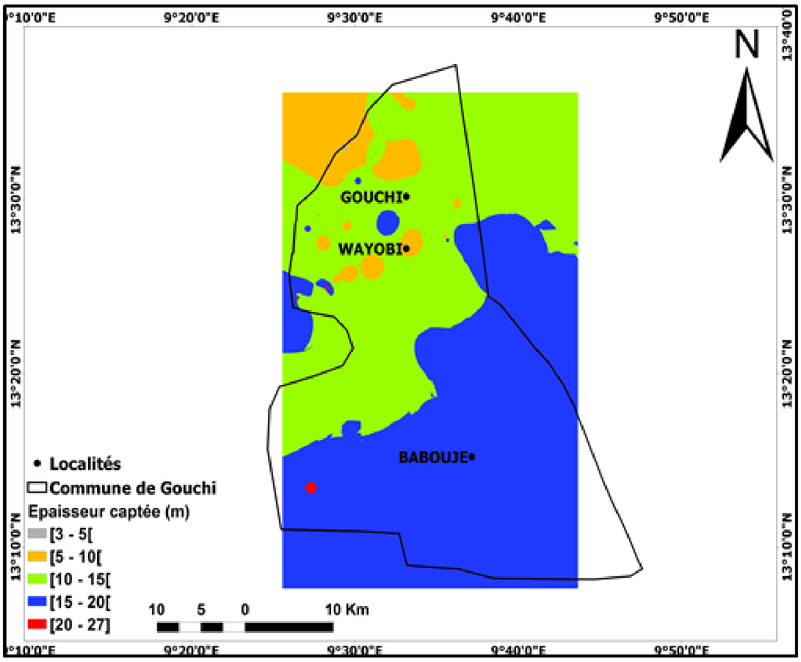

Figure 5. Spatial distribution of water table thicknesses

Table 2. Statistical results of hydrogeological parameters for 68 boreholes in the study area

Hydrodynamic properties	Paramètres statistiques globaux				
	Moyenne	Maximum	Minimum	σ	CV (%)
Groundwater depth (n=68)	20,10	49,43	2,70	6,36	31,65
Tchickness (m) (n=68)	12,85	27,80	3,00	4,22	32,88
Flowrate (m^3/h) (n=68)	5,46	30,00	0,20	3,76	68,80
Depth of Aquifer/NS (m) (n=28)	4,86	28,58	0,52	3,08	63,43

Table 3. Distribution of water table depth (a) and static level (b) values

Intervalle (a)	**Fréquence %**
[2 - 10[	7.35
[10 - 15[	19.12
[15 - 20[	30.88
[20 - 25[	25.00
[25 - 35[	11.76
[35 - 50]	5.88
Intervalle (b)	**Fréquence (%)**
[0,5 -2[	26,0
[2-4[	31,0
[4-6[	18,0
[6-8]	15,0
[8-28]	10,0

3.2. Plant Productivity

Water exploitation flow rates range from 0.10 to 30 m3/h, with an average of 5.23 m3/h and a coefficient of variation of 98.73% for the 84 sites surveyed (Table 4). This coefficient of variation highlights the wide disparity in this parameter. Moreover, these flows are generally very low in relation to the water potential of these aquifers (Table 4), opening up the possibility of large-scale water supply systems for populations and irrigation (PEA; mini-AEP...). It should be remembered that, overall, these flow values are not representative of the real productivity of these aquifers. In fact, the very short pumping tests carried out after the works have been completed do not allow us to test the performance of the water table, but rather to develop these works. In most cases, this productivity is left to the discretion of the contractor, which casts doubt on the flow rates delivered by the works. Similarly, the potential of the aquifer level tapped remains difficult to assess and is sometimes underestimated. We also note that there is no correlation between borehole flow rates and the thicknesses tapped.

Statistical values for the depths of water collected range from 3 m to 27.8 m, with an average of 12.85 m and a standard deviation of 4.22 (Table 4 and Figure 6).

Table 4. Flow distribution (m3/h)

Flow distribution		
Flow (m3/h)	Nbre Forage	%
0.1 à 0.9	13	15.48
1 à 3	30	35.71
4 à 5.9	09	10.71
6 à 7.9	13	15.48
8 à 10	11	13.10
11 à 20	07	8.33
30	01	1.20
Total	84	100

3.3. Depth of Water Table

The depth of the water table in the commune of Gouchi is predominantly very shallow. In fact, over 60% of the commune is characterized by water table depths of less than 20 m (Figure 6 left). This is the part of the commune where the structures tap the sedimentary aquifers of the ancient and recent quaternary. However, there are a few pockets where depths can reach 50 m (Figure 6 left). This is the area covered by the discontinuous basement aquifer.

3.4. Hydrodynamics - Piezometric Map

For sustainable management of an area's groundwater resources, it is imperative to carry out temporal and spatial monitoring of piezometric levels. Unfortunately, no such monitoring data existed in the commune, but the information obtained in the Winrock (2020) study shows that piezometric levels have risen and that water springs have appeared in the commune in recent years [14]. The data collected during this survey were also used to draw up the flow direction map. This map shows that groundwater flows generally from north-west to south-east (Figure 6 right). This general trend follows the direction of flow of surface water, whose hydrographic network is more or less fossilized (Korama). This means that there is a nappe-river relationship. This is particularly true in the northern part of the commune. At this time of year (February 2020), groundwater levels are in equilibrium with surface water levels in some places.

3.5. Hydrogeological Maps

3.5.1. Lithology

The N-S hydrogeological cross-section of the Gouchi commune shows that almost all the structures do not reach the bedrock (Figure 7a). Thus, two main types of sedimentary formations are encountered at depth (Figure 7b):

The Korama recent sand formation, of recent Quaternary age. This sand, mainly of eolian origin, is almost ubiquitous in the basin. These fine to medium-grained sands are highly permeable and can be up to 20 metres thick in this commune.

The Malawa sandstone formation, of ancient Quaternary age. It consists of fine to medium-grained sands, or clayey sands, often indurated. These sandstones are derived from ancient alluvial sands of the Chad series [12]. The Malawa sandstones, which can reach up to 100 meters in thickness, do not outcrop, as they are always covered by a thin layer of dune sand (as shown in Figure 7b). At their base, the Malawa sandstones lie unconformably on the crystalline bedrock, although no boreholes have reached the bedrock in the commune.

In most cases, all these formations form a single aquifer in the commune. Figure 7b shows that the boreholes tap mainly the Malawa sandstone aquifer.

3.6. Bacteriological Results

Bacterial counts of Total Coliforms and E. Coli in the water ranged from 0 to over 100 (or uncountable) colonies per 100 ml (Figure 8).

The statistical results of bacteriological sample analysis, broken down by type of structure, are shown in Table 5. Of the 164 samples, 74 showed the presence of total coliforms (TC) and E. Coli (EC) in groundwater. This means that 75.68% and 64.86% of groundwater samples present a bacterial risk of TC and EC contamination respectively. Figures 8 shows the spatial distribution of E. Coli and total Coliforms in the water. It can be seen that waters with more than 50 of these bacteria are in the majority, followed by those with less than 50 in 2nd position.

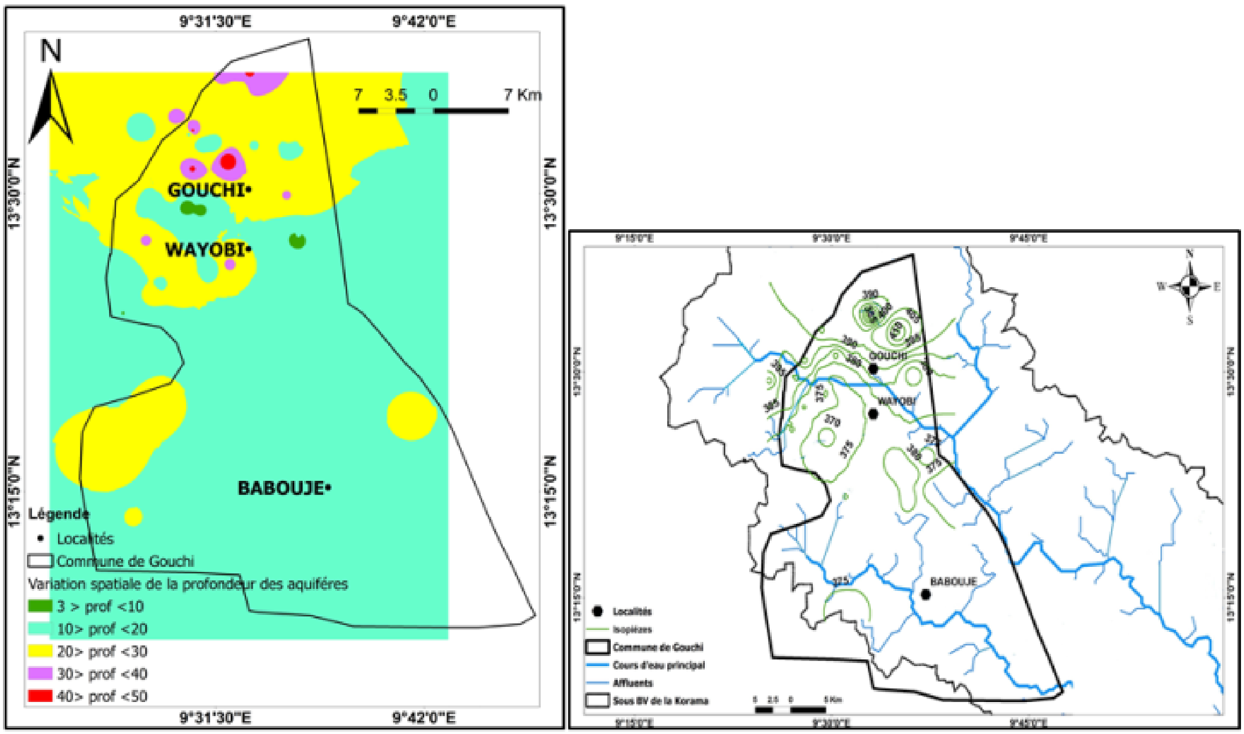

Figure 6. Depth of water table (left) and Piezometric map of study area (right)

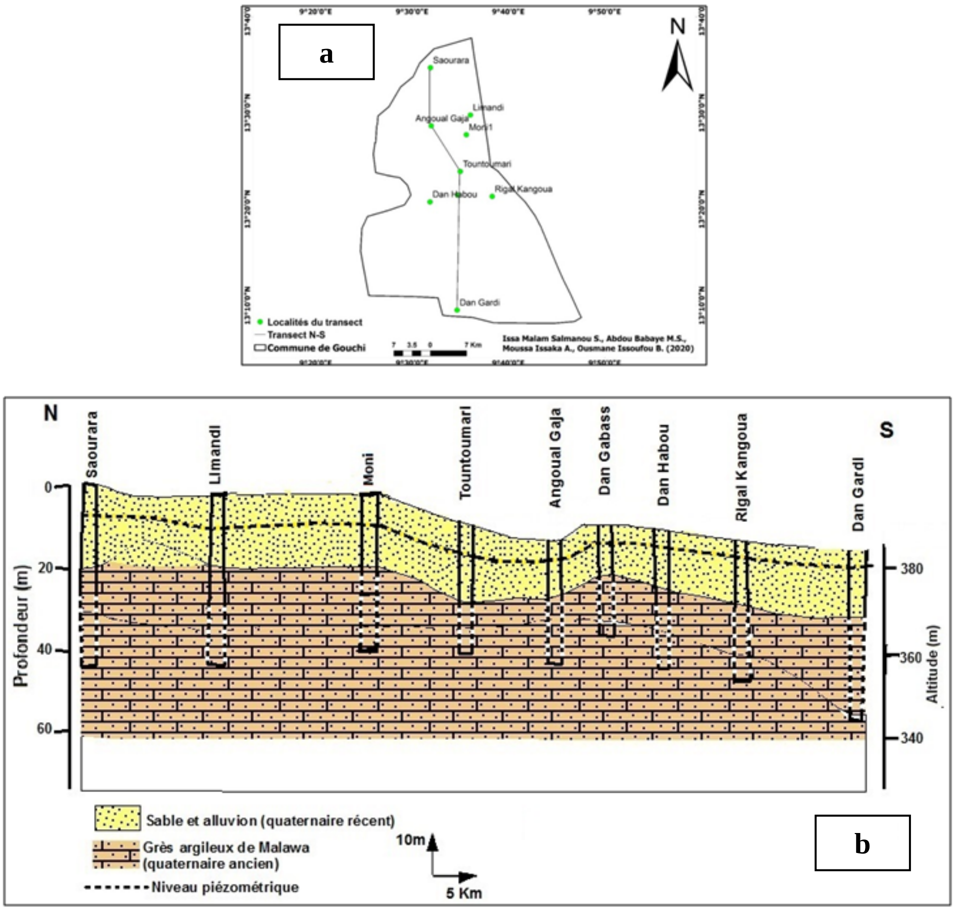

Figure 7. N-S section transect (a) and hydrogeological section (b) of the study area

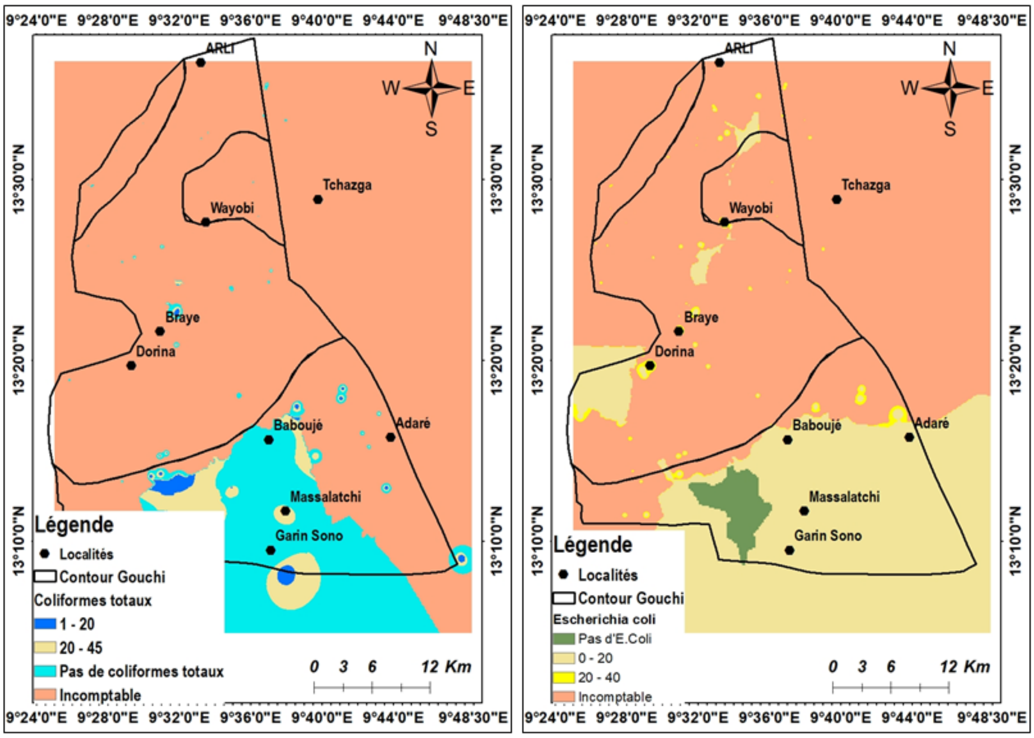

Figure 8. Spatial distribution of total Coliform (left) and Escherichia (b) type bacteria in the groundwater of the study area

Table 5. Summary of Water Points Surveyed in Gouchi Commune in February 2020

	Water Point Type	# of Water Points	Functional Status		# Sampled
			*F	**NF	
Water Source	Bonne fountaine	4	4	0	4
	PMH	218	195	23	113
	PEA	15	15	0	11
Dug Wells	PC	62	57	5	34
	PT	8	8	0	2
Totals		307	279	28	164

**F = Functional, *NF = Non-Functional; Bonne fountaine = Standpipe*

PEA = Mechanized Borehole; PMH = Borehole with Manual Handpump

PC = Hand-dug Well – Cement Lined; PT = Hand-dug Well – Not Cement Lined

3.7. Chemical Results

The results of the chemical analyses of the water were compared with [13] WHO (2011) standards for water consumption (Tables 6 and 7). The extreme values and numbers of samples with chemical element contents exceeding (or below) this standard in groundwater from the study area are presented in Tables 6 and7 for boreholes (AEP; PEA; BF and PMH) and wells (PC and PT) respectively. Of the 151 samples, the results show that two (02), one hundred and twenty-one (121) and twenty-three (23) are characterized respectively by Fluoride, Arsenic and Nitrate levels exceeding the WHO drinking water standard (Figure 9). Particular attention should be paid to these structures, so that the population can avoid the risks that may be caused by drinking these waters. The spatial distribution of chemical results also shows that structures with high nitrate levels are mainly located in recent sand aquifers and discontinuous aquifers characterized by shallow structures (Figure 9 left). On the other hand, high arsenic concentrations are more widespread in all aquifers (Figure 9 right).

4. Discussions

4.1. Relation Between Productivity, Thickness Tapped and Depth of Wells

Flow rates are generally very low in relation to water potential, especially in quaternary aquifers, which offer the potential for large-scale water supply systems for populations and irrigation (PEA; mini-AEP...) (Figure 10 and 11). It should be remembered that, on the whole, these flow values are not representative of the real productivity of these aquifers. In fact, the very short pumping tests carried out (maximum 6 hours) do not allow us to test the performance of the aquifer and to properly develop the workings, let alone estimate the aquifer's hydrodynamic parameters. It should also be noted that the sandy-loam and sandstone-clay nature of these aquifers requires long pumping to properly develop the structure. In most cases, this productivity is left to the discretion of the contractor, which casts doubt on the flow rates delivered by the works. However, the potential of the aquifer level tapped remains difficult to assess and is sometimes underestimated. Lastly, these results show that the productivity of wells depends on a number of parameters other than depth, notably the lithological nature of the reservoir and the thickness tapped [2,14,18] (Figure 10 and 11).

Table 6. Summary of results for physico-chemical parameters of borehole water in study area

Parameter	Measured Range	Guideline Value (WHO)	Comments
pH (SU)	0.52 – 8.83	6.5 – 8.5	72 samples between pH 6.5 – 8.5 47 samples < pH 6.5 1 samples > pH 8.5
EC (µS/cm)	50 - 3515	1000	104 samples <1000 mg/l 16 samples >1000 mg/l
TDS (mg/l)	26 – 2000	1000	107 samples <1000 mg/l 3 samples > 1000 mg/l
Fluoride (mg/l)	< 0.01 – 1.52	1.5	9 samples are ND 109 samples < 1.5 mg/l 2 samples >1.5 mg/l
Arsenic (µg/l)	2– 41	10	6 samples are ND 22 samples <10 µg/l 102 samples >10 µg/l
Nitrate (mg/l)	0.66 – 96	50 mg/l	112 samples <50 mg/l 18 samples >50 mg/l

Table 7. Summary of results for physico-chemical parameters of borehole water in study area

Parameter	**Measured Range**	**Guideline Value (WHO)**	**Comments**
pH (SU)	5.88 – 8.55	6.5 – 8.5	• 25 samples between pH 6.5 – 8.5 • 4 samples < pH 6.5 • 1 samples > pH 6.5
EC (µS/cm)	93 - 3999	1000	• 27 samples <1,000 mg/l • 3 samples >1,000 mg/l
TDS (mg/l)	48– 2000	1,000	• 29 samples <1,000 mg/l • 1 samples > 1,000 mg/l
Fluoride (mg/l)	< 0.01 – 1.36	1.5	• 1 samples are ND • 30 samples < 1.5 mg/l • 0 samples >1.5 mg/l
Arsenic (µg/l)	1 – 30	10	• 12 samples <10 µg/l • 19 samples >10 µg/l
Nitrate (mg/l)	2.08 – 56	50 mg/l	• 26 samples <50 mg/l • 5 samples >50 mg/l

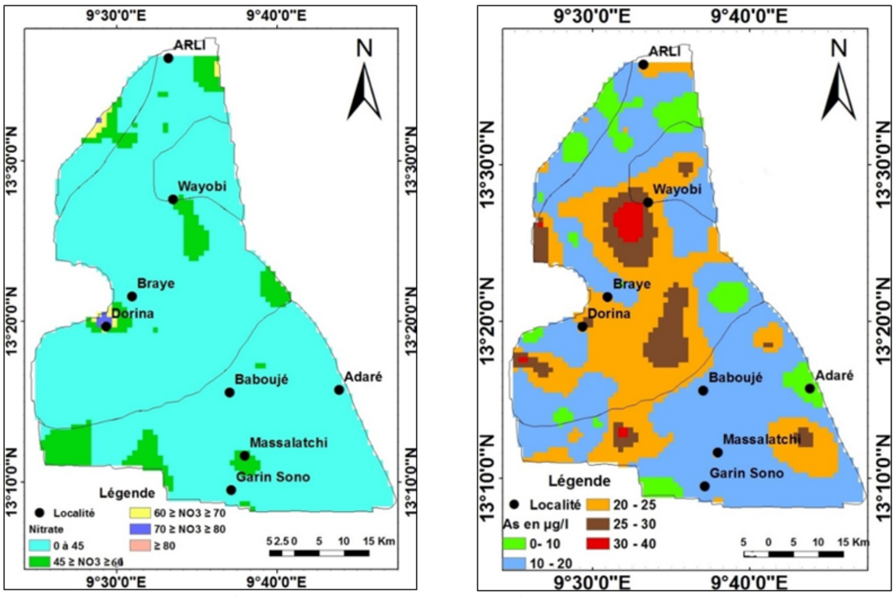

Figure 9. Distribution of structures with elevated NO_3 (left) and As (right) levels in the study area

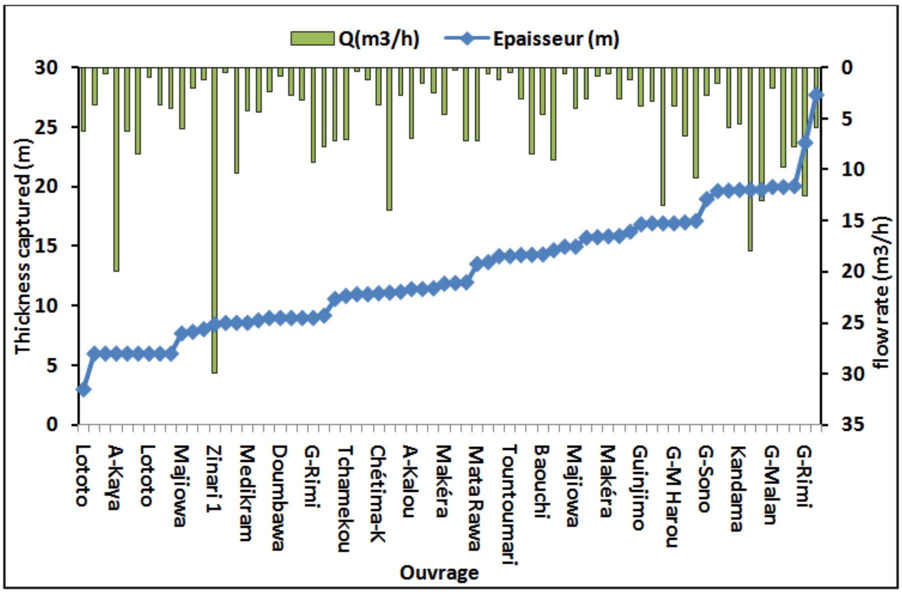

Figure 10. Relationship between the thickness captured and the flow rate of the water points

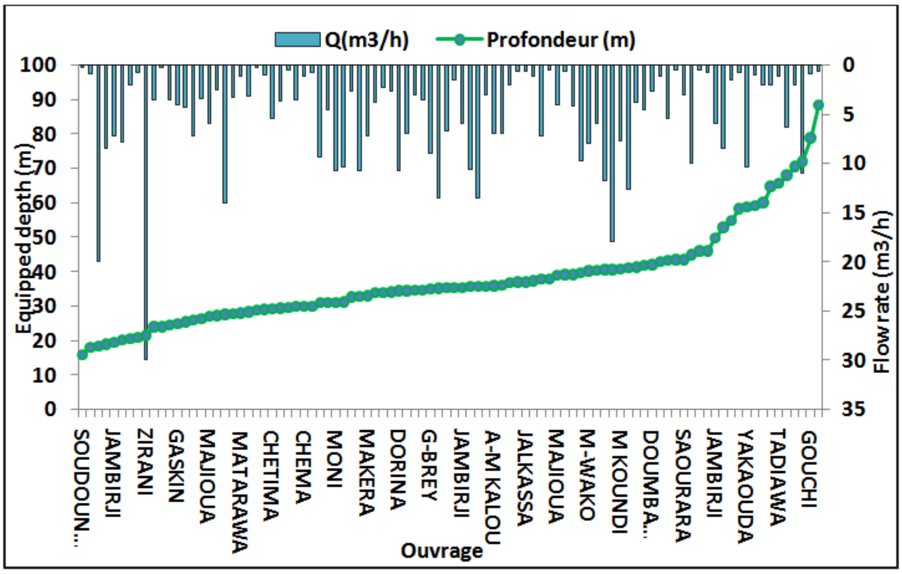

Figure 11. Relationship between equipped depth and flow rate of structures

4.2. Water Pollution

Bacteriological water pollution in the study area can be attributed to two main factors:

Direct and/or indirect recharge of groundwater by sometimes degraded precipitation and/or surface water, which is sometimes polluted by the environment. This is the main cause of bacteriological groundwater pollution [1,2,16].

The return of wastewater that stagnates around wells (or boreholes), on the one hand through percolation, especially if the speed of percolation is high, and on the other hand along borehole casings or well walls as a result of archaic pumping systems. This could be one of the probable causes of bacteriological pollution.

This pollution could compromise one of the main objectives of village hydraulics, namely the fight against water-borne diseases, mainly microbiological, one of the main causes of mortality and morbidity in the world in general and in developing countries in particular [16] .

Nitrate and arsenic are found at high levels in the waters of certain structures in the study area. The accumulation of these dissolved elements in groundwater, which exceeds drinking water standards, could increase the risk of water-borne diseases.Antrophic activities are at the root of the mineralization of water in certain chemical elements, including nitrates. In fact, agriculture and livestock farming contribute various chemical elements that are carried to the water table by infiltration water [17] (Schiewede et al., 2005. In this study, domestic activities developed around village wells are most often responsible for most of the nitrate point-source pollution observed. The extension and intensification of agricultural practices also contribute to high concentrations of NO_3 released by fertilizers following their use as soil fertilizers [21] (Moctar, 2012). In the commune of Gouchi, this practice has increased in recent years. It should also be noted that the shallowness of the water table and the sandy nature of the overlying formations could accelerate nitrate transfer into the water table [2,4].

- Unlike nitrate, the presence of arsenic in groundwater may be of geological origin. Several hypotheses have been put forward to explain the problem of As enrichment in the world's groundwater. Since its first discovery in Bangladesh, the use of fertilizers, pesticides, insecticides, waste disposal, wooden poles treated as compounds, etc., have been accused of being the anthropogenic sources of As enrichment in groundwater [22]. This hypothesis has been rejected, as the current state of knowledge indicates a mainly geogenic source and its release into groundwater by natural processes [2] [23-25], such as:
- Oxidation of pyrite (FeS2) or arsenopyrite (FeAsS) was postulated as the dominant As mobilization process due to the lowering of the water table as a result of excessive groundwater pumping [26,27] which was widely accepted at first.
- Another theory, known as the Fe oxyhydroxide reduction hypothesis, is now widely accepted as the main mechanism for As mobilization in groundwater from alluvial aquifers [22,23] [25,28] [29,30].

Arsenic mobilization in groundwater also appears to be triggered by intensive groundwater extraction for irrigation and the application of phosphate fertilizers [31].

For [32], As mobilization is associated with a recent influx of carbon due to large-scale irrigation pumping. According to [33] and [34], apart from Fe(III) hydroxide oxides, other solid phases such as phyllosillicates also play an important role in As cycling and mobilization. In Bangladesh, work by [35] has shown that the reductive dissolution of Fe oxyhydroxide present in the form of coatings on sand grains and weathered mica (biotite) is envisaged as the main mechanism for the release of As into groundwater in sandy aquifer sediments. In view of the above, we can safely say that As mobilization in groundwater is a complex natural geochemical process.

5. Conclusion Et Recommandations

This preliminary study carried out in the commune of Gouchi was of capital interest. In fact, it enabled us to analyze the parameters and hydrodynamic behavior of the aquifers, and to determine the current state of the chemical and bacteriological quality of the groundwater in the aforementioned commune.

In view of the above, it would be advisable to:

- Carry out a counter-analysis of the water in the various works, especially those with high levels of fluoride and arsenic;
- Draw up a communication plan for all stakeholders on the importance of rational management and better protection of these water resources, which are highly vulnerable to pollution;
- The creation of protection perimeters around these waterworks to minimize the risk;
- Setting up a monitoring network to regularly check water quality;

Implementation of Arsenic and Fluorine removal treatment techniques such as: nanofiltration, oxidation, precipitation/coprecipitation, reverse osmosis, selective adsorption, other membrane retention techniques.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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