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RESEARCH ARTICLE

PRELIMINARY STUDY ON THE GROUNDWATER RESOURCES OF THE KORAMA SUB-WATERSHED IN THE COMMUNE OF DOGO-DOGO/ZINDER REGION: HYDROGEOLOGICAL CHARACTERIZATION AND GROUNDWATER QUALITY

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Abstract

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The commune of Dogo-dogo is located in the extreme south of the Zinder Region, in a sub-catchment area of the Korama River, between 12°50' and 13°00' North latitude and 9°10' and 9°32' East longitude. This area is hydrogeologically based on the aquifers of the Malawa sandstone formations, characterized by an important potential groundwater resource and an abundant ecosystem, and has been subjected for years to the phenomena of climate change, the dynamics of land use and a galloping demography. This has resulted in changes in the quantity and quality of the water resource in this area. However, it seems necessary to undertake quantitative and qualitative studies of this resource. The main objective of this study is the hydrogeological and qualitative characterization of groundwater in the town of Dogo-dogo. The methodology adopted was based on the processing and statistical analysis of hydrogeological, chemical and bacteriological data, the elaboration of a piezometric map and a hydrogeological cross-section, which led to the following results The depths of the works vary from 45 to 97 m with an average of 68.73 m giving rise to water column thicknesses of more than 20 m. While, the values of water exploitation flows are very disparate, they vary from 0,3 to 24 m3/h with an average of 5,05 m3/h. Furthermore, the piezometric map shows that the direction of groundwater flow is generally from NW to SE. This general trend tends to follow the direction of flow of surface water, whose hydrographic network is more or less fossilized (Korama). As for the bacteriological results of the water, out of the 111 samples, 84 and 72 show respectively Total Coliforms (TC) and Escherichia. Coli in the groundwater. This could be explained by the lack of hygiene around the water points in conjunction with the shallow depths of the water in some places. All these aspects can compromise the drinking water supply of the populations. Finally, from the

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chemical point of view on the 111 water samples, two (02) and three (03) of these samples are characterized respectively by Arsenic and Nitrate contents exceeding the WHO standard of water consumption.

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Introduction:-

The earth seen from space appears as a planet surrounded by water on about ¾ of its surface, estimated at 1.4 billion km3. Only 3% of this water mass corresponds to freshwater, of which groundwater represents only 25% (source). Groundwater is a natural resource of great importance, used for domestic, agricultural and industrial purposes. Nowadays, due to the increasing population, the intensification of irrigated agriculture, and industrialization, there is a shortage of water. The groundwater resource, in some regions of the world, is facing problems of quality and quantity. In arid and semi-arid climates, such as Niger, where groundwater is the main source of drinking water for the population, the situation is complex. Indeed, these areas have been subject for several decades to climate variability phenomena. The Commune of Dogo-dogo, 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 in the area (Issa Malam S. Souleymane et al., 2018). The combination of these different phenomena could affect the quantity and quality of groundwater resources in an area (Lennon et al,. 2006). It is therefore necessary to undertake a study on the quantity and quality of this resource of the commune of Dogo-dogo, or the state of knowledge on these remains poor. The main objective of this study is the improvement of the state of knowledge of the groundwater resource in the commune.

Specific objectives of these studies are :

1. To process and analyze the hydrogeological parameters (exploitation flow, depth of the water table, thickness of the water table, depth of the borehole)
2. To elaborate a piezometric water map and a hydrogeological section of the commune ;
3. To process and analyze the physico-chemical and bacteriological parameters of water.

Materials And Methods:-

Presentation of the study area :

The Commune of Dogo-dogo is located in the extreme south of the Zinder Region, between 12°50' and 13°00' North latitude and 9°10' and 9°32' East longitude (fig. 1). It is bordered to the north by the Commune of Dungass, to the south by the state of Kano (Federal Republic of Nigeria), to the west by the Commune of Dantchiao and to the east by that of Malawa. It has an area of 263 km2 and an estimated population of 68,256 in 2012 (NSI, 2012). Applying the intercensal growth rate of 5.6%, the population at the end of 2018 is estimated at 94,651 inhabitants, or a density of 139 inhabitants per km2 (Plea, Dogo-dogo 2019). Agriculture is the main activity of the populations, followed by livestock occupying the second place.

Table 1:- Population trends in the commune from 2018 to 2030.

Year	2018	2020	2025	2030
Total Population	94 651	105 549	138 603	182 008

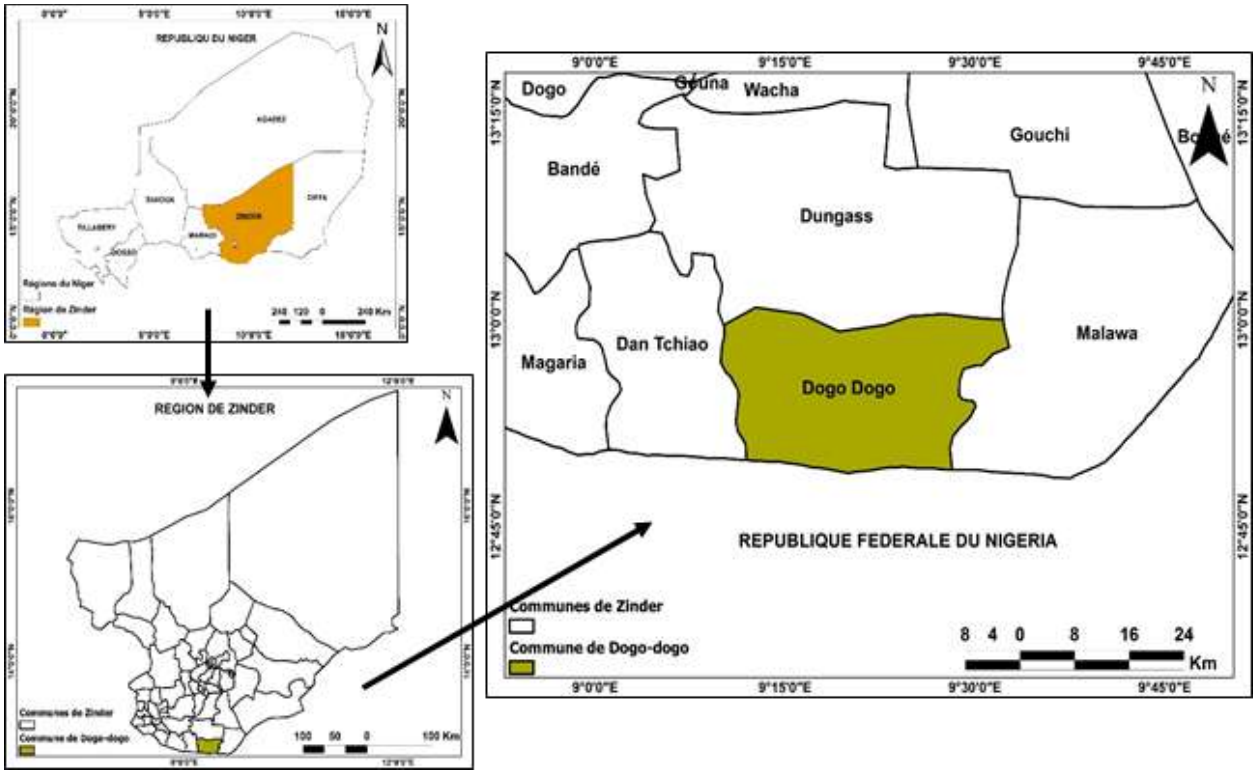

Figure 1:- Location of the municipality of Dogo-Dogo.

Rainfall

The climate in Dogo-Dogo is of the North Sudanese type, characterized by two seasons: a rainy season from June to September and a dry season from October to May. The average annual rainfall values recorded at the Dogo-Dogo station ranged from 410 mm (in 2011) to 687 mm (in 2013) with an interannual average of 578 mm over the seven years (Fig. 2).

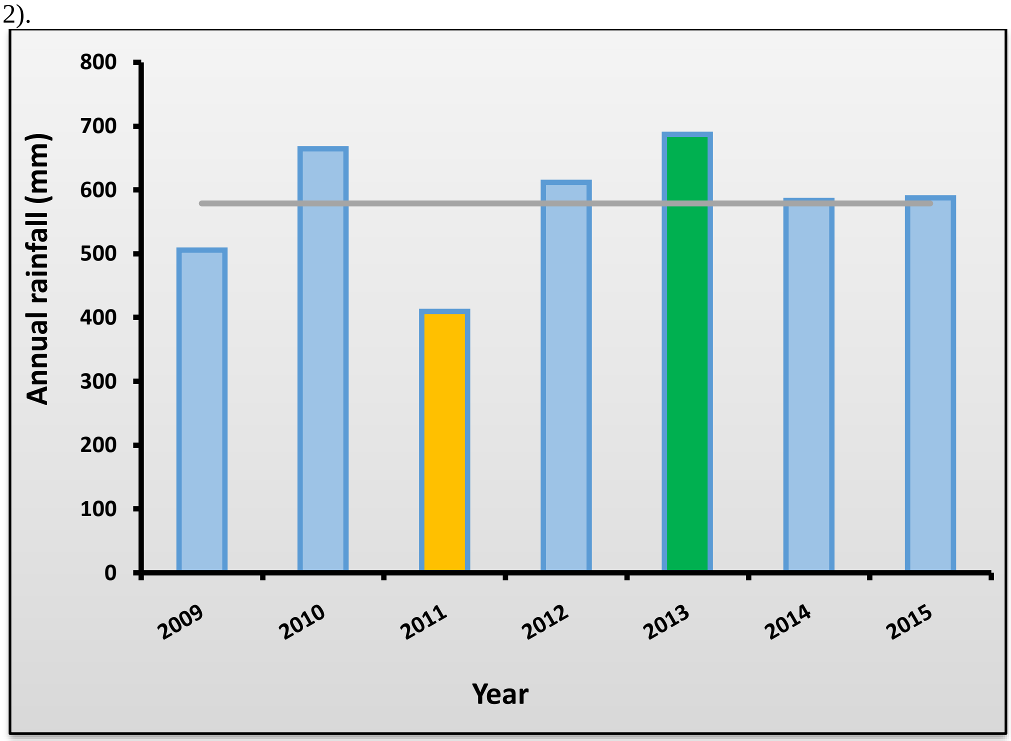

Figure 1:- Interannual rainfall at the Dogo-Dogo station.

Geomorphology

The portion of the Korama basin in the commune of Dogo-dogo is a very flat area occupied by stabilized former sand dunes. The inter-dune hollows, which can be several dozen meters deep, form numerous dry or flooded basins. The studied area is crossed from West to East by the fossil valleys of the Korama. The topographic slope is about 1‰. The landscape is marked by parallel dune strings, with a NNE-SSW orientation. The perfect rectilinear arrangement of the dunes cannot be explained solely by the presence of prevailing winds. Ancient faults replaying in the Quaternary are supposed (Faure, 1978).

Hydrography

The dense and well-structured hydrographic network is composed of several temporary streams feeding temporary pools (Fig. 3). The most important are those of Gajaoura, Signale and Bourdinga. These ponds, once developed, can constitute potentially important water resources for the development of agricultural activities in the area.

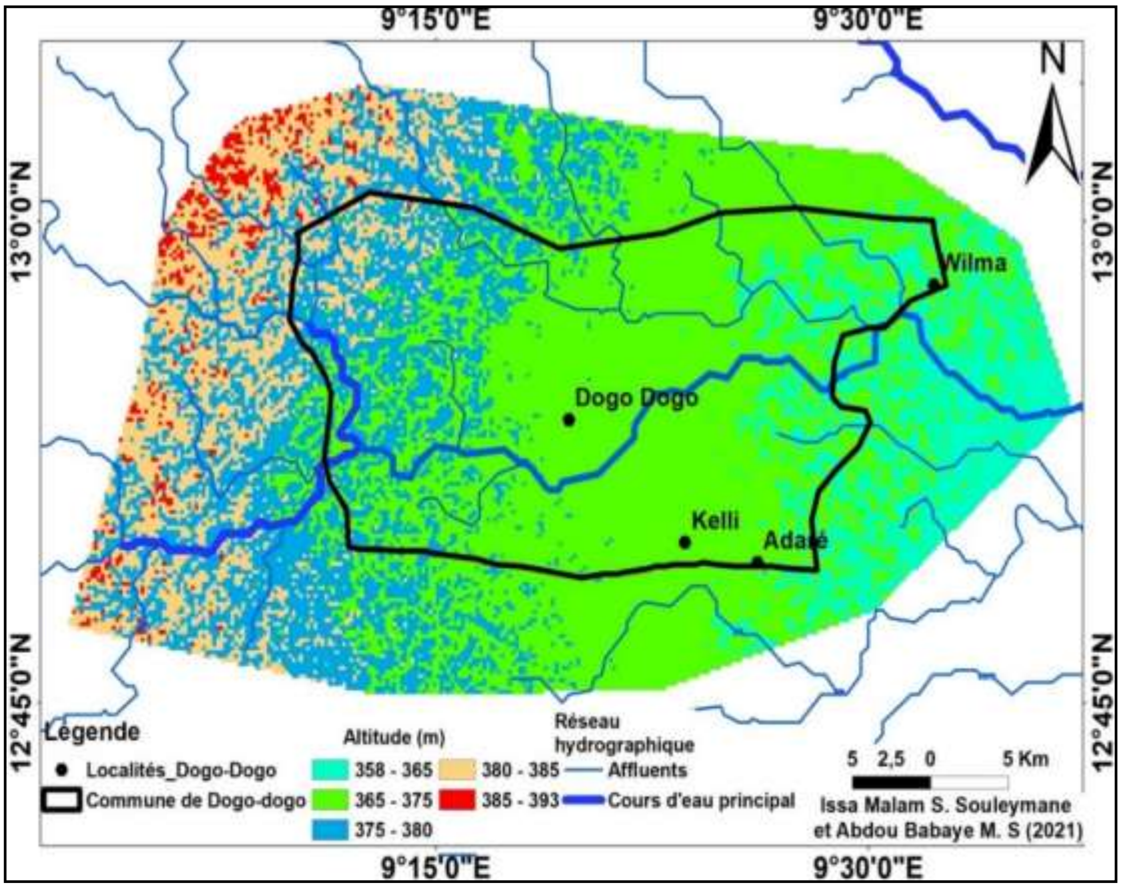

Figure 2:- Hydrographic networkof the municipality ofDogo-dogo.

Geology

From a geological point of view, the commune of Dogo-Dogo is essentially located on the sedimentary formations of ancient quaternary age (Malawa sandstone) of the Chad Basin (Fig. 4). These sedimentary formations form the main aquifer of the commune (Malawa sandstone).

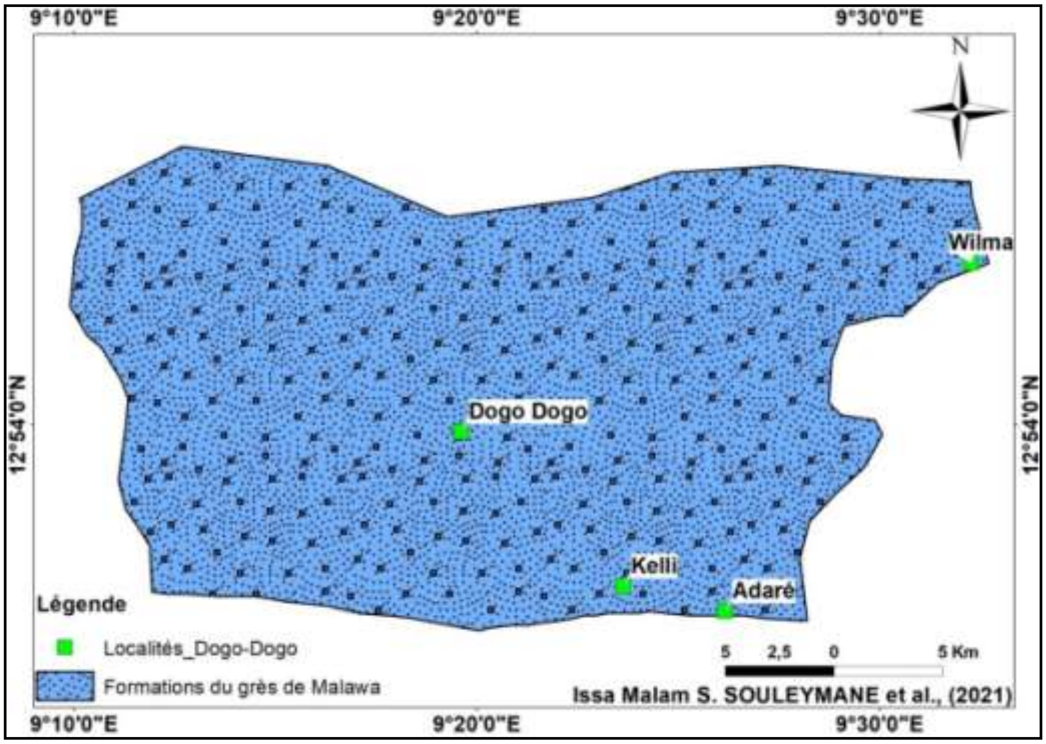

Figure 4:- Geological map of the commune of Dogo-Dogo.

Material:-

Data and tools

The data used in this study are :

Hydrogeological parameter data (drilling logs ; exploitation rate ; thickness of the aquifer; static level; drilled depth)

Chemical parameters data (Arsenic ; Nitrate and Fluorine)

The tools used are constituted by :

1. Hydraulic works (Wells, PMH, Mini-AEP and PEA) ;
2. Small hydrogeological equipment: Electrical probe, pH-meter, Conductivimeter for in situ parameter measurements;
3. Tablet for taking geographical coordinates; photos and questionnaires;
4. Bottles, pillboxes, coolers, sampler, sterile bags, torch, adhesive tape, markers for water samples;
5. Mobile laboratory including two POTALAB kits (Wagtech/Palintest)

Different software composed by : Arc Gis, Surfer, Excel, Drilling and Paint.

Methodology:-

Data collection

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

Sampling

The measurements of physical parameters in situ were carried out on all the works (wells, boreholes, hydrants) of the commune. In addition, more than 80% of the works, i.e. 111 out of 133, were sampled in order to have a clear and precise idea of the chemical and bacteriological quality of the groundwater. These bottles of water were hermetically sealed, labeled, placed in a cooler and then sent to the laboratory under the required conditions where they were immediately analyzed. GPS coordinates were also recorded for each water point.

Data processing

Hydrogeological characterization

The drilling logs were used to elaborate the hydrogeological section of the study area. The operating flow rate (Q) and specific flow rate (Qs) are determined from the interpretation of short and/or long term pumping tests by the semi-logarithmic method of Jacob (Cooper and Jacob 1946) and/or Theis (Theis, 1935).

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

The static level readings taken during the piezometric campaign and the dimensions of the boreholes determined by the DTM allowed the calculation of the piezometric level of the different water points. The absolute Z coordinates obtained by DTM were compared with the coordinates of certain water points levelled during previous work (ANTEA, 1994) using a WM102 GPS. This comparison showed a good correlation between these data. Furthermore, this method has been used by some authors (Koussoube, 2010 ; Madioune, 2012 and Issa Malam S. Souleymane, 2018). The piezometric map was then developed using Arc Gis software.

It should be noted that, several interpolation methods (IDW, ordinary Kriging, universal) were tested in order to find the most suitable one. Thus, the IDW interpolation method was chosen, since it has the lowest average error.

Chemical and bacteriological analysis of water

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

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

Thus, all of these kits allowed for the analysis of major, minor and even trace elements in water.

Several calibration tests were carried out on the different measuring devices mentioned above in order to ensure the reliability of the results of the analyses : the criteria of reliability are among others the fidelity, the accuracy and the sensitivity of the methods. Several calibrations and blank tests were repeated to ensure the functionality of the devices and the analytical methods.

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

Results:-

Hydrodynamic parameters

The depth of the water points in the commune of Dogo-dogo varies from 45 to 97 m with an average of 68.73 m and a coefficient of variation of 12.51% for the water points studied (wells and boreholes) (Table 2). This spatial distribution of depths corresponds to the minimum and maximum levels of the water table, which stabilize respectively at a depth of approximately 24 m and 41 m, resulting in water column thicknesses of more than 20 m. Moreover, the analytical result shows that more than 85% of the works capture these water tables between 30 and 40 m depth (table 3). In general, these average depths of the piezometric levels of these water tables highlight their low susceptibility to anthropic pollution. This remains to be confirmed by the results of chemical and especially bacteriological analyses carried out on these waters.

Table 2:- Statistical results of the hydrogeological parameters of the 68 boreholes in the commune of Dogo-dogo.

Parameters	Max	Min	Moyenne	Ecartype	Médiane
Flowrate (m3/h) (n=79)	24	0.3	5.05	3.82	3
Depth of Aquifer/NS (m) (n=80)	41	24	34.89	2.17	34.97
Tchickness (m) (n=79)	64	5.71	16.06	5.78	15.42
Depth drilled (m) (n=80)	97	45	68.73	8.6	67

Table 3:- Distribution of groundwater depth values.

Distribution of groundwater depth		
Depth. (m)	Nber of borehole	%
24 to 30	5	6.25
30 to 35	36	45
35 to 40	34	42.5
40 to 41	5	6.25
totals	80	100

Productivity of water points

The values of water exploitation flows vary from 0.3 to 24 m3/h with an average of 5.05 m3/h and a coefficient of variation of 3.82 on the 68 collected works (table 4). This coefficient of variation highlights a strong disparity in this parameter. The highest values are found at the Batsé da Tsada (Depth=79 ; Q=24 m3/h), Tamouli (Depth=82 m ; Q=18 m3/h), Zongon Tchili (Depth=79 m ; Q=18 m3/h), and Chakounou (Depth=70 m ; Q=18 m3/h) water points. While, the lowest values are observed on the works of Garin Fourtchi (Depth=52 m ; Q=0.30 m3/h), Angoual Makana (Depth=62.50 m ; Q=0.40 m3/h), Dan Kirey Tatabou (Depth=58 m ; Q=0.48 m3/h), Kazake (Depth=54 m and Q=0.5 m3/h). Thus, we note that there is no correlation between the values of flow rates of drilling with the thicknesses captured (Fig. 6). In fact, the statistical values for the thickness of the wells vary between 5.71 and 64 m for an average of 16.06 and a variation coefficient of 36% for the 79 water points (Table 2). The smallest values of thickness are obtained at the level of Tsallé (Thickness=5.71 m ; Q= 2.84 m3/h), Dan Makia (Thickness=5.71 m ; Q=5.40 m3/h), May Kiria (Thickness=5.71 m ; Q= 13. 05 m3/h), while high values are found in the water points of Wachawa (Thickness=64 m ; Q= 4 m3/h), Dan Takore (Thickness=57.2 m ; Q= 3 m3/h) and Angoual Kalgo (Thickness=34.5 m ; Q= 0.58 m3/h). Thus, the 10 to 20 m thick section represents more than 70% (Table 2 and Fig. 5).

Table 4:- Distribution of the flow rates of the water points (m^3/h).

Flow rates distribution		
Flowrates (m3/h)	Nberboreholes	%
0.3 to 1	21	26.58
1 to 2	8	10.13
2 to 3	11	13.92
3 to 5	10	12.66
5 to 8	14	17.72
8 to 10	4	5.06
10 to 15	6	7.59
15 to 18	4	5.06
24	1	1.27
Total	66	100%

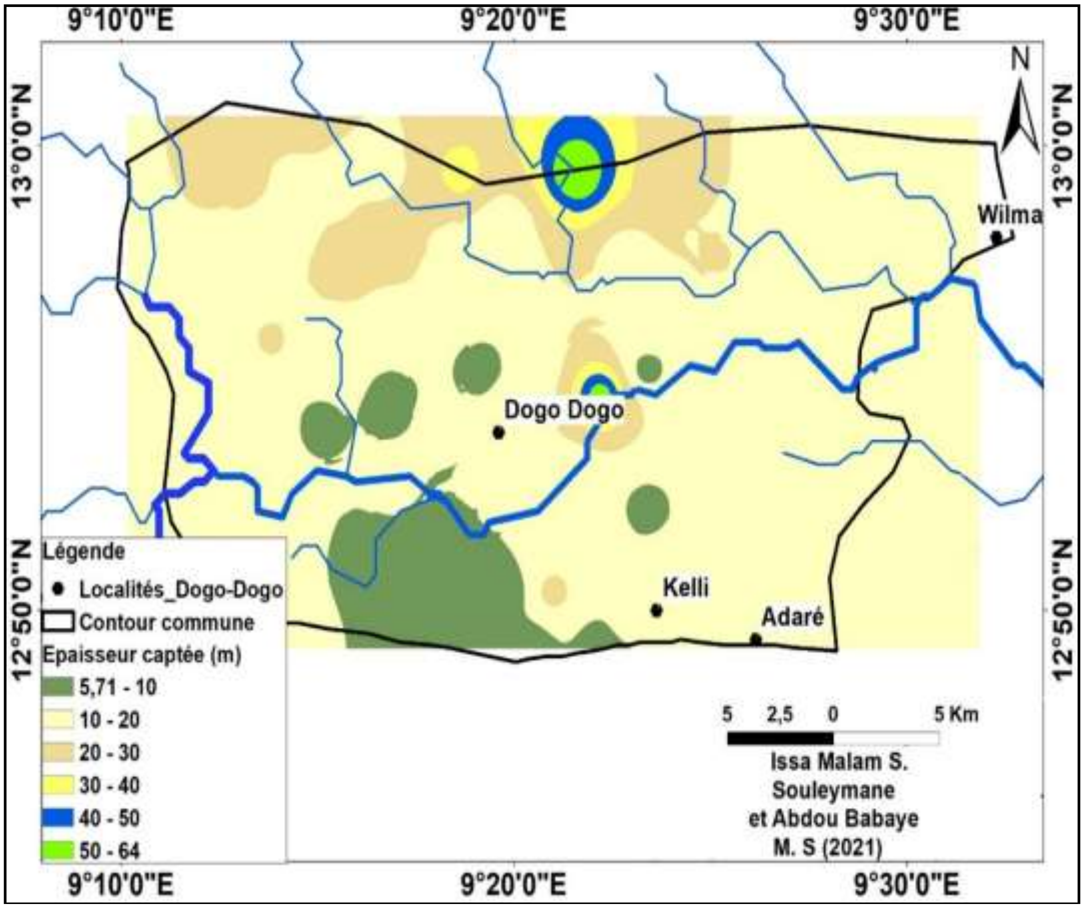

Figure 5:- Spatial distribution of the thickness of the water table.

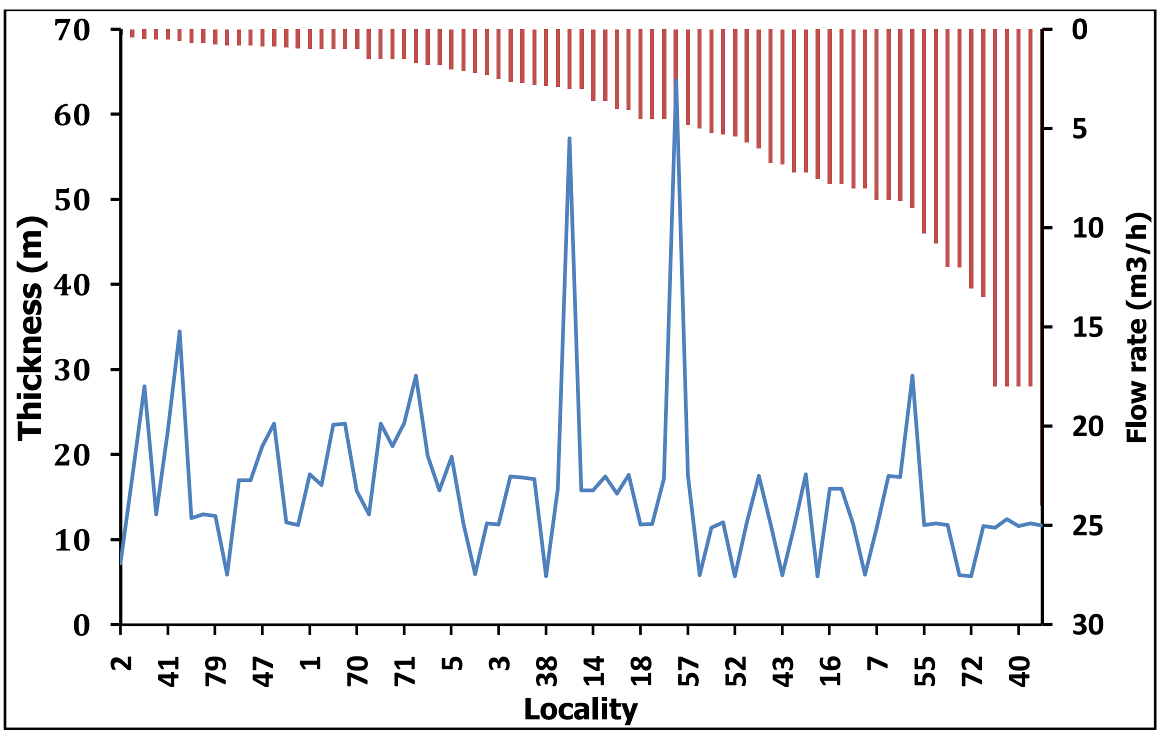

Figure 6:- Relationship between the thickness of the aquifer and the operating rate of the water points.

Depth of the aquifers

The depth of the aquifer in the commune of Dogo-dogo ranges from 24 m to 41 m. The range of 30 m to 35 m is more representative in the commune (Fig. 7). Thus, we can observe a lateral variation of the latter. Indeed, this depth increases going from North to South. This seems to be due to the general structural organization of the underlying basement in the Korama watershed.

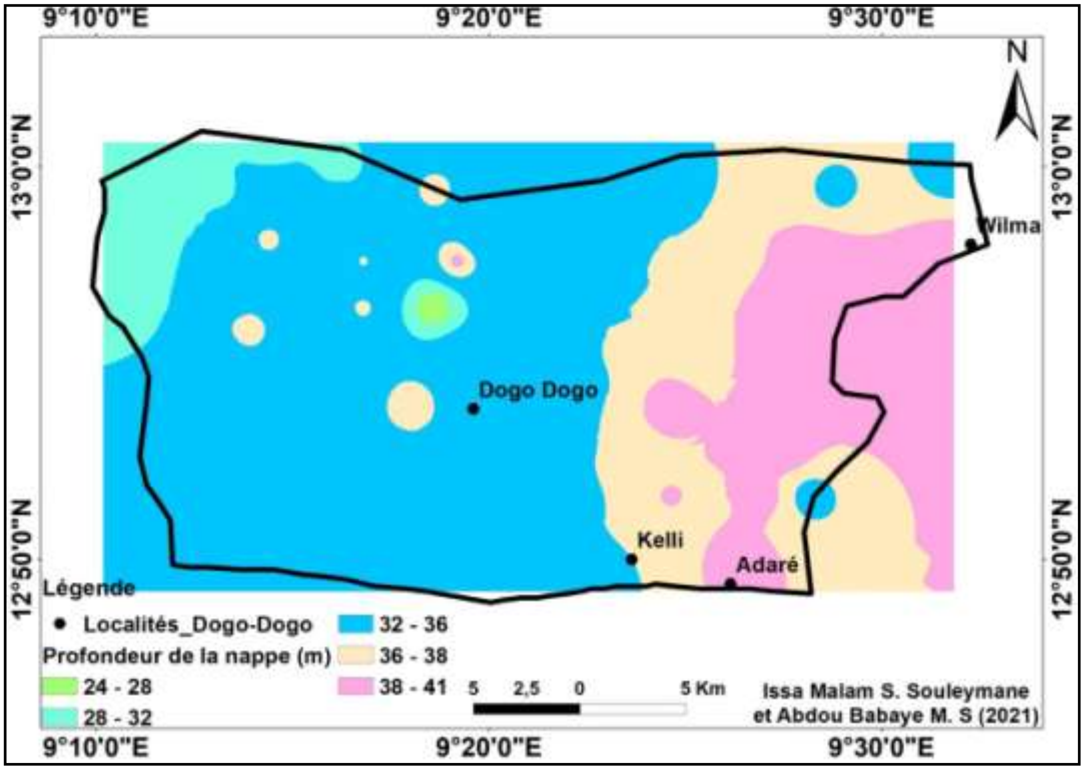

Figure 7:- Spatial distribution of aquifer depths in the commune of Dogo-dogo.

Hydrodynamics - Piezometric map

For a sustainable management of the groundwater resource of an area, it is imperative to perform temporal and spatial monitoring of piezometric levels. These data will allow to appreciate the seasonal or long term variations of these resources, as well as the direction of flow of these waters. Unfortunately, there was no data from these monitoring in this town, nevertheless the information obtained during this study shows that the depths of water levels in the works, during the period of August 2020, fluctuate between 24 m to 41 m with an average of 34.89 m. These values show a low variation of this parameter with a coefficient of variation of 6.22% on the 80 observed water points (Table 5). These relatively average depths of the water table highlight the low susceptibility of the latter to anthropogenic pollution.

The groundwater flow direction map shows that the flow direction of the groundwater is generally NW to SE (Fig. 8). This general pattern tends to follow the direction of flow of surface water, the drainage network of which is more or less fossilized (Korama). This suggests that the drainage patterns are derived from the structural organization of the underlying basement (Issa Malam Salmanou, 2018 ; Abdou Babaye, 2012 ; Koussoubé et al., 2003 ; Ousmane B, 1988). Thus, we observe on both sides of the commune, the presence of piezometric domes announcing the existence of the nappe-river relationship. It should be noted that at this time of year, the piezometric level is in equilibrium with that of the surface water in some places.

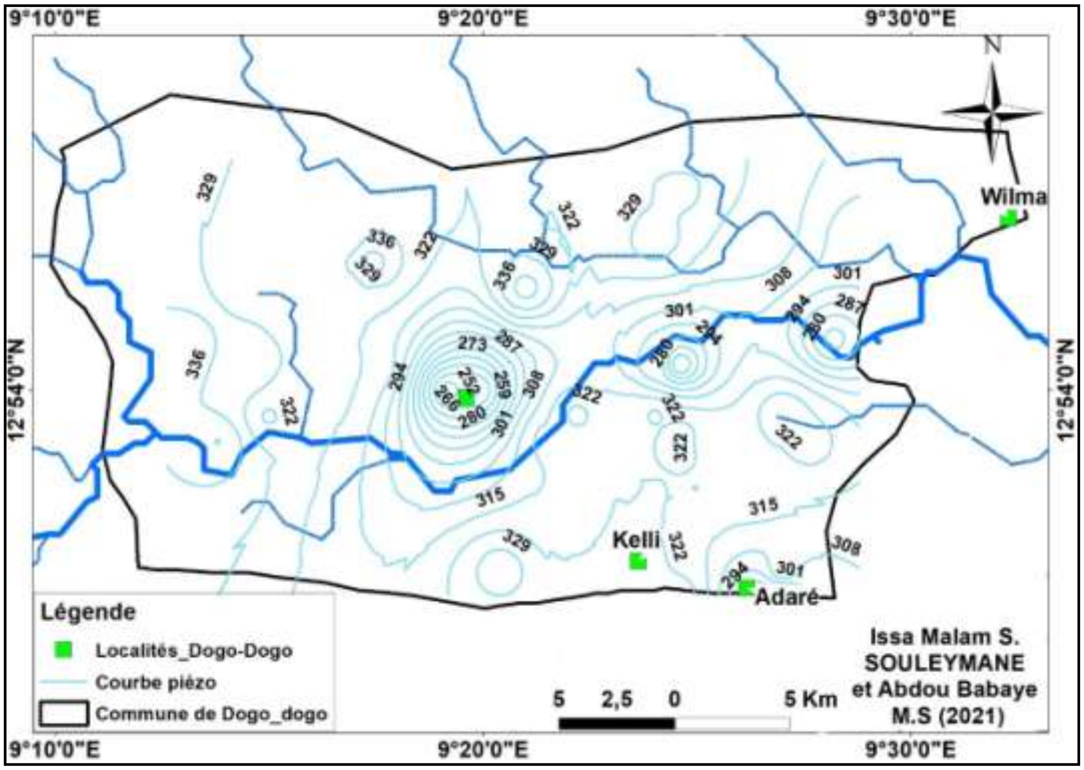

Figure 8:- Piezometric map of the study area (February 2021).

Hydrogeological maps

o **Lithology**

Generally speaking, the NE-SW hydrogeological section of the Dogo-dogo commune highlights two main lithostratigraphic units: the sedimentary formations of the ancient and recent quaternary. Thus, we can distinguish from bottom to top (Fig. 9):

The series with alternating sandstones, clays and gravels corresponding to the ancient quaternary formations;

The series of sand with variable granulometry with more or less clays representing the formation of the recent quaternary.

No water point reaches the bedrock in the study area. Nevertheless, this configuration confirms the general geological structuring of the Korama basin described by Faure (1978) and Greigert (1978). Indeed, according to Faure (1978), the Korama basin corresponds to an area of collapse by faulting of the basement. Thus, the filling of this basin was carried out during four (04) climatic episodes during the quaternary (Faure and Greigert, 1978). These climatic variations have conditioned the erosion and sedimentation phenomena. A syn-sedimentary tectonics seems to take place in the basin. Indeed, ancient faults replaying in the Quaternary are assumed. This phenomenon has mainly affected the series of alternating sandstones, clays and gravels corresponding to the ancient Quaternary formations.

From the hydrogeological point of view, all these formations can be aquiferous. However, in the municipality, the series with alternating sandstones, clays and gravels corresponds to the aquifer tapped by the hydraulic works (wells and boreholes). This aquifer formation is located at an average depth of about thirty meters (30 m).

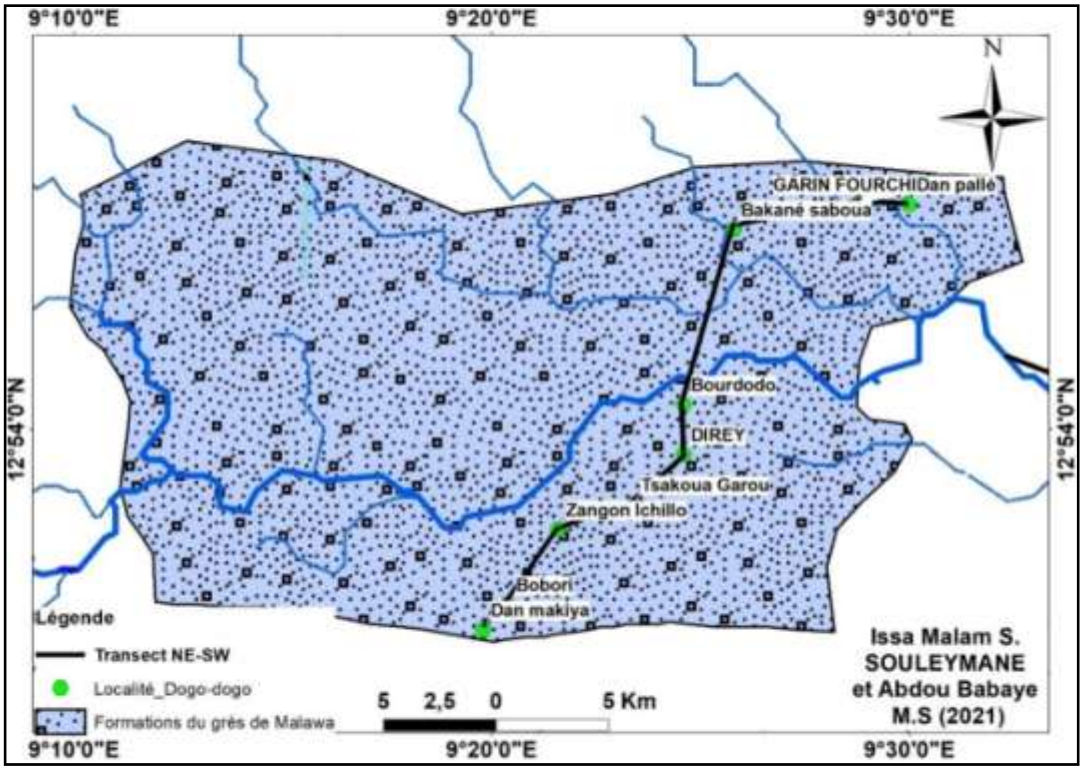

Figure 9:- NE-SW geological section transect.

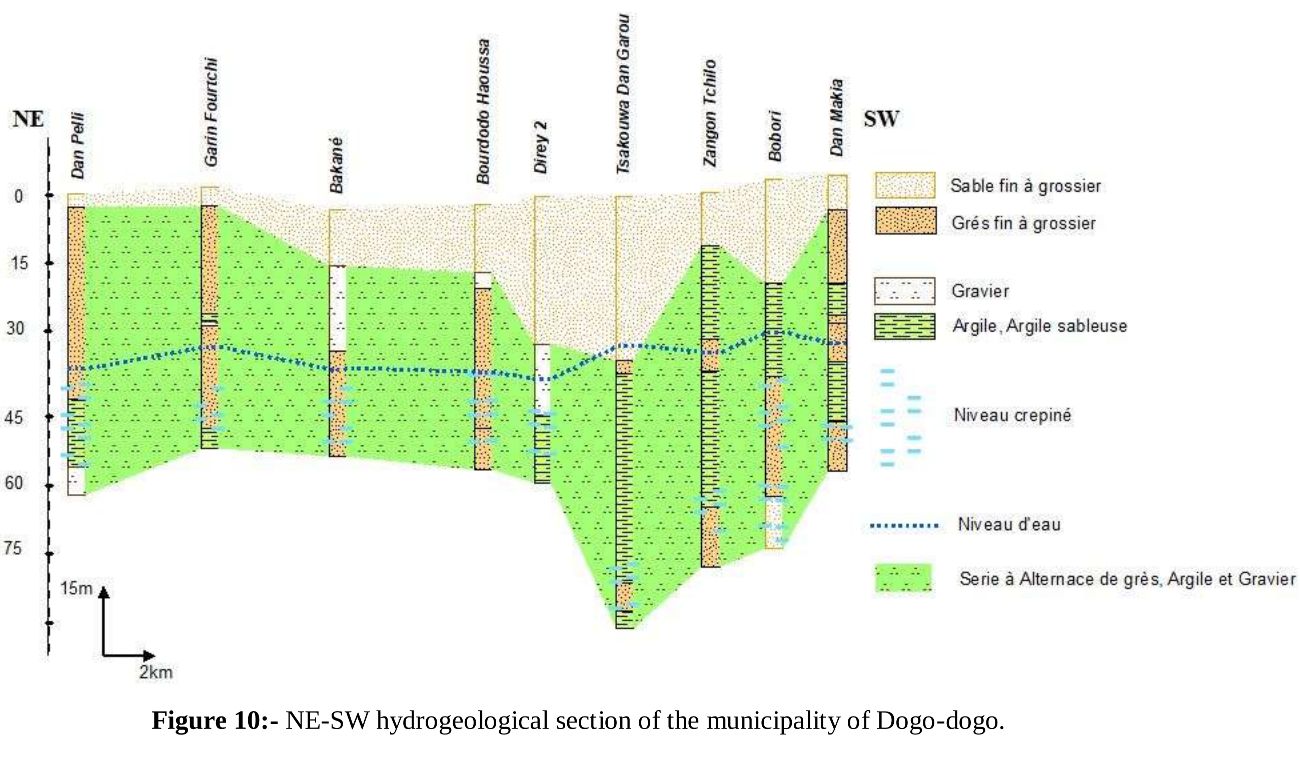

Figure 10:- NE-SW hydrogeological section of the municipality of Dogo-dogo.

Bacteriological results

Bacterial counts of total coliforms and E. Coli in the water ranged from 0 to over 1000 (or uncountable) colonies per 100 mL.

The statistical results of the analysis of the bacteriology samples, broken down by type of water point, are shown in Table 6. Of the 111 samples, 84 and 72 show the presence of Total Coliforms (TC) and E. Coli (EC) in groundwater, respectively. Thus, 75.68% and 64.86% of the groundwater samples show the bacterial risk of TC and EC contamination respectively. Figures 10 and 11 show the spatial distribution of E. Coli and Total Coliforms in the waters. Thus, we can observe that the waters with a number of these bacteria higher than 50 are in the majority, then those with a number of these bacteria lower than 50 occupy the 2nd position.

Table 6:- Summary of bacteriological results of the waters of the municipality of Dogo-Dogo.

Water Source	**Water Point Type**	**Total Coliform**		**E. coli**	
		Positive	**Negative**	**Positive**	**Negative**
Boreholes	MAEP	4	2	3	3
	Bonne fountaine	2	0	2	0
	PMH	64	24	53	35
	PEA	3	1	3	1
Dug Wells	PC	11	0	11	0
	PT	0	0	0	0
	Mare (ponds)	0	0	0	0
	Puisard (sump)	0	0	0	0
	Undefined type	0	0	0	0
Totals		**84**	**27**	**72**	**39**

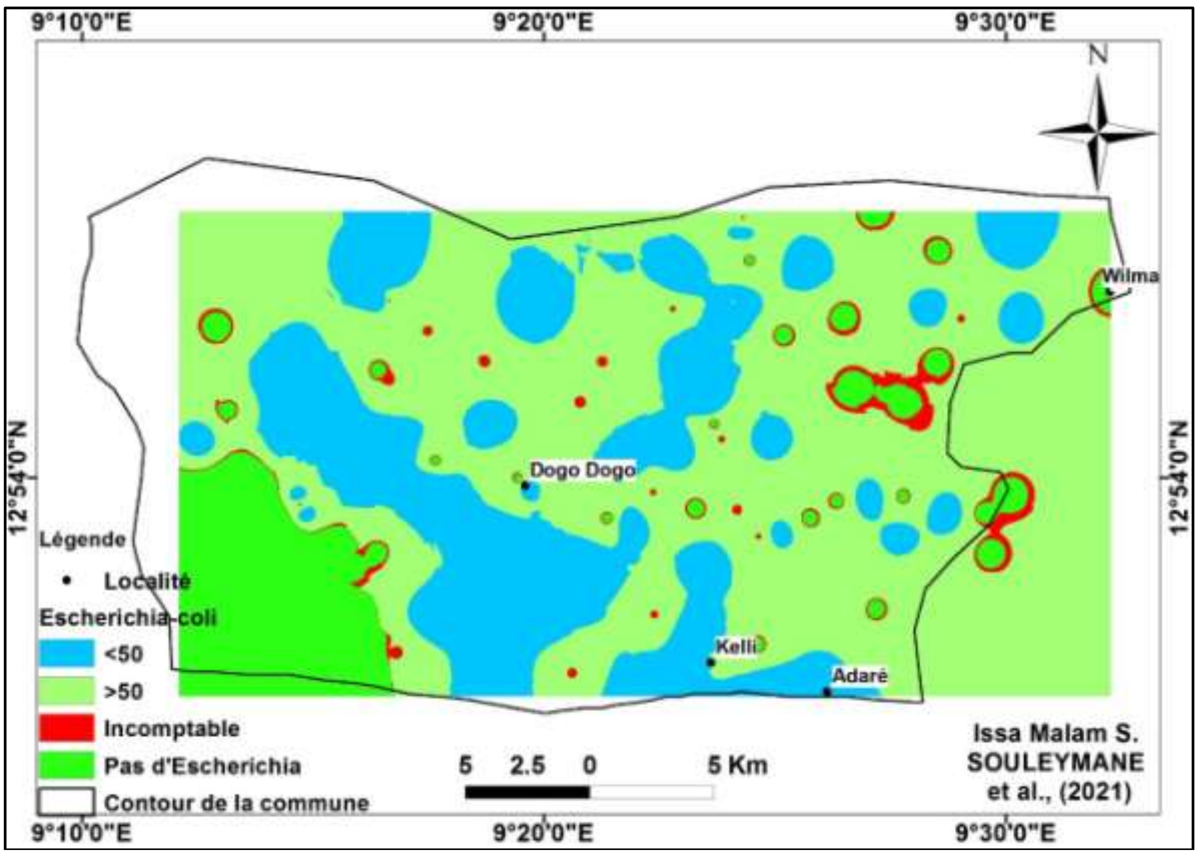

Figure 11:- Spatial distribution of Escherichi-coli type bacteria in the groundwater of the municipality of Dogo-Dogo.

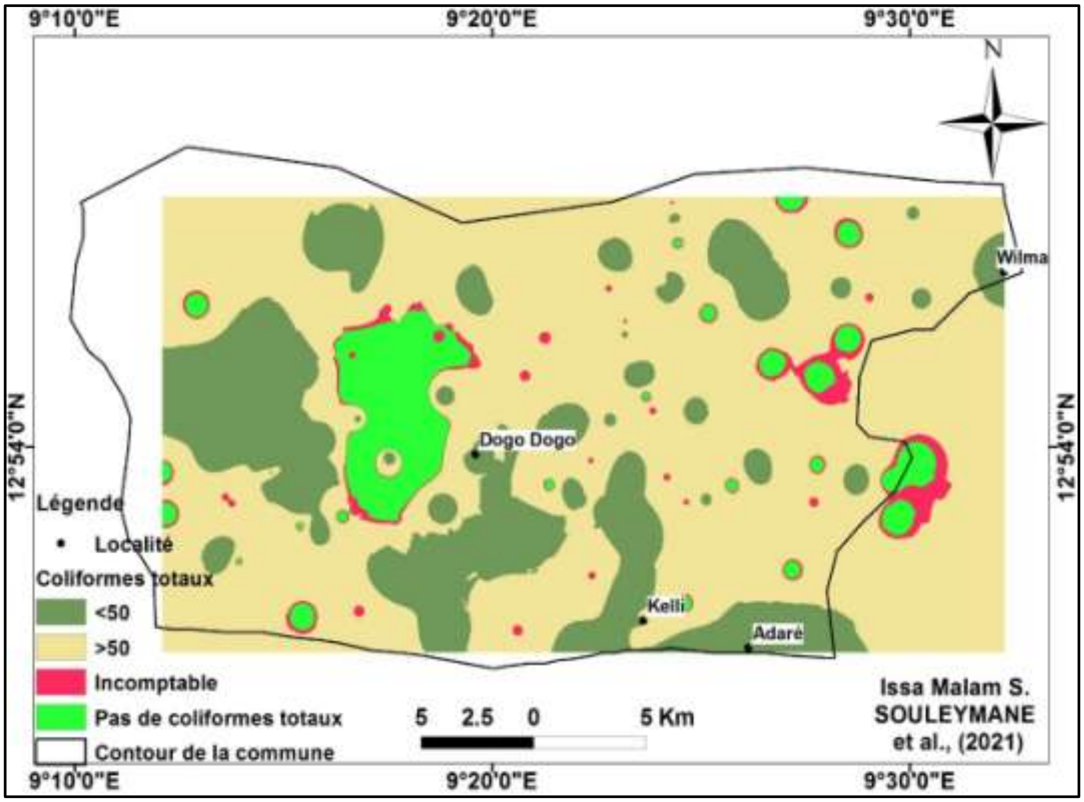

Figure 12:- Spatial distribution of total Coliform type bacteria in the groundwater of the commune of Dogo-Dogo.

Chemical results

The results of the chemical analyses of the water were compared to WHO (2011) standards for water consumption (Tables 7 and 8). Thus, the extreme values and numbers of samples with chemical element contents exceeding (or below) this standard in the groundwater of the study area are presented in Table 7 and 8 respectively for boreholes (AEP ; PEA ; BF and PMH) and for wells (PC and PT). The latter show, for all the works combined, two (02) and three (03) samples are characterized respectively by Arsenic and Nitrate levels exceeding the WHO standard for water consumption (Fig. 12). This means that these waters are mostly of very good physicochemical quality. The lists of works with high levels of chemical elements (NO3, As and F) are shown in Table 9.

Table 7:- Summary of the results of the physico-chemical parameters of the boreholes in the Commune of Dogo-Dogo.

Parameter	Measured Range	Guideline Value (WHO)	Comments
pH (SU)	4.94 – 7.80	6.5 – 8.5	• 86 samples between pH 6.5 – 8.5 • 35samples < pH 6.5 • 0samples >pH 6.5
EC (µS/cm)	27 - 761	1000	• 121 samples <1,000 mg/l • 0 samples >1,000 mg/l
TDS (mg/l)	13 – 475	1,000	• 121 samples <1,000 mg/l • 0 samples >1,000 mg/l
Fluoride (mg/l)	< 0.01 – 1.42	1.5	• 18 samples are ND • 93 samples <1.5 mg/l • 0samples >1.5 mg/l
Arsenic (µg/l)	3 – 39	10	• 75samples are ND • 34samples <10 µg/l • 2 samples >10 µg/l

Nitrate (mg/l)	1.56 – 100	50 mg/l	• 109 samples <50 mg/l • 2 samples>50 mg/l

Table 8:- Summary of the results of the physico-chemical parameters of the water from the wells of the Municipality of Dogo-Dogo.

Parameter	**Measured Range**	**Guideline Value (WHO)**	**Comments**
pH (SU)	4.94 – 7.80	6.5 – 8.5	• 18 samples between pH 6.5 – 8.5 • 2 samples < pH 6.5 • 0samples >pH 6.5
EC (µS/cm)	27 - 761	1000	• 20 samples <1,000 mg/l • 0 samples >1,000 mg/l
TDS (mg/l)	13 – 475	1,000	• 20 samples <1,000 mg/l • 0 samples >1,000 mg/l
Fluoride (mg/l)	< 0.01 – 1.42	1.5	• 2 samples are ND • 9 samples <1.5 mg/l • 0samples >1.5 mg/l
Arsenic (µg/l)	3 – 39	10	• 8 samples are ND • 3 samples <10 µg/l • 0 samples >10 µg/l
Nitrate (mg/l)	1.56 – 100	50 mg/l	• 10 samples <50 mg/l • 1 samples>50 mg/l

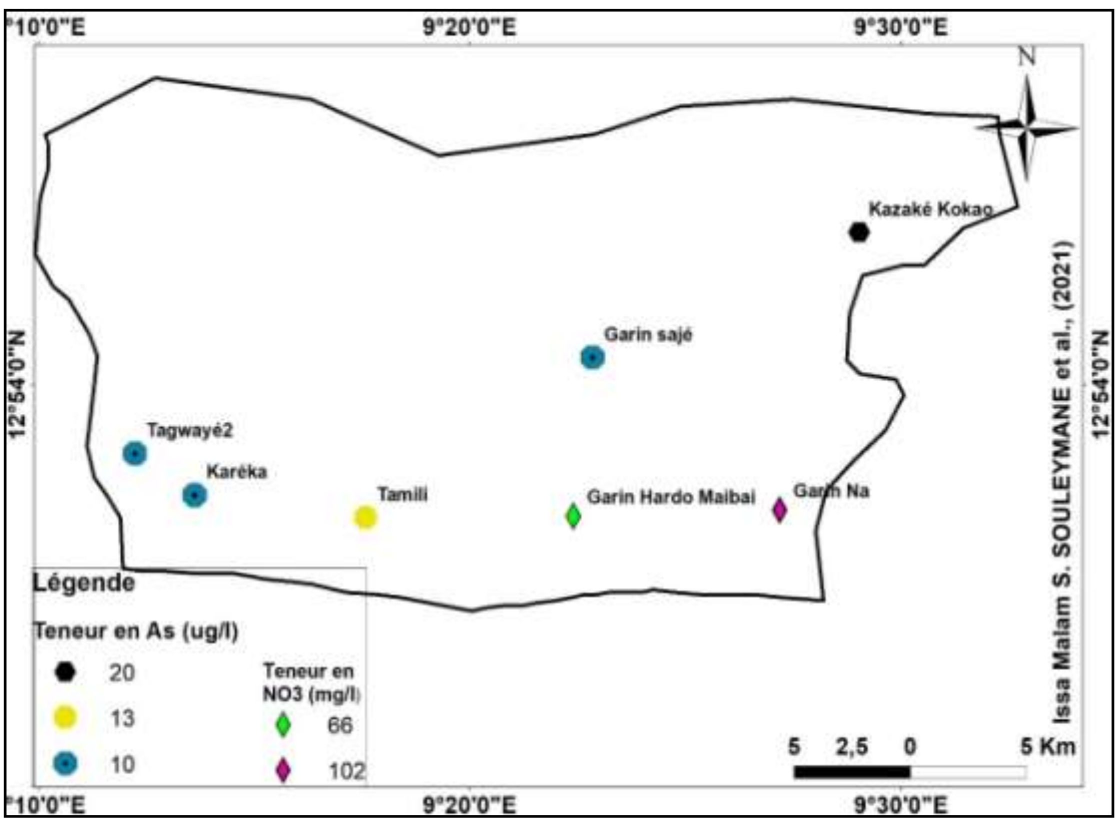

Figure 13: Distribution of water points with high As and NO_3 contents in the municipality of Dogo-Dogo.

Table 9:- The works of the municipality of Dogo-Dogo with high levels of Arsenic and Nitrate.

N°	Village	Longitude	Latitude	Water point type	As (µg/l)	NO_3(mg/l)
1	Kazaké Kokao	9.484	13	PMH	20	3.9
2	Garin Hardo Maibai	9.373	12.9	PC	0	66
3	Tamili	9.293	12.9	PEA	13	7.6
4	Garin Na	9.453	12.9	PMH	7	102

Discussions:-

Relationship between productivity/captured thickness and depths of the works

The flow rates are generally very low in relation to the water potential of these aquifers offering the possibility of the realization of large water supply systems for the population and for irrigation (PEA; mini-AEP...) (fig.13 and14). It should be remembered that, on the whole, these flow values are not representative of the real productivity of these aquifers. Indeed, the time of pumping tests carried out, very short, (maximum 6 hours of time), do not allow to test the performance of the water table and to develop the work and a fortiori estimate the hydrodynamic parameters of the aquifer. It should be noted, also that the sandy-silty and sandstone-clay character of these aquifers requires a long pumping to develop well the work. Also, most often this productivity is left to the appreciation of the company and this puts doubt in the appreciation of the flows provided by the works. However, the potential of the aquifer level tapped remains difficult to evaluate and is sometimes underestimated. Finally, these results show that the productivity of the works is a function of several parameters other than depth, but in particular the lithological nature of the reservoir and the thickness captured (Illias alhassane, 2018; Abdou Babaye, 2012) (fig.13 and 14).

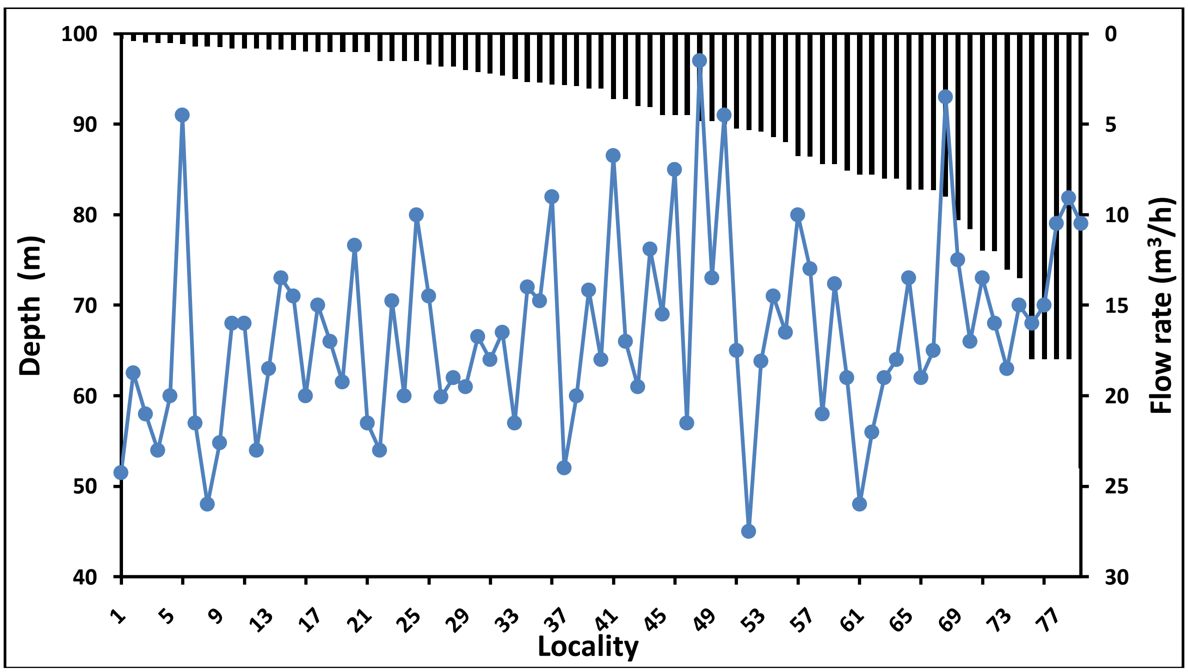

Figure 14:- Relationship between the equipped depth and the operating flow of the water points.

Water pollution

The bacteriological pollution of the water in the study area could be attributed to two main factors :

The direct and/or indirect recharge of groundwater by water, sometimes degraded, from rainfall and/or surface water (Ousmane B, 1988). This would be the main cause of bacteriological pollution of groundwater (Issa Malam S Souleymane et al., 2020).

The infiltration and/or percolation along the borehole casings, to the water table or to the water of the water point, of stagnant wastewater around the vast majority of water points, due to very poor hygienic conditions. This could be one of the probable causes of this bacteriological pollution.

This pollution could compromise one of the main objectives of village hydraulics, namely, the fight against waterborne diseases, mainly microbiological, one of the main causes of mortality and morbidity in the world in general and in particular in developing countries (OECD, 2003).

Nitrate and arsenic are found at high levels in the waters of some water points in the study area. The accumulation of these dissolved elements in the water tables exceeds the norms of potability and thus increases the risk of waterborne diseases.

The antrophic activities are at the base of the acquisition of the mineralization of water in certain chemical elements among which nitrates. Indeed, agriculture and livestock farming bring various chemical elements that will be carried to the water table by seepage water (Schwiede et al., 2005 ; Ahoussi et al., 2012 in Abdou Babaye et al., 2016). In the study area, domestic activities developed around village wells are most often responsible for most of the observed nitrate point source pollution. The extension and intensification of irrigation practices also cause high NO_3 concentrations from fertilizers due to their use for soil fertilization (Moctar, 2012). Indeed, in recent years there has been an increase in this practice in the area. Note also, the shallow depth of these water points and the sandy nature of the cover formations could accelerate the transfer of nitrate into the water (ISSA MALAM S. Souleymane, 2018).

Unlike nitrate, the presence of Arsenic in groundwater could be of geological origin. Several hypotheses have been put forward to explain the problem of As enrichment in groundwater worldwide. Since its first discovery in Bangladesh, the use of fertilizers, pesticides, insecticides, waste disposal, wooden poles treated as compounds, etc., have been blamed as anthropogenic sources of As enrichment in groundwater (NRECA, 1997). This hypothesis has been rejected, in fact, the current state of knowledge indicates a mainly geogenic source and its release into groundwater by natural processes (Bhattacharya et al, 1997 ; Nickson et al., 1998, 2000), such as :

Oxidation of pyrite (FeS_2) or arsenopyrite (FeAsS) was postulated as the dominant process of As mobilization due to lowering of the water table as a result of excessive groundwater pumping (Mandal et al., 1996 ; Mallik and Rajagopal, 1996) which was widely accepted in the beginning.

- Another theory, known as the Fe oxyhydroxide reduction hypothesis, is now widely accepted as the primary mechanism for As mobilization in groundwater from alluvial aquifers (Bhattacharya et al., 1997, 2001; Ahmed et al., 1998b; Nickson et al., 2000; Routh et al., 2000; McArthur et al., 2001; Dowling et al., 2002; Anawar et al., 2003).

-Arsenic mobilization in groundwater also appears to be triggered by intensive groundwater extraction for irrigation and application of phosphate fertilizers (Acharyya et al., 2000). On the other hand, Harvey et al. (2002) report that As mobilization is associated with a recent influx of carbon due to large-scale irrigation pumping. Foster et al, (2000) and Breit et al, (2001) report that besides Fe (III) hydroxide oxides, other solid phases such as phyllosillicates also play an important role in the cycling and mobilization of As.

The work of Stüben D et al., (2003) showed in Bangladesh, the reductive dissolution of Fe oxyhydroxide present in the form of coatings on sand grains as well as on weathered mica (biotite) is considered as the main mechanism of release of As in groundwater in sandy aquifer sediments. From the above, it is therefore evident that the mobilization of As in groundwater is a complex natural geochemical process.

Conclusion And Recommendations:-

This preliminary study has been of capital interest, in fact, it has allowed on the one hand to analyze the parameters and the hydrodynamic behavior of the Malawa sandstone aquifer and to know the current state of the chemical and bacteriological quality of the groundwater in the commune.

In view of all the above, it would be desirable :

1. The development of a communication plan for all stakeholders on the issue of rational management and better protection of these water resources that are very vulnerable to pollution ;

2. The realization of protection perimeters around these hydraulic works in order to minimize this risk;
3. Setting up a monitoring network for the regular control of the quality of these waters ;
4. Implementation of treatment techniques for the elimination of arsenic and fluorine such as : nanofiltration, oxidation, precipitation/coprecipitation, reverse osmosis, selective adsorption, other membrane retention techniques.

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