Groundwater Quality of Tahoua Region and Environs of the Iullemmeden Basin.

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ABSTRACT

The quality of groundwater in parts of Tahoua region, in the Iullemmeden Basin, around the border areas of SW Niger Republic and NW Nigeria has been evaluated. Results of the geochemical analysis of the groundwater of the Lower Zone aquifer show that the Continental Intercalaire has weakly mineralized water (conductivity <130 µS/cm) and the water can be used for all purposes. Also in the Lower Zone, the Alanbanya aquifer water is hard to very hard, of Ca-Mg-SO_4 type, with high nitrate content 0 - 482 mg/l. This may call for a bacteriological analysis, since this concentration is far from the WHO limit. In the Upper Zone aquifers comprising the Upper Tertiary continental (sands and sandstones) sediments of the Ader Doutchi (Continental Terminal) and the overlying Quaternary Formations, the conductivity is also high indicating its strong mineralization. The concentration of nitrate is up to 416 mg/l, the water being relatively hard (TDS up to 3140 mg/l), requiring that it be used carefully for domestic purposes.

INTRODUCTION

The groundwater studies of Madaoua District and other parts of Tahoua region of Niger Republic, within the Iullemmeden sedimentary basin, have been carried out. In this work, a study of groundwater quality in the Nigerien sector of the Iullemmeden basin is presented. This area lies within latitudes 13^0 00' 00" and 14^0 50' 00" and longitudes 5^0 00' 00" and 7^0 00' 00" covering an aerial extent of over 900 km^2 around the border areas of SW Niger Republic and NW Nigeria. This work responded to the need to understand the water chemistry of the aquifers across the border areas of the two countries for future purpose of human population development in the area. Much of the Sokoto basin area in Nigeria (the Nigerian sector of the Iullemmeden Basin) has been studied. The present area of study, the Tahoua region of the Niger Republic, close to the borders, is used as site of typical location (Fig. 1).

From previous studies, the groundwater aquifer flow in Sokoto basin dips towards the NW into Niger Republic[1], with little or no relationship with the hydrological surface water flow and drainages which occur towards the SW and WSW in both countries at the border region.

Various studies have been made of the hydrogeology of the Nigerian sector of the Iullemmeden basin. In the Niger Republic, similar works have also been done for the rest of the basin. Anderson and Ogilbae[2] worked on the aquifers in their description of northern Nigeria, presenting a description of the general hydrogeology of the region. The aquifers are made of Cretaceous to Tertiary interbedded sands, clays and limestones. Kogbe[3] worked on the geology of the Sokoto basin, the southern sector of Illuemenden basin. Oteze[4] found that, out of the nine sedimentary formations constituting the Sokoto basin, six are aquiferous with the most prolific being the Eocene-Miocene Gwandu Formation and the Maastrichtian Taloka Formation. Similarly, JICA[5] carried out a study on groundwater development in Sokoto State. Their work concentrated on the hydrogeological investigation resulting in the drilling of four boreholes in the basin. They also undertook a geophysical study where they estimated the thickness of weathered overburden to be between 52 to 75m.

In the Niger Republic sector of the Iullemmeden basin, records show that a programme of 395 hand-dug wells, financed by the European Development Funds started from 7th November, 1963 and lasted to 11th June, 1965. Boeck[6] described the water resources of the Iullemmeden basin. Greigert[7] investigated the hydrogeology of the basin and tried to produce a hydrogeological map. Margane[8] contributed also on the prospects of groundwater aquifers in Ader-Doutchi (Tahoua area). Dodo[9] studied the hydrogeology of the Iullemmeden basin using 1330 boreholes and came out with thirteen aquifers from Cambro-Ordovician to Quaternary Formations.

The Nigerien sector of the Illuemmenden basin extending over 434,000 km^2 constitutes 62% of the surface of the basin. The geological setting includes Basement Complex under a succession of Lower Cretaceous to Pleistocene continental and marine sediments within the basin estimated to be more than 2,000 meters thick. Quaternary age sediments underlie

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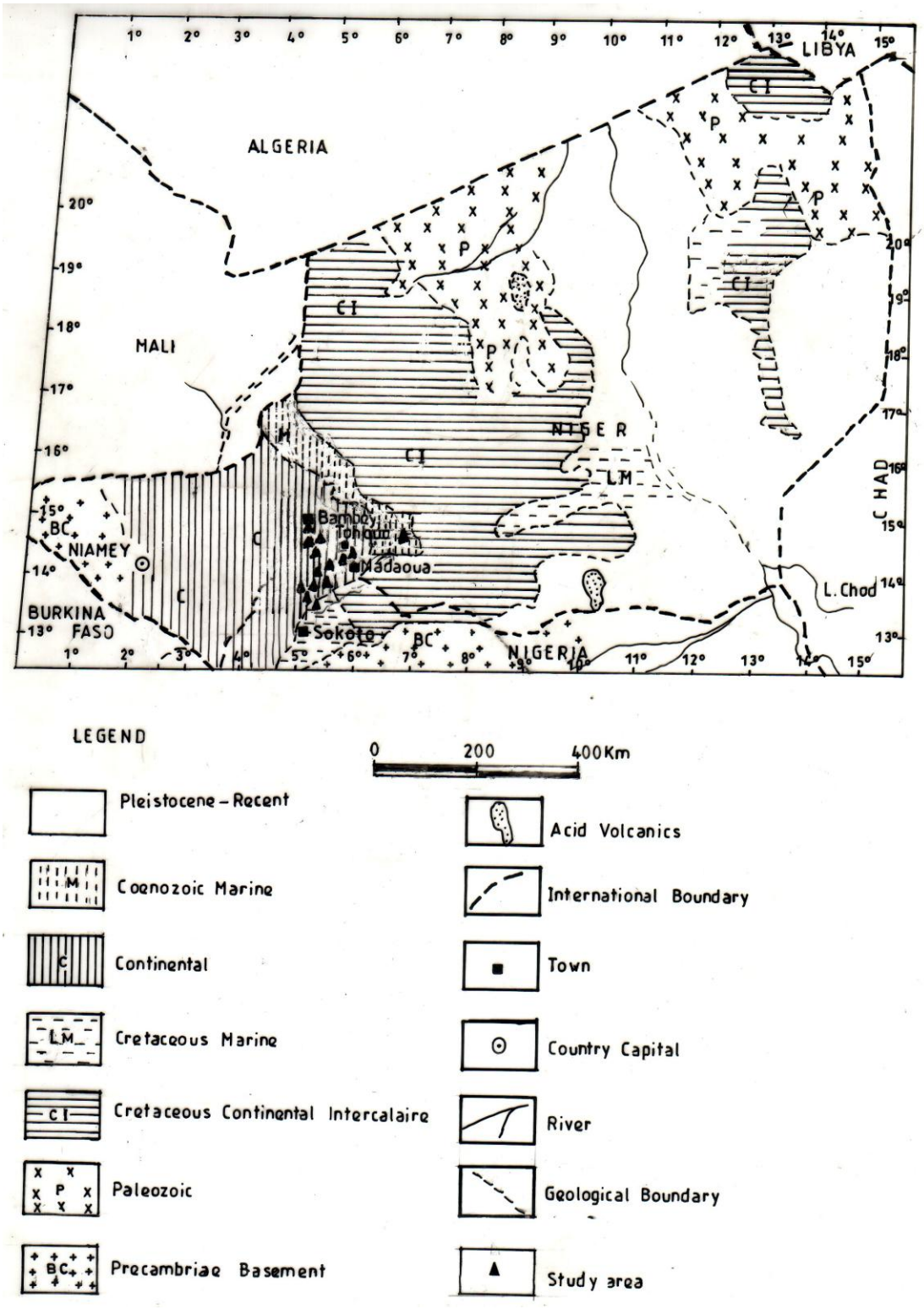

Fig.1: Map of the Study Area showing the well locations (in dark triangles).

the valleys of River Sokoto and its tributaries. These rocks contain three important artesian aquifers, in addition to regional unconfined groundwater bodies in all the principal outcrop areas and a perched water body in the outcrop of the Kalambaina Formation[2]. This formation corresponds to the Garadoua Formation of Niger Republic. Artesian aquifers occur at depth in the Gundumi Formation[2]. The sedimentary formations of the Sokoto basin of the Nigerian sector of Iullemmeden basin together with the groundwater aquifers dip gently

and thicken gradually towards the northwest with a maximum thickness of over 1000 m near the frontier of the Niger Republic.

There has been little or no attempt from previous works in Niger to study the water quality of the aquifers and their recharge zones in this area. Over the years, there has been migration of human populace and resources across the border for reasons based on economic and political instability with problems of desertification and deforestation. The surface and groundwater development of the area has an impact-bearing on the relative population movement across the border resulting from environmental water distribution.

This paper therefore presents results of some water quality studies of the southern Nigerien areas bordering with the Nigerian Sokoto basin, around the study area. The intention is to show, from the results, the portability of the available groundwater around the border regions of the two countries in the study area. The result of studies like the present one could guide the exploration, exploitation and usage of groundwater to improve on the control of human resources migration along the border areas.

EXPERIMENTAL

Water samples were taken all over the area from available hand-dug wells that possess concrete linings, using plastic containers pre-washed with distilled water and rinsed with the water prior to sample collection. Each sample is usually divided into two and to one part added conc. Nitric acid (HNO_3) in order to prevent the cations from adhering to the walls of the container. The second parts, free of this treatment are normally set aside for the analyses of the anions. All samples are transported to the laboratory within 48 hrs. before the start of analyses. A total of sixteen averages of chemical measurements were recorded each from about 4-5 well samples and on about 73 samples for Ca^{++}. Sample analyses were carried out in the field using portable laboratory kit (NIPON) for temperature, conductivity, Total Dissolved Solids (TDS), hardness, Ca, Mn and Cl, and pH. Results are shown in Table 1. Other results of laboratory analysis of water samples from concrete-lined wells in the study area and adjacent regions as presented in Table 2, were obtained by INC & UNDP[10]. The analyses were carried out in the Geological Laboratory in Niamey. In the laboratory, Na, K, Ca, Mg, were determined using Atomic Absorption Spectrophotometer (AAS); Cl, and HCO_3 determined by titrimetry, and NO_3, and SO_4 by turbidity/ spectrophotometry. TDS was determined by gravimetry and pH with a pH-meter. The coordinates of wells were taken using a GPS (Garmin) unit.

RESULTS

Surface water in the study area has a great turbidity and so makes adequate treatment necessary for domestic or public supply. Table 1 shows the analyses results of water sampled from wells in the area. Results indicate variation of the temperature, conductivity, TDS, hardness, Ca^{++}, Cl^{-}, Mn^{++} and pH levels in the wells exploiting from the Alanbanya Formations, the Continental Intercalaire (CI) as well as the alluvial deposits of the Quaternary. The measured electro-conductivity values (in µS/cm) were multiplied by a factor of 0.64 mg/l (1 mg/l = 1.56 µS/cm) to obtain the total dissolved solid (TDS in mg/l). Table 2 shows results by the Department of Geology Laboratory in Niamey. The TDS in the Tahoua region, after correction for temperature, varies from 3291 to 41.4 mg/l with average of 1668 mg/l (INC & UNDP[10],Table 2). In the Tahoua region and the adjacent Madahoua District, the conductivity (≥ 1500 µS/cm in the Dafan area, Table 1) is certainly due to organic pollution as indicated by corresponding high content of sodium. According to World Health Organization[11] (WHO), if the conductivity is less than 250 µS/cm, then the water quality is excellent for irrigation; for conductivity values between 250 to 750 µS/cm, water is good for irrigation; and is fair between 750 and 2250 µS/cm and poor between 2250 and 4000 µS/cm.

The Continental Intercalaire aquifer contains water very suitable for all uses while all others contain water high in dissolved solids, (Fig. 2).

Published results[10] of hydrogen-ion exponent (pH) values (Table 2) in water of the Tahoua region vary from 3.5 to 7.7 with a mean of 7.02. This implies that the water in the region is generally neutral except in the "Continental Terminal" where it is purely to weakly acidic (pH = 5.0 – 6.3). Groundwater analysis on 73 samples from different aquifers in this work shows pH to be neutral. Previous analyses data are older and were incomplete.

Analyses of calcium content of 73 samples in the study area show a dominant range of 0.1 - 556 mg/l with the highest value (556 mg/l). Normal range of calcium concentration in groundwater is from 10 – 100 mg/l. The average value in the area is 156.78 mg/l which is high, with the excessive calcium concentrations found mainly in the In-Waggar and Alanbanya Formations. The calcium may have been released from weathering of the overlying Garadoua Formation, which is calcium-rich.

The magnesium content of water in the area lies between 0.0 and 6.0 mg/l with an average of 0.6 mg/l. Drinking water limit for magnesium concentration recommended is 0.05 mg/l[12] to avoid magnesium staining.

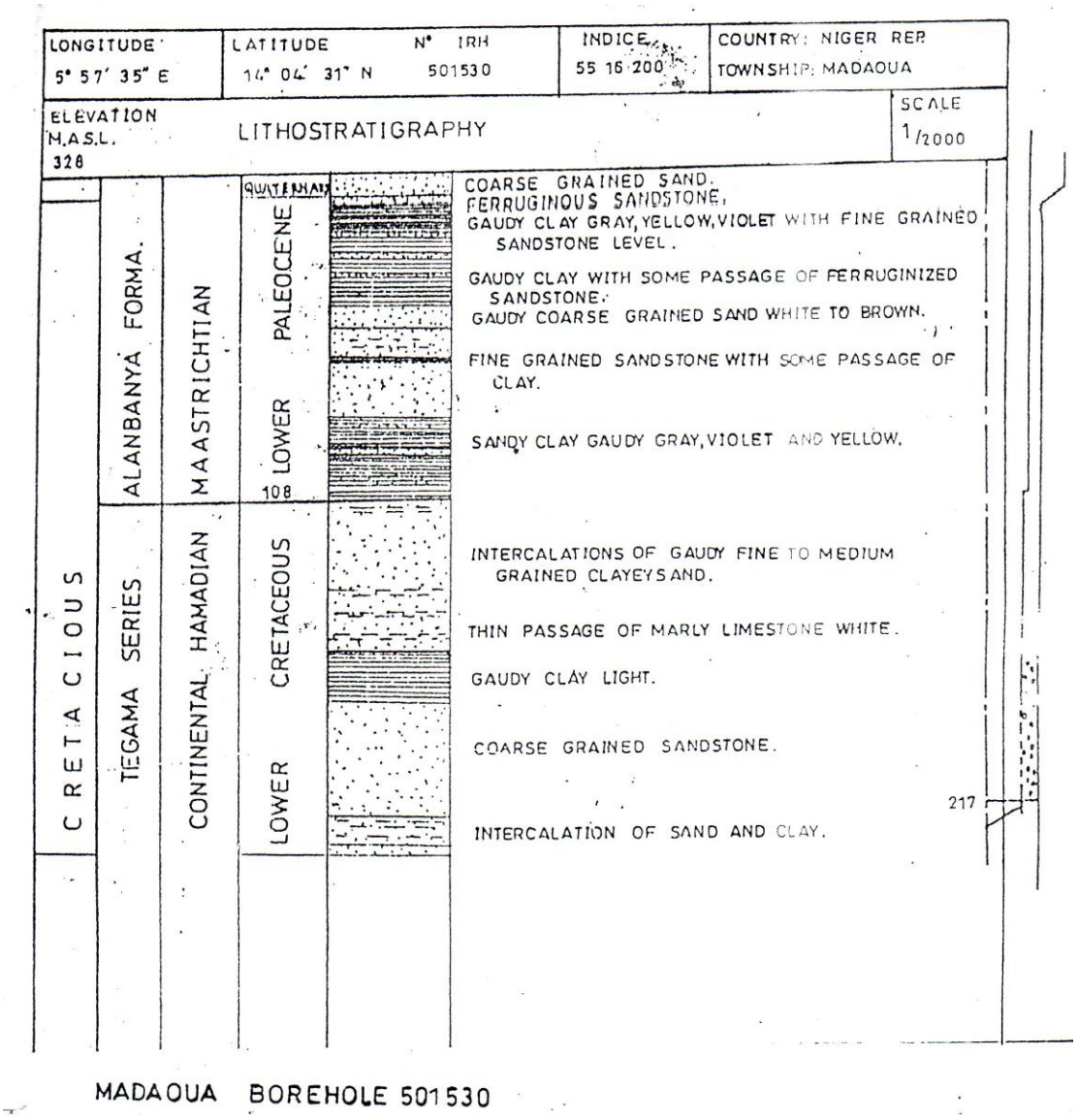

Fig. 2: A borehole lithostratigraphy in Madahoua area showing the Lower Cretaceous aquifer of the Continental Intercalaire/Hamadian Formation; Borehole bottom depth at 217 m below ground surface.

The normal concentration of sodium in groundwater is 10 to 100 mg/l. Sodium salts are highly soluble in water and once leached from sediments, they remain in solution. Groundwater in the area (Table 2) generally contains considerable quantities of sodium carbonate or bicarbonate that are possibly contents of fossil water.

The potassium concentration in the samples (Table 2) varies from 0.7 to 116 mg/l, with average of 17.14 mg/l. This analysis indicates that K concentration is higher than the normal (usually less than $1/10^{th}$ of that of sodium), even though the abundance of potassium in earth crust is similar to that of sodium. Thus the water in the area is polluted with the average of about 17 mg/l in the samples.

The bicarbonate concentration in all the samples is high and lies within published values elsewhere which range between 1 and 3950 mg/l, with average of 270.8 mg/l. Bicarbonate ions in groundwater are mostly derived from carbon dioxide and dissolution of carbonate rocks.

Sulphate concentration in the area of study varies from 0.6 to 2520 mg/l with an average of 700.0 mg/l. In this area, the sulphate is possibly derived from the evaporite minerals such as gypsum ($CaSO_4.2H_2O$) common in the Garadoua Formation. The wide range of concentration may be due to absence of the Garadoua Formation or presence of Quaternary deposit with low content of sulphide in some parts.

Chloride concentration in groundwater in the study area ranges from 0.2 to 200 mg/l with average of 20.99 mg/l. Most chlorides derives from weathering of sedimentary evaporites and crystalline rocks which are absent in the study area. The present concentration may result from fertilizers seepage and human wastes of high chloride content. Nitrate concentration (Table 2) in the area ranges from 0.0 to 482 mg/l with average of 66.11 mg/l.

Nitrates in groundwater are not derived primarily from mineral in rocks of the groundwater reservoir. Natural nitrates concentration ranges from 0.1 to 10 mg/l. Concentration may reach 600 mg/l or more from nitrate fertilizers pollution. The high nitrate concentration in wells in the area may have originated from direct discharge of contaminated surface water.

Table 1 : Physico-chemical measurements of well waters in the study area of Southern Niger Republic using portable laboratory kit (NIPPON). The authors, however, suspect the Manganese (Mn) values to be unreliably high.

S/No	Identification No.	Location	Coordinates	Temperature °C	Conductivity µs/cm	TDS	Hardness	Ca^{++} mg/l	Cl^{-} mg/l	Mn^{++} mg/l	pH
			Longitude Latitude								
1.	-	Dafan	-	32.0	1640.0	984.0	44.95	85.68	85.00	9.98	7.60
2.	-	Bambey	5°05' 24" 14°43' 05"	38.0	350.0	210.0	24.78	26.04	14.00	9.72	7.30
3.	-	Teneram	5°03'07" 14°46'32"	-	-	-	-	-	-	-	-
4.	501921	Illela	5°14'49" 14°27'24"	41.8	193.0	115.8	22.11	13.44	40.00	14.39	7.6
5.	500493	Tagae	5°15'56" 14°16'58"	29.0	175.5	105.3	16.28	34.02	65.00	-	7.6
6.	500508	Azao	5°07'15" 14°25'41"	31.5	708.0	424.8	63.18	88.2	40.00	12.15	7.6
7.	500122	Doguerawa	5°14'49" 13°48'19"	40.0	220.0	132.0	133.65	273.04	05.00	13.53	7.36
8.	500101	Guidan ider	5°18'47" 14°00'41"	29.2	448.0	268.8	490.8	60.48	35.00	14.09	7.2
9.	500156	Tsernawa	5°20'47" 13°53'17"	27.3	125.0	75.0	13.61	11.75	-	06.804	7.44
10.		Konni	5°15'00" 13°48'20"	44.4	250.0	150.0	15.06	26.04	05.00	00.00	6.84
11.	500296	Bazaga	5°06'12" 13°47'43"	26.5	1210.0	726.0	178.53	673.0	50.00	14.58	7.38
12.	501530	Madaoua	5°57'31" 14°04'29"	34.9	220.0	132.0	154.30	149.1	28.00	68.04	7.22
13.	502162	Bouza	6°02'31" 14°21'41"	40.0	150.0	90.0	155.76	109.2	05.00	92.58	6.93
14.	502179	Laba	6°56'11" 14°37'05"	39.0	110.0	66.0	13.75	10.75	05.00	05.00	7.03
15.		Tema	5°57'31" 14°04'29"	31.3	316.0	189.6	397.08	584.64	23.00	49.95	6.85
16.	502234	Keita	5°57'31" 14°04'29"	31.0	83.2	49.92	126.12	5.04	07.00	123.20	7.08

Date: 15-17 Nov. 1999.

Manganese concentration (Table 1) in the area ranges from 0.0 to 123.20 mg/l with an average of 27.12 mg/l. The authors suspect the measurement of these field values to be unreliably high and need be revisited because of no information elsewhere in the area for comparison. For drinking water supply, Mn concentration should not be present in excess of 0.05 mg/l to conform to established standard[13].

DISCUSSIONS

In the Quaternary aquifers, the specific electrical conductivity range from 200 µS/cm to 1000 µs/cm with an average water mineralization salinity. It is very low in the sand dunes sediments (150 to 250 µS/cm) and higher in the alluvial sands.

Location/Depth(m)	**Date**	**Form-ation**	**Coordinates** **Long./ Lat.**	**Ca** mg/l	**Mg** mg/l	**Na** mg/l	**K** mg/l	**HCO_3** mg/l	**SO_4** mg/l	**CL** mg/l	**NO_3** mg/l	**pH**	**TDS** mg/l
Sokoto 56	30-1-89	LB	5°42'21" 14°03'21"	83.1	0.0	21.1	2.4	278.0	69.2	2.7	2.2	7.6	427.8
Albaraka 20.2	30-1-89	LB	5°42'08" 14°99'07"	378.0	0.7	397.0	28.2	20.0	250.0	59.5	315	7.5	2616.0
Albaraka 20.21	3-2-89	LB	5°57'33" 14°46'46"	76.4	0.1	3.3	5.5	240.0	55.7	2.2	13.6	7.3	410.4
Taquileleli 13.9	17-2-89	CT	5°31'03" 14°51'28"	8.7	0.1	4.0	2.8	12.0	91.9	1.4	57.6	6.0	102.0
Kalfou-Dagaji 24.3	22-2-89	CT	5°43'30" 14°56'28"	216	0.3	80.1	11.9	54.0	899.0	5.5	35.3	6.6	990.0
Bourdi 3.0	2-2-89	W	5°53'55" 14°46'34"	141	0.7	81.4	26.9	-1.0	730.0	4.9	19.5	3.5	861.6
Barzanga 36.0	30-3-89	BZ	5°50'22" 14°36'34"	269	0.0	60.2	0.9	261.0	691.0	24.5	91.0	7.5	929.4
Mansala 5.6	28-2-89	G	5°53'35" 14°15'45"	556	0.6	76.7	23.3	8.0	2520.0	19.0	3.2	6.0	2052.0
Roureya 732	17-2-89	LB	5°27'40" 14°55'43"	272	0.8	25.2	31.5	2670.0	1850.0	12.9	7.4	7.5	1866.0
Kirakafada 12.5	22-3-89	G	5°26'31" 14°28'03"	102.0	0.1	23.8	3.7	292.0	166.0	5.6	58.1	7.5	490.2
Founkouey 15.4	6-2-89	Q	5°21'58" 14°46'10"	91.0	0.1	25.0	4.5	248.0	108.0	5.0	-	7.3	485.4
Malbaza	-	Q	5°31'22" 14°55'46"	50.0	0.4	4.6	17.2	323.0	26.0	10.0	0.0	7.5	279.6
Digayi 12.8	11-4-89	Q	5°30'00" 14°59'20"	58.0	0.3	29.7	11.1	249.0	29.7	4.4	3.6	7.3	288.0
Lohoudou 12.5	9-5-89	Q	5°38'07" 14°06'07"	106.0	0.1	17.9	5.7	299.0	158.0	4.4	10.2	7.3	436.2
Mogueur 13.0	7-2-89	CT	5°16'44" 14°38'37"	46.3	3.0	22.2	116.0	4.0	1.2	43.6	416.0	5.0	592.2
Badaguichir 19.7	10-2-89	CT	5°22'11" 14°41'18"	14.0	0.2	4.3	7.4	35.0	0.6	2.7	39.8	6.2	94.8
Siria 12.7	17-2-89	CT	5°26'07" 14°20'33"	34.3	6.0	21.8	2.8	21.0	12.3	18.3	270.0	6.3	292.8

Darey 17.4	10-2-89	G	5°30’18” 14°34’17”	82.8	0.0	22.1	0.7	180.0	40.4	7.8	119.0	7.2	355.2
Garadoua 46.6	30-3-89	G	5°53’23” 14°53’52”	68.2	0.1	6.1	4.3	284.0	89.1	2.5	11.3	7.3	340.2
Alibou 55.1	06-2-89	W	5°31’06” 14°48’15”	199.0	0.5	559.0	20.8	29.5	2230.0	44.7	-0.5	7.3	3291.0
Aha 36.3	10-2-89	W	5°29’48” 14° 31’35”	385.0	0.7	4750.0	25.5	337.0	3230.0	17.6	1.0	7.7	3144.0
Imbolaga 24.8	22-2-89	W	5°36’19” 14°56’08”	186.0	0.8	310.0	30.5	339.0	1150.0	27.6	10.9	7.6	1524.0
Karaji 138.9	3-4-89	W	5°28’30” 14°41’10”	334.0	0.7	536.0	28.0	395.0	2760.0	200.0	16.3	7.6	2946.0
Digaru 12.8	11-4-89	W	5°31’06” 14°59’40”	74.8	0.6	195.0	23.4	225.0	605.0	22.2	3.7	7.2	882.0
Quallage 69.1	2-2-89	BZ	5°51’55” 14°46’05”	104.0	0.4	359.0	14.4	336.0	863.0	32.0	5.0	7.7	1332.0
Esawa 39.3	2-2-89	LB/BZ	5°52’51” 14°41’38”	64.5	0.1	19.3	2.5	228.0	39.2	3.3	33.9	7.3	316.0
Lahanoba 24.5	6-4-89	LB/BZ	5°01’40” 14° 56’ 50”	260.0	0.3	51.4	10.3	273.0	391.0	18.9	482.0	7.2	1068.0
Moulela 72.5	6-4-89	LB	5°46’40” 14°57’08”	163.0	0.4	418.0	16.4	360.0	1290.0	41.2	6.2	7.5	1740.0
MamaKomo 60.9	9-5-89	LB	5°37’23” 14° 07’26”	530.0	0.9	95.9	36.2	359.0	2010.0	17.9	19.5	7.3	1782.0
Bagey 618.7	6-2-89	CI	5°33’51” 14°50’56”	13.3	0.3	9.3	11.5	22.8	22.8	1.1	-0.5	7.4	117.0
Tamasko 515.21	30-1-89	CI	5°39’32” 14°50’04”	6.1	0.4	4.4	14.1	44.0	7.3	8.3	-0.5	7.6	66.0
Ibohomane 400	3-2-89	CI	5°55’30” 14°48’00”	42.0	0.2	2.0	8.1	34.0	3.1	0.2	-0.3	7.0	41.4

The pH values range from 6.7 to 7.5 and high concentration of nitrate (about 416 mg/l) accompanied normally by high values of potassium are observed.

They are anthropogenic in origin. The sulphate concentration varies between 100 and 200 mg/l. In general, the Quaternary groundwater is relatively hard, of type containing Ca-Mg-HCO_3-SO_4, which must be used carefully for the excessive concentration of nitrates.

The chemical analysis of water in the Alanbanya Formation shows a wide variation. The specific electrical conductivity (Tables 1 & 2) varies according to the mode by which water feeds the aquifer, and ranges from 500 to 5380 µS/cm. Maximum of 70% of these values are less than 2000 µS/cm with an average of 1500 µS/cm. The pH values range generally from 6.6 to 7.6. The sulphate concentration ranges between 20 and 2529 mg/l while the calcium values are from 10 to 560 mg/l and Magnesium, 13 to 3000 mg/l. The Ca/Mg relation comprised between 1.3 and 14.0 mg/l. It could be observed that there are high values of nitrate which probably are not of anthropogenic origin. Normal nitrate concentration in groundwater ranges from 0.1 to 10 mg/l. Concentration may reach 600 mg/l or more when enriched from nitrate fertilizers. In the study area, nitrate concentration ranges from 0.0 to 482 mg/l, with an average of 66.11 mg/l. High nitrate concentration in the wells in the area may originate from direct discharge of contaminated surface water.

Alanbanya aquifer water is hard to very hard, of Ca-Mg-SO_4 type, with values that may indicate origin from the dead roots of plants accumulating nitrogen, for example, the various types of Accacia. In general, the total hardness reaches 47.8 meq/l.

The continental Intercalaire (CI) aquifer has groundwater content comparable with other weakly mineralized Formation waters and can be extracted for all uses. The specific electrical conductivity ranges from

69 to 300 µS/cm. The pH values are essentially neutral (6.5-7.9). Quite different from other waters, the CI water has low bicarbonate concentration.

CONCLUSION

The chemical quality of groundwater of the Madaoua District and adjacent areas of Tahoua region, part of the Iullemmeden Basin, in the Nigerien Republic has been determined. The Hamadian Formation is worth mention for its peculiar hard to very hard water quality containing high nitrate concentration. This may call for bacteriological analysis since its concentration (0.0 – 482 mg/l) is far from the WHO[11] limit of 40 mg/l. The physical and chemical qualities of the water in these aquifers are also determined to contribute to the understanding of groundwater resources potential of the area. Thus, from results of the geochemical analysis, the Continental Intercalaire water is weakly mineralized and is therefore suitable for all purposes. In the Quaternary deposits, the conductivity is high indicating its mineralization. The concentration of nitrate is up to 416 mg/l, the water being relatively hard (TDS, 3140 mg/l) and must be used cautiously for domestic purposes.

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