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RESEARCH ARTICLE

CONTRIBUTION TO THE HYDROCHEMICAL KNOWLEDGE OF AQUIFERS IN THE DEPARTMENT OF TANDJILÉ-EAST, SOUTHERN CHAD

Mahamat Nour Abdallah, Moussa Abderamane, Abderamane Hamit and Adil Bangba Frederic

University of N'Djamena-Department of Geology- Laboratory of Hydro-Geosciences & Reservoirs, N'Djamena, Chad.

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Abstract

The province of Tandjilé is one of the 23 provinces of the Republic of Chad. The drinking water supply rate in this region remains low. Part of the population obtains its water supply through open wells and / or surface water. Climatic and anthropogenic variations in recent years have shown how much groundwater can be influenced both in terms of its quality and its quantity to be used. The objective of this study is to provide knowledge on the state of the hydrodynamic and hydrochemical parameters of the aquifer of the department of Tandjilé-Est to help decision-makers in their approach. This study is based mainly on existing data collected in Chadian institutions and literary journals. The analysis of these data showed that the lithology is represented by clayey, sandy, lateritic formations and clay-sandy mixtures. The aquifers are sandy and sandy-clayey. The groundwater temperature values are in equilibrium with those of the air, the pH shows values close to neutrality and the electrical conductivity below standards (Chad, WHO). The groundwater in the study area is not very mineralized and the concentrations of elements indicating contamination (nitrates, chloride, etc.) are clearly in traces. Chemical analyzes revealed two chemical facies: calcium and magnesium bicarbonate and sodium and / or potassium bicarbonate.

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Introduction:-

In Chad, groundwater is estimated at more than 260 billion m³ that can be exploited and it is renewed each year by more than 20 billion m³(BRGM, 1988) which define agro-pastoral and economic activities throughout the country(Bonfiglioli, 1993, Van den Brink et al., 1995).

Today, this resource faces climatic variability(Mahamat Nour et al., 2021)unprecedented and anthropogenic activities(Zhu et al., 2019, Mahmood et al., 2020) which influence either on its quantity or on the quality which remains a very controversial subject in the clergy of the scientific communities(Wang & Qin, 2017). Already with the demographic explosion of the last ten years and the new activities which require more their uses(Rowlands et al., 2008), groundwater is influenced by excessive withdrawals and is not subject to any guarantee of quality control in most cases(Abderamane et al., 2013). According to the organization Action Contre la Faim (ACF,2006), poor water quality or lack of it causes more death than the conflicts of the last century(Jury & Vaux Jr, 2007, Garry & Checchi, 2020).

Corresponding Author:- Mahamat Nour Abdallah

Address:- University of N'Djamena-Department of Geology- Laboratory of Hydro-Geosciences & Reservoirs, N'Djamena, Chad.

The aquifer systems of the region of Tandjilé in general and more precisely, the Department of Tandjilé East, the subject of this study, coupled with the hydrographic networks (the Logone, the Tandjilé, etc.) remain a main source for the needs. humans in drinking water, for agriculture and animal husbandry, and off-season crops. The galloping demography of the region (Bonnet & Meurville, 1995) and cannot the development traits which will be naturally affected to their socio-economic life influence the physico-chemical quality of the resource? Does it have a matrix capable of supporting the amount of water to be mobilized?

To these questions, and had it not been for the vagaries of the climate of these decades, must be added the lack of monitoring tools in the Tandjilé sector in general and the Tandjilé-Est department in particular constitutes a major problem to characterize precisely the hydrodynamic and hydrochemical behavior of this water table.

To date, few studies have been carried out to clearly diagnose the Tandjilé-Est water table on the one hand and to characterize the hydrodynamic and hydrochemical functioning on the other.

The objective of this study is to provide knowledge on the state of the hydrodynamic and hydrochemical parameters of the aquifer of the department of Tandjilé-Est in order to help decision-makers in their approach.

Presentation of the study area

Located at coordinates 09°24' North latitude and 16°18' East longitude, the Tandjilé region (Department of Tandjilé-Est) is one of the 23 provinces of the Republic of Chad with an area of 17,558 km² (Figure 1).

Socioeconomic activities are mainly based on agriculture and fishing as well as supplementary breeding.

The climate which reigns there is of the Sudano-Guinean type characterized by a dry season rather long than the rainy season. The geomorphology of the region is quite flat; the floodplain to the north and west and the areas of koros (lateritic shells) a little south-east (Vizier & Fromaget, 1970).

The Department of Tandjilé-Est is crossed by important hydrographic networks, but the main river is the Logone (Figure 2). The waters of this river are drained from several sub-basins: Mbéré basin, Lim basin, Nya basin (Tellro Waï et al., 2012). The surplus of this river, during the flood, floods the plains which are favorable to agriculture (Tellro Waï et al., 2012).

The geology of the region is represented by sedimentary formations dating from the Continental Terminal and the Quaternary (Louis, 1970, Schneider & Wolf, 1992). These formations occupy the whole region except in the south-eastern part, another formation characteristic of lateritic crusts called the "koros" (Schneider & Thiéry, 2001). These are alluvium deposited by the Logone, fluvio-lacustrine clays and ancient sands (Pias, 1968). All these formations are covered by halomorphic, ferruginous and / or ferralitic soils.

The hydrogeological characteristics in this region are essentially those of the domain of sedimentary formations (Djoret & Favreau, 2014, Schneider & Wolf, 1992). In fact, in the region of Tandjilé, the aquifers are continuous and are almost all located in the fluvio-lacustrine layers with free water tables. However, in the extreme south-eastern part of the study area, certain layers of impermeable roofs in places (Schneider & Thiéry, 2001).

Data Collection

This study is based on existing data collected in various public structures in Chad such as the Documentation and Geographic Information Center (CDIG), National Research and Development Center (CNRD), National Water Laboratory (LNE), etc.

The data collected relate to geological, hydrogeological, hydraulic, chemical, and physicochemical data of the Tandjilé area. It should also be noted that the collection of this information was not without difficulty given that the study area does not have enough usable data, if they exist, they date from the 1970s and some rare ones from 2015 and 2017. For the scope of the subject, we placed more emphasis on the reliability of the hydraulic data and the chemical data collected in order to support the quality of the information.

The data concerned here are mainly the hydraulic structures for 155 samples chosen in the various departments of the Ministry of Hydraulics, of which 33 are selected. We have sorted in this database the hydrodynamic parameters

(piezometric level, flow rates, etc.), physico-chemical (temperature, electrical conductivity, and pH) and chemical (Ca^{2+} , Mg^{2+} , Na^+ , K^+ , HCO_3^- , Cl^- , NO_3^- , SO_4^{2-}) of the groundwater in the study area.

Work has been done on the production and processing of the various thematic maps.

Results And Discussion:-

Hydrodynamic parameters

The flow rates of the structures carried out in the study area vary between 2 and 21 m³/h. These flows are distributed in three parts of said zone: the central part has an average of between 2 and 7 m³/h; in the North-West of the zone the value is between 7 and 9 m³/h and in the East, the value oscillates between 9 and 21 m³/h (Figure 3). According to Lasm (2000) classification, the study area presents rather medium and high flows. These flows are above the operating threshold for supply boreholes in rural areas (Louis, 1970, Schneider & Wolf, 1992). However, we also notice that there is no relation between the flow rates and the drilled depth (Figure 4). The water tables captured are in alluvial aquifers with a free water table made up of detrital materials (sands, clays, etc.). This good productivity of the boreholes is due to their location in the zone with high recharge and in a continuous and permeable homogeneous aquifer (Abderamane, 2012).

Physicochemical parameters

The results obtained show the following average values: the temperature varies between 27 and 32°C. These values of the groundwater temperature would be in equilibrium with the temperature of the atmospheric air (Ngounou Ngatcha, 1993, Ngounou Ngatcha et al., 2007). The pH varies between 6.11 and 8.20. These values are close to neutrality. The electrical conductivity varies between 22 and 380 µS/cm. These low values of the electrical conductivity of the zone could be explained by the renewal of groundwater by the contribution of meteoric water and by constant exchange with surface water as well as the absence of minerals rich in dissolved elements (Schneider & Thiéry, 2001). The spatial distribution of electrical conductivity shows lower values around recharge areas and in floodplains (Figure 5).

Chemical parameters

Statistic data

The statistical description of the chemical data of groundwater in the Tandjilé area shows values strongly influenced by the extreme values (Figure 6). The minimum, average and maximum values are summarized in the figure 6. The analysis of this graph shows that Ca^{2+} , Na^+ , HCO_3^- and Cl^- are very variable for the sampled waters. These high values are observed in places and can be attributed to the process of water-rock interaction or by local contaminations. K^+ , SO_4^{2-} and NO_3^- show less variability. The distribution of the main ions depends both on the intensity of evaporation processes and on the intensity of water-rock interaction processes, which is related to the residence time of groundwater. A strong anthropogenic influence is also observed for a large amount of groundwater samples taken for this study and can be considered as an important phenomenon.

Order of abundance of chemical elements in water

The abundance of cations for all the waters analyzed varies in the following order: $\text{Ca}^{2+} > \text{Na}^+ > \text{Mg}^{2+} > \text{K}^+$ for groundwater (Figure 7a). The Ca cation is dominant with more than 39% of the sum of the cations (meq/L).

The anion concentrations decrease in the order $\text{HCO}_3^- > \text{Cl}^- > \text{NO}_3^- > \text{SO}_4^{2-}$ (Figure 7b). The HCO_3^- anion is the most abundant and represents 62% of the sum of the anions (meq / L). Chloride and nitrate ions represent respectively 27% and 8% of the negative charge.

Chemical facies and origin of water mineralization

The facies of groundwater are highlighted by the Piper diagram which was designed to locate the membership of chemical elements in the different poles of the triangle. For the 33 sample points concerned, they present two families of priority chemical facies: the families of calcium and magnesium bicarbonates, the majority (76%) and the families of sodium and potassium bicarbonates, the minority (21%). These chemical facies are typical of sedimentary zones near watercourses and therefore evoke the recent age of these waters (Ouandaogo, 2008, Mahamat Nour et al., 2019) (Figure 8). Moreover, the formations crossed are largely confused with clays and clay-sandy mixture explains all over the place that the aquifer captured is rich in clay minerals. Regarding the richness of water in bicarbonate elements could come from the influence of atmospheric CO_2 (Ngounou Ngatcha, 1993,

Mahamat Nour et al., 2019) seen that the piezometric levels of the water tables in the region are almost flush with the ground.

The mineralization of water is a function of the dissolved matter, its concentration and the temperature of the solution. The dissolved substances can come from the host rock, from the leaching of agricultural products from the immediate environment or even from rain. The increase of these parameters in the solution can induce an increase in mineralization and therefore define their origin (Mahamat Nour et al., 2019). The most probable hypothesis is that which would be linked to the lithology of the host matrix. The element that participates the most in the mineralization of groundwater in the study area is HCO_3^- (62%) followed by calcium (39%). The correlation matrix between the different chemical elements illustrates the relative proportions of these elements in solution and expresses the lithological nature of their membership. Table 1 shows the correlation matrix between items. The analysis of this groundwater table shows that all the chemical elements are more or less correlated with each other except Mg^{2+} vs Cl^- and NO_3^- with all elements. Groundwater chemistry is dominated by Ca^{2+} and HCO_3^- , due to interactions with the rock matrix as well as mixtures with the surface waters of swamps and large rivers such as the Chari and Logone which flow from the southern regions of the Lake Chad basin. In this context, the interactions between groundwater and the rock matrix of aquifers are brief. Along flow lines and with aging processes, isomorphic substitutions with clay minerals occur (base exchange phenomenon) and Na^+ and K^+ tend to increase predominantly.

Conclusion:-

The main objective of this study is to contribute to the hydrodynamic and hydrochemical knowledge of aquifers in the department of Tandjilé-Est with a view to sustainable management of groundwater resources.

To achieve the objectives related to the study, analyzes on the hydrodynamic and physicochemical functioning were carried out on 33 samples distributed over the entire study area. It should also be noted that the collection of this information was not without difficulty given that the study area does not have enough usable data, if they exist, they date from the 1970s and a few from 2015 and 2017.

It emerges from this analysis that the lithology is dominated by argillaceous formations and that the aquifer layer is free and permeable with very good operating flows. The chemical facies highlighted are calcium and magnesium bicarbonates and sodium and potassium bicarbonate facies. These waters present little mineralization.

Figures and Table:-



Figure 1:- Location of the study area.

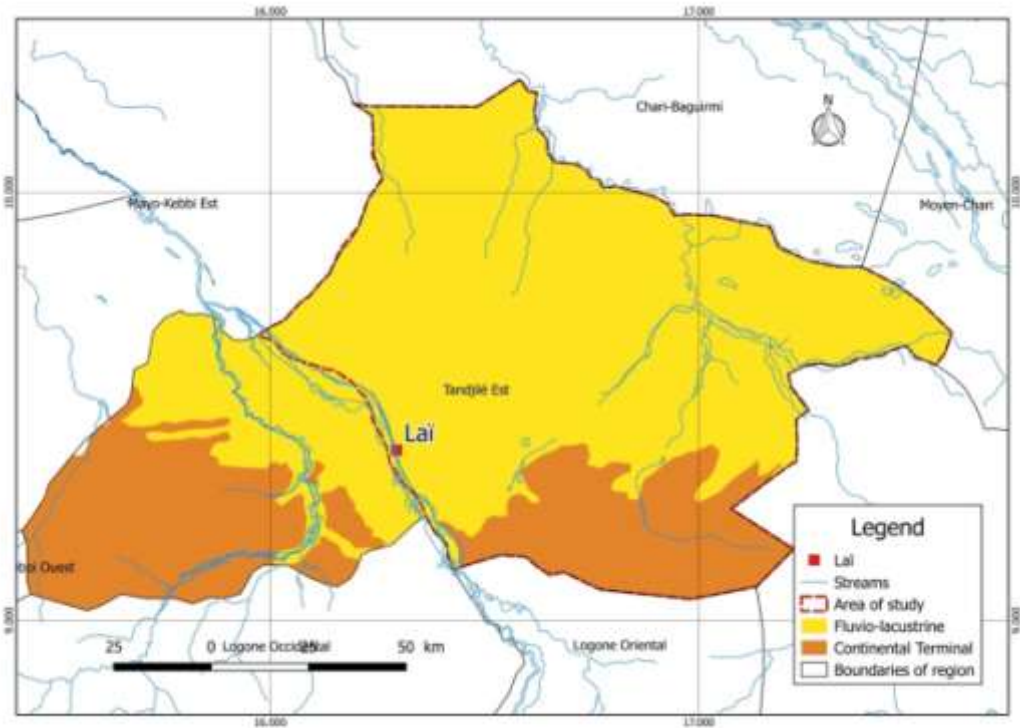


Figure 2:- Geological map showing the hydrographic networks (Louis, 1970).

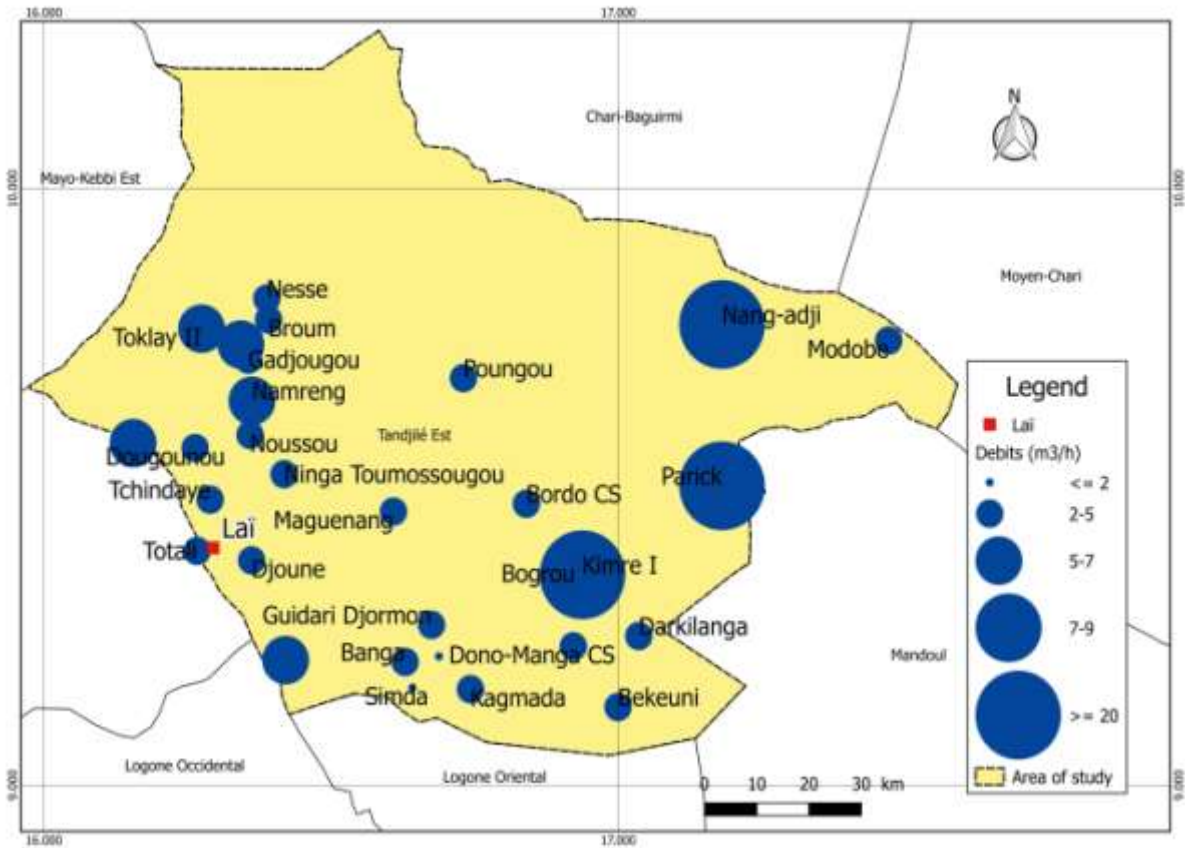


Figure 3:- Spatial distribution of operating flows.

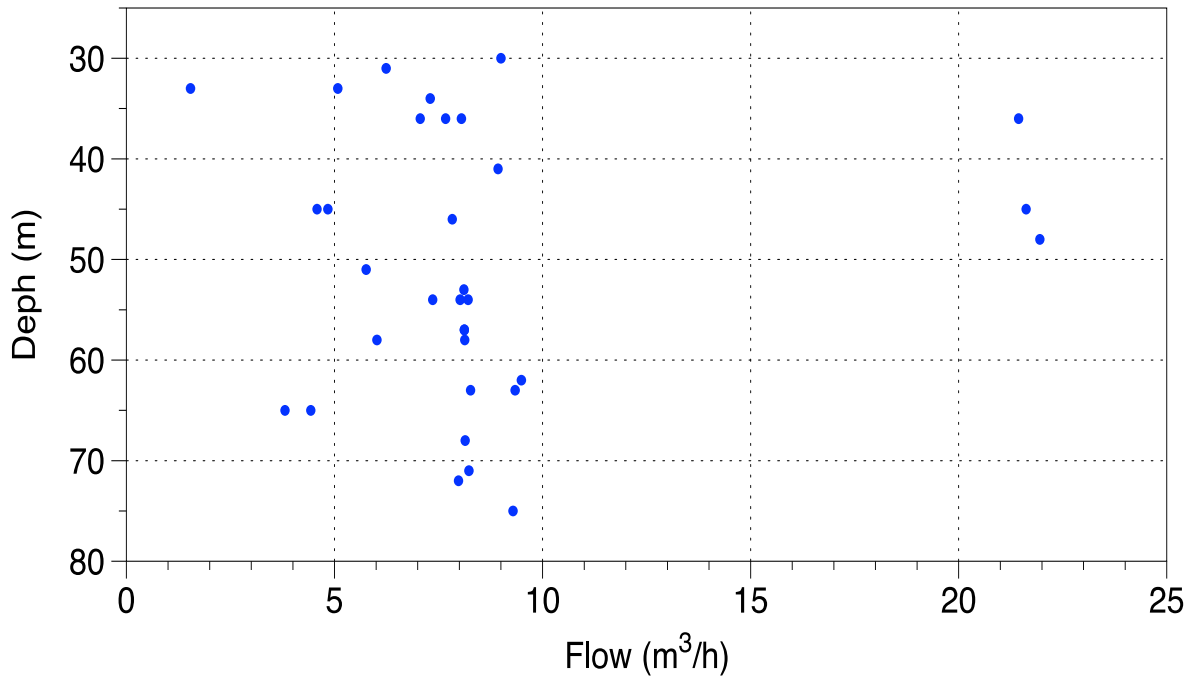


Figure 4:- Relationship between flow rates and drilled depths.

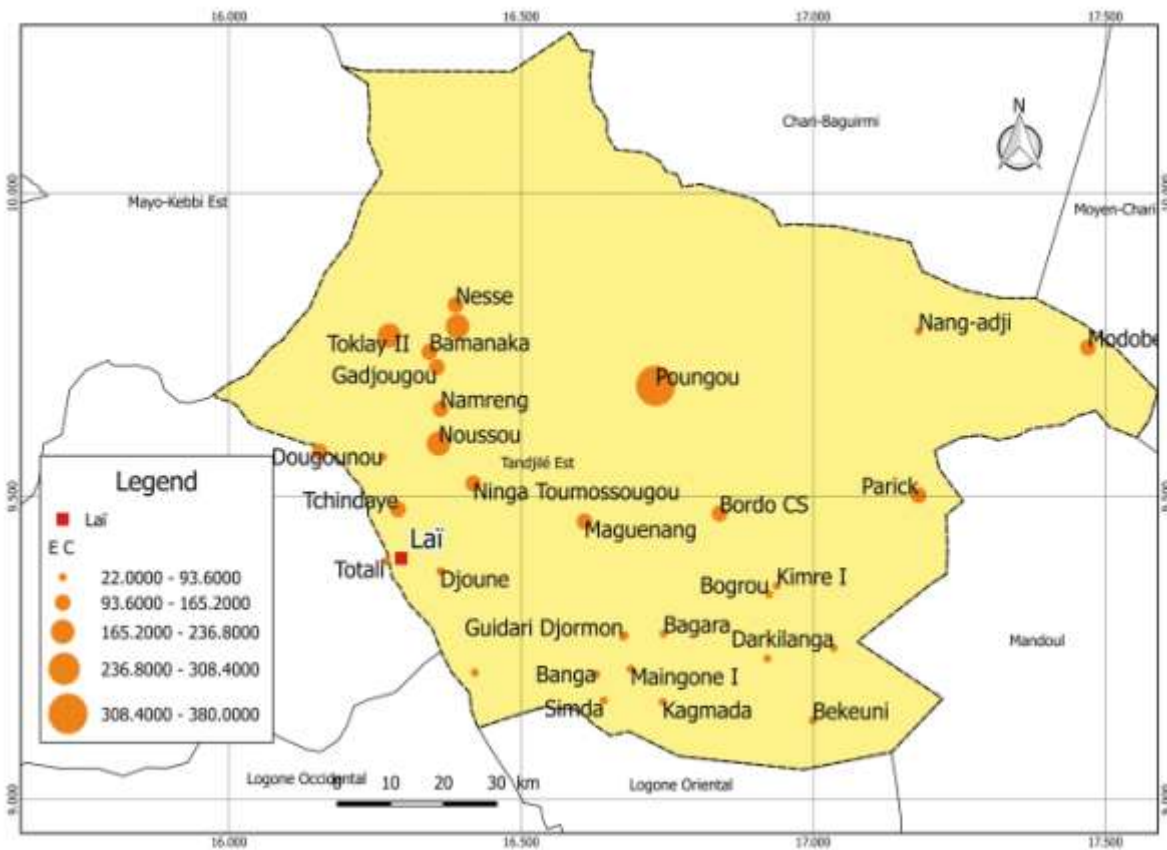


Figure 5:- Spatial distribution of electrical conductivity values.

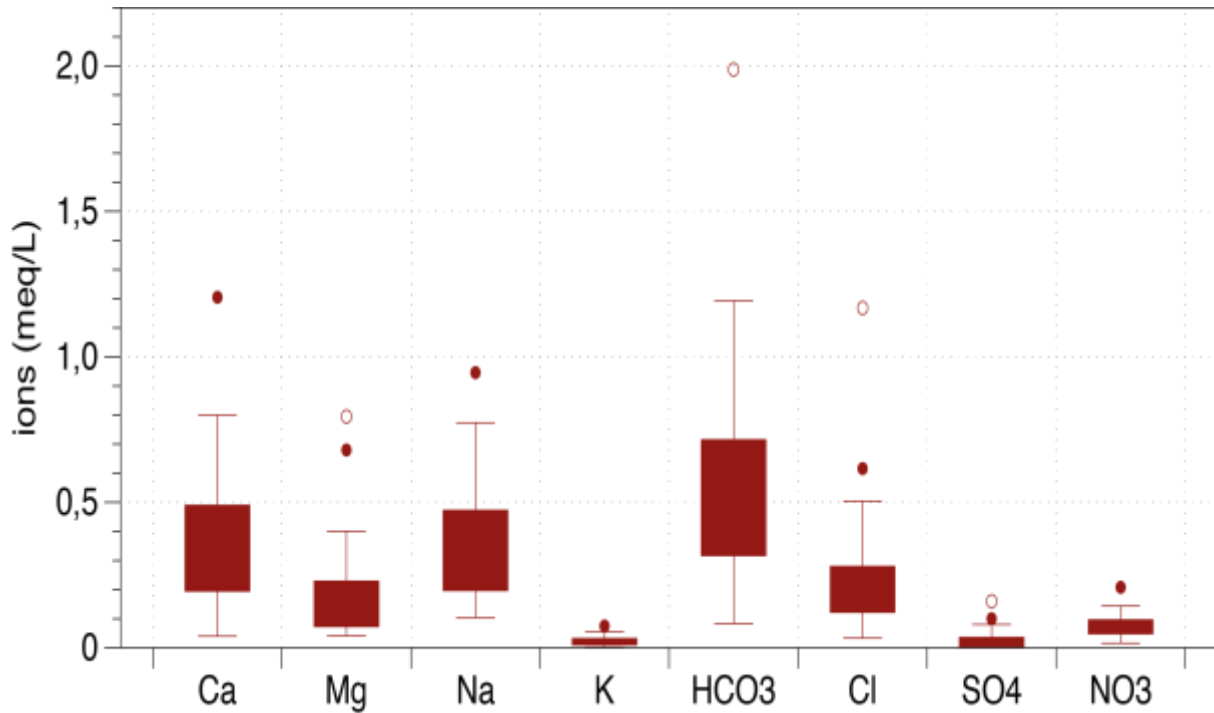


Figure 6:- Statistical description of chemical data.

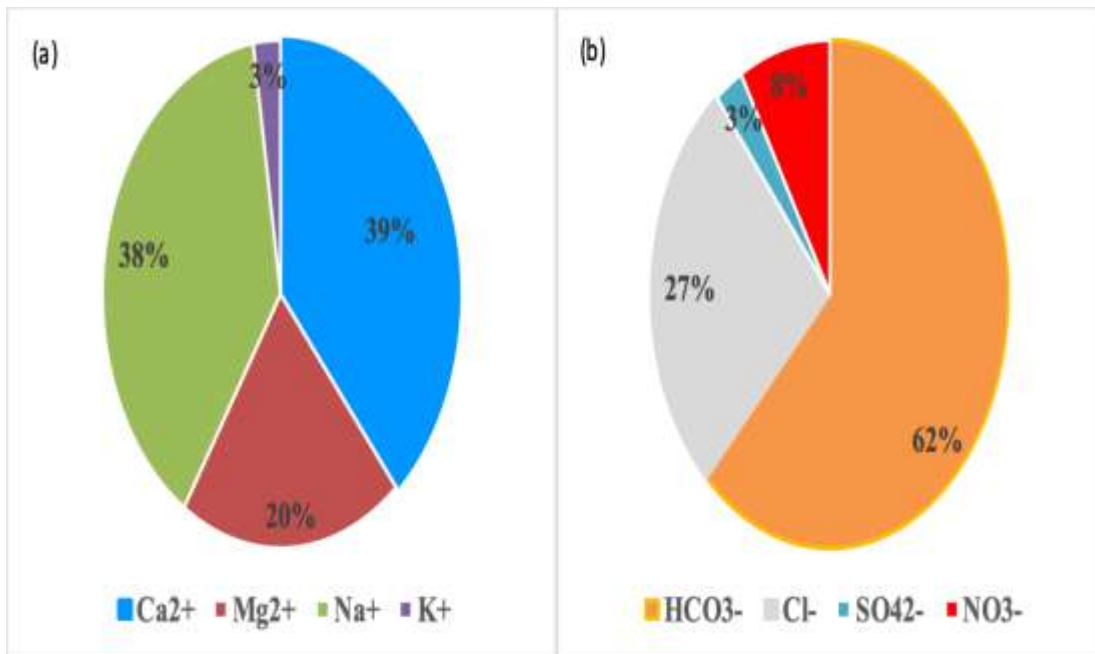


Figure 7:- Order of abundance of chemical elements.

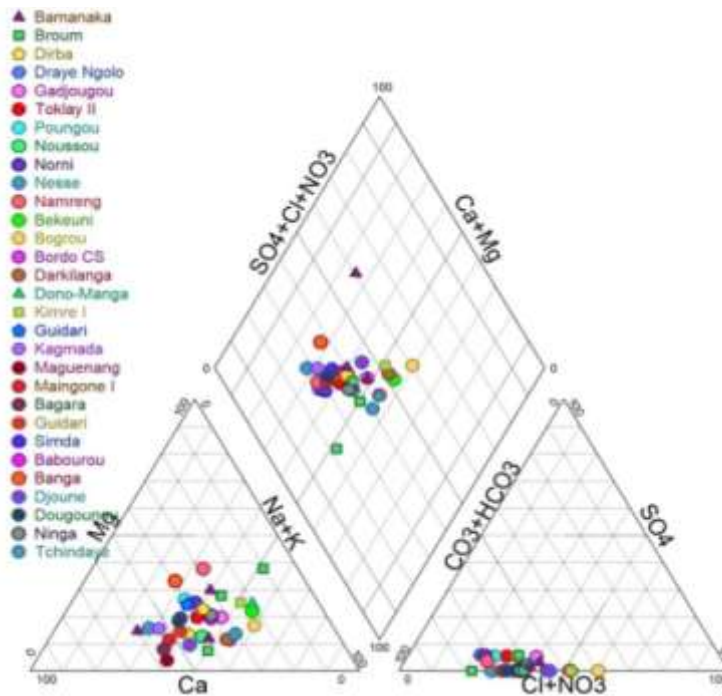


Figure 8:- Chemical facies of groundwater.

Tableau 1:- Correlation matrix between chemical elements.

Paramètres	T°C	pH	EC	Ca	Mg	Na	K	HCO3	Cl	SO4	NO3
T°C	1										
pH	0,35	1									
EC	0,13	-0,07	1								
Ca	0,07	-0,22	0,8	1							
Mg	0,01	-0,01	0,77	0,73	1						
Na	-0,01	-0,16	0,83	0,82	0,8	1					
K	-0,03	-0,16	0,8	0,84	0,83	0,95	1				
HCO3	0,07	-0,08	0,9	0,9	0,91	0,87	0,89	1			
Cl	0,05	-0,27	0,65	0,69	0,49	0,59	0,54	0,64	1		
SO4	0,01	-0,04	0,76	0,81	0,87	0,89	0,89	0,87	0,51	1	
NO3	0,11	-0,02	0,02	0,13	-0,03	0,01	0,04	0,04	-0,23	-0,11	1

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