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RESEARCH ARTICLE

IMPACT OF SEASONAL VARIATION ON FLUORIDE IONS CONCENTRATIONS IN GROUNDWATER IN THE MARADI REGION (CENTRAL NIGER)

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Abstract

The present study aims to study the impact of seasonal variation on fluoride ion concentrations in groundwater in the Maradi region. To achieve this goal, two (2) water sampling campaigns were carried out.Sampling was carried out over the entire study area. Water samples were taken from wells and boreholes.The results of this study show that the high levels of fluoride ions are obtained during the rainy season; likewise, this content of fluoride ions vary according to the variation of certain ions.

Introduction:-

In arid areas, groundwater is the main source of drinking water supply due to the scarcity of surface water (Marou et al., 2018; Taboune et al, 2004; El Alfy et al., 2006).They are preferred because of their availability and their drinking characteristics (Konan et al., 2017).Water is contaminated naturally or as a result of human activity (Soro et al., 2010).Studies carried out around the world show that the chemical compositions of the waters could be modified (Njueya et al., 2012; Fehdi et al., 2009; Djeuda, 1987; Nono et al., 2009; Mouafo, 2010; Bouziane et al, 2009; Kolsi et al., 2013).According to (Pierre Mazet, 2002), around thirty countries around the world were affected by endemic fluorosis in the 1980s due to waterconsumption.In Niger, groundwater in the Maradi region (central Niger) has fluoride ion levels often exceeding the limit concentrations recommended by the WHO (1.5 mg/L, WHO, 1982).More than 4,000 children in the department of Tibiri in this region suffer from dental fluorosis and 424 from bone fluorosis following the consumption of borehole water (DRSP, 1998; Lawan et al., 2001).According to (Raju et al., 2009; Shan et al., 2013), the release of fluoride ions into groundwater is generally governed by the climate or the mineralogical composition of the rocks. As a result, the chemical characteristics of groundwater vary in time and space (Gemail et al., 2017; Nezli et al., 2015). The objective of this study is to study the spatio-seasonal variations of the fluoride ion content in groundwater in the Maradi region.

Materials and Methods:-

Study area

The Maradi region is located in south-central Niger. It is located between the parallels 13°30' North and the meridians 7°06' East (figure 1). It covers an area of 41,796 km2 (INS, 2015).Its climate is of the semi-arid Sahelian type. It is characterized by very irregular rainfall, poorly distributed in time and space (UNDP-NE-Maradi, 2005).

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The soils of this region are mainlymade up of sedimentary formations, essentially of Precambrian eruptive and metamorphic rocks in its southern part along the border with Nigeria (Mignon, 1970).In its northern part, the soils are marked by basement formations which disappear under detritallands attributed to the " Continental intercalary" S.I. (Greigert, 1963) and the Continental Hamadien (Greigert et al., 1967). Is has tree and shrub steppe type vegetation (Alain et al., 1982).

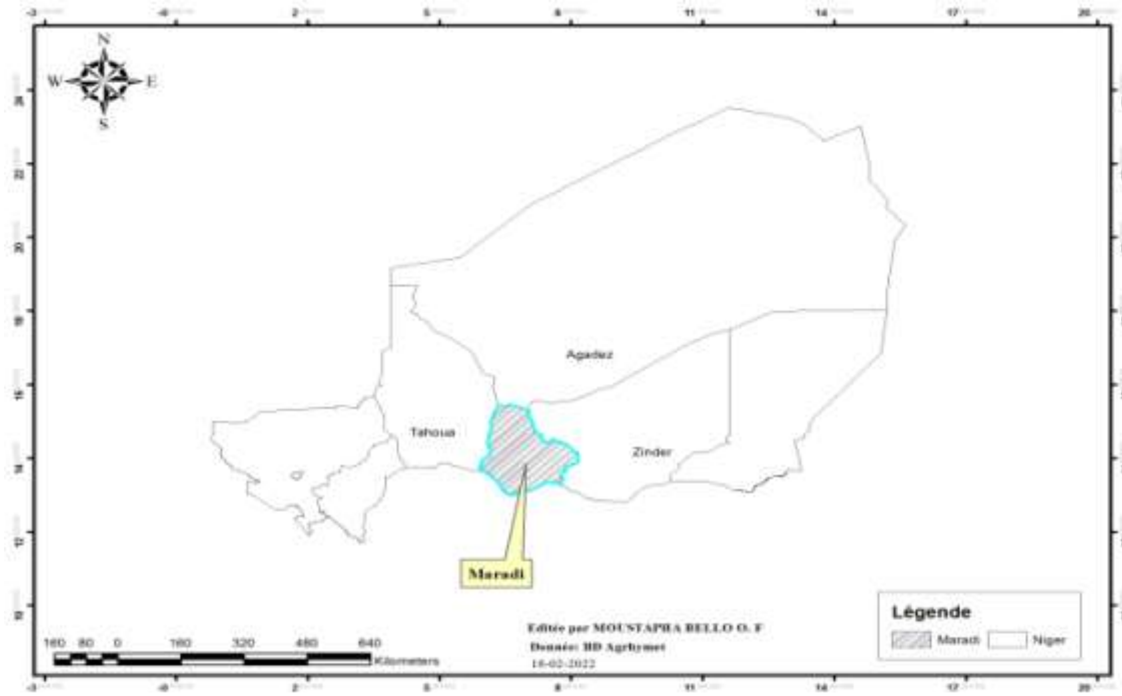

Figure 1:- Geographical map of the study area.

Sampling

To carry out this study, two (2) water sampling campaigns were carried out. The first in May 2020, just before the first rains, a period when the level of the water table is as low as possible, a period during which the concentrations of dissolved substances are assumed to be higher.The 2nd in November 2020, just after the last rains, a period when the water tables are at a higher level and the concentrations of dissolved substances supposedly lower.During these two campaigns, a total of 42 water samples were taken. The sampling points were wells and boreholes.The structures selected are those with high fluoride ion contents (Figure 2). The water samples were taken in polyethylene bottles.The bottles were first washed with water and then rinsed with distilled water before being filled with the water to be analyzed. The samples thus taken were transported to the laboratory in an appropriate thermos.Their temperature was measured in situ using a HANNA multivariate pH meter. The content of fluoride ions (wavelength 580 nm) and phosphate ions were measured by spectrophotometry using a DR3900 type spectrophotometer (HACH). The magnesium content was deduced from the following equation: $[Mg^{2+}] = (TH - DC) \times 0{,}24$.

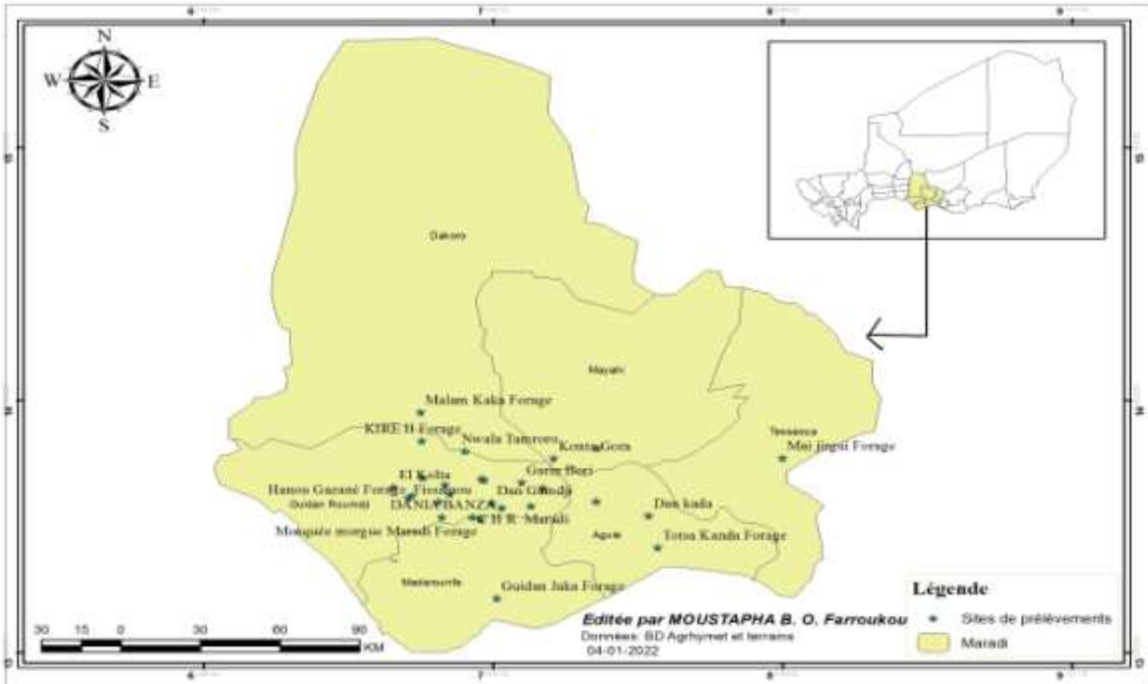

Figure 2:- Location of sampled sites.

Results:-

Seasonal temperature variation (T°C)

Table 1:- Results of seasonal variations in well water temperature.

Well		
Name PEM	**T °C (Mai 2020)**	**T °C (November 2020)**
Dania Banza PC1	33,9	27,5
Roura 1er Puits	31,9	29,1
Roura 2e puits	31,9	29,1
Fissataou PC1	32,4	29,8
Fissataou PC2	31,6	28,6
Hannou Ga zané PC	33,4	30,9
Malam Kaka PC	34,4	31
Kanda Tossa PC1	35,3	33,5
Kanda Tossa PC2	35	31,5
Dan Kada	31,3	30,9
Garin Bori	30,6	26,6
Lahiyarou	32,3	29,5

Table 2:- Results of seasonal variations in borehole water temperature.

Borehole		
Name PEM	**T °C (Mai 2020)**	**T °C (November 2020)**
Dania Banza forage	30,9	28,1
Hannou Ga zané forage	34,3	32,1
Malam Kaka forage	34,3	32,9
Guidan Jaka forage	34	32,9
Nwalla Tamroro forage	36,4	32,7
DRH Maradi	35	30,08
Tibiri Forage SEEN	32,6	29
Garin Kaka	36,1	30,4

Kiré	35	33,8

Tables 1 and 2 below give the sampling temperature during the two campaigns, respectively for well water and borehole water. The data in Table 1 show that, in May 2020, the water temperature in all wells is above 30°C, the maximum value recommended by the WHO for drinking water. In November 2020, 44,44% of water had a value above the WHO standard (25 – 30 °C). In May 2020, the temperature of the water in all the boreholes is above 30°C, the value recommended by the WHO for drinking water. In November 2020, 77.77% of water had a value above the WHO guideline value (25 – 30 °C) for drinking water.

Seasonal variation of fluoride ion concentration

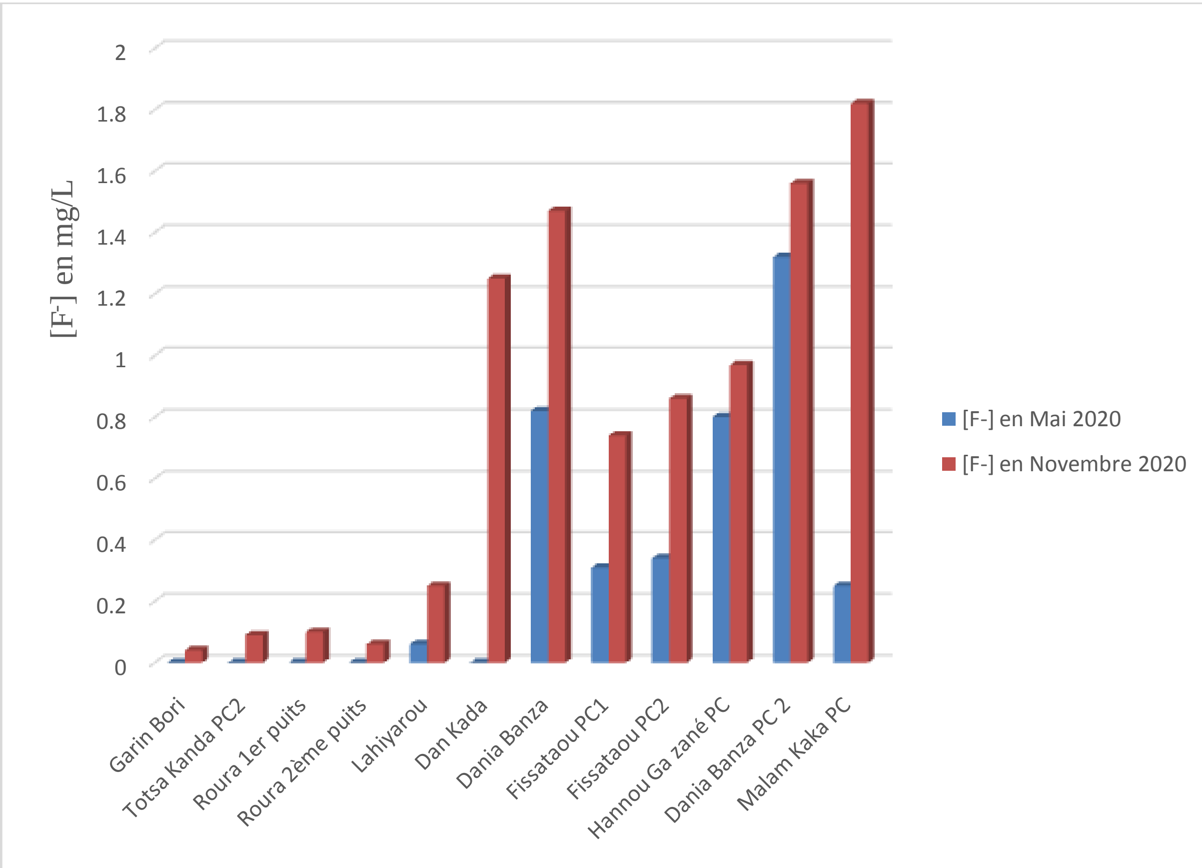

Figure 3:- Seasonal variation of [F^-] (Well water).

Figure 3 gives the fluoride ions concentrations in well water in May and November.Figure 4 gives those of borehole water in May and November. Figure 3 shows that, in all the wells, the fluoride ion contents in November 2020 (rainy season) are higher than those obtained in May 2020 (hot season). This figure also shows that these grades have more than doubles in some wells in some wells in the rainy season. Figure 4 shows that, in all the boreholes, the fluoride ion content in November 2020 (rainy season) is higher than that obtained in May 2020 (hot season). Also, this figure shows that, in some boreholes, the fluoride ion contents have more than doubles.

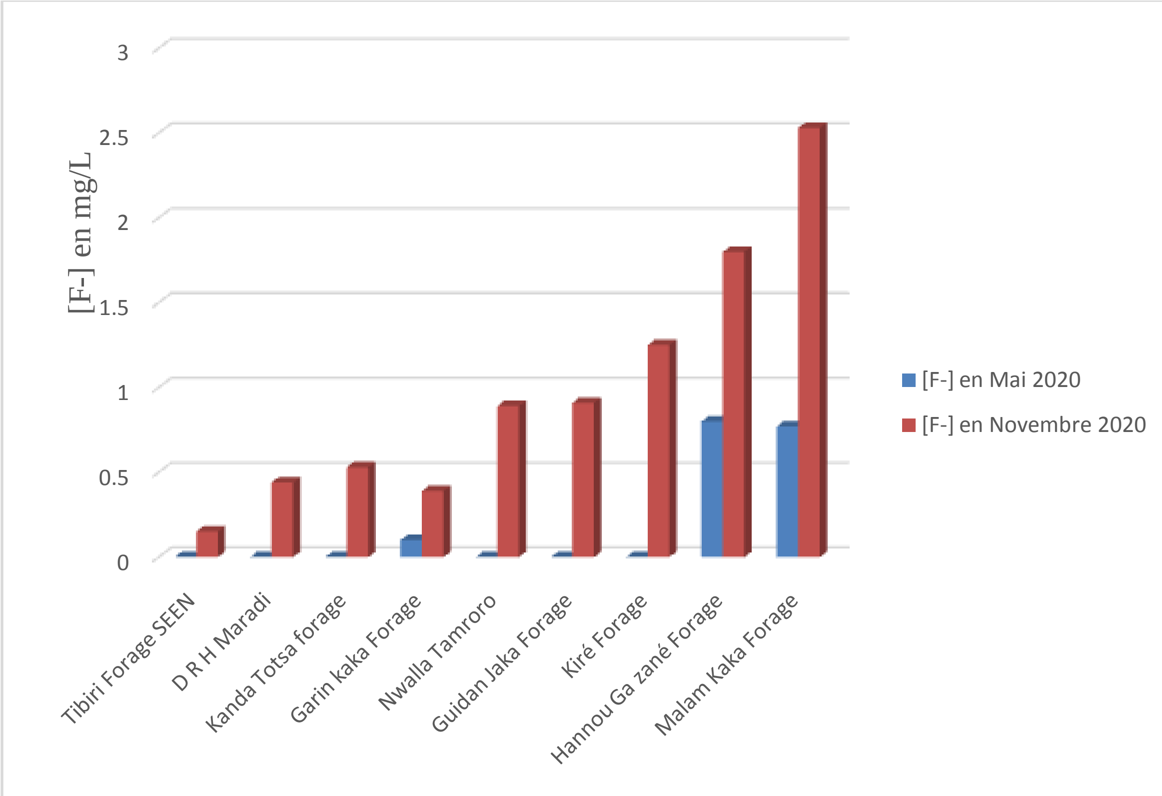

Figure 4:- Seasonal variation of [F^-] (borehole water).

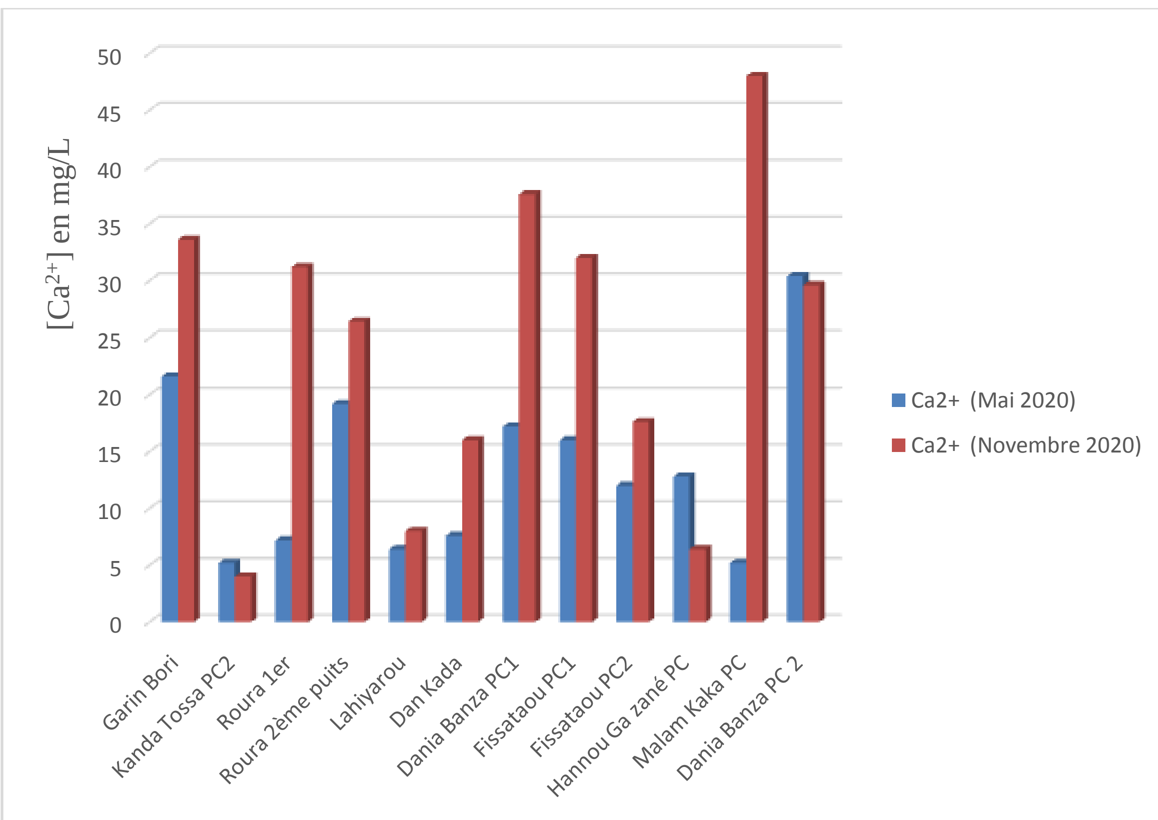

Figure 5:- Seasonal variation of [Ca^{2+}] (Well water).

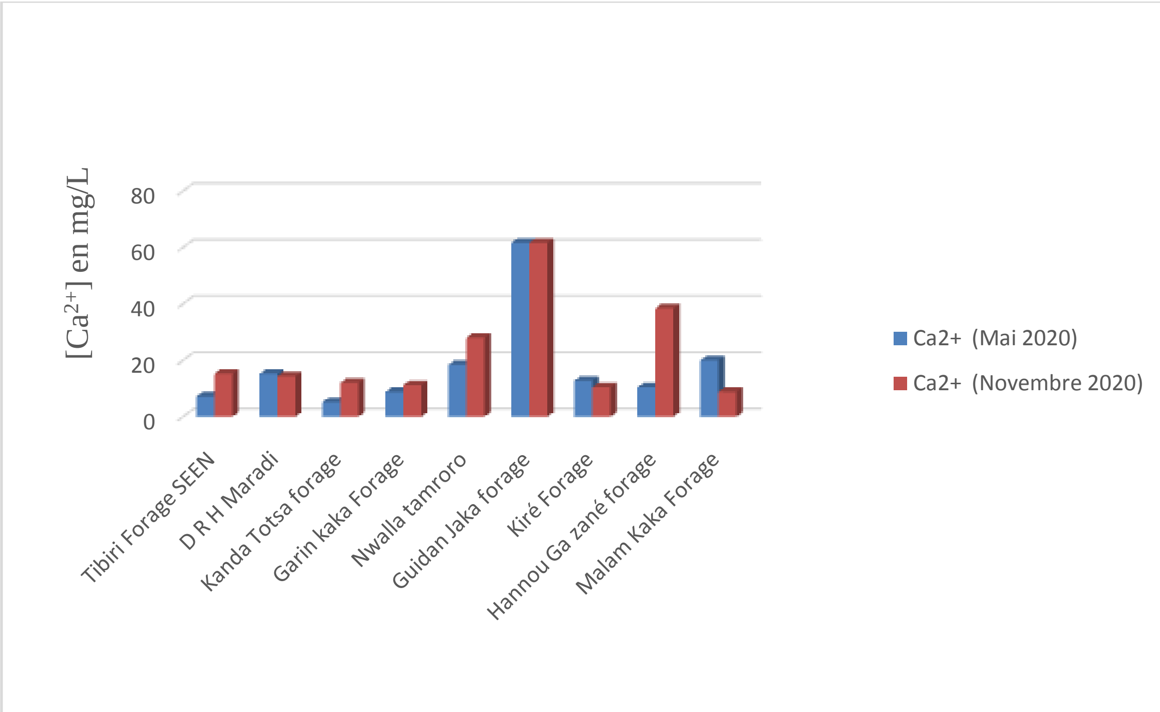

Figure 6:- Seasonal variation of [Ca^{2+}] (borehole water)

Seasonal variation of calcium ionconcentration

Figure 5 shows that the calcium ion content in November 2020 (rainy season) in 75% of well water is higher than that obtained in May 2020 (hot season). In some wells, these calcium ion contents have more than doubles. However, the calcium ion levels in all the wells are below the WHO guideline value of 100 mg/L for drinking water. Figure 6 shows that, in November 2020 (rainy season), the calcium ion contents in almost all the wells are higher than those obtained in May 2020 (hot season). However, this calcium ion content remained almost intact in other samples. However, calcium ion levels in borehole water are lower than the WHO guideline value of 100 mg/L for drinking water.

Seasonal variation of magnesium ionconcentration

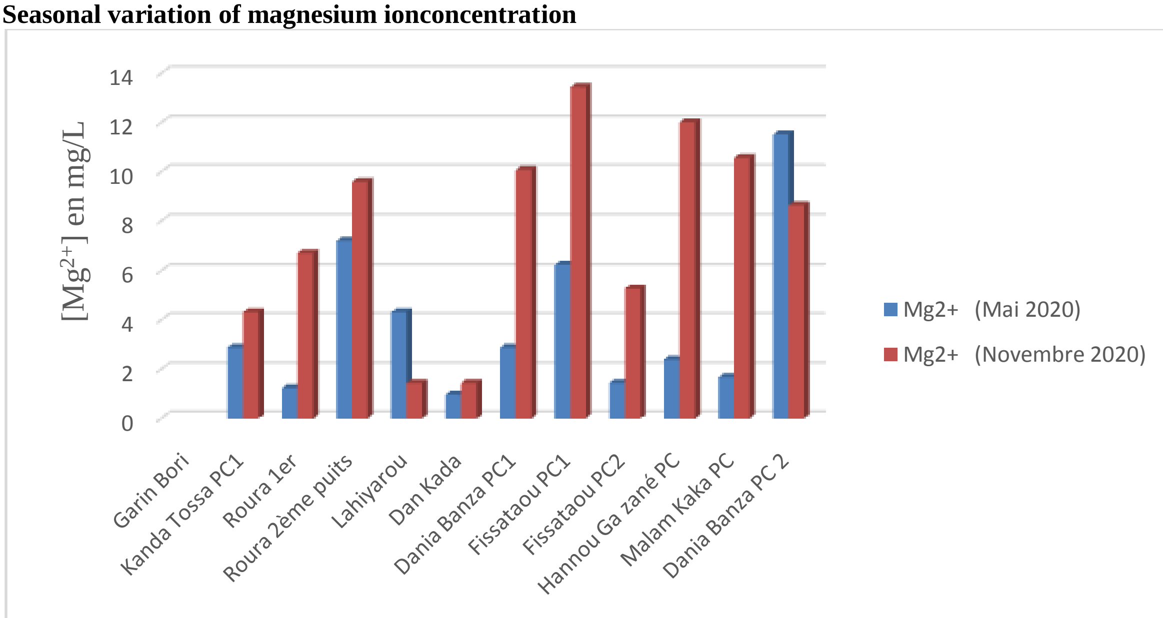

Figure7:- Seasonal variation of [Mg^{2+}] (Well water).

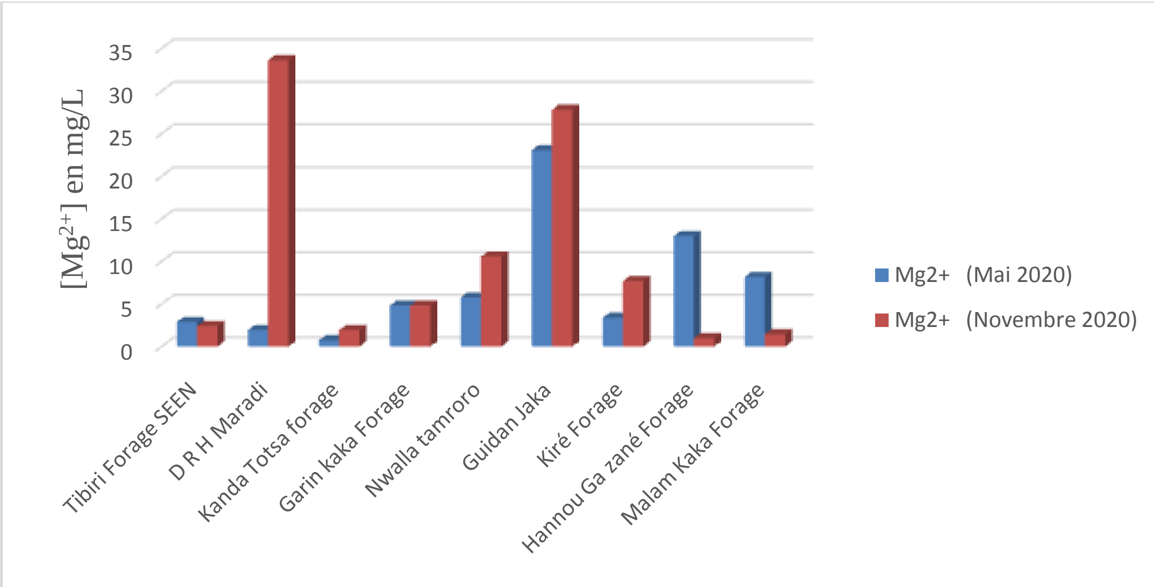

Figure 8:- Seasonal variation of [Mg^{2+}] (borehole water).

Figure 7 shows that, in November 2020 (rainy season), the magnesium ion contents in 81.81% of the wells are higher than those obtained in May 2020 (hot season). This figure also shows that these grades have more than doubles in other wells. However, these magnesium ion contents have values that do not exceed the WHO guideline value (50 mg/L) for drinking water. Figure 8 shows that the magnesium ion contents in November 2020 (rainy season) in 77.77% of samples are higher than those obtained in May 2020 (hot season). This figure also shows that, in some boreholes, the magnesium ion contents remained intact. Similarly, these results show that the magnesium ion content of borehole waters has values that do not exceed the guideline value set by the WHO, which is 50 mg/L for drinking water.

Seasonal variation of phosphate ionconcentration

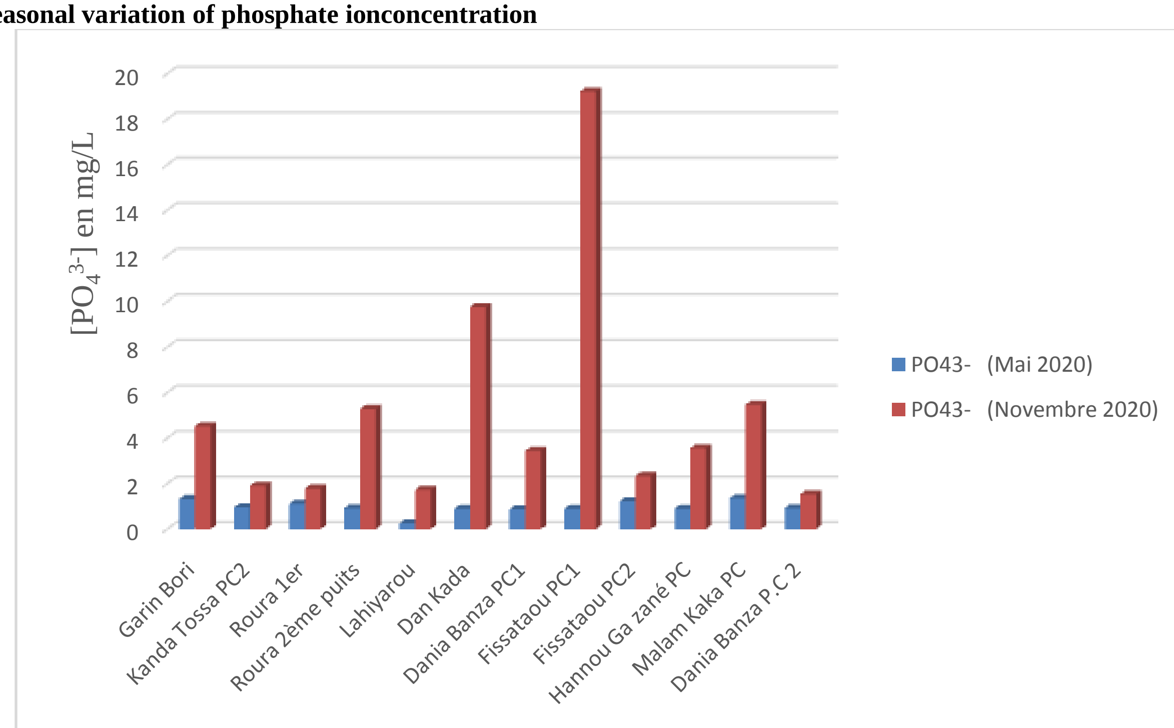

Figure 9:- Seasonal variation of [PO_4^{3-}] (Well water).

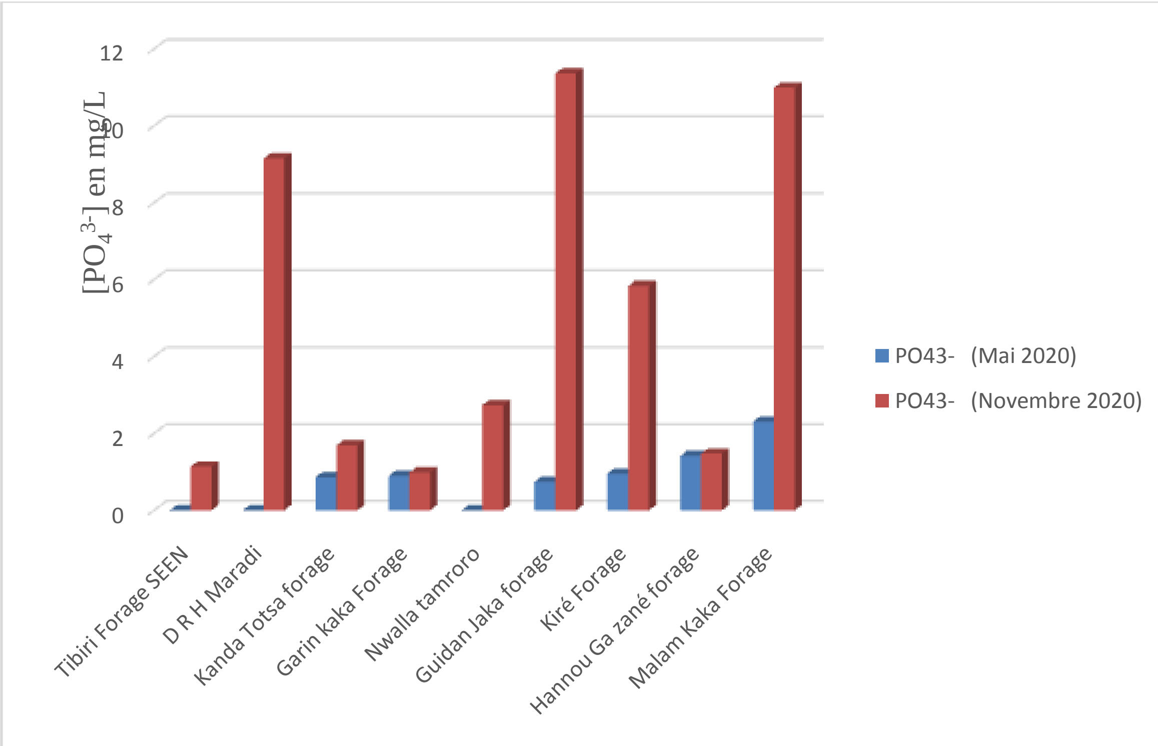

Figure 10:- Seasonal variation of $[PO_4^{3-}]$ (borehole water).

Figure 9 shows that, in November 2020 (rainy season), the phosphate ion contents in all the wells are higher than those obtained in May 2020 (hot season). This figure also shows that these phosphate ion contents have more than doubles in most wells. In November 2020 (rainy season), the phosphate ion contents in almost all the boreholes are higher than those obtained in May 2020 (hot season) (figure 10). Also, this figure shows that the phosphate ion contents have more than doubles in some boreholes. However, they remained intact in other boreholes.

Discussion:-

The results obtained show that the temperatures of the groundwater sampled (well water from the groundwater table and water from the boreholes capturing the hydrogeological tablecloth) are high. According to (Météorologie-Niger, 2009; Rodier, 1984), these high water temperatures could be due to climatic conditions linked to the geography of the study area.Still according to these authors, in this Sahelian zone, the ambient temperature can reach 45°C in the shade. Based on the work of (Ruth Angerville, 1999; Yves Travis, 1993), high levels of fluoride ions in groundwater may be due to high water temperature.According to (GIRAUD, 1975), temperature governs the kinetics of hydrolysis and, therefore, the possibilities of formation of neogenesis minerals rich in fluorine. According to the work of (GUEDDARI, 1984), hot and strongly alkaline springs are favorable to water fluoridation.From the above, the groundwater temperature in the Maradi region would contribute to the fluoridation of these.

Case of well water

The results show that the contents of fluoride ions in the wells, at high water, just after the rainy season, are higher than those in May, the period of water bases just before the rainy season. Sedimentary minerals are the main geological formation in the study area (Taylor, 2001).According to Taylor, the basement formations of the study area consist of a sequence of schists, quartz-schists, gneiss, and biotite porphyry granite.According to (Saxena and Ahmed, 2001), sandstones contain up to 180 ppm fluorides, limestones 220 ppm fluorides and clays 800 ppm fluorides in basement formations.The rise in the water level during the rainy season facilitates contact between the waters and the fluorinated rocks. These contacts could facilitate the release of fluoride ions during this season and explain the increase in fluoride ion content when the water table rises.Several mechanisms contribute to this change in fluoride ion content. These mechanisms include: oxidation and precipitation of certain chemical elements (Njueya et al., 2012). According to (Ramesam and Rajagopalan, 1985; Deshmukh, 1995); Agrawal, 1997),one of the major sources of the presence of fluoride ions in groundwater could result from the dissolution of fluorinated rocks (fluorite, fluoro-apatite, cryolite, apophyllite, amphibole and micas). The latter release fluoride ions into the water at different levels.

Calcium ion levels are higher during the rainy season. According to the work of (Jean-Marc, 1973), fluoride ions have a great affinity with calcium ions. Their presence in the waters could come from the dissolution of compounds rich in both fluorine and calcium, such as the minerals fluorite.According to (ABBOT, 1937), the fluorine concentration is then limited in this case, by the value of the solubility constant K_{ps} of the fluorine dissolution reaction. According to (Travi, 1993), when the pH is higher than 5, the F- and Ca^{2+} ions dominate in the solution.According to (Wadepohl, 1974), the strong presence of calcium ions in water could constitute an indicator of fluoride ion pollution. According to (Charnet, 2001), in sedimentary formations, the origin of fluorine comes from the leaching of rocks rich in calcium ions.

The highest magnesium ion contents are also obtained during the rainy season in most samples (figures 7 and 8). Still, according to (Charnet, 2001), the fluoride ion contents increase with the leaching of magnesium-rich minerals and the dissolution of apatite minerals.

The phosphate ion contents are high during the rainy season compared to the dry season. Their presence in water is either of natural origin (product of decomposition of organic matter, leaching of minerals containing phosphorus), or anthropogenic (phosphate fertilizers, animal defections, polyphosphates from detergents, etc.) (BRGM).According to (the national report on the situation of pesticides in Niger, 2016), organophosphate type pesticides are the most used in the study area. Still, according to this report in the study area in 2018, 7801.5 liters of pesticides are used with a coverage of 63.26% of area treated per hectare.According to the Environmental Protection Agency (EPA), pesticides contribute significantly to water fluoridation. The EPA estimates the intake of pesticides for a person who weighs 70 kg to be around 6.6 mg/day in fluoride.These phosphate sources are conducive to water fluoridation in the study area. According to (Sayyed Hussain, 2011), infiltration by leaching of phosphate fertilizers used in agriculture during the rainy season, fertilizers and pesticides, could promote water fluoridation.According to the work of (Andréas Schuld, 2003), phosphate fertilizers are a potential source of fluoride ion contamination. Similarly, according to the work carried out by (Foletti, 1997), excess fluoride in the water could result from the leaching of phosphate fertilizers which contain up to 4% fluorine.The leaching and then infiltration of phosphate fertilizers and pesticides would contribute to the fluoridation of water in the study area.

The above shows that the rainy season has an influence on the content of fluoride ions in well water.

Case of borehole water

The results obtained show that the contents of fluoride ions, calcium ions, magnesium ions and phosphate ions are higher in November than in May.

In addition, the piezometric measurements carried out during the two water sampling campaigns showed that the water level in the boreholes is higher in November than in May.This rising water indicates an influence of the rainy season on the water level in the boreholes.According to (Kilian, 1931), the soils of the Maradi region consist of a sequence of geological formations, from permeable to semi-permeable, and are favorable to infiltration. Also, according to (Bessoles and Trompette, 1989), the bedrock of the study area is a fractured bedrock. According to (ABABOU, 2005), multi-layered aquifers can exchange flows by drainage through permeable and semi-permeable layers (very fine sands; silts; silts...).According to (El Achheb, 2001), there is a possibility of water infiltration in the sedimentary basin. This may explain the rise in the water level in the boreholes in the study area.As in the case of wells, the rise in the water level in the boreholes can explain the variation in the contents of fluoride ions, calcium ions, magnesium ions and phosphate ions in these waters. Thisvariation is probably due to the dissolution of rocks, containing calcium, phosphorus, magnesium and fluoride, and/or to the infiltration of fertilizers and pesticides used in agriculture.

Conclusion:-

The objective of this study is to assess the impact of seasonal variations on the content of fluoride ions in groundwater in the Maradi region.This study shows that the fluoride ion content in the waters of the study area is higher in November than in May. This indicates high water fluoridation during the rainy season and could expose populations to dental and/or bone fluorosis.This increase in fluoridation could be due to the geology of the environment; and/or/ infiltration by leaching of phosphate fertilizers and pesticides used in agriculture.

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