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RESEARCH ARTICLE

INFLUENCE OF THE RAINY SEASON ON THE PHYSICO-CHEMICAL QUALITY OF THE WATERS OF GUIDIMOUNI (EASTERN NIGER)

Hassane Bouba[1], Moussa Issaka Abdoulkader[2], Dadisoumaila Mamane-Nasser[1], Abdourhamane Touré Amadou[1] and Zibo Garba[3]

1. Département de Géologie, FAST, Université Abdou Moumouni, Niamey (NIGER).
2. Département des Sciences Géologiques et Environnementales, FST, Université de Zinder (NIGER).
3. Université de Dosso (NIGER).

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Abstract

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In the eastern part of Niger, which is arid to semi-arid, market gardening production systems are based on temporary, semi-permanent to permanent basins or ponds and lakes. In Guidimouni, in the Damagaram, the market gardening production system is associated with two permanent lakes, located side by side. The objective of the present study was to analyse the seasonal physico-chemical variations and the aptitudes for using the waters of the Guidimouni lakes. Three water sampling campaigns were carried out. The chemical analyses of the samples thus taken were carried out in the laboratory. The physico-chemical quality (Conductivity, salinity, total hardness, complete alkalometric title, Na^+, K^+ content) of the lake waters vary according to the dry or rainy seasons. The well waters are suitable for consumption and irrigation, the waters of KoginKarfasa range from poor suitability for consumption in the dry season to excellent at the end of the rainy season. The waters of KoginKanwa are unfit for consumption and irrigation due to high Na^+ and K^+ contents during the dry and rainy seasons.The salinity of K.Kan's waters does not come from the surface but from the depths of the soil with a discontinuous character.

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Introduction:-

Climatic variations, manifested by droughts in the Sahel have led to environmental degradation (Fabeku&Okogbue, 2014; Gemenneet al., 2017; Ozer, LaminouManzo, Tidjani, Djaby& De Longueville., 2017). These droughts have impacted runoff, groundwater recharge and surface water bodies (Gal, 2016; Trichon, Hiernaux, Walcker&Mougin, 2017).

In eastern Niger, the consequences of the droughts were mainly: the drop in the water table level, the reduction in vegetation cover, the silting of oasis basins, the reactivation of sharp dunes, an increase in the number of dry fogs (Ambouta, Karimou, Tidjani, &Tychon,2018; MoussaIssaka, 2014; Tidjaniet al., 2016). Despite the return of rains observed since the 1990s (Lebel& Ali, 2009), they remain below those of the wet period and the response of the environment is slow (Hassane, 2013).

Corresponding Author:- Hassane Bouba
Address:- Département de Géologie, FAST, Université Abdou Moumouni, Niamey (NIGER).

In Damagaram, the rural commune of Guidimouni has two lakes, KoginKanwa (K. Kan) and KoginKarfasa (K. Kar), which belong to a group of basins on the Zinder-Gouré-Goudoumaria-Mainé-Soroa line (Amboutaet al., 2018). Both lakes are in inter-dune depressions and are largely dependent on the water table. In this area, market gardening increased from 218.26 ha to 239.31 ha between 1984 and 2001 (Ado Salifou, 2012).the municipality of Guidimouni is also experiencing significant demographic growth, with, for example, 51,169 inhabitants in 2009 and 69,587 inhabitants in 2012 (INS, 2012). "In the local perception, the waters of the two lakes do not mix!"For market gardening, it is the waters of K. Kar and the waters of the water table that the population uses, the waters of K. Kan are almost not used, despite the large size of the lake (Figure 1). For more than a decade, national food self-sufficiency policies have been encouraging high-intensity market gardening, with its water requirements, to replace the low yields of rain-fed crops (Nazoumou, Favreau, Adamou &Maïnassara, 2016). However, climate projections indicate uncertainties about the occurrence of droughts (Burke & Brown, 2008;Qing, Wang, Zhang & Wang, 2020). Guidimouni thus appears in a context that requires water control. Constraints include the uncertainty of sustainability and the threat to the quality of water resources.

Thus, the general objective of this work is to analyse the seasonal physico-chemical variations and the aptitudes for using the waters of the Guidimouni lakes. Specifically, the aim is to compare the physico-chemistry of the lake waters during the dry and rainy seasons, to deduce the source of the salinity of waters and to discuss the aptitudes for using these waters.

Materials and Methods:-

The rural commune of Guidimouni (13° 40' - 13° 45' N and 9° 27' - 9° 34'E) (Figure 1), is located 65 km from the urban community of Zinder, the regional capital, and covers an area of 1,123 km2. The geology of Guidimouni is part of a global presentation dominated by the crystalline rocks of the Damagaram, with the sedimentary formations of the terminal continental and Quaternary deposits superimposed on or adjacent to them (Greigert&Pougnet, 1967; Ousmane, 1988). In addition to the quartz plateaus, the geomorphology of the commune of Guidimouni consists of basins and dunes (Ibrahim, 2015). The climate of Guidimouni is integrated into the Sahelian climate. An interannual variability of rainfall is highlighted with an average of 402.42 mm over 20 years (1998 -2018). The population is engaged in livestock farming, fishing and agriculture.

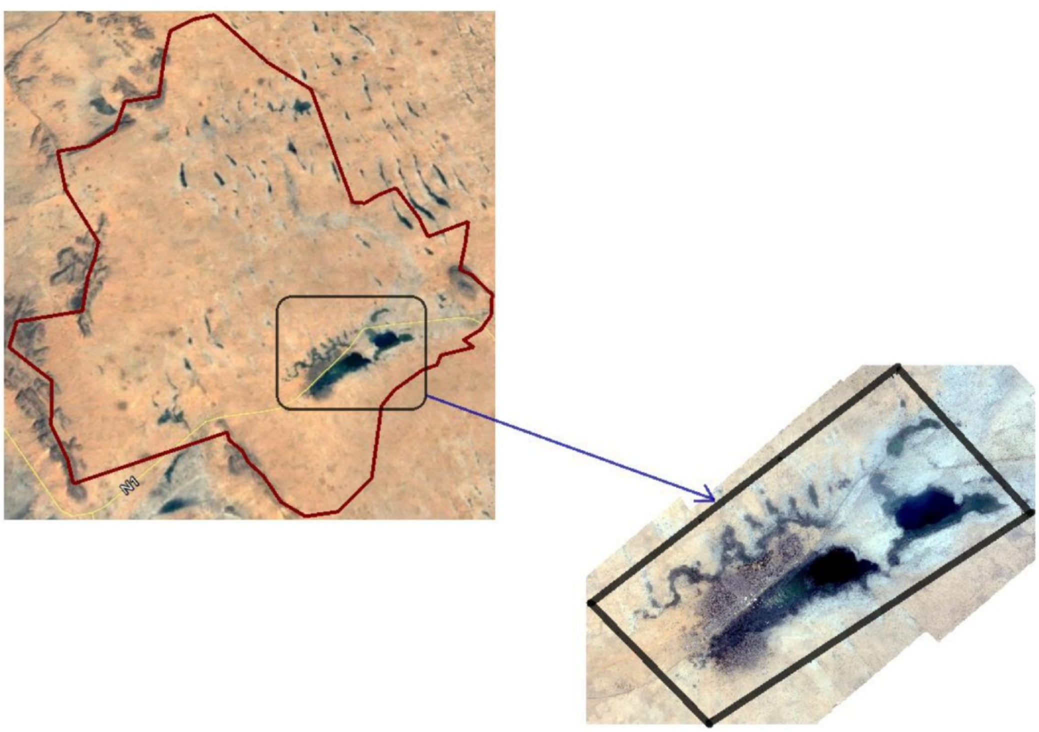

Figure 1:- Localisation.

Rainfall Data and Water Sampling:
The 2018 rainfall measurements were used to determine the impact of rain on the parameters of lake water samples taken during the rainy season. These data were obtained from Guidimouni's communal agriculture department. Three water sampling campaigns were carried out. These campaigns correspond to the beginning of the season (25/05/2018), the middle (13/07/2018) and the end of the rainy season (18/09/2018). The water from the lakes, from the outcropping aquifers and from the well was taken from a depth of 15 cm. Although the well and the ground water are all fed by groundwater, the choice to take these waters was based on the direct impact of runoff and the water-ground contact of the water from the ground water.

Measurements of the physicochemical parameters of the waters and assessment:
The conductivity was determined using the EUTECH conductivity meter and the pH was determined using the PALINTEST pH meter, both with direct reading. Potassium (K) and Sodium (Na) were measured using the JENWAY flame spectrophotometer and the other chemical elements were determined by titration (Ca^{2+}, Mg^{2+}, HCO^{3-}). Mineralisation and salinity were determined by calculation from conductivity according to the Rodier(2009) formula.To characterise the mineralisation and the elements that contribute to it, Principal Component Analysis (PCA) was applied to the 8 chemical and physical elements (KotchiOrouet al., 2016; Rabilou, et al., 2018a). An assessment of the suitability of water for irrigation and consumption was made (Wilcox, 1948).

Results and Discussion:-

Physicochemical characterization of the waters:
The waters of the two lakes are distinguished first of all by their colouring: the waters of K. Kar are relatively clear (Figure2) whereas those of K. Kan are greenish, even though both lakes are in the same environment.

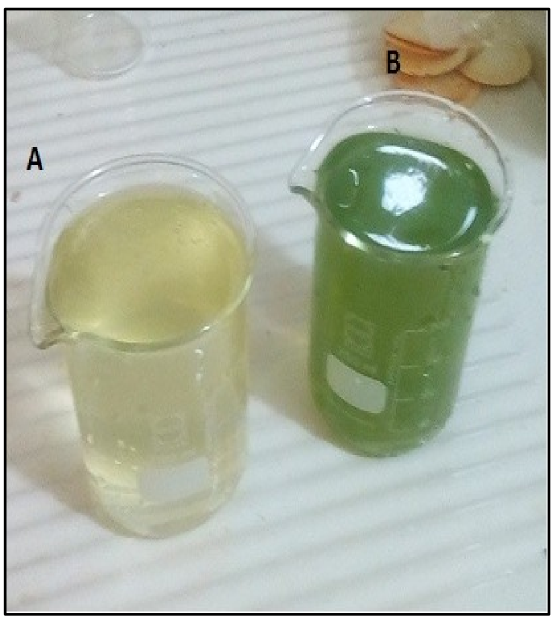

Figure 2:- Presentation of the lake waters: A = KonginKarfasa (K.Kar) and B = KoginKanwa (K.Kan).

As an example (Table 1), for the first season, before the rainy season, the Na^+ content in K waters. Kar is 320 mg.L^{-1} and those of K. Kan 3450 mg.L^{-1}, i.e. more than 10 times the Na^+ content of K. Kar. The Na^+ content in the well water is 24 mg. L^{-1}, is much lower than that of the two lakes. For K+, K. Kar's waters contain 110 mg. L^{-1} while K. Kan's water contains 480 mg. L^{-1}, which is more than 4 times higher. The well water has a content of 17 mg. L^{-1}. For $HCO3^-$, at the level of K. Kar the content is 1220 mg. L^{-1} while it is 5612 mg. L^{-1}at the level of K. Kan. This content is 63.4 mg. L^{-1}in the well water. The red contents (Table 1) are out of standard compared to the World Health Organization (WHO) standard. They exceed the tolerated values for human health.

Table 1:-

	PH	CE	Salinity	Ca++	Mg++	Na+	K+	NH4+	Cl-	SO4--	HCO3
Unity		*µs/cm*	*%*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*	*mg/l*
	6,5-8,5	**>180-1000**	**-**	**≤100**	**≤50**	**≤200**	**≤12**	**≤0,5**	**≤250**	**≤250**	**500**
C1	9,9	8347	5600	4,8	7,68	3450	480				5612
C2	9,63	7350	5056	6,4	4,8	1050	480				5490
C3	9,79	4252,5	2592	8	5,76	1250	200				4026
C1	8,81	1410	947,2	24	32,64	320	110				1220
C2	8,27	1322,25	855,04	32	20,16	160	80				732
C3	8,26	894,75	184,96	24	25,92	70	70				585,6
C1	7,68	298,66	213,12	27,2	10,56	24	17				63,4
C2	7,07	276,6	198,4	25,6	5,76	90	16				85,4
C3	6,93	571,25	177,28	24	1,92	24	15				87,8
C1											
C2	7,1	201,12	186,08	18,4	8,16	65	20				100,04
C3	7,09	363,75	231,36	24	9,6	35	20				108,58

Evolution of the electrical conductivity:
Electrical conductivity is the ability of water to conduct electrical current and is a function of the dissolved matter in the water in the form of ions (Derwich, Benaabidate, Zian, Sadki&Belghity, 2010). The conductivity of the first campaign (25 May 2018) of the waters is highest in the K. Kan waters and lowest in the well waters (Figure. 2). For the second campaign (13 July 2018), this conductivity decreased in all waters: -11.94% (K. Kan); -6.22% (K. Kar); 45.64% (groundwater) and -7.38% (Well) (Figure 2). In the third campaign, the variation in electrical conductivity distinguishes surface water from groundwater. The EC of lake water decreases: -42% (K. Kan) and -32.33% (K. Kar) while it increases in groundwater: +80.86% (Groundwater) and +106.52% (Well). The importance of the EC of lake water compared to groundwater can be explained by the importance of Na+ and K+ ions in surface water compared to groundwater (Table 1). The high conductivity of lake water can be the result of rainwater runoff that washes out potentially salt-rich soils, bringing in Na+ and K+ ions(Allalgua, Kaouachi, Boualeg&Ayari, 2017; Derwichet al., 2010; Loukman, Nakolendousse, MahamatNour&NguinambayeMenti, 2017; Nouayti, Khattach&Hilali, 2015; Zgourdah, Belghti, Samri&Elkharrim., 2015).

This high EC can also be explained by the importance of vegetation in these waters. Indeed, water-soil contact and organic matter (KotchiOrouet al., 2016). However, K. Kan has a high density of vegetation, mainly composed of typhaaustralis, whereas it is less dense in K. Kar.

The 3 measurement campaigns cover the dry season and the beginning and end of the rainy season. The EC measurements show variations due to this calendar. The high EC of the lake waters observed at the time of the first campaign can be attributed to the dry season, marked by a high evaporation of water and therefore a concentration of salts, which are associated with EC. This characteristic is peculiar to surface waters during the warm season. (Tfeilet al., 2018; Buhunguet al., 2018) found particularly high EC values respectively in the Aby lagoon in Côte d'Ivoire; on lakes in Mauritania and Lake Tanganyika in this season.During the two campaigns (2nd and 3rd) of the rainy season, lake water EC continued to decrease. This decrease can be associated with the contribution of rainfall, which favours the dilution of water and thus lowers the quantities of ions in solution.

Evolution of the Hydrogen Potential:
The hydrogen potential (pH), expresses the acidity or basicity of a water. It influences aquatic life and is involved in chemical reactions (Aguiza Abai, Ombolo, Ngassoum&Mbawala, 2014; Derwich et al., 2010; Tfeilet al., 2018). Lake waters are more basic (9.76 /+-0.15) in K. Kan than in K. Kar (8.45 /+-0.31) (Figure 3). During the 3 sampling campaigns, the pH of groundwater are neutral to slightly basic (7.02 +-0.14) whereas the well water had to 7.23 /+-0.40). However, in the dry season, the groundwater (7.02 +/- 0.14) was rather acidic to evolve towards basicity, whereas the well water (7.23 +/-0.40) had the opposite trend.

The pH of K. Kan's water is higher than the WHO standards (Table 1), whereas for K. Kar only the pH in the dry season (1st season) is higher than the norm. Thus, K. Kar's water in the rainy season and the groundwater are within the WHO standards. Compared to Sandao's work, (2013), the pH values of the groundwater are similar to the pH values he obtained from wells and piezometers in the area. According to Derwich et al, (2010); Tfeil et al, (2018); Tfeila et al, (2016) the pH increases during the warm season. Belghitiet al., (2013) explain the water pH by the nature of the terrain crossed when Buhungu et al., (2018), attribute the slight decrease in pH to the dilution effect with rain and its increase during the dry season by significant evaporation

Total Hardness (TD) and Alkalimetric Title (TAC):

The total hardness (TD) of water conditions its use (drinking, market gardening...). It refers to the calcium and magnesium salt content (Buhungu et al., 2018, Nechad, Fadil&Fadil, 2014). This parameter has not been measured for groundwater. Compared to the WHO classification, all waters have on average hardness levels that classify them from soft to moderately hard water: K. Kan (41.33 +- 4.62); K. Kar (176 +-17.44) and wells (89.33 +- 22.03). Thus, the waters of K. Kan are very soft, those of K. Kar are moderately hard and those from the well are soft (Table1). For both lakes, the value of DT decreased between the dry season campaign (1st campaign) and the rainy season campaign (2nd campaign), although it increased in the second rainy season campaign (Figure 4A).

For well water, on the other hand, the DT continued to decrease between the dry season campaign and the two rainy season campaigns (Figure 4A). It became very mild in the third season.

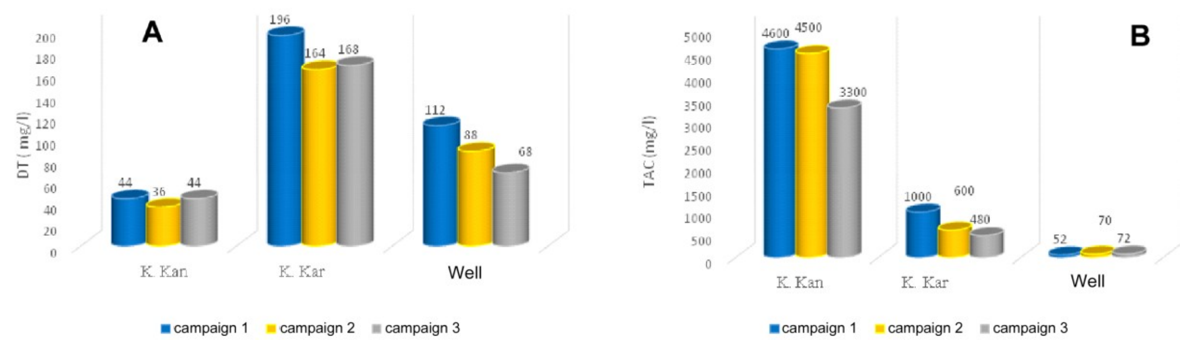

Figure 4:- Total alkalinity (TAC) and total hardness (TD) of the 3 measurement campaigns.

The Complete Alkalimetric Titration (TACK) of the waters is the hydroxide, bicarbonate and carbonate content. It corresponds to the neutralisation of all carbonic species (Nechadet al., 2014; Tfeilaet al., 2016). The TAC of lakes K. Kan (4133.33 +- 723.42) and K. Kar (693.33 +- 272.27) decrease from the dry season to the rainy season, whereas for the well water (64.66 +- 11.02), the TAC has an inverse variation; it increases from the dry season to the rainy season (Figure 4B).

Thus the TAC variations observed in lake waters can be explained by the contribution of rainfall in the rainy season, which favours the dilution of the carbonate components.Whereas at the well level, the variation can be associated with groundwater recharge, which is not direct. These seasonal variations in DT are similar to those found by Buhunguet al. (2018) at the level of Lake Tanganyika (Burundi) with high values of DT in the dry season and low values in the rainy season. He links this variation to the dilution effect of water by the lake's tributaries. And, Nechadet al. (2014) found the same variations at the Ain Regrag springs in Morocco but attribute it to the lithological nature. Contrary to our results, Allalguaet al. (2017) observed high DT values in the wet season and low DT values in the dry season in Souk-Ahras, Algeria.

Mineralisation:

The Principal Component Analysis (PCA) used to characterize waters lake's mineralisation indicate that factorial planes F1 and F2 are correlated (Figure 5).The projection gave K. Kan: F1 (77.98%) and F2 (22.02%; Fig. 5. A), K. Kar : F1 (72.01%) and F2 (27.99%; Figure 5B) and for the well: F1 (100%) and F2 (00.00%; Figure 5C). It is mainly the factor F1 which dominates in the mineralisation of these waters. At K. Kan, mineralisation is carried by the salinity group, EC, $HCO3^-$ and K^+ ions (Figure 5A). At K. Kar it is the group of $HCO3^-$; K^+ and Na^+ions (Figure

5B). For shaft water, only the factor F1 controls the mineralisation, carried by the salinity group, EC, Ca^{2+}; K^{+} and Mg^{2+} (Figure 5C).

The factor F1 is the axis of mineralisation of both natural and anthropogenic origin (Eblinet al., 2014).The mineralisation of the surface waters of the two lakes has $HCO3^{-}$ and K^{+} ions in common. These ions have a surface origin and are thought to come from the dissolution of evaporite rocks, the natron that gave its name to Lake K. Kan.The mineralisation of the shaft water is partly inherited from surface water and part of it is thought to come from alkaline earths (Mg^{2+} and Ca^{2+}) derived from clays. Rabilouet al. (2018b) found similar results for the mineralisation of waters from the continental Intercalaire/Hamadien of Zinder region to those of the Guidimouni well and explained it by rainfall leaching and alteration of silicate minerals and/or carbonates.

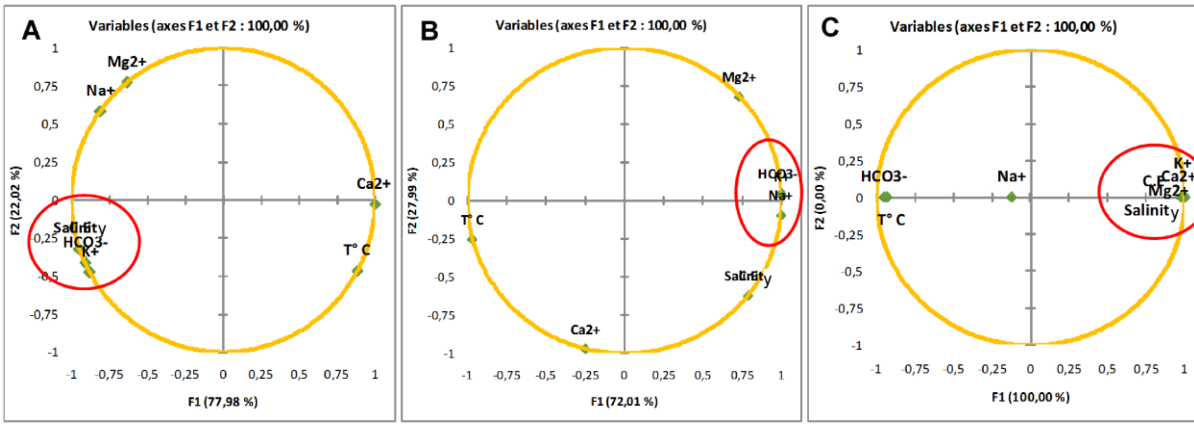

Figure 5:- Mineralisation of Guidimouni's waters.

The rain was a characteristic feature of these 3 campaigns. In fact, between the first and second campaign, a cumulative of 115 mm was recorded, compared with 276.5 mm between the second and third campaign. Decreases in salinity and mineralisation coincide with the rainfall contributions (Figure 6). The dilution thus caused is well marked for the mineralisation of surface water, K. Kan= -29% and -49.7% and K. Kar= -37.3% and -78.8% and very weakly in well water: -6.9% and -10.6%. This dilution is less important for salinity. In fact, rainwater feeds the water table and the latter, in contact with the lake water, favours the dilution of the water. Thus, the chemistry of the waters of the Guidimouni lakes is essentially linked to the litho-chemical nature of the lake soils.

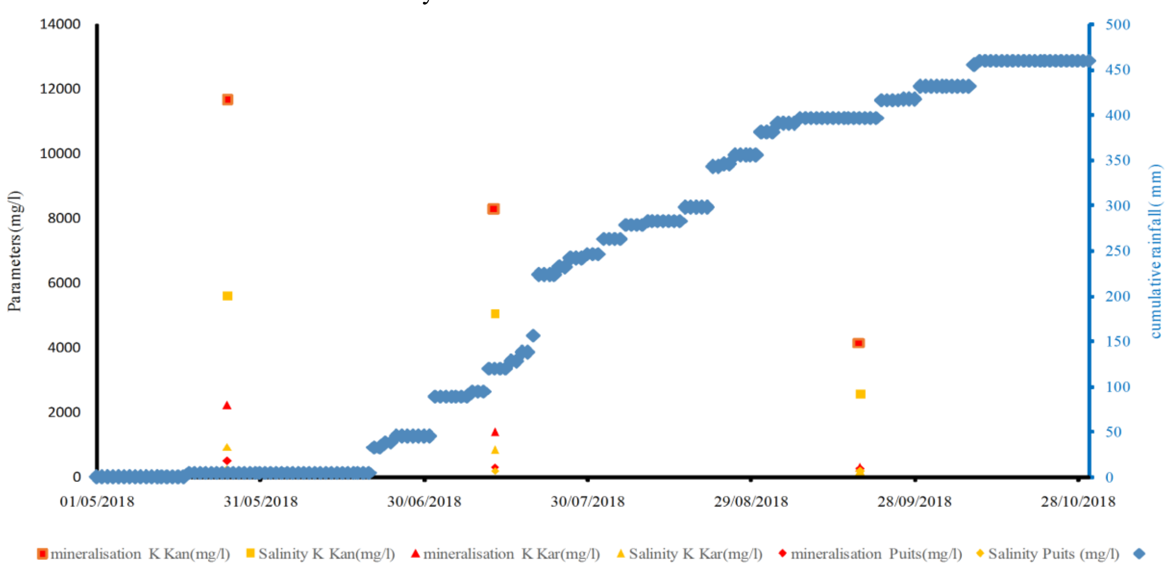

Figure 6:- mineralisation and salinity vs. rainfall.

Suitability of the waters for use:

The K.Kan waters with the highest Na levels (~100%) and conductivity (above 3500 µS.cm-1) are bad for use (Figure 7). Water from the well is excellent for use all year round, even if the Na content increases in the rainy season. The suitability changes are mainly observed for the K.kar waters. The water changes from mediocre in the dry season, to acceptable in the middle of the rainy season, to excellent at the end of the rainy season (Figure 7).The observed changes in K.kar water suitability are induced by the rainwater input and the dilution it causes.Thus, these waters are suitable for consumption and irrigation in contrast to the K.kan, which are not. The excellent quality of water from the well to irrigation is similar to that found by Sandao (2013) for the groundwater of Korama/South Zinder. K.kan waters are of poor quality and are not used because the plants used do not tolerate sodium-saturated water well. To use these kinds of waters in irrigation, Belhaj, (2017) proposes very permeable soil conditions; good leaching and salt-tolerant plants.

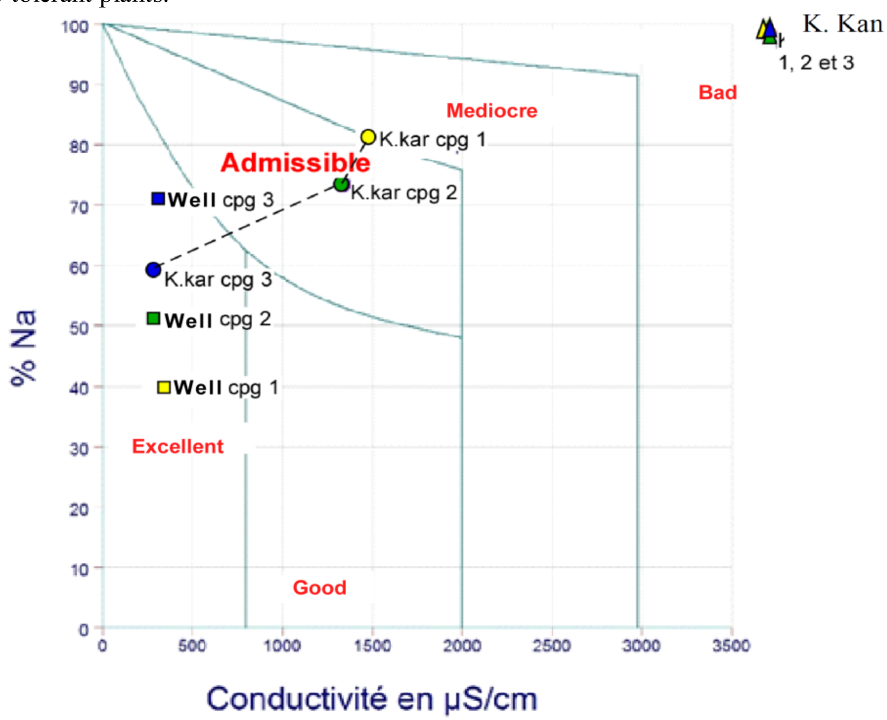

Figure 7:- Wilcox's diagram for the use of Guidimouni waters.

Conclusion:-

The general objective of this work is to analyse the seasonal physico-chemical variations and the aptitudes for using the waters of the Guidimouni lakes. The comparison of the lake waters highlights the basicity of the lake waters. The waters of KoginKanwa are strongly mineralised with a complete alkalimetric titration (TAC), higher contents of Na^+, K^+ compared to those of KoginKarfasa. This physical-chemical composition of the lake waters varies according to the dry and rainy seasons. The water quality shows an aptitude for consumption and irrigation of the well water on a permanent basis. K. Kanwa's water is very poor for use in any season due to the high Na+ and K+ content. The impact of season and rainfall is observed in K. Karfasa, where the water level goes from poor for use in the dry season to acceptable in the middle of the rainy season and excellent at the end of the season.The salinity of the K. Kan waters should be investigated in the soil analysis. It is clearly established that it does not come from the surface soils drained by water. Better still, its presence in the K. Kan waters alone suggests that it comes from discontinuous saline subsoils.

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