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Study of the Mineralization of Groundwater in the Agadez Municipality: Application of Statistical and Multivariate Analysis Methods

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Abstract Groundwater is of paramount importance in most parts of the world. However, this resource, which was once of good quality, is currently threatened by various point and diffuse sources of contamination. This study aims to evaluate the physicochemical quality of the groundwater of the municipality of Agadez and explain the phenomena at the origin of the mineralization of these waters. It is based on various hydro-chemical methods and multi-varied statistical analysis techniques. A series of physicochemical and microbiological analyzes carried out on samples taken from wells and boreholes were carried out. The results of these analyzes were processed from multi-varied statistical methods including Principal Component Analysis (PCA) and Hierarchical Ascending Classification (AMP). The results of the Principal Component Analysis and the Hierarchical Ascending Classification indicate that the mineralization of the studied waters is controlled by three major phenomena: the mineralization residence time which results in the hydrolysis of minerals, the phenomenon of oxidation-reduction and mineralization by infiltration of water into the aquifer. This study also showed that the water resources studied, mainly well water, were strongly influenced by anthropogenic activities, with the presence of certain bacteria that are the consequence of recent human pollution. Overall, the quality of the groundwater is good but in some cases requires specific treatment before supply.

Keywords PCA, Ascending Hierarchical Classification, mineralization, groundwater, Agadez

1. Introduction

In Africa, groundwater in urban and rural areas suffers from multiple constraints due to high population growth and unsuitability or even lack of sanitation [1]. Sewage systems, septic tanks, factory sewage and solid waste are the main sources of groundwater pollution in the urban sector; in peri-urban and rural areas, agriculture, via agricultural inputs, also contributes to degrading the quality of groundwater and watercourses [2]. The region of Agadez is in the Sahelo-Saharan zone and therefore an arid zone, not having a huge amount of permanent surface water. The main source of water supply for populations remains groundwater. The table water of these regions are generally renewed by infiltration of surface water [3]. This process is not without impact on the composition of these waters, especially considering the lithology and the wastes (pollutants) contained in the area's soil surface. Therefore, it would not be necessary to direct research for an understanding of the chemical composition of these waters for better planning and management of water resources. This study, of the mineralization of groundwater in the Agadez municipality: application of statistical and multivariate analysis methodsis therefore initiated in line with this concern. The objective of this study is to characterize the groundwater of the study area for an understanding of the acquisition of mineralization of these waters. The applied methodology is based on multi-varied statistical methods (Analysis in Principal Normed Components (ACPN) and Ascending Hierarchical Classification (AMP)). This analysis makes it possible to synthesize and classify a large number of data in order to extract the main factors which are at the origin of the simultaneous evolution of the variables and their reciprocal relationship [4-11]. It makes it possible to highlight the similarities and the graphical position that would present two or more chemical variables during their evolution. The different methods used in this study will make it possible to know on the one hand the mechanism of mineralization of the water of the studied sites and on the other the relations which exist between these water resources and the anthropic activities of the zone of study.

1.1. Presentation of the study area

The region of Agadez is located in northern Niger, it covers an area of 667,799 km^2 (about 53% of the total area of the country). It is limited by Algeria and Libya to the north, Chad to the east; the regions of Diffa, Zinder and Maradi in the south and the Tahoua region and Mali in the west. The region is subdivided into 6 departments Aderbissanit, Arlit, Bilma, Iferouane, Ingall and Chirozerine. The area concerned by the study is in the municipality of Agadez (Figure 1).

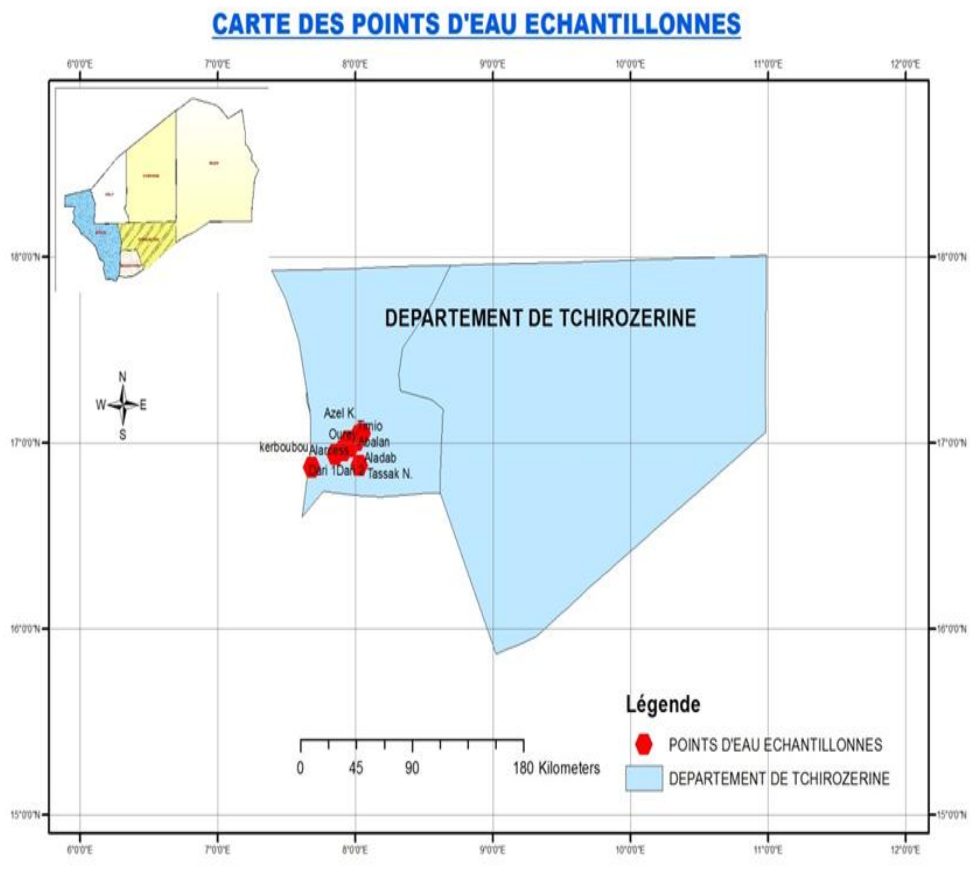

Figure 1: The study area in the municipality of Agadez

Climate plays a very important role in determining the physico-chemical parameters of an environment [12]. The study area is marked by the alternation of two seasons: a short rainy season that runs from June to September and a very long dry season that runs from October to June. Annual rainfall is characterized by significant spatial and temporal variability. The average annual rainfall is very low with only 111mm. The climate of this desert zone is of

Sahel-Saharan type. The region is one of the warmest in the world, it is dominated by the Aïr massif, surrounded on the west by the plain of Talak and on the east by the desert of Ténéré. The Aïr Massif is a mid-mountain area of about 70 000 km^2 which culminates at 2020 meters at Mount Indoukat-n-Taglès in the Bagzane Mountains. The Ténéré Desert with an area of about 400 000 $km^2$is a vast expanse of sand (ergs) cut from north to south by the Kaouar cliff along which are the oases of Séguédine, Dirkou and Bilma. The region has significant groundwater reserves despite its geographic position [3]. Although few of these groundwater are annually renewed. The main aquifer systems are characterized by:

Agadez sandstone aquifers: It consists of two large groups: the sandstones of Teloua (which contains the water table Teloua 1, 2 and 3) and the sandstones of the aquifers (Chirozerine 1 and 2) which is an alternation of clayey sandstone to glomerulus of analcimes and coarse conglomerate vacuolar sandstones.

The intercalary continental aquifer: it is a general aquifer of captive aquifer type with open water areas near the outcrops. It consists of continental sandstone-sandstone and sandy-clay deposits of the lower Cretaceous.

Namur aquifer: it is a multilayer series composed of sandstone and clay silts with a depth often exceeding 300 m. In the vicinity of the 17 ° 30 parallels the series is outcropping and seems to exist in depth towards the 17 ° parallels. This Namurien aquifer consists of the Tara water table at the top of a thickness of 25 to 50 m and the water table of Guezouman located at the base between 50 and 60m.

The Precambrian basement aquifer: the basement of the basin is a foliated diorite with amphibolic enclaves with associated veins of quartz, pegmatites.

Alluvial aquifers: these are shallow aquifers buried under permeable soil with coarse sand; their renewal is ensured by rainwater.

2. Materials and Methods

Water samples were collected in ten (10) boreholes and five (5) wells well distributed throughout the municipality of Agadez (Figure 1) during the month of October.

These water samples were collected in 1 liter polyethylene bottles. The samples were taken to overflow in the flasks previously rinsed with water from the water, then corked and labeled. For specimens for bacteriological analysis, sampling was performed in sterilized glass vials by autoclaving at 121 °C for 20 minutes. In the absence of adequate equipment for the sampling of well water, the sump is replaced by a bucket (new and polyethylene). The sample is taken by immersing our sterilized bottle in the bucket so as to avoid any contact with the air at the time of filling. In the case of drilling the walls (internal and external) of the fountain are flamed with a torch. After collection, the bottles are hermetically sealed with the sterilized capsule and a tape. The samples were labeled and transported in a cooler heated to 4 °C. The bacteriological analysis was carried out immediately, within 24 hours after the sampling. The different physicochemical parameters and methods used in the sampled water analyzes are described in Table 1 below:

Table 1: Different methods of analysis

Methods	**Volumetry**	**Spectro-photometer**	**Filter membrane technique**	**Physical reading**
Paramters	TAC, TCa, TH, Ca^{2+}, Mg^{2+}, Cl^-, HCO_3^-	SO_4^{2-}, NO_3^-, NO_2^-, Fe^{2+}, k^+, F^- Mn^{2+}, Fer total	Escherichia coli Fecal streptococci	Conductivity, Temperature, Turbidity, TDS, pH,

The germs sought in this study are:

- Fecal streptococci
- Fecal coliforms (Escherichia coli)

The filtration technique for isolating and determining these seeds was used. The method is very sensitive and allows bacteria to be determined at low concentrations.

Field measurements include temperature (T °C), hydrogen potential (pH), electrical conductivity (EC) and Solid Dissolved Solid (TDS). These parameters were measured using a multi-parameter device of brand cyber scan PC

300. Turbidity was measured in the laboratory. This measurement is made using a HACH 2100Q portable turbidimeter. These analyzes were carried out using a spectrophotometer brand hach DR 1900 using the conventional methods recommended by Rodier [13].

3. Results and Discussion

3.1. Descriptive analysis

The different results of in situ measurements and laboratory analyzes of the waters of the municipality of Agadez are given in Table 2.

Table 2: Descriptive statistics of the physicochemical results of the waters of the municipality of Agadez

Physico-chemical Parameters	Units	Norms OMS 2011	Min	Max	Moy
T°	°C		27.60	33.50	30.91
pH	-	6.5-8.5	6.48	8.48	7.18
CE	$\mu S.cm^{-1}$	400	152.0	1194.0	417.33
TDS	$mg.L^{-1}$	1000	76.00	597.0	208.68
Turb	N.T.U	5	0.25	8.25	2.45
TH	°F	10	0.56	26.60	12.32
NO_3^-	$mg.L^{-1}$	50	2.20	248.00	39.77
NO_2^-	$mg.L^{-1}$	0.2	0.00	0.15	0.06
F^-	$mg.L^{-1}$	1.5	0.00	2.08	0.92
Cl^-	$mg.L^{-1}$	250	10.65	92.30	27.22
HCO_3^-	$mg.L^{-1}$	NE	75.64	431.88	217.21
Fe^{2+}	$mg.L^{-1}$	0.3	0.00	0.28	0.06
Mn^{2+}	$mg.L^{-1}$	0.2	0.10	0.30	0.13
ca^{2+}	$mg.L^{-1}$	NE	2.08	88.40	39.39
Mg^{2+}	$mg.L^{-1}$	NE	0.09	12.00	5.93
SO_4^{2-}	$mg.L^{-1}$	250	0.40	80.00	27.76
Na^+	$mg.L^{-1}$	250	66.92	816.39	235.76
K^+	$mg.L^{-1}$	12	0.30	15.50	7.17
Fer total	$mg.L^{-1}$	0.3	0.03	1.78	0.60

Temperatures recorded in the waters vary between 27.6 ° C at Toudou Billa and 33.5 ° C at Chibinitene for an average of 30.913 ° C. The pH values range from 6.48 to Azelk and 8.48 at Kerboubouwith an average value of 7.181 ± 0.599. Overall, the waters are moderately mineralized with the exception of Ourey and ToudouBilla waters where the waters are weakly mineralized with conductivities of 152 $\mu S.cm^{-1}$ and 162 $\mu S.cm^{-1}$respectively. The waters of Tassak N are highly mineralized waters with a high electrical conductivity value of (1194 $\mu S.cm^{-1}$). The electrical conductivity ranged from 152.3 $mg.L^{-1}$ at Ourey and 1194 $mg.L^{-1}$ at Tassak Nfor an average of 417.33 $mg.L^{-1}$. The dissolved salt level (TDS) determines the concentration of dissolved salts. It plays an important role on the conductivity because the dissolved mineral salts influence the conductivity. The TDS shows values between 76 $mg.L^{-1}$ and 597.00 $mg.L^{-1}$ with an average of 208.68 $mg.L^{-1}$.

3.1.1. Major cations

Calcium levels are low ranging between 2.08 $mg.L^{-1}$at Kerboubou and 88.4 $mg.L^{-1}$ at TassakN for an average of 39.38 $mg.L^{-1}$. The magnesium values obtained vary from 0.096 $mg.L^{-1}$ to Kerboubou and 12.00 $mg.L^{-1}$ to Aladab with an average value of 5.933 $mg.L^{-1}$. Sodium also has high values ranging from 66.92 $mg.L^{-1}$ to ToudouBilla and 816.38 $mg.L^{-1}$ to Ourey for an average value of 235.75 $mg.L^{-1}$ exceeding the who standard. Potassium values just like sodium are very high. Potassium values range from 0.30 $mg.L^{-1}$ at Kerboubou and 15.5 $mg.L^{-1}$ at Tassak N for an average of 7.16mg.L^{-1}. Local potassium values such as Tassak N (mg.L^{-1}), Toudou B (13.2 mg.L^{-1}), Aladab (15.5 mg.L^{-1}). Abalan (12.5 mg.L^{-1}) are above the WHO standard.

3.1.2. Major anions

Like cations anions exist with some doses in the groundwater of the region. Bicarbonates (HCO_3^-) have levels ranging from 75.64 mg.L^{-1}at Toudou to 431.88 mg.L^{-1} at Ourey with an average of 217.21mg.L^{-1}. The chloride levels recorded are low and vary from 10.65 mg / l to Toudou 1 and 92.3 mg / l to Oureyfor an average of 27.21 mg.L^{-1}. One of the most important elements in drinking and health-related drinking water is fluoride. It occurs in water as fluoride ions (F^-). F^-Concentrations below 0.5 mg.L^{-1} in drinking water may promote tooth decay [14]. At very high concentrations (above 1.5 - 2 mg.L^{-1}) fluoride in the drinking water may cause dental or bone fluorosis [15]. In the analyzed waters F-concentrations ranged from 0.00 mg.L^{-1} to Abalan and 2.08 mg.L^{-1} to Alikinkin an average of 0.92 mg.L^{-1}. Sulphate ions (SO_4^{2-}) at concentrations above the guideline value in drinking water may cause diarrhea in humans [16].

The sulphate contents vary between 0.4 mg.L^{-1} at Toudou 2 and 80.00 mg.L^{-1} at Ourey with an average of 27.76 mg.L^{-1}. Nitrite ion values range from 0.00 mg.L^{-1} to chibinitene to 0.150 mg.L^{-1} to Tassak with an average value of 0.056 mg.L^{-1}. The presence of nitrites indicates recent contamination resulting from the infiltration of wastewater and a start of oxygen deficiency [17-18]. Nitrate contamination may be considered acceptable at 50 mg.L^{-1} in some localities. Nitrate levels range from 2.20 mg.L^{-1} at Kerboubou to 248.00 mg.L^{-1} at Tassak with an average value of 39.76 mg.L^{-1}. Localities such as Ourey (180 mg.L^{-1}) and Tassak N (248 mg.L^{-1}) exceed the norm.

3.1.3. Trace metallic elements

The metal trace elements considered are: total iron, manganese and ferric ions. The waters are rich in iron with contents ranging from 0.03 mg.L^{-1} to Toudou1 and 1.78 mg.L^{-1} to Kerboubou for an average of 0.59 mg.L^{-1} Overall. The analyzed waters have a total iron content higher than the WHO standard. The highest value was obtained at the level of Kerboubou water (1.78 mg.L^{-1}) exceeding the who standard. Iron is essential for the human body but very high concentrations affect the organoleptic properties of water and also stain the laundry. The guide value of the O.M. Total iron in drinking water is 0.3 mg.L^{-1}. The ferrous ion content in the groundwater of the region is heterogeneous. They range from 0.00 mg.L^{-1} at Kerboubou to 0.28 mg.L^{-1} at Dari 2 and at Ourey for an average of 0.059 ± 1.15 mg.L^{-1}. Manganese levels are generally low in water except at Tassak (0.30 mg / l). Kerboubou (0.2 mg / l). Dari 1 and Dari 2 (0.2 mg / l) where the contents are higher than the norm.

3.1.4. Microbiological parameters of waters

The purpose of the bacteriological study is to detect faecal pollution. Human and animal waste is the main source of potential pathogenic germs (causes of enteropathies in humans) [1].

The results of the microbiological analyzes on water show that there is no presence of faecal coliform bacteria (Escherichia coli) and faecal streptococci in water. However, colonies of bacteria not researched by our analyzes have developed. Faecal coliform (Escherichia coli) and faecal streptococci values in water samples meet WHO standards (0 colony units per 100 ml).

It should be noted that sampling points that show signs of contamination are uncoated wells used for mixed consumption (humans and animals). The origin of contamination with fecal germs could come from the cords used to draw water. The latter are mostly exposed on the ground. Pulled by animals or often contaminated by the dirty hands of some users. It has been noticed that a large number of wells are poorly maintained.

3.2. Results of the multi-variable statistical analysis

3.2.1. *Principal Component Analysis (PCA)*

The statistical study from PCA gives many results which are presented in Tables 3, 4 and 5. Table 6 lists the intrinsic values. the variances expressed for each factor and their totals. The factor F1. with a variance expressed of 41.38% is the most important of all. Then come the factors F2 and F3 with respectively 19.02% and 12.71% of the variance expressed.

Table 3: Intrinsic values and percentages expressed for the main axes

	F1	**F2**	**F3**
% Intrinsic values	7.864	3.615	2.415
%Total variance expressed	41.388	19.029	12.711
Cumulative variance expressed (%)	41 .388	60.417	73.127

The representation using the first two factors satisfactorily accounts for the scatterplot structure because the sum of the variance expressed by these factors is 60.41%.

The contribution of the different variables to the definition of the main factors is given in Table 7. Each factor is defined by a number of key variables in the demonstration of the mechanism of mineralization of water. This table shows that the factor F_1.

The most important is defined by the electrical conductivity CE (r = 0.79).The dissolved salt TDS (r = 0.79), the nitrate ions NO_3^- (r = 0. 87), chloride ions Cl^- (r = 0.80), bicarbonate ions HCO_3^- (r = 0.77), sulfate ions SO_4^{2-} (r = 0.78) and sodium ions Na + (r = 0.81). Hydrogen potential pH (0.62). Nitrite ions NO_2^- (r = 0.69) and total iron (0.66) correlated to a lesser degree. .

The factor F_2 is defined by TH (0.78), calcium ions Ca^{2+} (r = 0.73) and magnesium ions Mg^{2+} (0.83).

Table 4: Correlations between variables and factors

	F1	**F2**
T°	-030	-0.26
pH	0.62	-0.51
CE	0.79	0.29
TDS	0.79	0.29
Turb	0.57	-0.25
TH	0.54	0.78
NO_3^-	0.86	-0.06
NO_2^-	0.69	-0.51
F^-	0.47	0.34
Cl^-	0.80	-0.21
HCO_3^-	0.77	-0.32
Fe^{2+}	-0.15	0.10
Mn^{2+}	0.68	-0.17
ca^{2+}	0.55	0.73
Mg^{2+}	0.42	0.83
SO_4^{2-}	0.78	-0.06
Na^+	0.81	-0.40
K^+	0.30	0.56
Fer total	0.66	-0.36

3.2.2. Analysis of the correlation matrix

The existing link between all the two-by-two variables and the correlation coefficients between these different variables are given by the correlation matrix (Table 5). Based on the critical correlation coefficient r = 0.64. There are many weak and weak, weak strong and positive correlations between some variables. Thus the pH is strongly correlated with the anion HCO3- (0.64). The ions SO_4^{2-} (0.60) with the ions Na^+ (0.66) and the iron Total (0.70).

Electrical conductivity is strongly correlated with TDS (1) at TH (0.71). Mn^{2+} (0.78), and Ca2 + (0.73). It should be noted that the electrical conductivity (C.E) describes the inorganic salts present in solution in water. As for the total hardness of water. It is mainly related to the amount of calcium and magnesium in water from which a very strong correlation with Ca^{2+} (0.99) and Mg2 + (0.88).

NO_3^- ions are strongly correlated with Cl^- (0.90). Nitrate ions (NO_3^-) are present in nature where they are part of the nitrogen cycle. They represent the most soluble form of nitrogen. Mainly used as inorganic fertilizer for plant growth and synthesis of organic nitrogen compounds. Excess nitrates can be found quickly in groundwater. Waste containing organic nitrogen is also a source of nitrates obtained from different biochemical processes (ammonification and nitrification) [17].

The latter (HCO_3^-. Na^+. SO_4^{2-} and Cl^-) are also very well correlated with each other. Indeed there is a correlation between Cl- ions with HCO_3^- (0.75) and a strong correlation with Na^+ (0.92) and SO_4^{2-} (0.85). HCO_3^- ions are strongly correlated with SO_4^{2-} (0.73) and Na^+ (0.89) ions.

3.2.3. Analysis of the space of variables of the factorial plane

The data are represented in the reduced space of the first two principal components in Figure 3. This plane represents 60.42% of the variance for the analysis of the variables used.

The F1 factor with 41.39% of the total variance is represented by CE, TDS, NO_3^-, Cl^-, HCO_3^-,SO_4^{2-}.Na+,pH. NO_2^- and total iron, turbidity, Mn^{2+}. This grouping indicates that these parameters are solved by the same phenomenon. The nutrients pH. SO_4^{2-}. NO_2^- and NO_3^- have a mainly anthropogenic origin and are introduced in the subsoil. either by leaching of fertilizers applied or by the discharge of wastewater. The presence of nitrates is also attributed to the degradation of organic matter by microorganisms in the upper layers of the soil, with the production of CO_2 to be driven in depth by the infiltration water. Sodium (Na^+) is derived from the alteration of feldspars in igneous rocks. The attack of clay minerals and the dissolution of soluble salt grains contained in sedimentary rocks or evaporite beds. Common sources of chlorides (Cl^-) are halite (NaCl) and minerals related to evaporite deposits [19]. The solution of iron and manganese is controlled by the oxidation-reduction process.

The factor F_1 thus represents an axis of mineralization by infiltration of water into the aquifer and oxidation-reduction.

The F_2 factor with 19.03% of the total variance is defined by TH Ca^{2+} calcium ions and Mg^{2+} magnesium ions, Ca^{2+}. Mg^{2+} and TH are derived from the weathering of rocks following a long water-rock contact time and acid hydrolysis of silicate minerals. The factor F2 thus defines an axis of mineralization of the water by the phenomenon of dissolution of the rock following a long water-rock contact time (mineralization residence time by acid hydrolysis of the minerals).

The mineralization of groundwater is therefore acquired by three major phenomena including the phenomenon of dissolution by acid hydrolysis of rock minerals. The phenomenon of infiltration of surface and underground water and the phenomenon of oxidation-reduction.

The graphical representation in the factorial space of the statistical units (Figure 4) shows the distribution of the water points according to the different factors F1 and F2. The analysis of this graph showed two main groupings of water points:

The first group consists of Toudou 1. Toudou 2. Timio. Azel K. Abalan. ToudouBilla and Tassak N. These waters are concentrated on the F_1 factor. Which represents an axis of mineralization by infiltration of water into the aquifer and redox. On the whole ,they are acidic waters moderately hard and weakly mineralized. The contents of bicarbonates and the electrical conductivity values of these waters are low. with the exception of the waters of TassakNtalamtTassak waters are highly mineralized with high values of bicarbonate (334.28 $\mu S.cm^{-1}$) and electrical conductivity. (1194 $\mu S. cm^{-1}$).

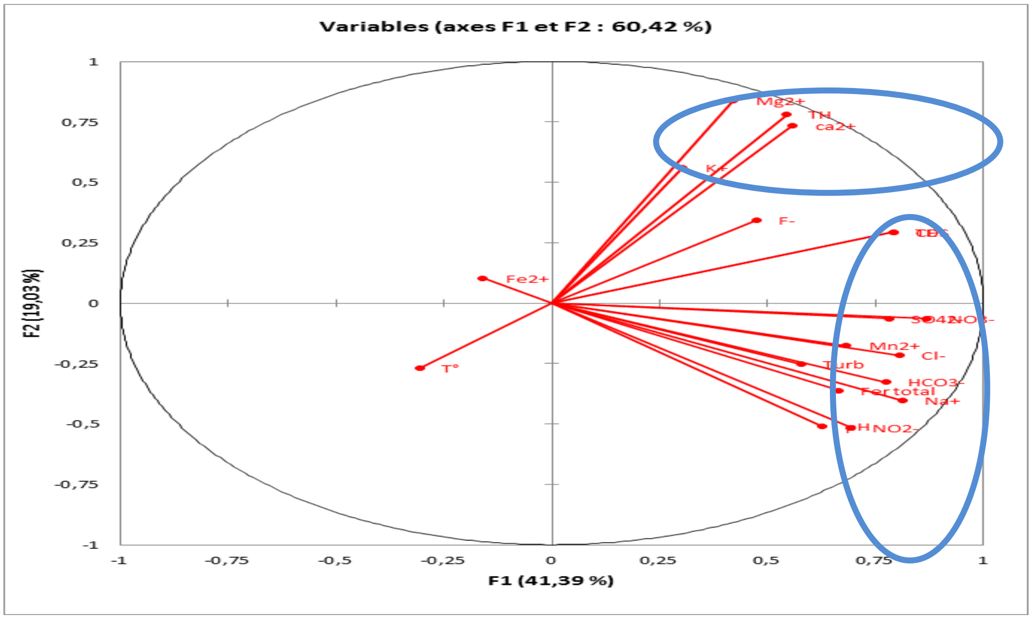

Figure 3: Analysis of the statistical units of the factorial plane F1xF2

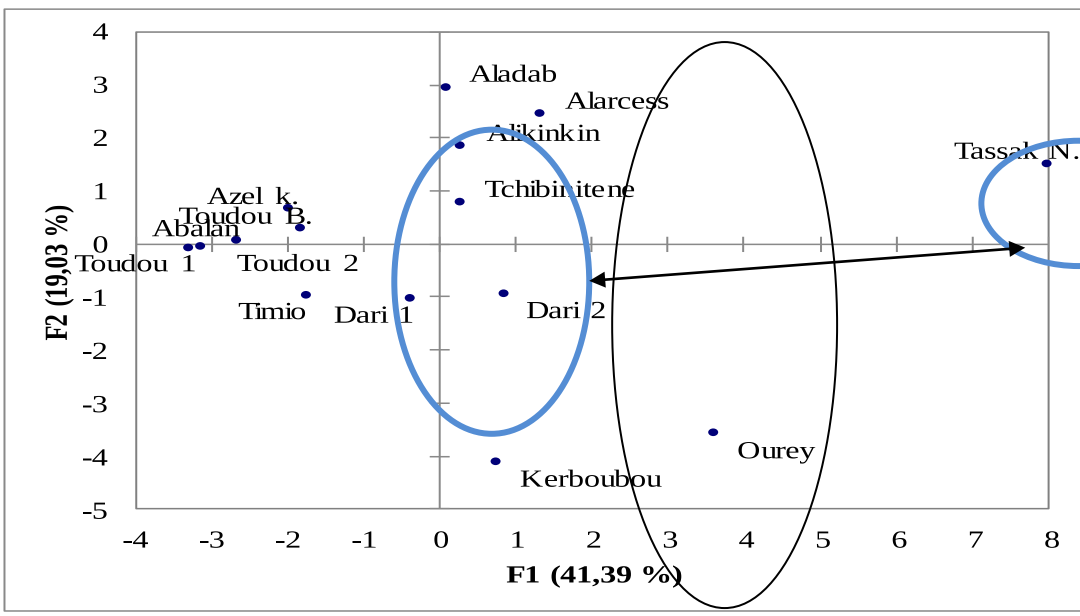

Figure 4: Space of the static units of factorial plane F1-F2

The second group. consists of the waters of Kerboubou. Alikinkin. Alarcess. Chibinitene. Aladab. Dari 1. Dari 2 These waters are concentrated in the turn of the factor F1 which represents an axis of mineralization of the water by the phenomenon of dissolution of the rock following a long water-rock contact time. These waters are generally moderately hard and moderately mineralized. The electrical conductivity values exceed the WHO standard. The exception is made in Kerboubou waters which are very mild (TH = 0.56 ° F).

Analysis in Ascending Hierarchical Classification (AMP). The ascending hierarchical classification is said to be ascending because it starts from a situation where all individuals are alone in a class. then are gathered in larger and larger classes. The Dendrogram (Figure 5) from the Hierarchical Ascending Classification (CAH) highlights two main groups of variables.

The first group consists of pH. Turbidity. F-. SO_4^{2}-. Cl-. Fe2 +. Mn2 +. Ca2+. Mg2 +. K +. Total iron. NO3-. NO2-. This group accounts for the mineralization-residence time or the phenomenon of mineral hydrolysis with the oxidation-reduction mechanism. It also indicates a massive presence of nitrogen compounds NO2- and NO3- so a strong contribution of anthropogenic activities in the mineralization of groundwater.

The second group consisting of HCO_3-. CE. TDS. Hardness. Na +. indicates a mineralization by infiltration of water in the aquifer. This group also highlights the phenomenon of the hydrolysis of minerals present in the rocks that make up the bedrock of the aquifers that shelter the waters of the region. Indeed. the presence of HCO3- ions is related to the dissolution of carbonates.

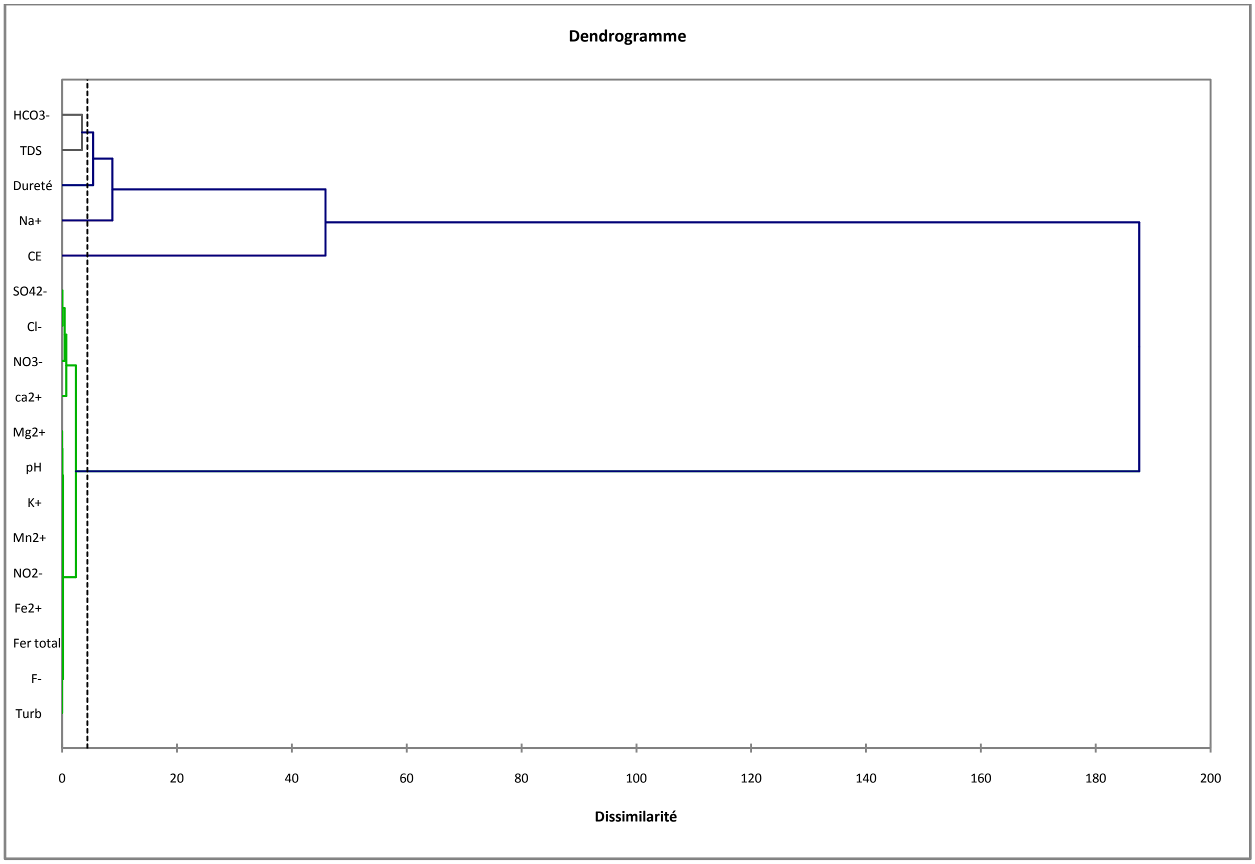

Figure 5: Dendrogram of waters of the municipality of Agadez

3.3. Discussion

The physicochemical analyzes show that the waters of the municipality of Agadez are neutral (6.48<pH<8.48) and moderately mineralized overall. The chemical quality parameters are for the most part below the WHO potability standard. except at some points where fluorine. nitrate and sulphate contents are high and sometimes well above the norm. Metal trace elements also have high levels in water. sometimes close to the norm and sometimes far exceeding the norm (iron). Overall. the waters of the region are moderately hard. with hardness related to granitic basements. and very often very fine variegated clay sandstones of the region.

The correlation matrix indicates that the chemical parameters influencing the mineralization of the waters of the zone are bicarbonate. electrical conductivity. fluorine. sodium. hardness (related to the presence of calcium and magnesium) and chloride. These ions are derived from the alteration of rocks and the hydrolysis of silicate minerals [20]. Ions like Cl^-. SO_4^{2-} NO_2^- and NO_3^- come from rain and leaching from the soil as indicated by the results of the multi-variate analysis. Indeed. the Principal Component Analysis has shown that two other phenomena contribute to the mineralization of the waters in the study area. It is the pluvi-leaching of soils and the intervention of anthropic activities in the pollution of surface water.

The physicochemical analyzes show that for the same given water table the different water points taken as a sample often have very variable characteristics from one point to another. Indeed, the graphical representation in the factorial space of the statistical units showed two main groupings of the water points. The first group consists of the waters of Toudou 1, Toudou 2, Timio, AzelKileweye, Abalan, Toudou B, Tassak. On the whole. they are acidic. moderately hard and weakly mineralized waters with the exception of Tassak waters which are highly mineralized. The second group consists of the waters of Kerboubou, Alikinkin, Alarcess, Tchibinitene, Aladab. These waters are generally moderately hard and moderately mineralized waters. The exception is made to the waters of Kerboubou which are very mild (TH = 0.56 ° F).

4. Conclusion

The graphical representation in the factorial space of the statistical units revealed two (2) classes of water. The first group contains waters that are generally moderately hard acids and weakly mineralized. The bicarbonate contents and the electrical conductivity values of these waters are low. with the exception of Tassak waters. Tassak waters are highly mineralized with high values of bicarbonate and electrical conductivity.

The second group contains waters that are generally moderately mineralized medium hard water. The electrical conductivity values exceed the WHO standard. The exception is made to the waters of Kerboubou which are very mild (TH = 5.6).

The Principal Normed Component Analysis (PCA) and the Ascending Hierarchical Classification (AMP) indicate that the mineralization of the waters of the municipality is controlled by three major phenomena. These are the mineralization-residence time of the water in contact with the host. or the hydrolysis for groundwater (wells and wells). the redox and the pluvio-leaching of the soil by the infiltration of water. substances related to human activities. In addition, bacteriological analyzes of the waters in the study area showed the absence of faecal coliform bacteria (Escherichia coli) and faecal streptococci. Anytime indicates these analyzes indicate the presence of certain bacteria such as pathogenic intestinal bacteria that could come from pollution by human or animal waste. Indeed. almost all villages in the town of Agadez do not have adequate sanitation. Since latrines are non-existent. people have their personal need in nature. added to those of farm animals.

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