World Journal of Advanced Research and Reviews
eISSN: 2581-9615 CODEN (USA): WJARAI
Cross Ref DOI: 10.30574/wjarr
Journal homepage: https://wjarr.com/

(Research Article)

Study of the physico-chemical quality of groundwater in the municipality of Bosso (Diffa, eastern Niger)

Maman Kabirou ILLIASSOU GAMBO *, Mamane Imrana CHAIBOU OUSMANE, Oumarou Farroukou MOUSTAPHA BELLO, Awali ABDOUL BARI IDI and Abdou Salam MANZOLA

Materials, Water and Environment Laboratory, Department of Chemistry, Faculty of Science and Technology, Abdou Moumouni University, Niamey (Niger), BP: 10662 Niamey (Niger).

World Journal of Advanced Research and Reviews, 2026, 30(01), 1626-1636

Publication history: Received on 04 March 2026; revised on 13 April 2026; accepted on 16 April 2026

Article DOI: https://doi.org/10.30574/wjarr.2026.30.1.0942

Abstract

The objective of this study is to assess the potability of five boreholes in the municipality of Bosso. The analyses focused on physical parameters measured in situ (pH, electrical conductivity EC, and temperature) and chemical parameters measured by volumetry: ion content (HCO_3^-, Cl^-, Ca^{2+}, Mg^{2+}, and hydrometric titre) and, by spectrophotometry, ion content (SO_4^{2-}, F^-, NO_3^-, NO_2^-, Na^+, K^+, total iron). The results show an average temperature of 29.14°C and a pH that complies with potability standards in most cases (80% of samples). Electrical conductivity varies from 2500 µS/cm to 11140 µS/cm, with an average of 6207 µS/cm. The F^-, NO_3^-, NO_2^-, total iron, Ca^{2+}, and Mg^{2+} contents comply with WHO (2011) and MSP Niger (2021) guidelines. However, excessive concentrations were found for sulfate ions (2700 mg/L), chlorides (368 mg/L), and sodium (1500 mg/L). As a result, only one in five boreholes (20%) provides water suitable for human consumption. Interpretation of the data using the Piper diagram revealed two main hydrochemical facies: a chlorinated or sodium sulfate facies (60%) and a sodium bicarbonate facies (40%). Applying Richard's diagram for irrigation suitability classifies 80% of the water as poor and 20% as fair, due to the risk of soil salinization and alkalization.

Keywords: Diffa (Niger); Bosso; Hydrochemistry; Groundwater; Drinking water; Multivariate Statistical Methods

1. Introduction

All over the world, pressure on water resources, and particularly groundwater resources, is increasing, mainly due to growing demand and the deterioration of water quality. Widespread access to drinking water, irrigation, urban expansion, industrial development, and tourism are all factors that increase these pressures [1]. These water resources have become a major challenge for the survival of the human race because, at present, they are the most essential and most threatened natural resources [2]. Anthropogenic pollution and climate change threaten both surface water and groundwater, the largest reservoir of fresh water available on the planet. In this sense, understanding the hydraulic properties of aquifers and the hydrochemical characterization of the water they contain is necessary for the planning and management of groundwater resources [3]. Its preservation therefore becomes an important issue if humans are to be able to adequately meet their drinking water needs in the coming decades.

Niger's geographical location gives it a role as a crossroads for trade between North Africa. Its demographics are characterized by accelerating population growth, with the annual growth rate rising from 3.3% for the period 1988-2001 to 3.9% for the period 2001-2012. This significant demographic pressure on natural resources has resulted in an increase in the production of various types of waste.

---

* Corresponding author: ILLIASSOU GAMBO Maman Kabirou

In recent years, the Diffa region has been subject to significant anthropogenic pressure resulting from economic expansion, particularly in agriculture, and the prevailing insecurity in the area. This situation has led to significant migratory movements, with populations from northeastern Nigeria and southeastern Niger moving to the Diffa region. These massive migratory flows have a direct impact on water resources and their quality, particularly in certain localities in the region. The aim of this study is to assess the potability of groundwater in the municipality of Bosso.

2. Material and experimental methods

2.1. Presentation of the study zone

The municipality of Bosso, located in the Diffa region of Niger, lies between 13°42'00“ north latitude and 13°18'39” east longitude. This locality, which borders Chad (to the east) and Nigeria (to the south), covers an area of 1712 km^2 and has an estimated population of 65022 inhabitants.

2.2. Inventory of water points

As part of this study, an inventory methodology was applied, including sampling of five (5) water points spread across four (4) villages, in order to characterize the groundwater resources of this municipality. The table below lists the different water points and their geographical coordinates.

Table 1 Geographic coordinates of sampling points

		GPS coordinates	
N°	Villages names	Latitude	Longitude
1	BLANGANA	13°16'32,9"	13°41'48,4"
2	BOSSO 1	13°18'19,8"	13°42'58,3"
3	BOSSO 2	13°18'15,1"	13°43'04,9"
4	GAMGARA	13°16'02,1"	13°41'05''
5	N'GORSO	13°08'5,1"	13°43'27,4"

Figure 1 Map of the study zone and sampling points

2.3. Materials used

In order to carry out this study, a set of measuring instruments was used in the field. The following physicochemical parameters were determined: a Hanna pH meter was used to determine the hydrogen potential (pH) and temperature (T); electrical conductivity (EC) was determined using a WTW conductivity meter. Ion concentrations (HCO_3^-, Cl^-, Ca^{2+}, Mg^{2+}, and hydrotimetry) were measured by volumetry, and concentrations of SO_4^{2-}, F^-, NO_3^-, $NO2^-$, and total iron were measured using a HACH DR/2010 spectrophotometer and a WAGTECH/7100 photometer.

3. Results and discussion

3.1. Temperature

Water temperature is an important factor in the aquatic environment because it governs almost all physical, chemical, and biological reactions [4]. In the study zone, the average temperature was 29.14 °C, with a minimum of 24.2 °C and a maximum of 31.6 °C. These values comply with WHO (2011) and MSP Niger (2021) standards.

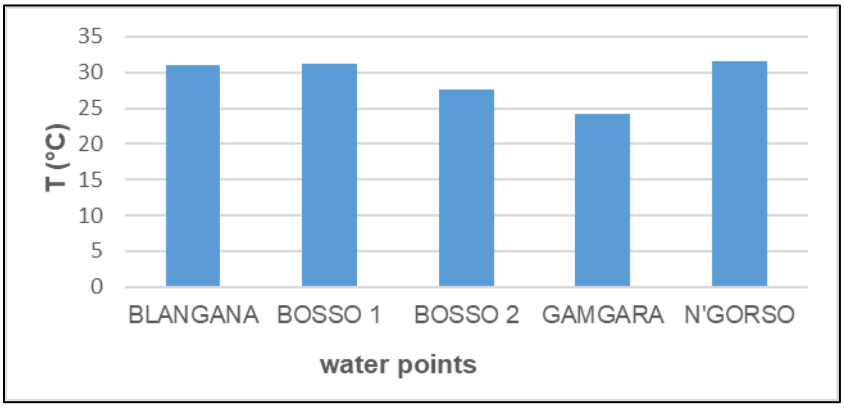

Figure 2 Temperature values at different water points

3.2. Hydrogen potential

The pH of water provides information about its acidity and alkalinity [5]. Among the water samples analyzed, four (4) out of five (5) had a pH between (6.5 and 8.5), in line with WHO (2011) and MSP Niger (2021) standards. A higher-than-normal pH value (8.8) was observed at the water point in the village of GAMGARA, suggesting a possible influence of the alkaline nature of the surrounding soil and other geochemical factors such as mineral dissolution.

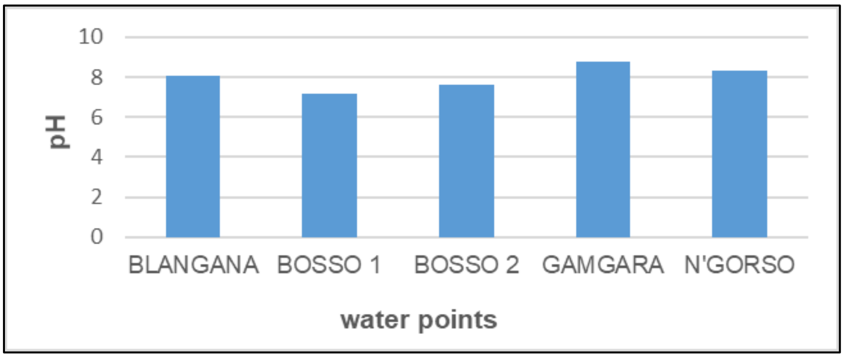

Figure 3 pH value of different water sources

3.3. Electrical conductivity

Conductivity is used to assess the overall mineralization of water [6]. In the study zone, electrical conductivity varies between 2500 µS/cm and 11140 µS/cm, with an average of 6207 µS/cm. These high electrical conductivity values in these water samples could be attributed to the phenomenon of surface water or groundwater leaching and also the natural dissolution of mineral salts in soil and rocks through erosion, runoff, and degradation of organic matter, which can affect taste and also health.

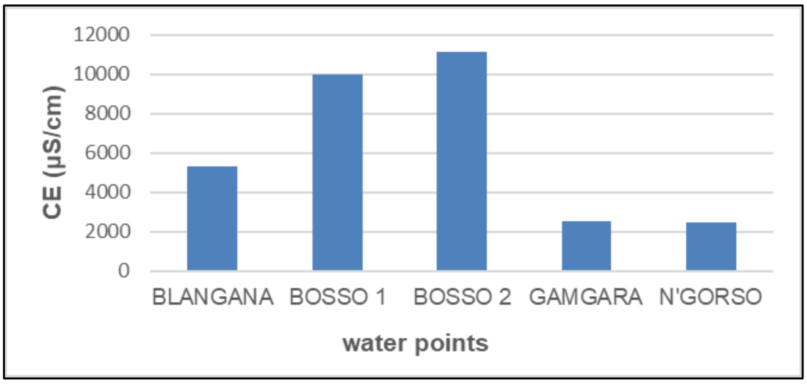

Figure 4 Conductivity values for different water points

3.4. HCO_3^- ion content

The bicarbonate ion content in groundwater depends mainly on the presence of carbonate minerals in the soil and aquifer, as well as the CO_2 content of the air and soil in the catchment zone [7]. High concentrations were observed in the village of BLANGANA (1386.8 mg/L) and in the village of BOSSO 1 (1171.2 mg/L). These high concentrations of bicarbonate ions could be mainly related to the dissolution of carbon dioxide (CO_2) in water and interaction with carbonate minerals.

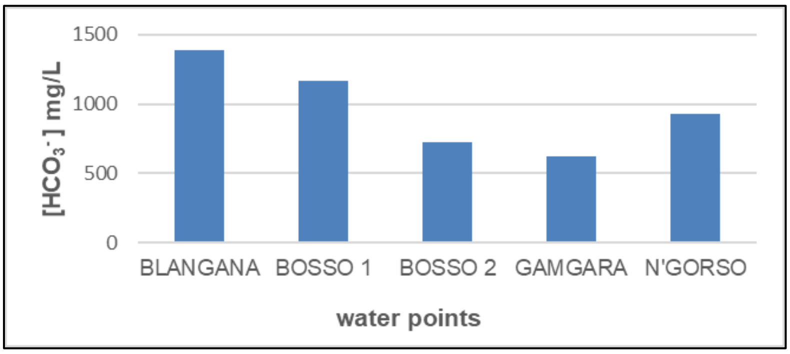

Figure 5 Variation in HCO_3^- content at different water points

3.5. SO_4^{2-} ion content

Under natural conditions, sulfate ions, the most common form of dissolved sulfur in natural waters, have two main sources: geochemical and atmospheric [8]. The sulfate values in the waters studied vary greatly, with the highest value observed in the village of BOSSO 1 (2700 mg/L) and the lowest value in the village of GAMGARA (90 mg/L). The high sulfate content observed in these water samples could be due to the dissolution of sulfide minerals, such as the percolation of groundwater through geological formations containing minerals such as gypsum, anhydrite, or pyrite. High sulfate concentrations can mainly cause gastrointestinal disorders, taste problems, and corrosion of infrastructure.

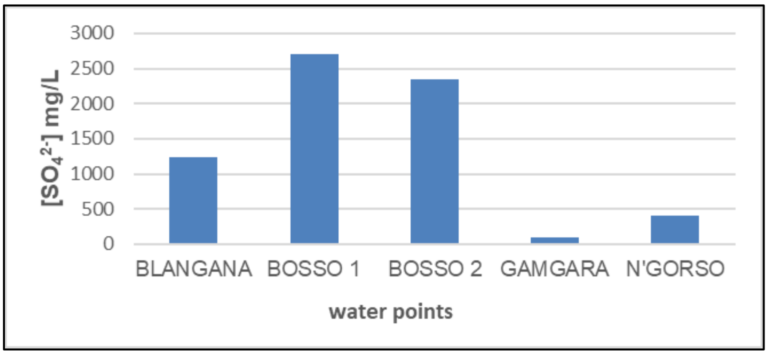

Figure 6 Variation in SO_4^{2-} content at different water points

3.6. Cl^- ion content

Cl^- ions are important inorganic anions found in varying concentrations in natural waters, usually in the form of sodium (NaCl) and potassium (KCl) salts. They are often used as indicators of pollution [9]. A higher-than-normal content was observed in the village of BOSSO 2 (368 mg/L). This higher-than-normal value could be due to the dissolution of halogenated minerals, such as the percolation of groundwater through geological formations containing halogenated minerals. High levels can alter taste, cause corrosion of infrastructure, and disrupt aquatic ecosystems.

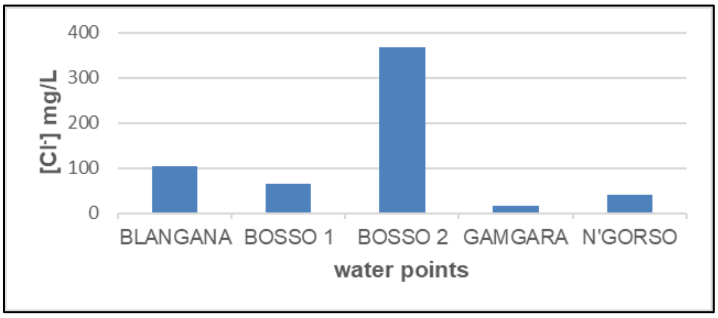

Figure 7 Variation in Cl^- content at different water points

3.7. F^- ion levels

The figure below shows the variation in fluoride ion levels at our various sampling points. All these concentrations comply with the standards (1.5 mg/L) set by the WHO (2011) and the Niger Ministry of Public Health (2021).

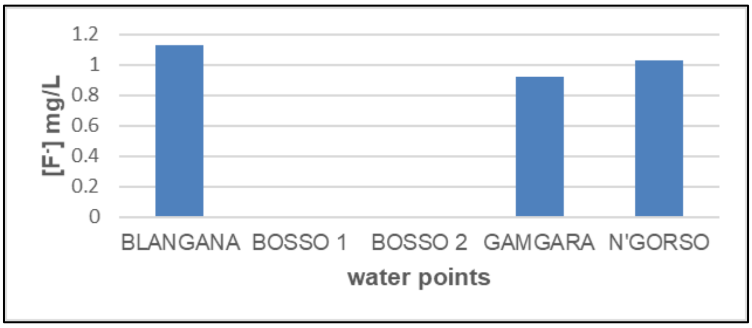

Figure 8 Variation in F^- content at different water points

3.8. NO_3^- ion content

Nitrate ions are present in water due to the leaching of nitrogenous products in the soil, the decomposition of organic matter, and synthetic or natural fertilizers [10]. They can also be linked to the bacterial oxidation of ammonia [11]. All recorded values comply with the standards (50 mg/L) set by the WHO (2011) and the Niger Ministry of Public Health (2021).

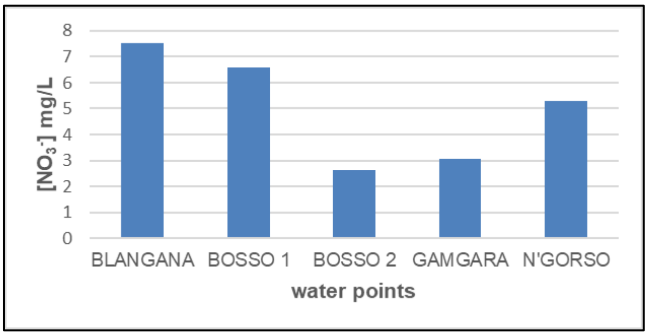

Figure 9 Variation in NO_3^- content at different water points

3.9. NO_2^- ion content

NO_2^- ions originate either from incomplete oxidation of ammonia, where nitrification has not been completed, or from reduction of nitrates under the influence of nitrifying action. Water containing nitrite ions should be considered suspect, as they are often associated with a deterioration in microbiological quality [12]. All recorded values comply with the standards (1.5 mg/L) of the WHO (2011) and the MSP Niger (2021).

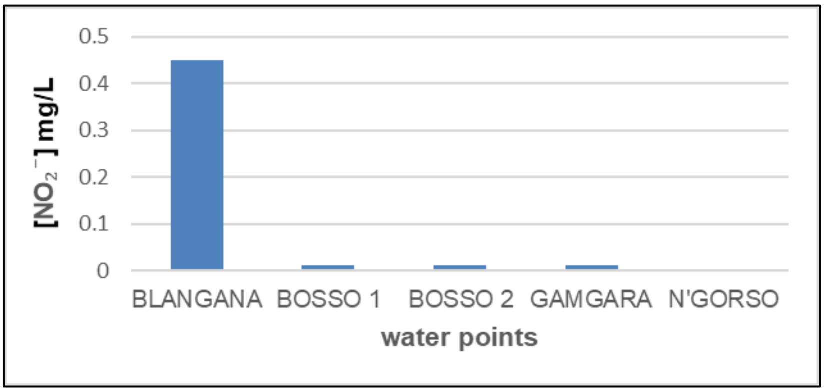

Figure 10 Variation in NO_2^- content at different water points

3.10. K^+ ion content

K^+ ions regulate water content within cells [13]. Its presence, which is fairly constant in natural waters, does not usually exceed 10 to 15 mg/L [6]. High potassium concentrations were found at the BOSSO 2 (68 mg/L), BOSSO 1 (44 mg/L), and BLANGANA (40 mg/L) water points. These high concentrations could be due to the natural weathering of potassium-rich rocks or human influences such as irrigation.

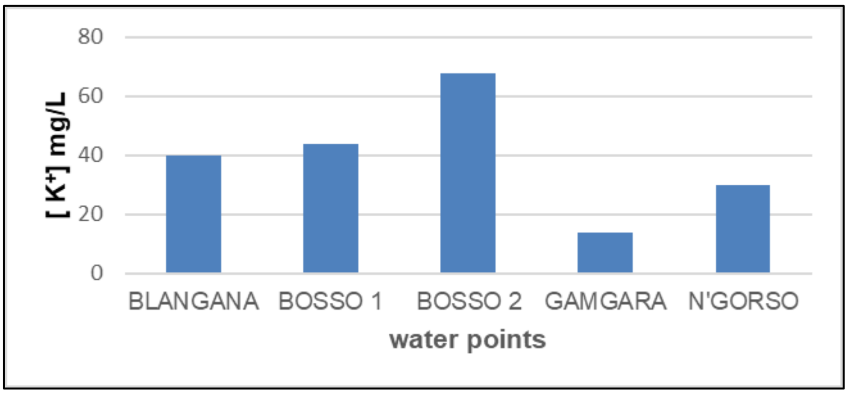

Figure 11 Variation in K^+ content at different water points

3.11. Na^+ ion content

Water with excessive Na^+ ion content becomes brackish and takes on an unpleasant taste, making it undrinkable [14]. High concentrations of sodium ions were found at the BOSSO 1 (1500 mg/L), BOSSO 2 (1020 mg/L) and BLANGANA (683 mg/L). These high concentrations of sodium ions can make the water unpleasant to taste (salty taste) and pose health risks, especially for sensitive individuals such as those with high blood pressure, the elderly, or babies, by increasing cardiovascular risks.

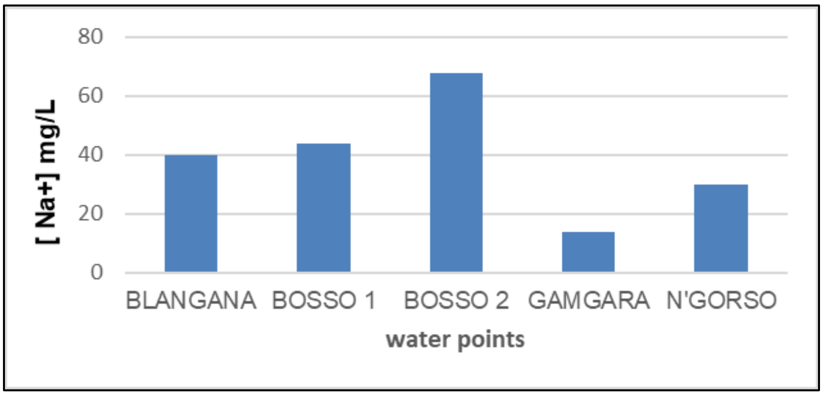

Figure 12 Variation in Na^+ content at different water points

3.12. Ca^{2+} ion content

Ca^{2+} ions are generally the dominant element in drinking water, and their content varies mainly according to the nature of the terrain traversed (calcareous or gypsum terrain) [15]. High concentrations of calcium ions were found at the BOSSO 2 (192 mg/L) and BOSSO 1 (112 mg/L) water points. However, these high concentrations do not affect the quality of the water.

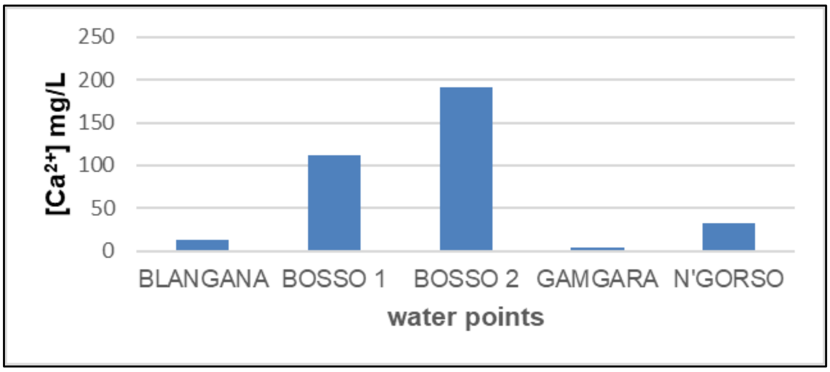

Figure 13 Variation in Ca^{2+} content at different water points

3.13. Mg^{2+} ion content

These ions originate from the attack of magnesium-rich rocks by carbonic acid and the dissolution of magnesium in the form of carbonates and bicarbonates [15]. A higher-than-normal value was found at the BOSSO 2 water point (97.2 mg/L), which could contribute to water hardness and also have a laxative effect.

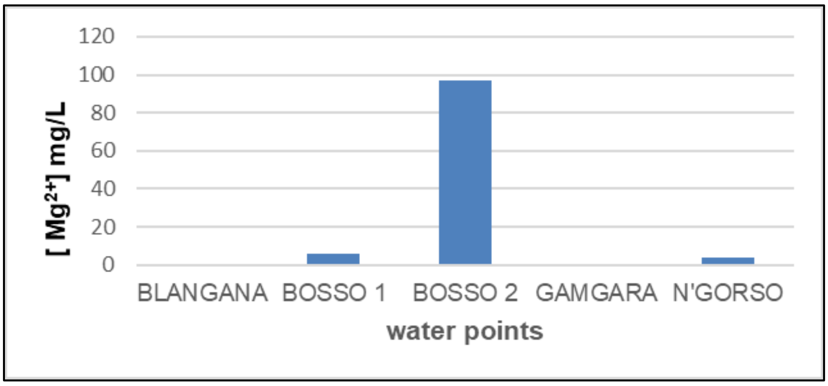

Figure 14 Variation in Mg^{2+} content at different water points

3.14. FeT content

Iron and manganese are mineral impurities with no significant effects on health. Excessive concentrations of these metals affect the organoleptic properties (color and unpleasant taste) of mineral water [16]. The analysis results for all our water samples show a slightly variable total iron content of less than 1 mg/L, which complies with standards.

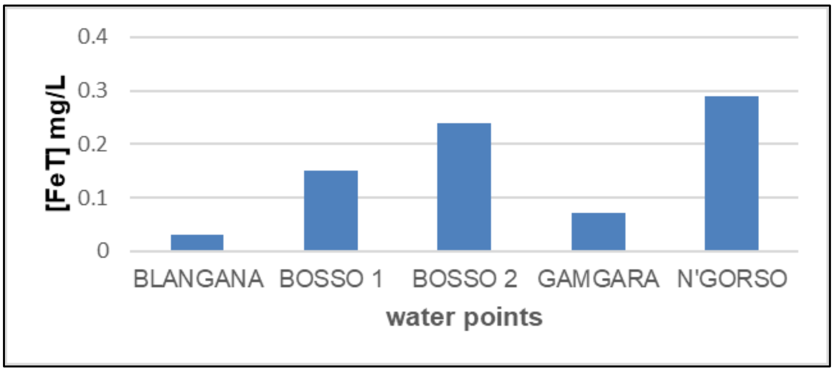

Figure 15 Variation in FeT content at different water points

3.15. Chemical facies of water obtained from the Piper diagram

The reporting of the results of water analyses from the municipality of BOSSO on the Piper diagram shows variability in chemical facies.

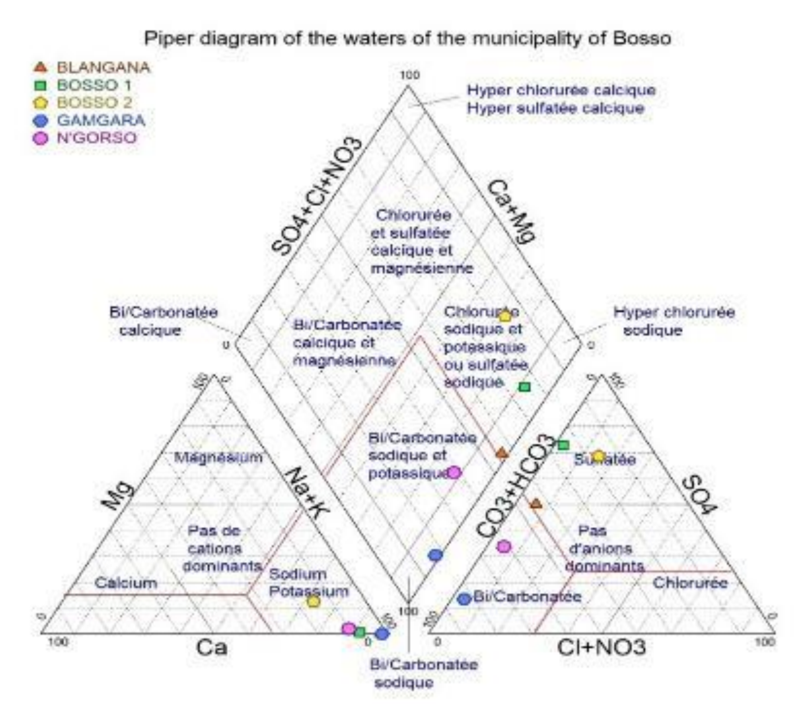

Figure 16 Hydrochemical facies of water chemical analysis results on the Piper diagram

Analysis of the figure reveals two distinct poles:

- The first pole is characterized by a sodium chloride and potassium chloride or sodium sulfate facies.
- The second pole is characterized by a sodium bicarbonate and potassium bicarbonate facies.

3.16. Stiff diagram

The representation of the water samples in the Stiff diagram confirms the existence of sodium chloride and potassium chloride or sodium sulfate facies in most of the groundwater samples from this study zone.

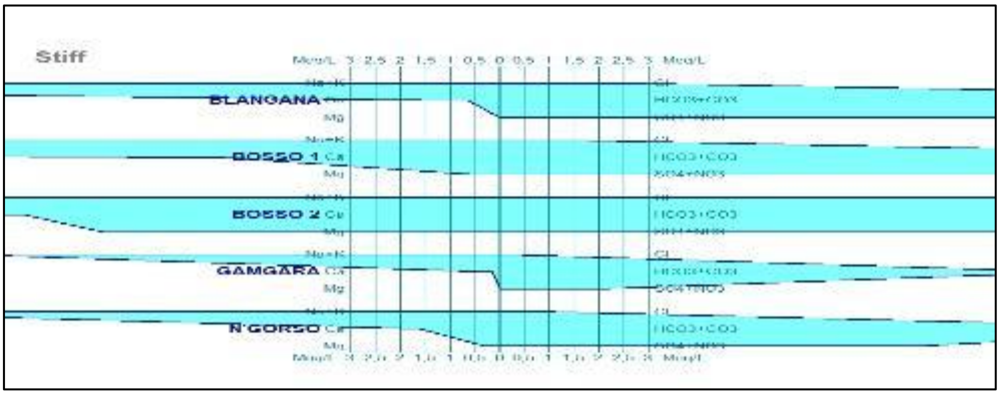

Figure 17 Chemical facies of waters obtained from Stiff's diagram

3.17. Plotting water analysis results on the Wilcox diagram

This diagram is based on the values of the sodium absorption ratio and the electrical conductivity of the ions contained in the water. The waters in the study area are plotted on the Wilcox diagram.

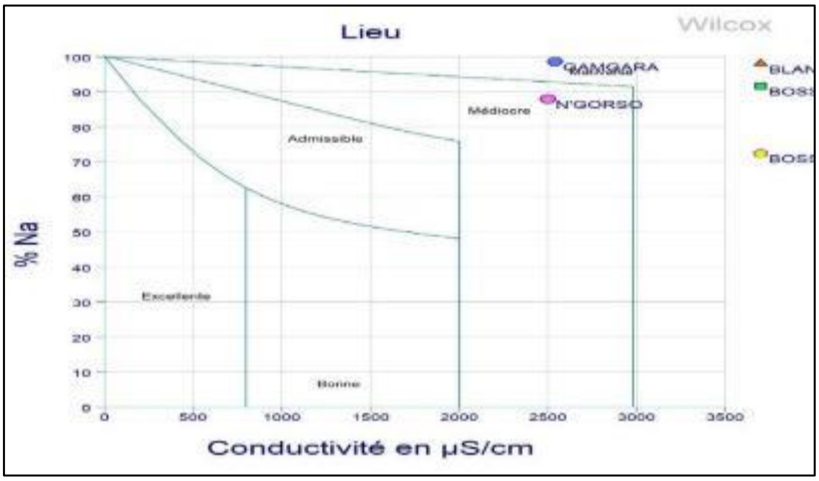

Figure 18 Water analysis results plotted on the Wilcox diagram

Analysis of the figure reveals two distinct classes:

- poor class, with electrical conductivity between 2000 and 3000 and sodium content between 0 mg/L and 100 mg/L for the water source in the village of BLANGANA;
- poor class, with electrical conductivity above 3000 and a sodium percentage between 0 mg/L and 100 m/L for the water sources in the villages of BOSSO1, BOSSO2, and N'GORSO.

3.18. Correlation circle

In order to understand the hydrochemical functioning of the hydrological system studied, the physicochemical data were subjected to a multivariate statistical study using principal component analysis (PCA). The statistical analysis covered 16 variables (electrical conductivity (EC), total hardness (TH), hydrogen potential (pH), temperature (T°), magnesium (Mg^{2+}), calcium (Ca^{2+}), potassium (K^+), sodium (Na^+), bicarbonates (HCO_3^-), carbonates (CO_3^-), nitrates (NO_3^-), nitrites (NO_2^-), chlorides (Cl^-), sulfates (SO_4^{2-}), fluorides (F^-) and total iron (FeT). The analysis of PCA variables in the F1-F2 factorial plan is represented in the figure above. The variables (EC), (TH), (SO_4^{2-}), (Cl^-), (Na^+), (K^+) and (Ca^{2+}) are well represented and show not only a very strong positive correlation between themselves but also with the F1 axis (main component (Dim 1)). This first dimension explains 57.69% of the total variance in the data. This dimension reflects the main sources of mineralization in the water in this study area. The grouping of these elements shows that they are dissolved by the same phenomenon but through different mechanisms. The Na^+, Ca^{2+}, and K^+ ions could come from the hydrolysis of silicate rocks and numerous minerals such as corrolite and sylvinite. The SO_4^{2-} and Cl^- ions could come from rainwater infiltration. This factor is considered to be a naturally occurring mineralization axis (water-rock contact or residence time). The variables most correlated with Dim 2 are: NO_3^-, NO_2^-, F-, CO_3^-, and HCO_3^-. This third principal dimension (Dim 3) explains 12.50% of the total variance in the data. This dimension includes a few major anions, whose presence could be due to pollution of mainly anthropogenic origin, either through leaching of chemical fertilizers, domestic wastewater discharges, or decomposition of organic matter.

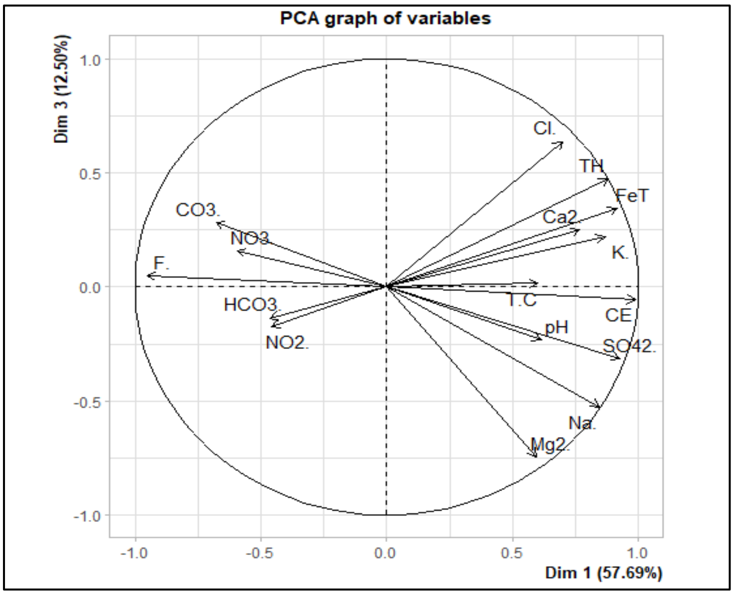

Figure 19 Correlation circle of different physicochemical parameters

4. Conclusion

The objective of this study is to determine the physico-chemical quality of borehole water in the municipality of Bosso, Diffa region (eastern Niger). The results show that the majority of samples have pH and concentrations of fluoride, nitrate, nitrite, total iron, calcium, and magnesium that comply with the drinking water standards of the WHO and the Niger Ministry of Public Health. High concentrations were observed for sulfate, chloride, and sodium ions. The high electrical conductivity in most samples, with an average of 6207 µS/cm, indicates significant overall mineralization of the water.

The overall analysis reveals that only one of the five water points studied fully meets the standards for human consumption. The identification of dominant sodium and potassium chloride or sodium sulfate chemical facies, as well as sodium and potassium bicarbonate, highlights the hydrochemical complexity of the groundwater table. In addition, the assessment for irrigation is concerning, with 80% of water points classified as poor quality and 20% as mediocre quality.

Compliance with ethical standards

Acknowledgments

I would also like to express my sincere gratitude and thanks to the staff of the Regional Directorate for Water and Sanitation (DRH/A) in Diffa in general, and in particular to Mr. Mahamane Sani MOUSTAPHA ALASSANE, hydrogeologist and head of the water analysis laboratory, who guided my first steps in water analysis, there by facilitating the completion of this work.

We would like to thank Dr. Mamane Imrana CHAIBOU OUSMANE for analyzing and interpreting the data, as well as Dr. Oumarou Farroukou MOUSTAPHA BELLO, who provided invaluable assistance in preparing this manuscript.

Disclosure of conflict of interest

The authors declare that they have no conflicts of interest.

References

[1] International Association of Hydrogeologists. 41st International Congress of the IAH “Groundwater: Challenges and Strategies” Marrakech (second circulation), (September 15-19, 2014).

[2] Sehibi, Z (2015). The Physicochemical Quality of the Waters of the OUED RHUMEL A. Master's Thesis. University of Frères Mentouri Constantine, Algeria, 52p.

[3] Naima El Hammoumi et al, (2012). Assessment of groundwater quality for use in drinking water and agriculture: Tadla plain, Morocco 54-66p.

[4] Chapman D., Kimstach V. Selection of water quality variables. Water quality assessments: a guide to the use of biota, sediments and water in environment monitoring, Chapman edition, 2nd ed. E & FN Spon, London, (1996) 59-126.

[5] Nisbet E.G. and Verneau O. Chemical components of running water, discussion and proposed classes as a basis for interpreting chemical analyses. Ann. Limn, 6(2) (1970) 161-190.

[6] Rodier J. et al. Water analysis, 9th edition. DUNOD (publisher), Paris, France. (2009) 1579.

[7] Matthess G. Geol. Mijinbouw, 53, 194. -In Forstner U and Wittmann GTW Metal pollution in the Aquatic Environment, (1994) 355-359.

[8] Deliste C.E. and Schmidt J.W. The effects of sulfur on water and aquatic life in Canada. In: Sulfur and its inorganic derivatives in the Canadian environment, NRCC No. 15015, Associated Committee on Scientific Criteria for the State of the Environment, National Research Council of Canada, Ottawa (1977).

[9] Abdoulaye Demba N’diaye, Khadijettou Mint Mohamed Salem, Mohamed Brahim El Kory, Mohamed Ould Sid’ Ahmed Ould Kankou, Michel Baudu. Contribution to the study of the spatio-temporal evolution of the physicochemical quality of water on the right bank of the Senegal River, J. Mater. Environ. Sci. 5 (1) (2014) 320-329.

[10] Samak, H. (2002) Physicochemical and bacteriological analysis at the LNS of drinking water in the city of Bamako during the period 2000 and 2001. 77.

[11] BENGOUMI M, TRAOURE A, BOUCHRITI N, BENGOUMI D and El HARAIKI A. (2004).-Water quality in poultry farming, Quarterly journal of scientific and technical information-Volume 3-No. 1, p: 5-29.

[12] RODIER. J, Water Analysis; Natural Waters; Wastewater; Seawater; Dunod Publishing, 8th edition; pages (945 to 1075), 1976.

[13] Mercier J., The Great Book of Water, Publisher: La reconnaissance du livre, Collect Art de vivre, 2000, ISBN 2-8046-0341-5 / EAN 9782804603410, p. 97.

[14] Bouziani, M. (2000). Water : from scarcity to disease, Tlemcen, Algeria : Ibn Khaldoun, Editions, ISBN : 978-9961-710-71-5, p: 247

[15] Nouayti Nordine, Driss Khattach, Mohamed Hilali. Evaluation of the physical and chemical quality of groundwater in the Jurassic aquifers of the upper Ziz basin (Central High Atlas, Morocco), 2015.

[16] Achour S., Chabbi F and Tibermacine A.A. (2017). Iron and manganese in natural waters and chemical oxidation processes. The case of Algerian waters, Larhyss Journal, 4(14), 139-154.