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RESEARCH ARTICLE

ASSESSMENT OF THE QUALITY AND POTABILITY OF GROUNDWATER FROM BOREHOLES IN THE PERIPHERAL AREAS OF NIAMEY

Ibrah Landi Ali[1], Chaibou Ousmane Mamane Imrana[2], Adamou Ibro Abdourahamane[1], Hamadou Younoussa Bachirou[3] and Manzola Abdou Salam[2]

1. Department of Chemistry, Faculty of Science and Technology, Dan Dicko Dankoulodo University of Maradi (UDDM), Maradi, Republic of Niger.
2. Abdou Moumouni University of Niamey, Materials-Water and Environment Laboratory, BP 10662 Niamey (Niger).
3. University of Dosso, Higher School of Digital Sciences.

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Abstract

The city of Niamey has experienced rapid population growth and urban expansion in recent years, leading to difficulties in accessing safe drinking water in several urban and peri-urban areas. In response to this situation, part of the population relies on water from boreholes, whose quality remains uncertain. The present study aims to evaluate the physico-chemical potability of water from selected boreholes located in the peripheral districts of Niamey. Eight samples were collected and analyzed using standardized methods, including volumetric and spectrometric techniques, at the laboratory of the Niger Water Exploitation Company (SEEN). The results show that more than 80% of the boreholes have physico-chemical quality that complies with the drinking water standards established by the World Health Organization (WHO). However, two boreholes exhibit exceedances of certain recommended chemical limits, which may pose a health risk to consumers.

Introduction:-

The issue of water has become particularly pressing today, both at the global level and in countries characterized by limited water resources. Despite the efforts of the international community to improve this situation, the problem remains alarming. Of the 783 million people who lack access to safe drinking water, more than half live in Africa (Dione, 2014). The growing gap between supply and demand, competition among different uses (agriculture, industry, tourism), pollution of water resources, and the prevalence of waterborne diseases represent major challenges for both developing and industrialized countries (Nanfack et al., 2014; Faye, 2017; Monjour et al., 2005).
In Africa, access to safe drinking water remains particularly problematic. The continent is the region of the world where urban areas are the most disadvantaged, with only half of the urban population having access to quality water (Dos Santos, 2012; AFC, 2016). Rapid population growth, combined with accelerated urbanization and difficult

Corresponding Author:-Ibrah Landi Ali
Address:-Department of Chemistry, Faculty of Science and Technology, Dan Dicko Dankoulodo University of Maradi (UDDM), Maradi, Republic of Niger.

socio-economic conditions, is places increasing pressure on available resources. In this context, some populations resort to alternative solutions for their water supply.

Given the vital importance of water, it is essential to ensure safe access to good-quality water, not only for domestic consumption and hygiene (Mohamed, 2025; WHO, 2018; Houeha, 2007), but also for essential productive activities such as agriculture. According to WHO guidelines (2020), water safety and quality are fundamental pillars of human development and well-being. Access to reliable drinking water is indeed one of the most effective means of promoting public health and reducing poverty. From this perspective, regulations related to drinking water safety constitute a central tool for health protection, both in industrialized and developing countries (Jimba& Long Sieber, 2023; Sy et al., 2014; Kamgho, 2010).Niamey, the capital of Niger, has experienced strong demographic growth for several decades (Chippaux et al., 2002; Dongo et al., 2008), accompanied by rapid urban expansion. This dynamic exerts considerable pressure on drinking water supply infrastructure, particularly in peripheral neighborhoods where public networks remain insufficient.

Faced with these constraints, a significant portion of the population relies on groundwater resources through traditional wells and boreholes. However, some of these facilities present contamination risks related to their location, the lack of adequate sanitary protection, and their proximity to potential sources of pollution.
Furthermore, in recent years there has been a multiplication of domestic boreholes (private boreholes) as well as semi-industrial boreholes intended for the commercialization of packaged water. However, most of these facilities are constructed and operated without systematic and rigorous monitoring of the physicochemical and bacteriological quality of the water.In this context, the central issue lies in assessing the quality of the groundwater exploited in Niamey and evaluating the health risks associated with its consumption. The absence of regular monitoring and compliance control therefore raises major public health and sustainable water resource management concerns.

Materials and Methods:-

Description of the Study Area:-

The city of Niamey is located in southwestern Niger, between latitudes 13°28′ and 13°35′ North and longitudes 02°03′ and 02°12′ East (Figure II-1). It covers an area of approximately 239 km² (Motcho, 2006). The Niger River flows through the city in a northwest–southeast direction. The relief is generally gentle. On the left bank of the river, upstream of the alluvial plain, there is a plateau rising to approximately 230 m above sea level. Urban development in Niamey mainly takes place on this plateau, which is covered by relatively thin CT3 formations.

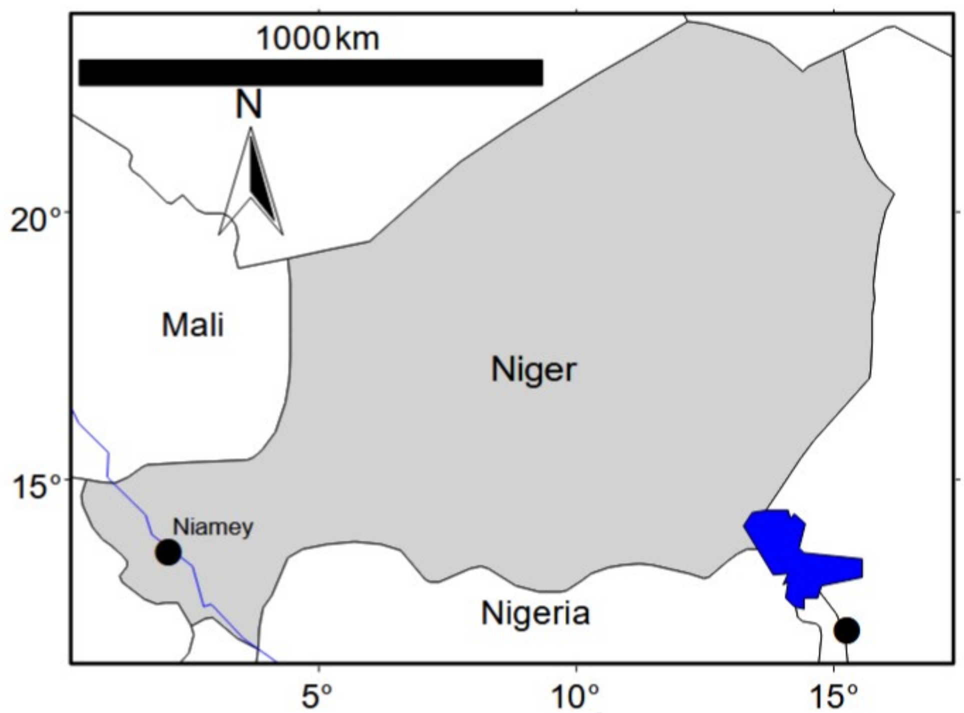

Figure 1: Study Area

Sampling:-
Water sampling constitutes a crucial step, as the reliability of analytical results and their interpretation directly depend on it (Rodier et al., 2009). The adopted procedure first consisted of allowing the water to run for approximately two (2) minutes in order to flush the system and obtain a representative sample. The flow rate was then reduced to ensure controlled sampling. The bottles were filled to the brim, avoiding any air bubbles, and then tightly sealed. The collected samples were immediately placed in a cooler to prevent any alteration.
A total of eight (8) water points were selected for sampling, as illustrated in Figure 2.

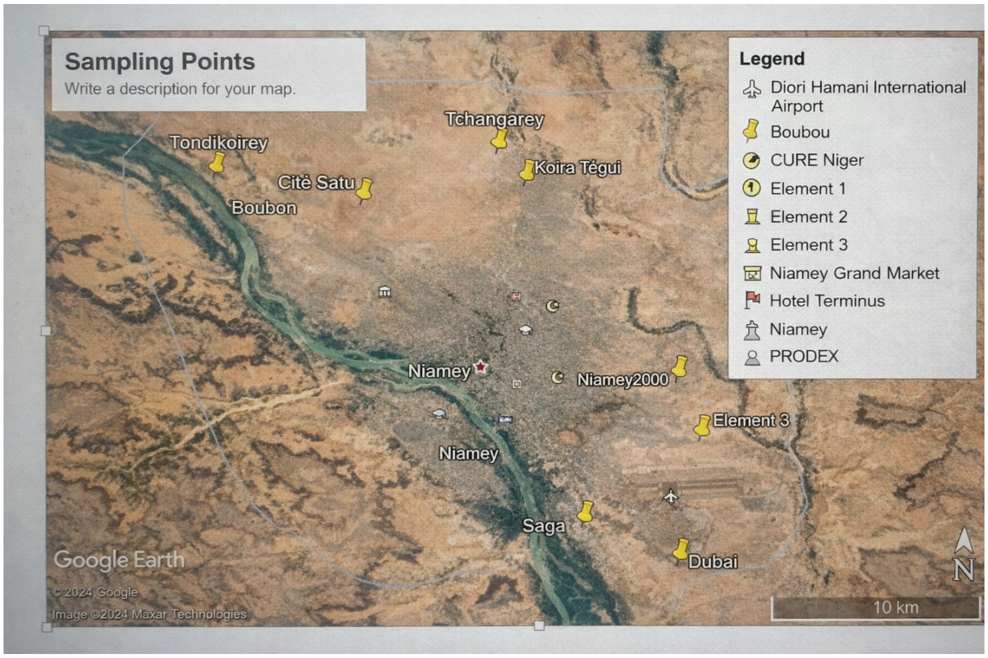

Figure 2: Sampling Points

Analysis of Physical and Chemical Parameters:-
Physical parameters were measured directly at the sampling sites, while chemical analyses were carried out in the laboratory. Concentrations of nitrates (NO_3^-), nitrites (NO_2^-), fluorides (F^-), total iron, and residual chlorine were determined by spectrophotometry using a Hach spectrophotometer. Total hardness was evaluated by complexometric titration using EDTA.

Results and Discussion:-
Tablerecap of the results:-
This table summarizes the results of all the parameters analyzed in our samples.

Table: Recap of the results

Paramètre/ Zone	Tondi Koirey	Dubaï	NY2000	Cité Satu	Tchangarey	Saga Ecole Bello	Koira tégui	Kobontafa	Normes OMS
PH	6,67	7,72	5,74	5,64	5,45	6,95	7,46	6,15	≥ 6,5- 9,5≤
Turbidité	1,28	3,3	0,14	25,6	1,3	0,5	2,78	0,64	5 NTU
Conductivité	401	194,4	71,7	36	70	2207	34,6	82,3	50 < Cond<400 µS / cm
TDS	200,5	97,2	35,9	18	35	1103,5	17,3	41,2	1000 mg/l
Fer	0	0,14	0,01	0,04	0	0	0,03	0	-

NO_3^-	34,76	5,72	14,08	2,64	8,36	7,48	2,2	2,2	50 mg/l
NO_2^-	0,0165	0,03	0,0132	0,0099	0,0165	0,0231	0,0066	0,0264	0,2 mg/l
SO_4^{2-}	4	113	0	0	0	106	0	0	400 mg/l
K^+	3,1	0,8	0,5	0,3	0,3	14,5	0,1	0,5	12 mg/l
F^-	0,12	2,46	0,69	0	0,09	0,39	0,25	0	1,5 mg/l
AS	0	0	0	0	0	0	0	0	0,01 mg/l
THa	72	788	31	21	24	678	31	31	500 mg/l
Ca^{2+}	19,6	69,2	4,4	3,6	5,6	151,6	7,6	3,6	100 mg/l
Mg^{2+}	5,59	100,9	4,86	2,92	2,43	72,66	2,92	5,35	30 mg/l
Cl^-	40	40	15	10	15	225	10	10	250 mg/l

pH:-
The hydrogen potential (pH) values of the analyzed water samples (Figure 3) range from 5.45 to 7.46. Approximately half of the boreholes show values below the lower limit of the WHO standard (6.5–9.5), indicating relative acidity of the water. This acidity may be related to several factors, including anthropogenic inputs such as the use of fertilizers and pesticides in agriculture, or the infiltration of organic and industrial waste that generates acidic compounds. Natural processes, such as the dissolution of carbon dioxide in groundwater or the weathering of silicate rocks, may also lower the pH. From a practical perspective, a pH below 6.5 can make water aggressive, promoting the corrosion of metal pipes and the release of metals into the distribution network.

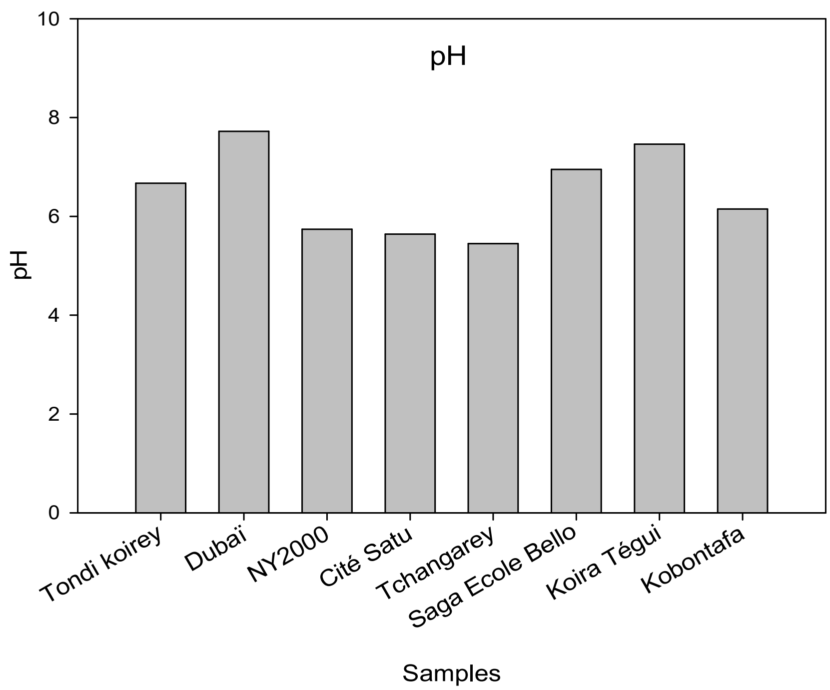

Figure 3: Hydrogen Potential (pH) Diagram

Total Dissolved Solids (TDS):-
Figure 4 presents the values of total dissolved solids (TDS) measured in the different samples. These values range from 18 mg/L to 1103.5 mg/L. The majority of the water points fall below the guideline value recommended by the WHO for drinking water (1000 mg/L). However, the Saga Éole borehole shows a particularly high content (1103.5 mg/L), slightly exceeding the standard. This high TDS concentration indicates excessive mineralization resulting from a significant presence of dissolved salts. Such a value can not only affect the organoleptic quality of the water (salty or bitter taste) but may also have adverse effects on human health, including digestive disorders (laxative effect) in sensitive individuals, as reported by Maoudo et al. (2020).

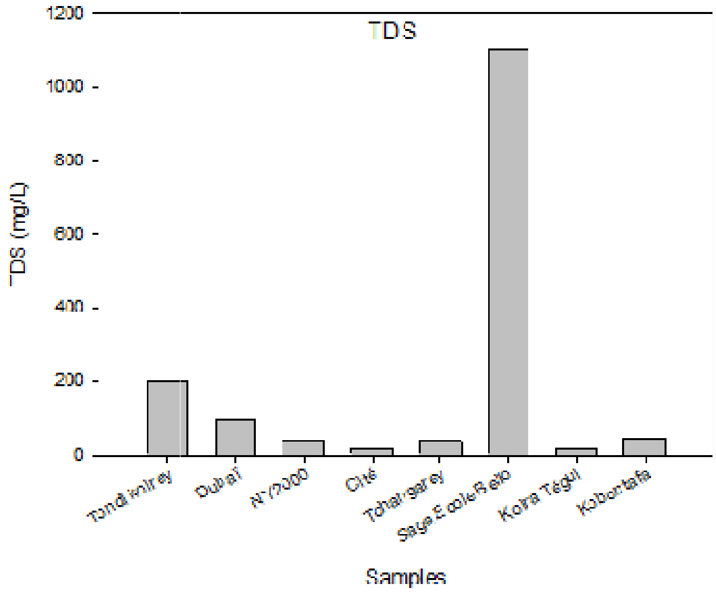

Figure 4 : TDS Diagram of the Analyzed Water Samples

Conductivity:-

The electrical conductivity values of the different water points are presented in Figure 5. Overall, the majority of the analyzed samples have values within the range recommended by the WHO for drinking water (50 ≤ EC ≤ 400 µS/cm). However, the Ny2000 and Koira Tégui boreholes show values below the minimum standard (50 µS/cm), indicating water with low mineralization and therefore low concentrations of dissolved salts. In contrast, the Saga Éole borehole exhibits a very high value (2207 µS/cm), far exceeding the WHO guideline. This water is therefore highly mineralized and should be consumed in moderation.

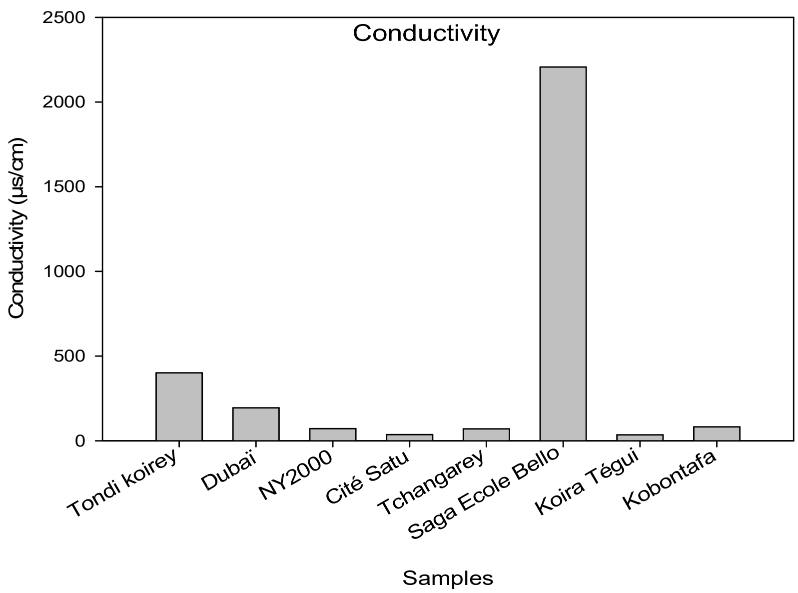

Figure 5 : Conductivity Diagram of the Analyzed Water Samples

Turbidity:-

The turbidity values of the analyzed water samples range from 0.5 to 25.6 NTU (Figure 6). The lowest value was recorded at the SAGA borehole (0.5 NTU), while the highest value was observed at the Cité Satu site (25.6 NTU). This high turbidity can be attributed to the presence of suspended materials (clays, silts, organic matter) as well as colloidal particles capable of absorbing, scattering, or reflecting light. From a regulatory perspective, the WHO guideline value for drinking water is set at 5 NTU. Thus, most of the analyzed samples fall below this threshold and are therefore compliant. However, the high turbidity recorded at Cité Satu (25.6 NTU) far exceeds this standard, which could not only affect the aesthetic quality of the water (cloudiness, coloration) but also promote the growth of microorganisms by protecting pathogens from the disinfectant action of chlorine.

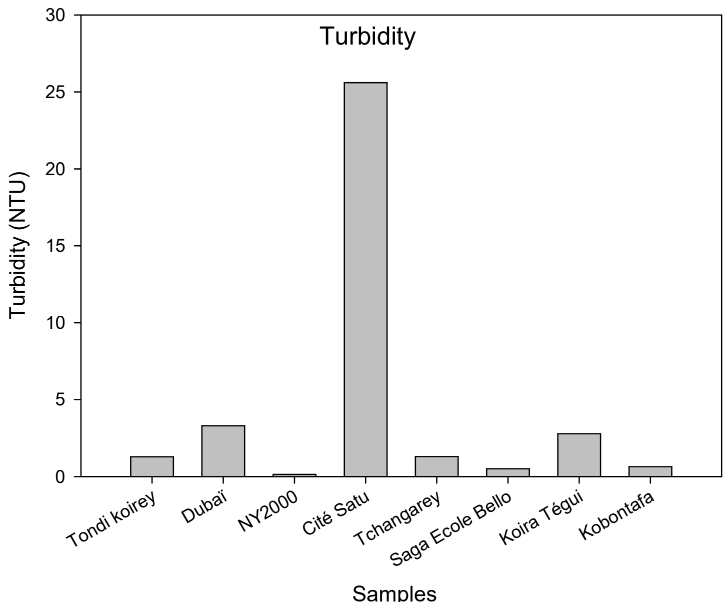

Figure 6 : Turbidity Diagram of the Analyzed Water Samples

Nitrates:-

The analysis results show that nitrate concentrations in the different water points (Figure 7) range from 2.2 to 34.76 mg/L. All these values remain below the maximum limit of 50 mg/L set by the World Health Organization (WHO) for water intended for human consumption. This situation reflects good water quality with respect to the nitrate parameter, suggesting a low influence of anthropogenic activities. However, the highest value recorded (34.76 mg/L) at the Tondi Koirey borehole, although below the standard, could indicate a local vulnerability of the borehole to diffuse pollution, probably linked to agricultural practices or the proximity of human activities generating domestic waste (Adjagodo, A. et al., 2016; Soltani Chamse Eddine, T.A., 2023; Youmbi et al., 2013). From a health perspective, these concentrations do not pose an immediate risk to the population, particularly regarding the risk of infant methemoglobinemia, which is often associated with nitrate levels exceeding the standard. However, regular monitoring is necessary to prevent any progression toward critical levels, especially in peri-urban neighborhoods where pressure on water resources is increasing.

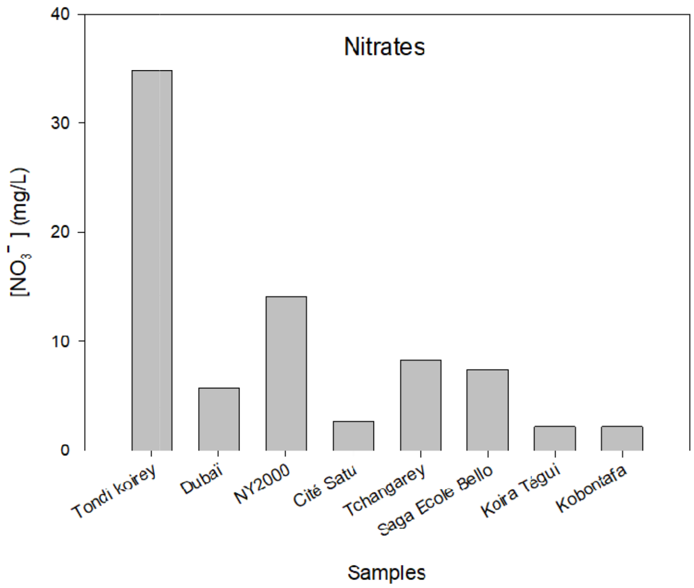

Figure 7 : Nitrate Diagram of the Analyzed Water Samples

Nitrites:-

The concentrations of nitrite ions measured in the analyzed water (Figure 8) range from 0.013 to 0.03 mg/L. These values are well below the limit recommended by the World Health Organization (WHO) for water intended for human consumption, indicating good sanitary quality with respect to this parameter. This further supports the potability and health safety of the water concerning the metabolic risk associated with nitrites (methemoglobinemia, particularly in infants) (Faivre, J., et al., 1976; Chébékoué, S. F., 2008). The low nitrite content can be explained by limited denitrification activity in the aquifer or by a notable absence of recent organic pollution.

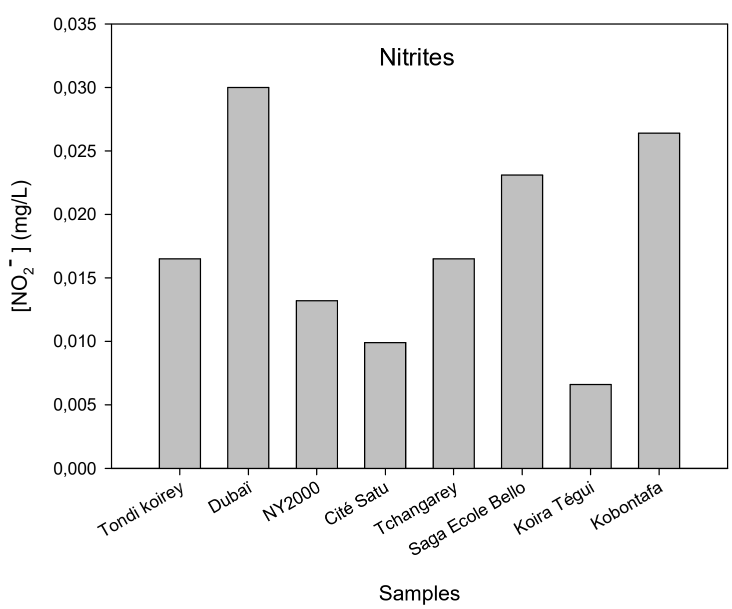

Figure 8 : Nitrite Diagram of the Analyzed Water Samples

Chloride Ions:-

Figure 9 illustrates the variation in chloride ion concentrations in the analyzed borehole waters. The values range from 10 to 225 mg/L, which remain below the maximum limit of 250 mg/L set by the World Health Organization (WHO) for water intended for human consumption. These results indicate that the groundwater in the study area complies with the potability standard regarding chlorides. From a health perspective, the measured concentrations do not pose a risk for consumption.

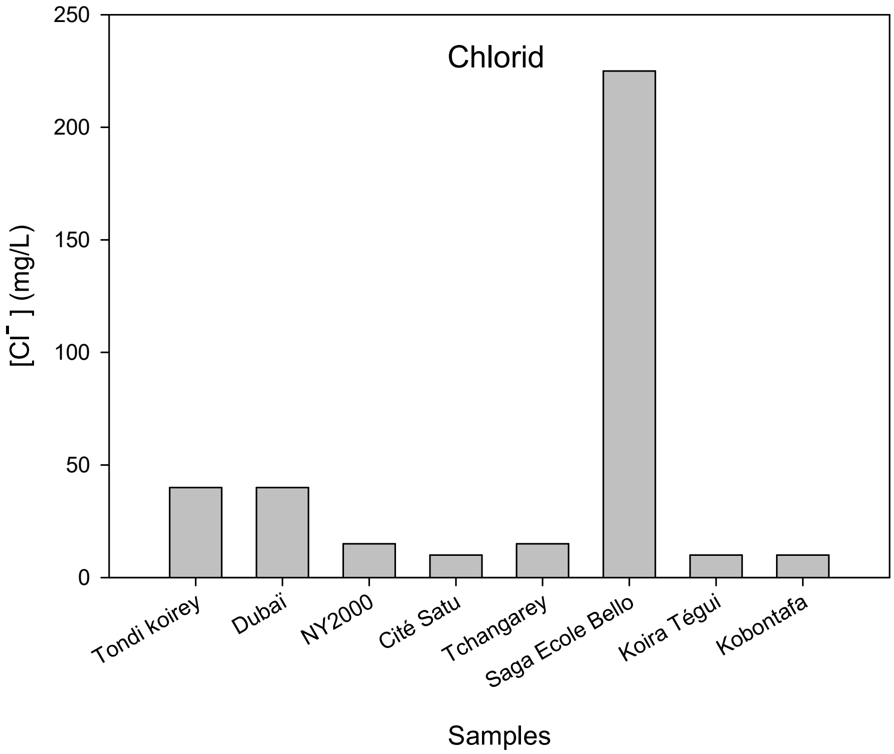

Figure 9 : Chloride Diagram of the Analyzed Water Samples

Fluoride Ions:-

Figure 10 presents the variation in fluoride ion concentrations in the analyzed water samples. Overall, the results show that most water points comply with the 1.5 mg/L limit set by the World Health Organization (WHO). However, a notable exception is observed at the Dubai neighborhood borehole, where the concentration reaches 2.46 mg/L, exceeding the guideline value. This elevated concentration could be explained by the geological nature of the aquifer, particularly the dissolution of fluoride-bearing minerals (fluorite, apatite) present in certain formations. Such a value, above the standard, exposes consumers to long-term health risks, particularly dental fluorosis, and, with prolonged ingestion, skeletal fluorosis. This situation highlights the need for enhanced monitoring of this borehole, as well as the implementation of appropriate solutions (blending with low-fluoride water, defluoridation techniques) to ensure the health safety of the local population.

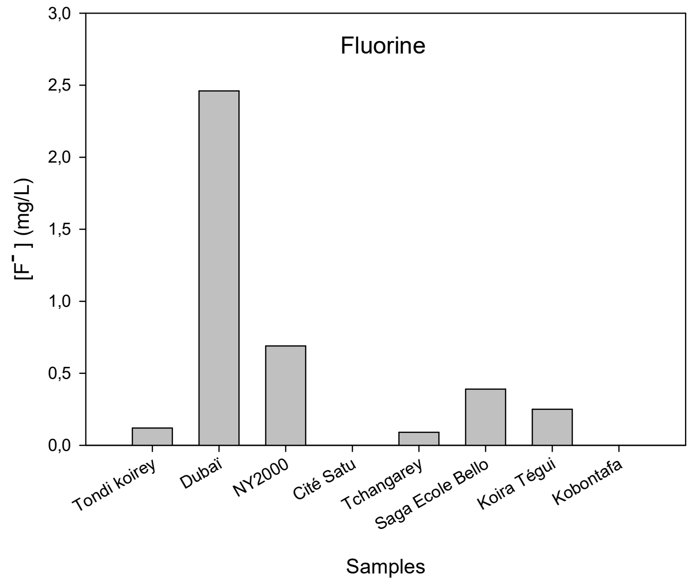

Figure 10 : Fluoride Diagram of the Analyzed Water Samples

Sulfate Ions:-
The sulfate ion concentrations measured in the groundwater (Figure 11) range from 0 to 106 mg/L. These values are well below the WHO guideline value of 500 mg/L. Thus, the analyzed waters do not pose risk associated with high sulfate levels. This low content may reflect limited contribution from sulfate-bearing geological formations (such as gypsiferous or evaporitic formations) to the chemical composition of the region's waters. It also confirms that the waters remain suitable for human consumption with respect to this parameter.

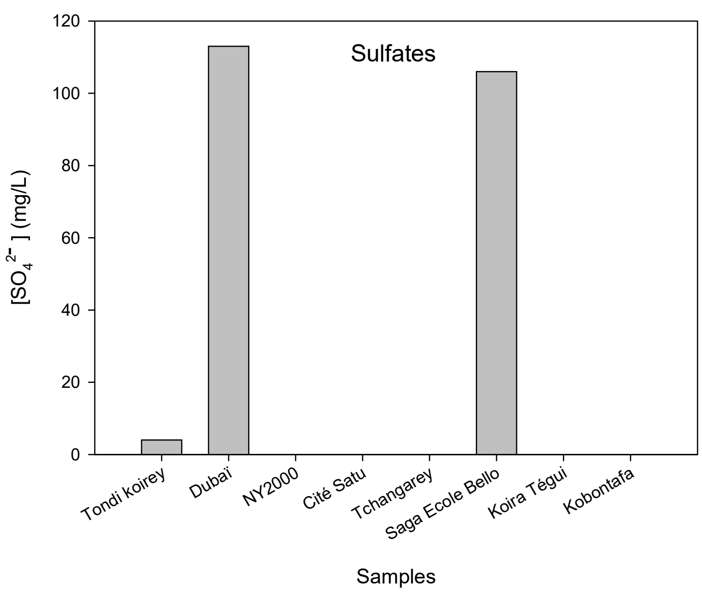

Figure 11 : Sulfate Diagram of the Analyzed Water Samples

Total Iron:-
The total iron concentrations in the analyzed groundwater (Figure 12) range from 0 to 0.14 mg/L. All these values are below the WHO guideline limit of 0.3 mg/L. Therefore, the studied waters do not present a risk of discoloration, iron deposits, or organoleptic alteration (metallic taste), which are often associated with high iron content (FakhfekhHamdeni, R., 2017). These results likely reflect low mineralization of the aquifers in iron-bearing

minerals and suggest that the conditions for iron dissolution (pH, oxygenation, rock type) do not favor significant mobilization of this element in the study area.

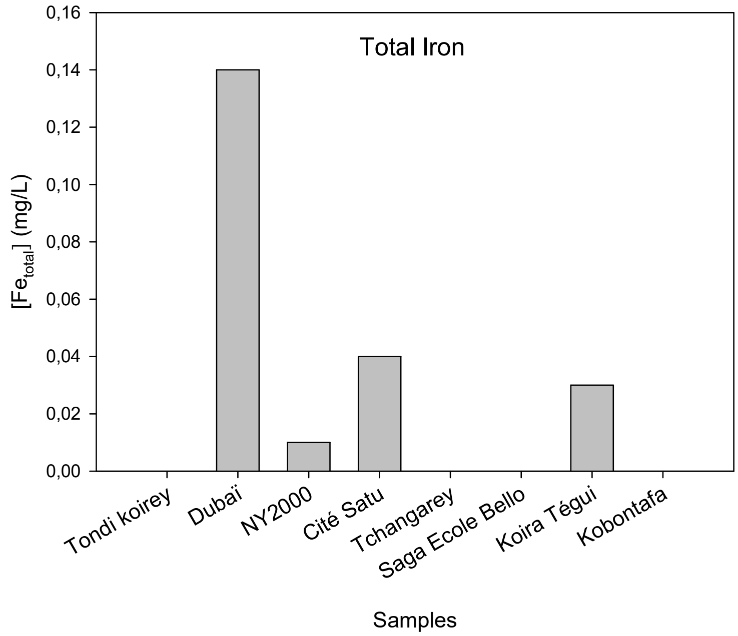

Figure 12 : Total Iron Diagram of the Analyzed Water Samples

Total Hardness (TH):-

The total hardness (TH) of the analyzed groundwater ranges from 21 to 788 mg/L (Figure 13). The highest values, Total hardness of the groundwater ranges from 21 to 788 mg/L, reflecting considerable variability in mineralization. The boreholes located in the Dubai neighborhood and at Ecole Bello Saga exhibit the highest values, indicating significant dissolution of carbonate and/or gypsum-bearing rocks within the aquifer.

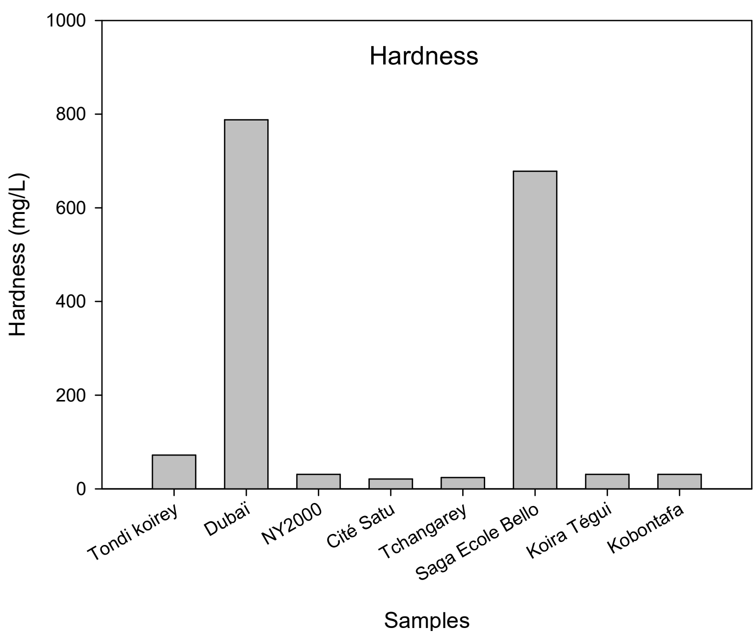

Figure 13 : Total Hardness Diagram of the Analyzed Water Samples

Hydrochemical Facies Analysis Using the Piper Diagram:-

The Piper diagram indicates that the groundwater is predominantly of the Ca–Mg–Cl–SO_4 hydrochemical facies, reflecting a relatively homogeneous chemical composition dominated by calcium, magnesium, chloride, and sulfate ions. The Kobontafa sample stands out by its evolution toward a Ca–Cl facies, marked by higher chloride and nitrate contents. Overall, groundwater mineralization appears to be controlled by both water–rock interactions and anthropogenic influences, particularly domestic and agricultural activities, revealing spatial variability in groundwater quality across the study area.

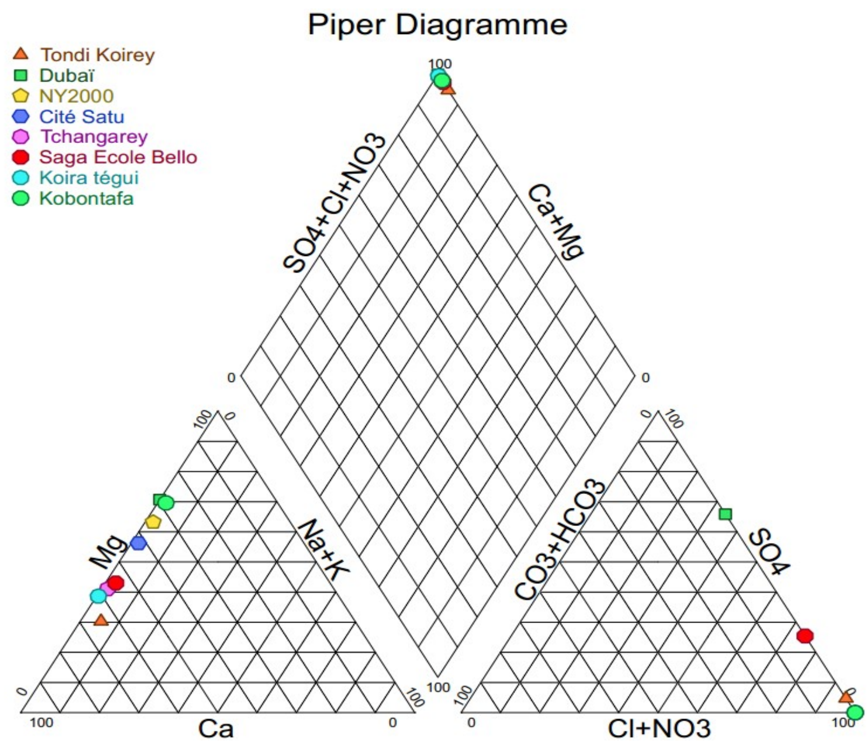

Figure 14:Hydrochemical Facies

Conclusion:-

The study showed that the majority of the physicochemical parameters of the groundwater comply with the World Health Organization (WHO) drinking water standards. The waters exhibit a slightly acidic to neutral pH and a low to moderate degree of mineralization depending on the site. Only the Saga and Dubai boreholes showed certain parameters exceeding the recommended limits. Overall, the waters are soft to moderately hard and display satisfactory physicochemical quality. It should be noted, however, that this study was limited to physicochemical analyses, as its main objective was to assess potential chemical contamination of the groundwater. In this context, the parameters analyzed provide sufficient information to meet the study objectives and to evaluate the chemical quality of the investigated waters.

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