**Physico-chemical Potability Assessment of Groundwater in Selected Localities of the Agadez Region: A Case Study of the Urban Commune of Agadez and the Rural Communes of Dabaga, Gougaram, and Ingall**

**Abstract**  
Groundwater represents the main source of drinking water supply for the populations in the Agadez region, primarily through wells and boreholes. This study aims to evaluate the physico-chemical quality of groundwater in four communes of the region: the urban commune of Agadez and the rural communes of Gougaram, Dabaga, and Ingall. Sampling was conducted according to the protocol described by Rodier, and the analysis focused on eleven (11) physico-chemical parameters determined by spectrophotometry, titrimetry, and direct reading. The results show that in the urban commune of Agadez, most samples comply with WHO standards, except for borehole F4, which exhibited a fluoride concentration of 5.6 mg/L, well above the recommended limit of 1.7 mg/L. In the commune of Dabaga, high nitrate concentrations were observed in well samples P2 (52.36 mg/L) and P3 (55.44 mg/L). These samples also showed abnormally high nitrite levels, reaching 1.62 mg/L and 15.84 mg/L respectively, greatly exceeding permissible limits. In Gougaram, although most analyzed waters comply with WHO standards, samples P2 and F5 showed significant exceedances of nitrites, nitrates, and hardness. Borehole F1 also stands out with very high fluoride concentration. Finally, in the rural commune of Ingall, most samples comply with WHO standards, except for boreholes F2 and F3, which present elevated values of conductivity and fluoride, surpassing the recommended thresholds.

**Keywords:** Groundwater, Quality, Physico-chemical, Agadez, Dabaga, Gougaram, Ingall.

**1. Introduction**

Water is a vital and indispensable resource for all forms of life. Although the Earth is largely covered by water, only **2.5% of this resource consists of freshwater,** which is essential for the survival of human, animal, and plant species (Gilli, 2012).

Among these reserves, groundwater plays a crucial role in supplying drinking water in many regions around the world. However, this resource, once known for its quality, is now severely threatened by multiple sources of contamination, both point and diffuse (S.G. Eblin et al., 2014). This situation is especially concerning in rural areas, where access to quality water becomes a critical issue due to the increasing degradation of the environment and pollution of natural resources.

The consumption of contaminated groundwater can have serious consequences on human and animal health, as well as on ecosystem balance. Indeed, people using such water as drinking water are exposed to diseases in the short or long term. In many regions, groundwater is the **only available source of water** for domestic consumption, agriculture, and industry. Thus, what should be a source of life sometimes becomes a source of disease.

Given these challenges, it is imperative to implement **concrete and specific actions** to prevent pollution risks, preserve the natural quality of groundwater, and ensure its sustainable availability (Corneille Bakouan et al., 2017).

Groundwater, whether from confined or unconfined aquifers, is widely exploited by humans for various uses. However**, shallow aquifers** are particularly vulnerable to contamination, especially due to human activities (Bouselsal Boualem et al., 2015; Halimatou Sadia Sani Oumarou et al., 2018).

The **chemical composition** of groundwater varies greatly depending on the geological nature of the formations it traverses and on physico-chemical interactions with substances encountered during flow. Although the African continent has significant water resources, it suffers from a lack of distribution and sanitation infrastructure, preventing a large portion of the population from accessing quality drinking water (Abdou Salam Fall et al., 2017).

Niger, like other Sahelian countries, faces major water-related challenges, sometimes particularly severe in certain localities. Although the country is crossed by a major watercourse—the Niger River and has considerable groundwater resources (Hassane, 2010), managing these resources and adequately supplying the population, both in urban and rural areas, remains a major challenge.

In urban areas, groundwater is subjected to many pressures, notably due to rapid population growth and the insufficiency or even absence of adequate sanitation systems (H. Amadou et al., 2014). This situation increases the risk of contamination of aquifers and compromises the quality of water intended for consumption.

In recent years, **preserving water quality** has become an essential requirement, both for environmental protection and for public health. Whether for human consumption or industrial use, water quality must be rigorously controlled.

In the Agadez region, groundwater represents the main source of drinking water supply (Illias Alhassane et al., 2019). Water supply to rural populations there is mainly ensured by wells and boreholes. However, apart from some physico-chemical analyses performed after drilling and before making the facilities available, water quality is generally not regularly monitored.

It is in this context that the present study was initiated, with the objective of assessing the physico-chemical potability of groundwater in selected localities of the Agadez region.

**2. Materials and Methods**

**2.1. Water Sampling Method**

Sampling for physico-chemical analysis is of great importance, as the results directly reflect the chemical characteristics of the collected water. Samples must be taken in clean containers, rinsed several times with the water to be analyzed, and then tightly sealed without leaving any air bubbles inside. The bottles must be clearly labeled and transported in coolers, as described by Rodier et al. (2009).

In total, thirty (30) water samples were analyzed, distributed as follows:

Seven (07) samples were collected from the urban commune of Agadez (CUAZ), as detailed in Table I.

Table I: Sampling locations in the urban commune of Agadez

|  |  |
| --- | --- |
| **Collection location (Location)** | **Origin of water** |
| Toudou district | drilling (F1) |
| Toudou district | drilling (F2) |
| Next to the stand | Private drilling (F3) |
| Birdagh | drilling (F4) |
| Ikirkiwi Ibizgane | drilling (F5) |
| Hospital | drilling (F6) |
| Adoua district | drilling (F7) |

• For the rural commune of Dabaga (CRD) eight points were sampled, which are recorded in Table II.

Table II: Sampling locations Rural commune of Dabaga

|  |  |
| --- | --- |
| **Collection location (Location)** | **Origin of water** |
| Tassalam-Salam | Cemented Well **(**P1) |
| Ajighir | Cemented Well (P2) |
| Intatat | Cemented Well (P3) |
| Kowilla | Cemented Well (P4) |
| Tchizé | Cemented Well (P5) |
| Boughol | Cemented Well (P6) |
| Maraba Aoudaras | Cemented Well (P7) |
| Assada /Aoudrass | Cemented Well N° (P8) |

• In the rural commune of Gougaram (CRG), samples were collected and grouped in Table III.

Table III Dates and Places of Sampling Rural Commune of Gougaram

|  |  |
| --- | --- |
| **Collection location** | **Origin of water** |
| Mazlélé | Cemented Well /Elh Mouhamad (P1) |
| Ezil | drilling (F1) |
| Hadabdalé | Cemented Well (P2) |
| Tchimazel | drilling (indien)(F2) |
| Ebargass | drilling MCF/PASEHA3 (F3) |
| Tassalat | drilling (F4) |
| Tchissawalene | drilling (F5) |

• Finally, in the rural commune of Ingall (CRI), eight points were sampled.

Table IV: Dates and Locations of Sampling in the Rural Commune of Ingall

|  |  |
| --- | --- |
| **Collection location** | **Origin of water** |
| Bintina | Private drilling (F1) |
| Tiguidan-Tessoum | drilling (PASEHA 3) (F2) |
| Téguirwit | drilling (F3) |
| Téguirwit2 | drilling (F4) |
| Téguirwit 1 | drilling (F5) |
| Injigaren | drilling (F6) |
| Injitène | drilling (F7) |
| Injitène | drilling (F8) |

**2.2. Analysis of Physical and Chemical Parameters**

The parameters measured at the sampling sites include temperature and pH. However, all other parameters were analyzed in the laboratory.

Ions such as nitrates (NO₃⁻), nitrites (NO₂⁻), total iron, fluorides (F⁻), and residual chlorine were determined by spectrophotometry using the Palintest 7100 spectrophotometer. Water hardness was determined by titrimetry using EDTA.

**3. Results and Discussion**

**3.1. Temperature**

The temperatures obtained for the different samples studied are presented in Figure 1.

For the urban commune of Agadez, the results show that the minimum recorded temperature was 22.5 °C in borehole (F7), while the maximum temperature was 24.9 °C in borehole (F4), with an average of 23.78 °C. The majority of the temperatures tend towards ambient temperature (25 °C), as noted by H. Amadou, LAOUALI M.S, and MANZOLA A. (2014).

For the commune of Dabaga, the minimum temperature is 21.3 °C, and the maximum temperature is 25.5 °C. In the rural commune of Gougaram, the minimum temperature is 20.3 °C, while the maximum is 26.7 °C. Finally, for the samples from the rural commune of Ingall, the minimum measured temperature is 21.3 °C, and the maximum temperature is 24.5 °C.

However, all of these measured temperature values do not have a significant impact on the variability of certain inorganic and microbiological parameters of the water.

Figure 1: Diagram of water temperatures studied for the four (4) municipalities

**3.2. pH**

According to Figure 2, in the urban commune of Agadez, pH values range from 6.9 to 8.2, with an average value of 7.49. It is observed that the boreholes comply with the WHO (2017) guidelines, which set pH values between 6.5 and 8.5. This pH compliance was observed in all samples from the rural commune of Dabaga. In the rural commune of Gougaram, the recorded pH values also comply with regulations for water intended for human consumption. In the rural commune of Ingall, most of the waters are alkaline, with a minimum value of 7.8 and a maximum value of 9.1, giving an average of 8.47. However, in some samples, the pH value exceeds the upper limit recommended by WHO, which suggests a pH range between 6.5 and 8.5. This may be due to the geological nature of the terrain.

Figure 2: Variation in the pH of the waters studied for the four (4) municipalities

**3.3. Conductivity**

The conductivity values obtained for the different water samples studied in the various communes are shown in Figure 3.

The results for the urban commune of Agadez show that the conductivity of the water is within the normal range, varying from 194 μS/cm (F7) to 850 μS/cm (F6), with an average of 376.42 μS/cm. These results indicate that the water is lightly mineralized.

In contrast, for the rural commune of Dabaga, a very high maximum conductivity of 2300 μS/cm was recorded for well P3, with a minimum value of 250 μS/cm. The average conductivity of this water is 773.25 μS/cm.

High conductivity values of 1180 and 1562 μS/cm were respectively recorded for boreholes F1 and F2 in the rural commune of Gougaram. The average conductivity of these waters is around 737.71 μS/cm, indicating that the water is moderately mineralized.

Very high conductivity values of 9010 and 3240 μS/cm were recorded for boreholes F2 and F3 in the commune of Ingall. With an average value of 2053.12 μS/cm, these results exceed the WHO (2017) recommended range of 180 to 1000 μS/cm. These high values are likely due to the dissolution of certain geological formations of the aquifer (Maman Sani Abdou Babaye et al., 2016).

Figure 3: Conductivity of the waters studied for the four (4) municipalities

**3.4. Chlorides (Cl⁻)**

The chloride concentrations (Figure 4) are below the drinking water standard (250 mg/L) in all the samples studied from all the communes, with average values of 0.017 mg/L, 0.095 mg/L, 0.0385 mg/L, and 0.00625 mg/L for the urban commune of Agadez (CUAZ), the rural commune of Dabaga (CRD), the rural commune of Gougaram (CRG), and the rural commune of Ingall (CRI), respectively. These results are in compliance with WHO standards (2017).

Figure 4: Variation in chlorides in the waters studied for the four (4) municipalities

**3.5. Nitrates (NO₃⁻)**

The results of the nitrate ion analyses (Figure 5) show that, for the urban commune of Agadez, the minimum value is 16.28 mg/L (F5) and the maximum value is 47.17 mg/L (F6), with an average of 34.99 mg/L. These results indicate that the nitrate concentrations in the eight boreholes are below the WHO (2017) standard of 50 mg/L for water intended for human consumption. However, slight increases in nitrate concentrations are observed at wells P2 (52.36 mg/L) and P3 (55.44 mg/L) in the rural commune of Dabaga. For the samples from the rural commune of Ingall, the average is 26.33 mg/L.

However, for the rural commune of Gougaram, a high value of 293 mg/L was recorded at well P2, along with a slight increase at borehole F5 (54.56 mg/L). These high values could be due to agricultural and livestock activities, as reported by Amadou Haoua et al. (2014) and by Marou Gourouza et al. in (2009).

Figure 5: Diagram of nitrates in the waters studied for the four (4) municipalities

**3.6. Nitrites (NO₂⁻)**

In the boreholes studied in the urban commune of Agadez, as shown in Figure 6, the results indicate that nitrite ion concentrations are below the WHO limit of 3 mg/L. The same observation applies to samples from the rural communes of Ingall, Gougaram, and Dabaga, except for well P3 in the rural commune of Dabaga, which shows a high value of 15.84 mg/L. This elevated level could be related to agricultural activities.

Figure 6: Variation of nitrites in the waters studied for the four (4) municipalities

**3.7. Bicarbonates (HCO₃⁻)**

The bicarbonate concentrations (Figure 7) in our water samples range from 122 mg/L to 292.8 mg/L in the urban commune of Agadez. In the rural commune of Dabaga, the values range from a minimum of 91.5 mg/L to a maximum of 347.7 mg/L. For the rural commune of Gougaram, the lowest value recorded is 46.4 mg/L, and the highest is 299 mg/L. Finally, in the rural commune of Ingall, concentrations range from 35 mg/L to 435 mg/L. A particularly high value of 622.2 mg/L was recorded at borehole F2 in this commune.

These high bicarbonate concentrations observed in certain sampling points may be explained by the dissolution of carbonates and/or the hydrolysis of silicates under the influence of meteoric water more or less enriched in CO₂, as reported by Rabilou et al. (2018).

Figure 7: Variation in bicarbonate of the waters studied for the four (4) municipalities

3.8. Total Hardness (TH)

The total hardness levels in our water samples (Figure 8) range from 35 to 150 mg/L of CaCO₃ in the urban commune of Agadez. In the rural commune of Dabaga, the minimum value is 55 mg/L of CaCO₃, and the maximum is 240 mg/L of CaCO₃. In the rural commune of Gougaram, values range from 65 mg/L to 410 mg/L of CaCO₃. Finally, in the rural commune of Ingall, hardness values range from a minimum of 5 mg/L to a maximum of 140 mg/L of CaCO₃, with an average of 41.87 mg/L of CaCO₃.

The variation in total hardness (TH) observed in the water from different wells and boreholes may be related to the geological nature of the soil, particularly its magnesium and calcium content. According to WHO (2017) drinking water guidelines, an acceptable range for total hardness is between 100 and 300 mg/L of CaCO₃. These results indicate that the sampled waters are generally soft to moderately hard.

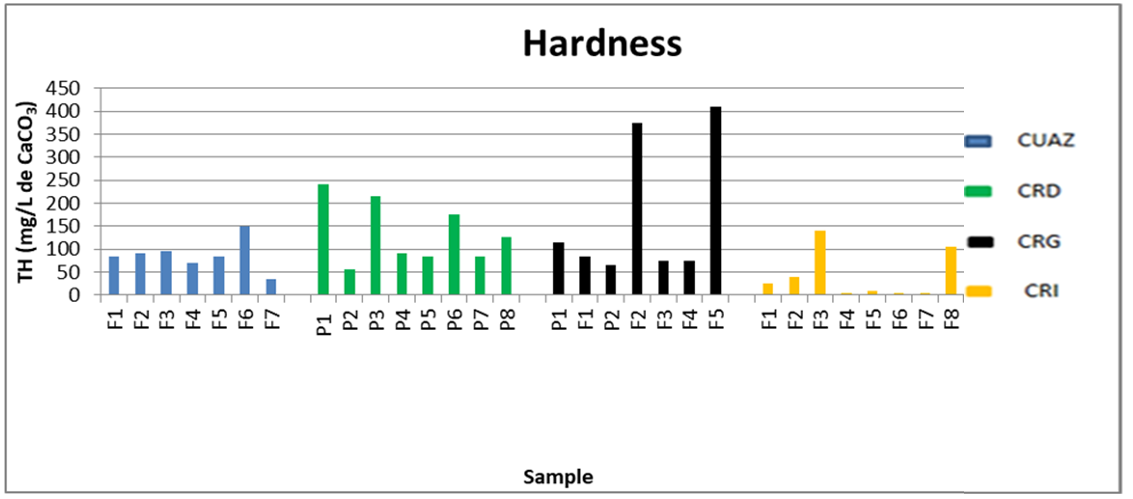


Figure 8: Variation in the hardness of the water studied for the 4 municipalities

**3.9. Total Iron**

The analysis of the samples (Figure 9) shows that the total iron content in the water from all the communes complies with the WHO (2017) drinking water standard of 0.3 mg/L, except for borehole F5 in the urban commune of Agadez, which recorded a high value of 7 mg/L. This elevated level may be related to the nature of the piping used in that particular installation.

Figure 9: Total iron content of the waters of the 4 municipalities studied

3.11. Fluoride (F⁻)

Fluoride concentrations in our water samples (Figure 10) range from 0.14 mg/L to 5.6 mg/L in the urban commune of Agadez. In the rural commune of Dabaga, the minimum value is 0.45 mg/L and the maximum is 3.2 mg/L. In the rural commune of Gougaram, values range from 0.17 mg/L to 7.9 mg/L. Finally, in the rural commune of Ingall, fluoride levels range from a minimum of 0.02 mg/L to a maximum of 11.25 mg/L.

The WHO (2017) guideline value for fluoride in drinking water is 1.5 mg/L. However, some of the values obtained in this study exceed this limit significantly. These findings are consistent with those reported by Mahamadou HIMA et al. (2019).

Figure 10: Variation in fluoride in the waters of the 4 municipalities studied

**4. Conclusion**

This study focused on evaluating the physico-chemical quality of groundwater in four (4) communes of the Agadez region. The results obtained show that most of the analyzed parameters comply with the drinking water standards set by the World Health Organization (WHO). However, certain water points display elevated levels for some parameters, particularly fluoride, nitrates, nitrites, conductivity, and total hardness. These exceedances, observed in a few boreholes and wells, warrant special attention due to the potential health risks involved. It is therefore recommended to implement regular monitoring of groundwater quality and to apply appropriate corrective measures for non-compliant water points, in order to ensure safe drinking water for the affected populations.

Disclaimer (Artificial intelligence)

We; Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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