**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 is the main source of drinking water for the population of the Agadez region, primarily accessed through wells and boreholes. This study aims to assess the physico-chemical potability of groundwater in four (4) communes of the Agadez region: the urban commune of Agadez and the rural communes of Gougaram, Dabaga, and Ingall. Sampling was conducted by Rodier's protocol, and nine (09) parameters were analyzed using spectrophotometry, titrimetry, and direct reading methods. The results show that most groundwater samples from the urban commune of Agadez comply with WHO drinking water standards, except for borehole F4, which recorded a high fluoride concentration (5.6 mg/L), significantly exceeding the WHO limit (1.7 mg/L). In Dabaga, high nitrate concentrations above the permissible limit were observed in well samples P2 (52.36 mg/L) and P3 (55.44 mg/L), along with excessive nitrite levels in the same samples (P2: 1.62 mg/L; P3: 15.84 mg/L). In Gougaram, while most samples met WHO standards, samples P2 and F5 showed elevated levels of nitrites, nitrates, and total hardness. Borehole F1 also had a very high fluoride content. In the rural commune of Ingall, most samples complied with WHO standards, except for samples F2 and F3, which showed elevated values of conductivity and fluoride ions exceeding recommended limits.

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

**1. Introduction**

Water is a vital and fundamental source that humans generally seek. In the universe, the Earth contains 2.5% of fresh water, yet it is an essential element for the survival of a species, not only human but also animal and plant (Gilli, 2012).

Groundwater is of paramount importance in most regions of the world. However, this resource, which was once of good quality, is currently threatened by various point and diffuse sources of contamination (S.G. Eblin et al., 2014). Access to it by rural populations for drinking has become a crucial problem due to environmental and natural resource pollution. Groundwater contaminated by various pollutants that render it unfit for consumption can endanger human and animal life as well as the environment as a whole. People who use contaminated groundwater as drinking water may suffer from diseases in the future. Many regions of the world depend entirely on groundwater resources for various uses. As a result, water, which is a source of life, becomes a source of disease. Specific concrete actions are therefore necessary to control the risk of water pollution and protect the natural quality of groundwater (Corneille BAKOUAN et al, 2017).

Groundwater from confined and surface aquifers is a water resource exploited by humans for various uses. The chemical composition of water from the natural environment is highly variable. It depends on the geological nature of the soil from which it originates and also on the reactive substances it may have encountered during flow. The African continent, the poorest on the planet, has significant water resources. However, it lacks the distribution and sanitation infrastructure that would allow African populations to access drinking water (NTOUTOUME, 2012).

Niger, like other Sahelian countries, faces water problems that can be quite serious in certain localities. The country is certainly crossed by a major watercourse, the Niger River, and also contains significant groundwater reserves (Hassane, 2010). However, there is the problem of controlling the resource and supplying different consumers in both urban and rural areas. Indeed, groundwater in urban areas is subject to multiple constraints due to strong population growth and the unsuitability or even absence of sanitation (H. Amadou et al, 2014).

In recent years, water quality has become a major and mandatory operation to protect the environment and the health of living beings, or to exploit it for human consumption or industrial use.

Groundwater constitutes the main source of drinking water for the population in the Agadez region. Indeed, in this region, the drinking water supply for rural populations is provided by wells and boreholes. Most of these structures, apart from a few physicochemical analyses conducted to ensure the potability of the water after drilling and before delivery to the population, do not undergo any regular quality control. Therefore, this work was initiated to assess the physicochemical potability of groundwater in several localities in 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 in the aquifer (Kherici, 1993).

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 attributed to agricultural and livestock activities, as reported by Amadou Haoua et al. (2014).

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.

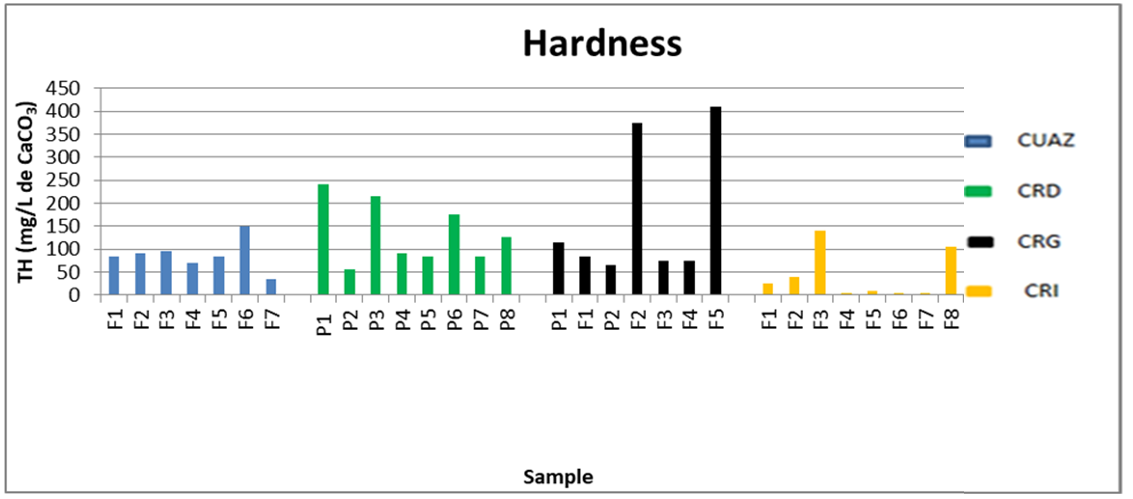


Figure 8: Variation in the hardness of the water studied for the 4 municipalities

**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.

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