Python-Based Water Quality Evaluation of TranzaandAlbarikaWells

Abstract

Introduction: The increase in waterborne diseases in certain remote areas of Benin led the study to conduct surveys on the different waters used by these inhabitants.

Aims: This study is conducted to assess the probable risks related to the physicochemical and bacteriological quality of well water consumed by the population of the Tranza and Albarika neighborhoods.

Place and Duration of Study: Water samples were collected from 20 wells (open and closed in Albarika and Tranza districts) in the Parakou commune and analyzed at the LaKReCA laboratory between April and July 2024.

Methodology:A two-stage methodology was used to approach this study. Thus, a survey was conducted with the aim of determining the actual fraction of the population using well water as drinking water. The physicochemical and bacteriological parameters were determined according to standard normalization in order to assess water quality using Python software for the statistical study.

Results: The results show that 26.66% of the inhabitants of the Tranza and Albarika districts are subscribers to SONEB against 20.01% who use well water as drinking water. In addition, the waters are colored (16.16±5.86 Pt/Co), cloudy (69±3.22 NTU), loaded (678.58±6.07 µS/cm), rich in magnesium (132.42±7.87mg/L), calcium (52.73±1.68mg/L), chlorine (88.23±1.96mg/L) and have high alkalinity contents (194.49±16.57mg/L). They are hard (185.09±5.09 mg/L) and can cause waterborne diseases depending on their total coliform (23 CFU) and E. coli (5 CFU) contents. The correlation between the parameters shows that a magnesium content equal to 67 mg/L leads to a high value of total coliform and calcium in well water.

Conclusion: Ultimately, the origin of the pollution can be attributed to sanitation, household waste, the transfer of pollutants from surface layers, the conditions of drawing water and the structure of the wells. In the long term, the use of well water could constitute a significant health risk for the majority of the inhabitants of Tranza and Albarika in the city of Parakou.

***Keywords**: Well water, Python, Polluants, Waterborne diseases, Tranza, Albarika*

1. Introduction

Water is a very important element of our ecosystem, of surface or underground origin, which participates in the maintenance and survival of all living beings. Water is both a strategic resource and the fundamental and necessary basic element for a healthy economy [1]. When its quality is unsatisfactory, it can cause health risks [2],[3]. Water quality depends on determining natural factors (soil, subsoil, etc.) and agricultural, industrial and domestic human activities producing discharges that end up directly or indirectly in aquatic environments [4],[5]. These pollutants can infiltrate and disperse locally in aquifers when the installations are poorly insulated (case of livestock buildings, industries, during domestic sanitation, etc.) or migrate into deep aquifers [6]. Socio-economic conditions, marked by low and precarious household incomes and consumption habits, lead the population of the Tranza and Albarika districts of the commune of Parakou to use different sources of water other than the drinking water supply network [7]. Among these sources of water, we can cite well water, rain water or watercourses without prior treatment [8]. It is sometimes based on organoleptic parameters (colour, odour and taste) to assess the quality of water; which does not guarantee the potability of drinking water [9], [10]. Thus, clear water (from wells, cisterns, streams, etc.) used by the population generally contains germs responsible for several waterborne diseases such as cholera, typhoid fever, dysentery, gastroenteritis, intestinal parasites, etc. [11], [12]. It is urgent to assess the physicochemical and bacteriological quality of well water consumed by the population of the Tranza and Albarika districts in order to draw the attention of municipal officials to the risks to which their citizens are exposed.

2. Study area, material and analysis methods

2.1. Municipality of Parakou

The Parakou region is located in the "Souda-Guinean" climate zone characterized by a rainy season and a dry season, each with a roughly equivalent duration. The average annual rainfall is 1175.9 mm in 72.1 rainy days in Parakou. The drought is almost absolute in January-February and the rainfall then increases gradually from March to September, which is the wettest month. The months of the peak rainy season (May to October) receive nearly 90% of the total rainfall in about ten rainy days each (100 mm/month). The average annual temperature is 26°C with a hydromorphic soil that is mostly rocky, clayey and tropical ferruginous or the pedological processes are roughly identical. The analyses were carried out in the Kaba Laboratory for Research in Chemistry and Applications (LaKReCA) located in the university center of Natitingou and partner laboratories.

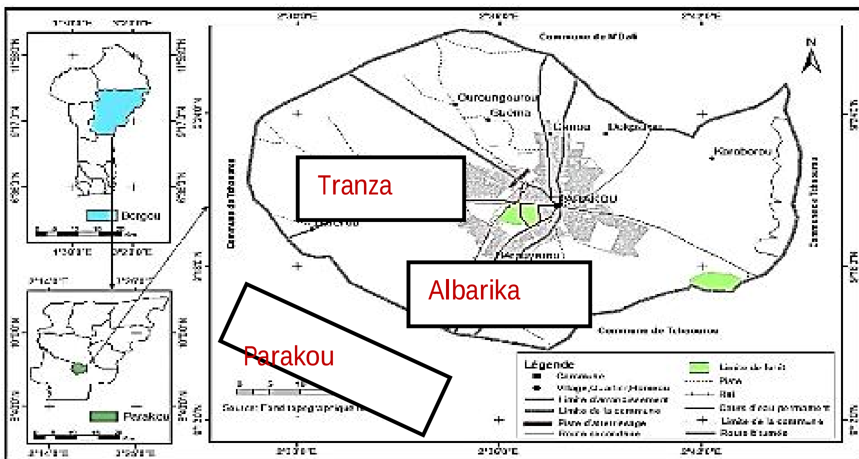

Fig 1 : Map of the Tranza and Albarika neighborhoods

2.2. Material and methods of analysis

2.2.1. Data collection material

The aim of this survey is to identify households that actually use well water as drinking water. At the same time, we collected information on water-related health problems and possible treatments of wells and water. The source population for this survey is all the houses in the Albarika and Tranza neighborhoods. Thus, we targeted households, mainly those with the most inhabitants, chosen at random with open and closed wells (Albarika (2); Tranza (2)) using survey forms developed and sent to the owners. The interview method used is developed by Florence [13].

2.2.2. Methods of analysis

2.2.2.1. Sampling methods

The water samples are collected in twenty (20) wells. The total number of samples collected was based on the survey sheet. The sampled neighborhoods are those where the well water consumption indices are high during the survey phase. The sampling was done aseptically following the NB ISO5667-11 Version 2007 standard [14].

2.2.2.2. Physicochemical parameters

The characterization of water through physicochemical parameters such as: pH temperature (T), conductivity (χ), was done using the multi-parameter type (WTW multi 3420) according to the NF EN 27888 and NFT 90-008 standards. The color and turbidity were determined using the DR 1900 spectrophotometer using the 120 to 455 nm programs for color then 950 for turbidity according to the NF EN 27888 standard.

2.2.2.3. Alkalinity

The alkalinity determination was done by adding at least five (5) drops of mixed indicator to 100 ml of the sample to be analyzed and then letting the 0.2N sulfuric acid solution flow drop by drop until the color changes. Let V be the volume of the sulfuric acid solution used, the alkalinity (Alc°) is given by the formula:

$$Alc° = V * 50$$

2.2.2.4. Total hardness, calcium and magnesium

Total hardness or hydrotimetric titer (TH) was determined by taking 50 ml of water to be analyzed and then adding 2 ml of a buffer solution (pH = 10) and 5 drops of NET (Eriochrome Black T). Then titration is carried out with a volume V of the EDTA solution (diamine tetraacetic acid: 0.02N) until the indicator changes from burgundy red (or dark pink) to blue. Total hardness is measured by the EDTA titrimetric method (expressed in French degrees (°f)), according to standard NF T90-003. Let V be the volume of the EDTA solution used in mL, the total hardness is given by the formula:

$$\mathbf{TH = 4.10^{-4} * V\ mg/L}\ \text{ou}\ \mathbf{TH = 4 * V}\ °f$$

The waters were classified into different categories so that below 8°f: the water is described as very soft; soft for TH between 8 and 15°f; hard for TH between 15 and 30°f and very hard above 30°f.

Calcium (calcium hardness) was measured by adding 2ml of potassium hydroxide solution, pH between 12 and 13 (8N) to 50ml of water to be analyzed. Then titrate with an EDTA solution (0.02N) until the indicator changes from burgundy red (or dark pink) to blue. The calcium content in mg/L is given by the formula below with V1 (ml) the volume of the EDTA solution used.

$$[Ca^{2+}] = 4.10^{-4} * V_1$$

The magnesium content (mg/l) is determined by the difference between the total hardness (TH) and the calcium hardness ($[Ca^{2+}]$) according to the formula:

$$[Mg^{2+}] = TH - [Ca^{2+}]$$

Magnesium and calcium contents were determined according to ISO 6059:1984(fr).

2.2.2.5. Chloride

Chloride ions were measured using the Mohr method according to standard NF ISO 9297 February 2000 / T90-014 by adding 2 to 3 drops of 10% potassium dichromate solution ($K_2Cr_2O_4$) to 100 ml of the sample to be analyzed, to obtain a yellow color. The mixture is titrated with a volume V of silver nitrate solution (0.1 N) with stirring until a brick red color appears, marking the end of the chloride measurement. The chloride ion content in mg/L is given by the formula:

$$[Cl^-] = 10^{-3} * V$$

2.2.2.6. *Ammonium*

Ammonium was determined using a LANGE DR 1900 spectrophotometer according to ISO 7150 using program 93 by introducing 1 ml of Rochelle Salt reagent and 1 ml of Nessler reagent into 25 ml of sample to be analyzed.

2.2.2.7. *Enumeration of microbiological germs*

The indicator parameters of bacteriological pollution, namely: total coliforms and Escherichia-coli, were determined using the Chrom-agar culture medium. Using a micropipette, 0.1 ml of each sample was taken and then poured into petri dishes containing the culture medium in the presence of the burner until solidification. The Petri dishes were inoculated in an incubator at 37°C for 48 hours, for the enumeration of total coliforms according to the NFV-08-05 standards, then at 44°C for 48 hours according to the ISO 9308 standard, for Escherichia coli. The enumeration of bacteria (Coliforms: orange-yellow colonies; Escherichia coli: blue colonies) is done by counting the colonies marked on the bottom of the Petri dish with an indelible marker. The result is expressed in colonyformingunits (CFU) and in number of bacteria per 100 mL [15].

2.3. Statistical study

The figures and statistical analyses were made with Excel and the Python application of Jupiter Notebook through the program below. The Python software has been used to create the parameters dictionaries and dataframe. Then, the codes were used to convert the dataframe into csv, to calculate and plot figure following the program below which is based on matplotlib, numpy and seaborne libraries.

```
# VARIATION OF PARAMETERS OF WELL
parameters={'Well':['PFT','POT','PFA','POA'],'Ca':[53,31,74,52],
            'pH':[6.7,6.5,6.7,6.9],'Mg':[43,200,67,219],
            'CT':[6,5,75,45]}
```

```
# CREATE A DATAFRAME
parameters_df=pd.DataFrame(parameters)
```

```
# Create DataFrame in csv
parameters_df.to_csv('parameters.csv', index=False)
```

```
# Read csv file
parameters_df=pd.read_csv('parameters.csv')
```

```
# Print the DataFrame
print(parameters_df.head())
```

```
  Well  Ca   pH   Mg  CT
0  PFT  53  6.7   43   6
1  POT  31  6.5  200   5
2  PFA  74  6.7   67  75
3  POA  52  6.9  219  45
```

```
# Print the figure
sns.pairplot(parameters_df,)
```

Fig 2: Python program to study the correlation between physicochemical parameters

The models obtained made it possible to establish the degree of correlation between the different parameters and to assess their influences on the open and closed wells water quality in Tranza and Albarika districts.

3. Results

3.1. Statistical study of the surveys carried out in the Albarika and Tranza districts

3.1.1. Types of water consumed by the population

The results of the survey conducted on the types of water consumed by the population of Albarika and Tranza are recorded in Table 1.

Table 1. Types of water consumed by the population

Consumeur	Well water	SONEB water/Drilling	Rainwater/Backwater/Other	**Total**
Effective	3	4	8	15
Percentage	22.95	24.6	52.45	100

From the analysis of this table, it emerges that the subscription rate to SONEB of the population of the Albarika and Tranza neighborhoods is approximately 24.6%. The part of the population that uses well water for various purposes, including drinking, represents 52.45% against 22.95% for consumption.

3.1.2. Aspect of the well environment

The results of the survey conducted on the environmental aspect of the wells of the population of Albarika and Tranza are recorded in Table 2.

Table 2. Well environment

	Sky Well		Distance WC/Well		Water Closer (WC)		Garbage Removal	
Well Frame	**Closed**	**Opened**	**Observed**	**Not observed**	**Modern**	**Traditional**	**Subscribed**	**Not Subscribed**
Pourcentage %	32	68	66.66	33.33	20	80	20	80

According to the analysis of the table, none of the wells in the houses visited has a depth greater than 20m. The depth of the wells varies between 5 and 15 m. Of the wells surveyed, 68% are not covered and the water from these wells does not receive any treatment. Clearing is very rarely done when the wells dry up. From a visual point of view, the color of the water is generally acceptable except in cases where the internal wall of the well is clogged with plants and in particular moss or ferns. Traditional toilets are poorly designed (no coping) and maintained in some places. Pollution of well water is linked to ablutions and the discharge of human waste into the environment. Among those who have a sanitation facility, 66.66% of the houses respected the minimum distance between the toilet and the well, compared to 33.33%. Furthermore, a low rate of 20% of subscription to household waste collection is recorded due to the absence of waste collection agents in the Albarika and Tranza neighborhoods. Poor management of the well environment is said to be responsible for malaria and waterborne diseases (diarrhea, skin diseases and dysentery) which generally affect preschool and school-age children in the Tranza and Albarika neighborhoods.

3.1.3. Physicochemical parameters of water samples

3.1.3.1. Conductivity, Temperature, pH, Color and Turbidity

The values obtained for the physicochemical parameters are recorded in the table below.

Table 3. Physicochemical quality of sampled waters

Parameters	**PFT**	**POT**	**PFA**	**POA**	**Beninese Standard**	Average
Conductivity(µS/Cm)	572±262	536.66±7.44	704±3	901.6±3.6	2000	678.6±69.1
pH	6.80±0.09	6.5±0.8	6.70±0.05	6.90±0.02	6.5<pH<8.5	6.71±0.25
Temperature (°C)	30.1±0.1	30.0±0.4	29.66±0.67	29.16±2.07	-	29.7±0.8
Turbidity (FAU)	67±8	85±3	66.0±0.0	59.0±2.1	5	69.0±3.2
Color (Pt/Co)	20±7	12±10	17±2	16±3	15	16.2±5.9

The hydrogen potential of the well water samples analyzed in the Tranza and Albarika districts vary between 6.5±0.84 and 6.9±0.02. In addition, the water from the wells analyzed is slightly acidic with an average pH of 6.71±0.25. The conductivity of the well water samples analyzed in the Tranza and Albarika districts in the commune of Parakou varies between 536.66±7.44 µS/Cm and 901.66±3.59. The well water is weakly mineralized and slightly hard with an average conductivity of 678.58±6.07 µS/cm. The highest conductivity content is found at the Albarika open well (POA: 901.66±3.59 µS/Cm) and the low value is found at the Tranza open well (POT: 536.66±7.44 µS/Cm). That values found comply with Beninese standards. The temperature of the well water samples analyzed in the Tranza and Albarika districts vary between (29.16 ±2.07°C) and (30.1±0.01°C). The temperature values recorded are higher than the maximum acceptable temperature in Benin which is set at 25°C. The turbidity of the analyzed water samples vary between 66±01 NTU and 84.66±2.70 NTU and these values are higher than 5 NTU recommended by Beninese standards. The color of the analyzed samples varies between (12.00±10.23 and 20.00±7.07 PtCo). In addition, 75% of the wells (PFA; POA; PFT) have high organoleptic characteristics compared to the Beninese standard (15 PtCo) against 25% of the wells (POT) which have lower values. The majority of the water from the wells is very colored and does not meet the standards compared to the visual observation which does not present any defective aspect.

The values of Conductivity, Temperature, pH, Color, Turbidity were used to construct the histograms in Figure 4.

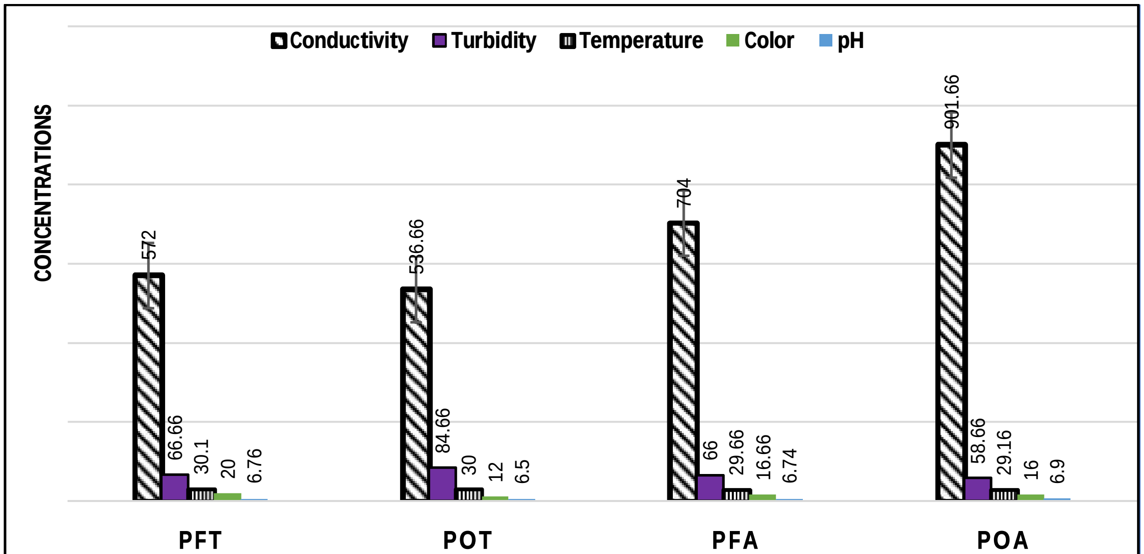

Fig 3.Histogram of Conductivity, Temperature, pH, Color and Turbidity

From this figure, the histograms of pH, temperature and color of the samples have the same size for the different types of well waters analyzed while the conductivities of the closed and open wells of Tranza (PFT and POT) represent half of those of the open wells of Albarika (POA). It is deduced that the wells of Albarika are doubly rich in electrical charges compared to those of Tranza.

3.1.4. Determination of total hardness, calcium, magnesium and alkalinity

The results for calcium, magnesium, alkalinity and hardness are recorded in the table below.

Table 4. water content in Total hardness, calcium, magnesium and alkalinity

Parameters	PFT	POT	PFA	POA	Beninese Standard	Average
Calcium (mg/L)	53.53±1.14	31.09±1.36	74.2±3.6	52.1±0.6	100	52.73±1.68
Hardness(mg/L)	96.03±5.77	231.66±13.35	141.3±1.5	271.3±1.9	200	185.1±5.6
Magnesium(mg/L)	42.80±3.95	200.57±23.61	67.13±2.65	219.2±1.3	50	132.4±7.8
Alcalinity(mg/L)	98.66±2.20	47.66±2.20	583.3±60.5	48.3±1.3	-	194.4±16.5

The total hardness of the well water samples analyzed in the Tranza and Albarika districts varies between 96.03±5.77mg/L and 271.3±1.9 mg/L. The high hardness is found at the open well Albarika (PFA: 271.3±1.9mg/L) and the low value is at the closed well Tranza (PFT: 96.03±5.77 mg/L). It is noted that the hardness of 50% of the wells is lower than the Beninese standard set at 200mg/L compared to the other wells which have high values. From the classification we note that half of the waters are hard against the remaining 50% which are very hard. The magnesium content of the well water samples analyzed in the Tranza and Albarika neighborhoods varies between 42.80±3.95/L and 219.2±1.3 mg/L. The high magnesium content is found in the open well of Albarika (PFA: 219.2±1.3 mg/L) and the low value is in the closed well of Tranza (PFT: 42.8±3.95/L mg/L). The calcium content of the well water samples analyzed in the Tranza and Albarika neighborhoods varies between 31.09±1.36mg/L and 74.2±3.6. The high calcium content is found in the closed well of Albarika (PFA: 74.20±3.65 mg/L) and the low value is in the open well of Tranza (POT: 31.09±1.36mg/L). The values obtained on the alkalinity of the waters vary from 47.66±2.20 mg/L to 583.33±60.55 mg/L. The lowest value is observed at the open well Tranza (POT: 47.66±2.20mg/L) and the high value at the closed well Albarika (PFA: 583.33±60.55 mg/L). The wells (POA; PFT; POT) have values that are lower than the Beninese standard set at 200mg/L. The water from these wells is less alkaline, while the water from the closed well Albarika PFA is very alkaline and has a value much higher than the Beninese standard.The values of the total hardness, calcium, magnesium and alkalinity contents made it possible to obtain the histogram in figure 4.

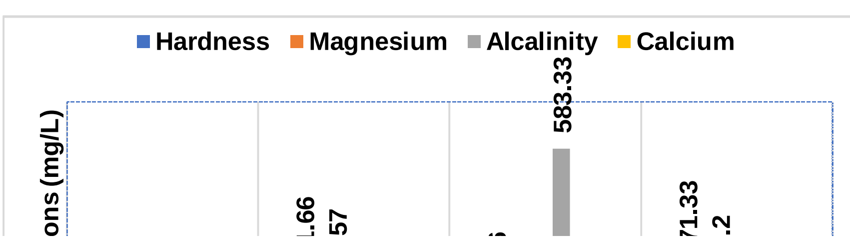

Fig 4. Histogram of Hardness, Magnesium, Alkalinity and Calcium

From figure 4, the histogram of Hardness, Magnesium, Alkalinity and Calcium content of the waters have almost the same size at the level of the open well Albarika and Tranza (POT and POA). The closed well of Albarika (PFA) has an alkalinity rate ten times higher than that of the other wells compared to the calcium content which is almost similar in all the sampled wells.

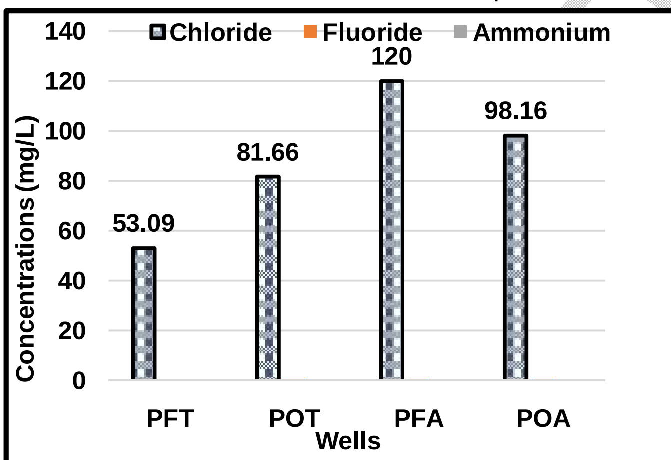

Fig 5. Histogram of chloride, fluoride and ammonium in well water

The histograms of fluorine and ammonium are almost zero compared to those of the chloride ion contents which increase from the PFT to the POA. It is noted that the chloride ion contents of the PFT, POT and POA wells represent respectivelyhalf, third and two fifths of the chloride ion content of the PFA well. The chlorine histograms of the closed and open wells of Albarika (PFA and POA) have larger sizes than those of the closed and open wells of Tranza (PFT and POT).

3.1.5. Biological parameters

The values obtained for total coliforms and Escherichia coli are reported in the table below.

Table 5. Evolution of CT and E. coli in the analyzed well waters

Samples	PFA	POA	PFT	POT	Beninese standards
CT (100/ ml UFC)	6	5	75	45	0
E. coli (100/ ml UFC)	0	0	0	2	<1

CT : Total coliformes ; **E. coli** : Escherichia coli

The results obtained show that the waters of the analyzed wells are subject to biological pollution mainly linked to total coliforms (TC), of which the waters most loaded with coliforms are those of the closed wells of Tranza (PFT: 75 CFU) compared to the others which contain less (PFA: 45 CFU, PFA: 5 CFU and PFT: 6 CFU). It is noted that only the waters of the open wells of Tranza (POT: 2 CFU) are contaminated by Escherichia coli. The pie chart in the Figure below shows the distribution of these germs (Total Coliform and E. coli) at the level of the different wells.

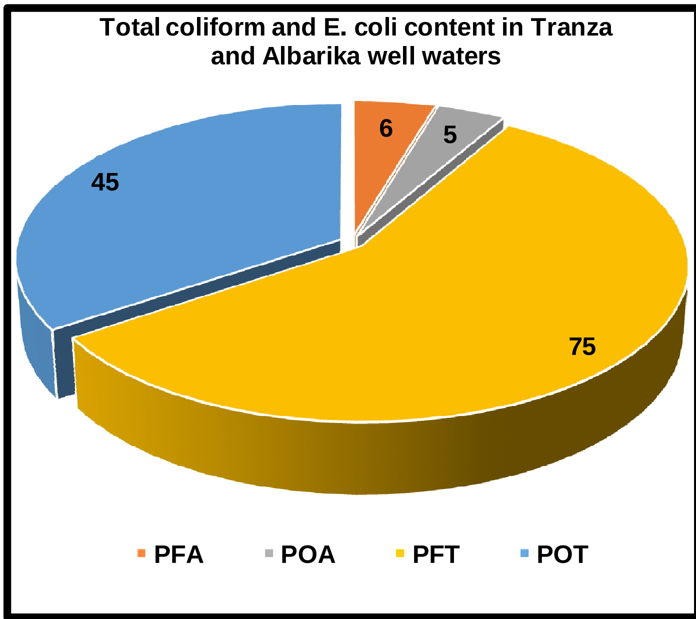

Fig 6. Distribution of Total Coliforms and E. coli at the level of the different wells

From the pie chart it is noted that the waters of the closed wells of Tranza (PFT) have a large coverage in total coliforms and are followed by the waters of the open wells of the same district. On the other hand, the total coliforms occupy more or less reduced and almost identical areas at the level of the open and closed wells of Albarika. This shows that the majority of the wells of this district are maintained.

3.2. Evaluation of the quality of the waters analyzed in relation to national and international standards

The assessment of the quality of well water allowed us to produce the table below.

Table 6. Assessment of the water quality of the Tranza and Albarika wells

Parameters	PFT	POT	PFA	POA	Beninese Standards	Conformity (%)
Conductivity (µS/Cm)	572±262	536.66±7.44	704±2.94	901.6±3.5	2000	100%
pH	6.76±0.09	6.5±0.84	6.74±0.05	6.9±0.02	6.5<pH<8.5	100%
Temperature (°C)	30.1±0.08	30.0±0.4	29.66±0.67	29.16±2.07	-	-
Turbidity (FAU)	66.66±8.11	84.66±2.70	66.00±0.01	58.66±2.08	5	0%
Color (Pt/Co)	20.00±7.07	12.00±10.23	16.66±2.90	16.00±3.26	15	25%
Calcium (mg/L)	53.53±1.14	31.09±1.36	74.20±3.65	52.13±0.60	100	100%
Hardness (mg/L)	96.03±5.77	231.6±13.4	141.33±1.57	271.3±1.9	200	50%
Magnesium (mg/L)	42.80±3.95	200.5±23.6	67.13±2.65	219.2±1.3	50	25%
Alcalinity (mg/L)	98.66±2.20	47.66±2.20	583.33±60.55	48.33±1.36	-	-
Fluoride (mg/L)	0.21±0.04	0.56±0.18	0.40±0.07	0.55±0.08	1.5	100%
Ammonium (mg/L)	0.21±0.01	0.20±0.02	0.27±0.04	0.27±0.08	0.5	100%
Chloride (mg/L)	53.09±2.52	81.66±1.74	120.0±1.2	98.16±2.35	250	100%

CT (100/ ml UFC)	6	5	75	45	0	0%
E. coli (100/ ml UFC)	0	0	0	2	<1	75%

The assessment of the quality of well water led to the study of the compliance of the values of the different parameters with Beninese standards. The percentage of wells that complied with the standards was useful to better understand the quality of these waters. A rate of 25% is granted to a well that complies with the standards. As a result, some parameters (pH, Calcium, fluoride, ammonium, conductivity and chloride) of the wells present compliances that are equivalent to 100% compared to others (E. coli: 75%; hardness: 50%; Magnesium and Color: 25%; Total Coliforms and Turbidity: 0%). On the other hand, no well complies with Beninese standards when considering the total coliform and turbidity contents of the well water. The wells comply differently with Beninese standards when considering the other parameters. The compliance results show that the majority of wells do not comply with Beninese standards. Therefore, it is up to local authorities to raise awareness among the populations of these areas about the dangers associated with the consumption of polluted well water, the rules of hygiene, the methods of treating well water and cleaning up the various water sources before any consumption.

3.3. Study of water quality through the degree of correlation between parameters

3.3.1. Correlation between physicochemical and bacteriological parameters

The various graphs in figure 7 were produced in order to assess the degree of correlation between the physicochemical and bacteriological parameters.

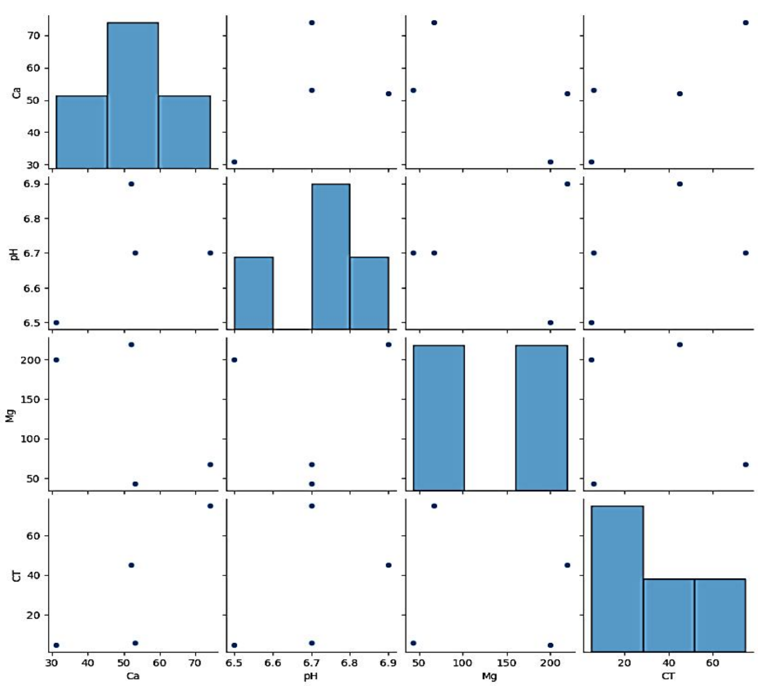

Fig 7.Correlation between physicochemical and bacteriological parameters

From the analysis of these graphs,the calcium content of the water increases with the total coliform rate in a linear manner. This content is high for a low magnesium value but for a calcium content equal to 54 mg/L, we have a magnesium content greater than 200 mg/L. The same observation is observed in relation to the pH which went from 6.7 to 6.9 for a calcium content equal to 54 mg/L. This shows that this calcium value makes the water of the wells from slightly acidic to neutral depending on the area where the wells are installed. The high content of total coliforms and calcium are obtained for a pH equal to 6.7. It shows that the pH is ideal for the development of germs and the acceleration of the mineralization of calcic rocks into calcium. Furthermore, a higher pH leads to an increase in the magnesium content in the wells. The high content of total coliforms and calcium is obtained for magnesium contents below 100 mg/L. The other figures reveal at the level of all parameters two histograms having the same sizes. This indicates that some water sources have almost identical contents of total coliforms (40 UCF), magnesium (200 mg/L), calcium (50 mg/L) and hydrogen potential (6.7).

All the figures display a high histogram at the level of total coliforms (70 UCF), calcium content (75 mg/L) and hydrogen potential (6.9). This proves that some waters are loaded with germs and minerals.

3.3.2. Evolution of calcium, pH and Total Coliform contents as a function of magnesium

The assessment of water quality led to the study of the variation of other parameters when based on the magnesium content of water.

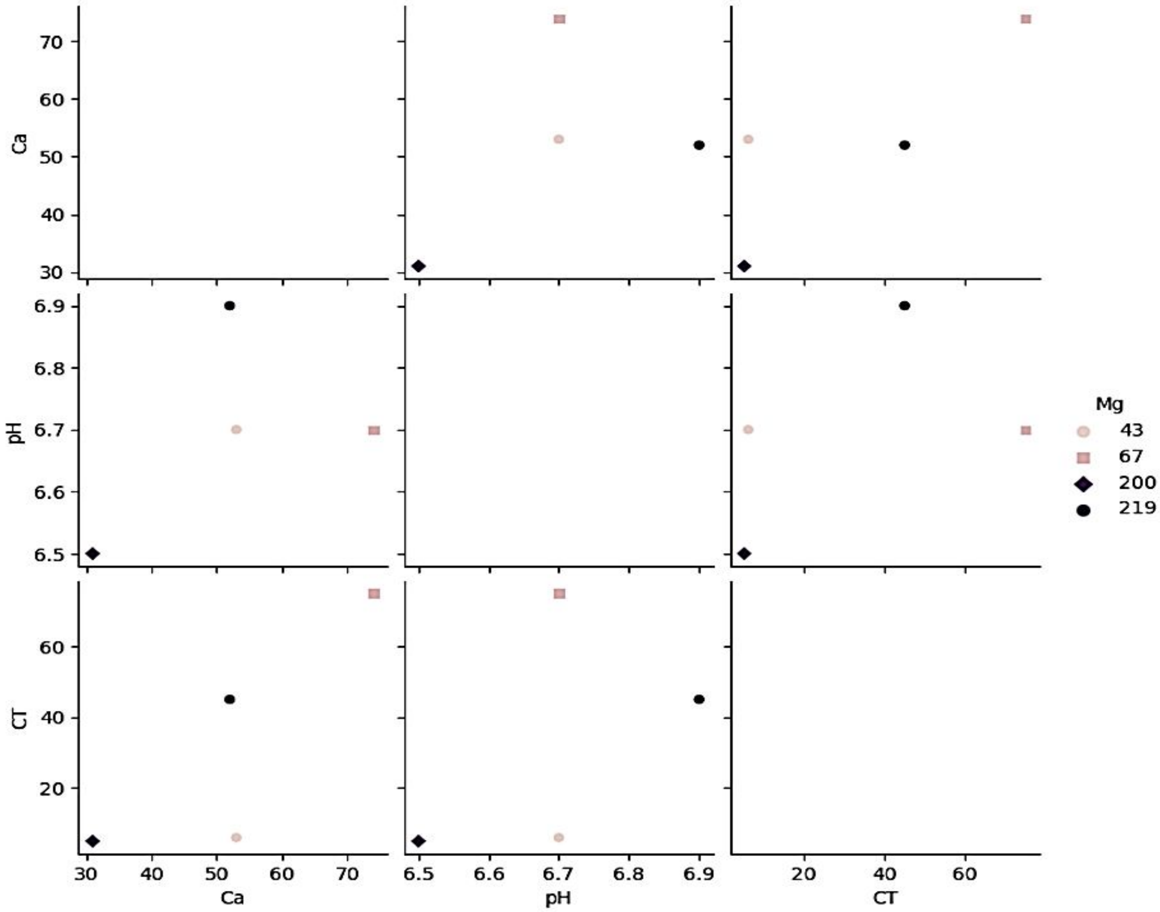

Fig 8. Evolution of calcium, pH and Total Coliform contents as a function of magnesium

The analysis of figure 8 shows low total coliform and calcium contents and less than 30 mg/L for a high magnesium content (200 mg/L). The pH variation is observed based on the calcium content and total coliforms.The high magnesium content prevents calcic rocks from mineralizing, prevents pathogenic germs from multiplying, and creates a slightly acidic environment.The environment is relatively neutral with average levels of calcium and total coliforms, even though it has a magnesium content of 219 mg/L.The maximum calcium ion content is reached with a relatively low magnesium content of 67 mg/L.

4. Discussion

The surveyed population has a higher percentage (52.45%) who use well water for various purposes than those who use it as drinking water (22.95%). The majority of local communities use water for washing and cooking, which is the explanation for this increase in the percentage. [16]. This observation is due to the low resources of the majority of the population who have difficulty subscribing to the SONEB water distribution network as Kassi pointed out [17]. This low rate of access to drinking water could explain Benin's vision for 2025, which predicts less than 40% of surface water resources as drinking water [18]. The surveyed show 68% of wells which are not covered and their water does not receive any treatment. Similar situations were reported by Mayi who worked on the wells of Douala in Cameroon [19]. In terms of sanitation facilities, 80% of houses have a traditional Water Closer (WC) compared to 20% modern WCs [20]. Thus, water can be polluted directly by fecal matter, or indirectly by fecal germs carried by insects, dead plants, dust, scoops, ropes, runoff water or by agricultural chemicals [21]. Among those who have a sanitation facility, 66.66% of houses respected the minimum distance between toilets and wells.Compliance with the construction distances of these toilets is based on compliance with the IWRM laws which offer everyone the right to a healthy, satisfactory and sustainable environment[22]. The non-compliance with well construction standards by 33.33% of residents would contribute to the anthropogenic pollution of these wells [2], [23]. In addition, a low rate (20%) of subscription to household waste collection was recorded due to the absence of waste collection agents in the Albarika and Tranza neighborhoods. Developing countries are regularly confronted with these situations, such as the case highlighted by Ndiaye who conducted his studies in 2021 on household waste management in the commune of Grand-Yoff in Senegal [24]. Poor management of the immediate environment of wells is said to be responsible for malaria and waterborne diseases (diarrhea, skin diseases and dysentery) which generally affect preschool and school-age children in the Tranza and Albarika neighborhoods. These results corroborate those of Mangenda who made the same observation in the municipality of Kalamu in Kinshasa [25]. The characterization of the well waters shows pH values of the samples ($6.5 < pH < 8.5$) which respect the Beninese standards s[26], [27]. In addition, the water of the wells analyzed is slightly acidic with an average pH of 6.71 ± 0.25. The low acidity of these waters, perhaps due to the presence of mineral acids such as sulfuric acid and nitric acid from industrial pollution and acid rain [28].Overall, the open wells of Tranza recorded a lower acidity of the well waters with a total average pH of 6.5 ± 0.84 compared to the waters of the closed wells of the same area with a pH of 6.76 ± 0.09. The pH of the waters of the open wells are close to 5.6 and prove that their acidity could be related to acid rain. Regarding public health and safety, these waters could lead to skin diseases[29]. According to the criteria of electrical conductivity, the values obtained after analysis of the water samples show that the wells are poorly mineralized [30], [31]. However, these results obtained on the mineralization of the waters are in conformity with those of Lagnika on the waters of the wells in the commune of Pobè [32], [33]. The recorded temperature values are higher than the maximum acceptable temperature in Benin which is set at 25°C. These high temperature values would be due to the generally very high ambient temperatures in the city of Parakou [34]. The minimum value of turbidity (58.66 NTU) is greater than 40 NTU and reflects the turbid nature of these waters due to the presence of suspended particles. This observation was made by Yao who worked on the distribution of particles according to the turbidity during the water flocculation process[35],[36]. This reinforces the arguments of the authors who claim that the quality of well water cannot be assessed by the senses [37]. It is noted that the wells of Albarika are doubly rich in electrical charges compared to those of Tranza. This remark was made by Mzahma who worked on the irrigation of plants by effluents [38]. From the classification based on hardness, it's noted that half of the waters are hard against the remaining 50% which are very hard. The quality of the soil in the Albarika district would be responsible for this hardness. These results corroborate those of Boukhechba who found that land rich in minerals (magnesium and calcium) contributes to water hardness [39]. It can be said that the magnesium content ishigher than those obtain by kandana in the contributes to the hardness of the water in the Albarika district [40]. The water analyzed is rich in magnesium and does not meet the Beninese standard which sets the magnesium content at 50 mg/L [41]. These values are double that obtained by Kaboré (100 mg/L) [42]. Consumers of this water will be exposed to a high dose of magnesium which would be linked to several factors, such as local geology, the depth of the well and human activities in the region [28]. The calcium content of the well water meets the Beninese (100 mg/L) and WHO (200 mg/L) standards [43]. The low calcium value could be linked to the presence of other ions such as magnesium which would reduce the solubility of calcium in water [32]. The water from these wells is less alkaline, while the water from the Albarika PFA closed well is very alkaline and has a value much higher than the Beninese standard. This high rate may come from the dissolution of surrounding rocks and minerals in the soil [45]. All urban, rural or industrial land uses can influence the quality of surface or ground water available in a watershed [46].

The identical size of the histograms of hardness, magnesium content, alkalinity and calcium of the waters of the open wells Albarika and Tranza (POT and POA) can be justified by their high mineralization under the effect of the dissolved oxygen content of the ambient air of these wells which are not covered [47].The magnesium and calcium contents can be justified by the contamination of well water by discharge from local cement factories and the surrounding calcareous environment.[48]

The closed well of Albarika (PFA) has an alkalinity rate ten times higher than that of the other wells. The limestone richness of the soil of Albarika in the commune of Parakou would be responsible for this observation [49].

The well water which contain total coliforms could be sources of certain waterborne diseases in the study area[50]. On the other hand, the waters of the wells (PFA, POA and PFT) which having no content of E.coli allow us to say that they are not loaded with these pathogenic germs. The waters of the open wells of Tranza (POT) which contain them have then undergone fecal pollution because these microorganisms are indicators [4]. The E.coli value obtain in this water (2 UFC) is low than those obtain by kandana in drilling water (60 UFC) and show that the well water quality parameters generally deviate from the water quality guidelines for domestic use [51].The tools used to draw water in this district and the lack of maintenance of these wells would contribute to the presence of E.Coli in these waters [17]. The sediments and adjacent soils can be responsible for bacteriological pollution of well water[52]. It can be noted that the values of pH, calcium content, fluoride, ammonium, conductivity and chloride make the waters of the wells studied conform to Beninese standards [53], [26]. There was a significant difference in this water quality parameters between the different wells that was mainly attributed to anthropogenic activities and point and diffuse sources of pollution [54]. Furthermore, the total coliform and turbidity contents of the well waters make the waters of these wells not conform to Beninese standards. It can be deduced that the waters of these wells are unfit for any use and especially for consumption [55]. Some closed and open wells in the Tranza district respect the well-WC distance and this observation was made by Halas at the level of the different wells in his work [56]. The correlation between calcium and magnesium can be justified by the fact that there is a competition during their transformations into minerals. These results corroborate those of Mousmoudi who states that the increase in calcium content improves the mineralization of the culture medium [57]. The analysis of the variation of magnesium content according to other parameters shows this value of magnesium (67 mg/L) in water considerably increases the presence of calcium ions compared to a high value which is favorable to the multiplication of germs and the neutrality of water. Similar results have been obtained by studies based on the prediction of water quality from physicochemical parameters [58]. Furthermore, for total coliforms in water sources, higher magnesium values (1.070 mg/L) were associated with higher probabilities of total coliform contamination, while higher phosphate values (0.968 mg/L) were associated with lower probabilities of total coliform contamination[59].

CONCLUSION

The quality of the wells water of Albarika and Tranza districts is little known and the survey revealed that it's consumed by 20.10% of the population. The study found that the values of the physicochemical and bacteriological parameters of these waters are high and are due to anthropogenic pollution resulting in significant values for color, turbidity, magnesium content and total hardness. Through the values obtained, it can be said that these wells do not comply with Beninese standards and their waters are the basis for the increase in waterborne diseases in the study area. Furthermore, the study of the correlation revealed a strong relationship between the different parameters resulting in a strong multiplication of pathogenic germs and a neutrality of the waters for a high magnesium content unlike a low magnesium content of the waters which considerably increases the presence of calcium ions.
The municipal authorities must raise awareness among the population on the dangers linked to the consumption of untreated well water, the rules of hygiene through an Information, Education and Communication (IEC) program, the methods of treating well waters and on the techniques of sanitation of the different sources of water before any consumption.

DISCLOSURE OF CONFLICT OF INTEREST

The authors declare that they have no competing interests.

Disclaimer (Artificial intelligence)

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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