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Evaluation of the Physico-Chemical Parameters of Water from Boreholes, Wells, Taps and the Milo River: Case of the Kankan Urban District

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Abstract

The aim of this work is to evaluate the quality of water from: boreholes, wells, taps and Milo river in the urban municipality of Kankan. Sampling campaign was carried out at nine sites based on the frequency of water usage by the population. Physical parameters were measured *in situ* and chemical ones were performed using the colorimetric method. The results showed that electrical conductivity (464 - 703 µS), pH (5.10 - 5.75) and turbidity (15.53 - 22.88 NTU) as well as the temperatures recorded respectively from ordinary well water, boreholes, and Milo river do not comply with Standards. The results of the chemical parameters of the water showed that the concentration of nitrite ions (0.02 - 2.20 mg/L) is very high in tap water, while borehole water has high concentrations of ammonium ions (0.26 - 0.6 mg/L), nitrate ions (56 - 129 mg/L), and lead ions (0.05 mg/L). Phosphate ions (11 - 20 mg) are abundant in ordinary wells and the Milo River, while zinc ions (3.71 - 4.42 mg/L) and iron (II) ions (0.5 mg/L) are found in greater concentrations in ordinary wells and the Milo River respectively. These results show that most of these water sources are polluted. The Stata 15 software was used for statistical analysis of data and the correlation test between the chemical parameters gave very significant values ($r = 0.80$; $p < 0.05$).

Keywords

Water Quality, Physicochemical Parameters, Ordinary Wells, Boreholes, Taps and Milo River

1. Introduction

Surface water pollution refers to the contamination of rivers, lakes, and oceans by harmful substances, often due to human activities and certain natural disasters [1] [2]. It can have serious consequences on aquatic ecosystems leading to the death of species that inhabit them, changes in color, and/or the nature of the water, etc., biodiversity, and human health [3]. Water quality is a critical parameter that greatly affects human health and aquatic life [4]. Indeed, proper water management to ensure rural development remains a challenge, as according to the latest estimates from the United Nations, 2 billion people still had no access to drinking water at home in 2020, and about 771 million people had to travel at least 30 minutes from their homes to access drinking water, with over a hundred million people worldwide drinking untreated water of poor quality [5]. This water pollution is a fundamental issue for developing countries where the population boom is high and where governments have divergent investment priorities [6]. In these countries, 90% to 95% of all wastewater and 75% of all industrial waste, on average, are discharged into surface waters without prior treatment [1] [7].

In Guinea, more precisely in the urban community of Kankan, a significant amount of toxic waste is generally discharged, caused by erosion into the Milo River, ordinary wells, and stagnates around the boreholes. During the winter period, the area being agricultural in nature, the waters, infected by various chemicals, are discharged daily. To successfully carry out this study, field visits, interviews with resource persons, and photography were conducted to identify the different sites for water sampling to analyze quality. This interview also made it possible to understand the different uses the population makes of the waters of the Milo River, namely: watering vegetable crops, fishing, washing vehicles and clothes, the body, etc., exposing them to a health risk because today, along this river has become a dumping ground for all sorts of waste and the abusive use of pesticides and fertilizers, it has become an uncontrolled landfill. Despite this advanced level of pollution, it is also used as a source of drinking water by SEG (Société des Eaux de Guinée).

As a contribution to the efforts of monitoring and protecting against water pollution, we have chosen the present study: in the urban commune of Kankan (Republic of Guinea) in 2024.

The goal of this work is to evaluate the quality of these waters for sustainable and risk-free use.

2. Materials and Methods

2.1. Presentation of the Study Area

2.1.1. Geographic and Administrative Situation

The urban district of Kankan "Nabaya" is located between 10˚23'05" North latitude and 9˚18'25" West longitude. It is bordered to the east by the rural district of Balandou; to the west by the rural district of Gbérédou Baranama; to the north by the rural district of Karifamoriah and to the south by the rural district of Tinti Oulén (**Figure 1**). It is, in terms of area, the second-largest city in the Republic of Guinea after the capital Conakry and the largest [8]. Located in Upper Guinea, it is the capital of the Kankan prefecture and covers an area of 334 km^2 with 504,325 inhabitants, equating to 44 inhabitants per km^2. Its geographical position gives it the reputation of being a crossroads city in the Sub-region [9].

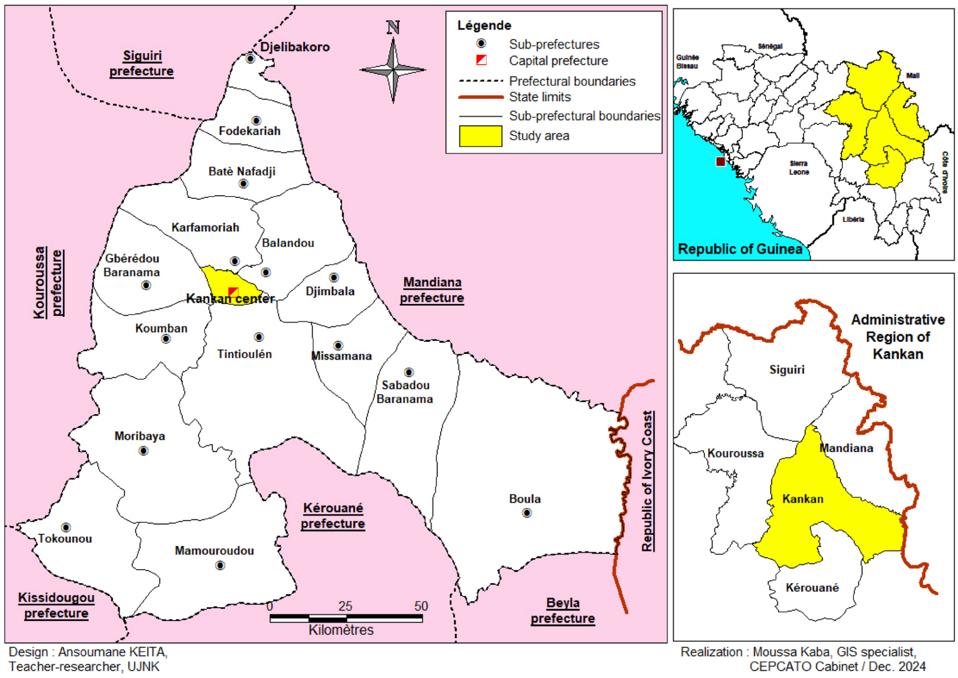

Figure 1. Presentation of the area (Map Info Software 7.5/CEPCATO Office).

2.1.2. Hydrographic, Morphological and Climatological Characteristics of the City of Kankan

The city is traversed by the Milo River and fed by other tributaries such as Séngnè Dèbèkoro, Manfénda, Kokoudouni, and Gboutouroun. The urban commune of Kankan is characterized by a morphology mainly influenced by the Milo River (a tributary of the Niger) with significant demographic growth on both banks. The landscape is marked by plains and plateaus, with the presence of valleys and internal depressions. The climate is of the sub-Sudanese type and is characterized by an alternation of two seasons, a dry season from November to April which records very high and constant temperatures (averaging 30˚C) and a rainy season from May to October with rainfall varying between 1,100 and 1,800 m^3 of water per year [10].

2.1.3. Geolocation of Sampling Sites

Water samples were collected at nine sites, taking into account the urban area, the representativeness of pollution sources, and operational feasibility (**Figure 2**). The geographic coordinates of these various sampling sites are represented in **Table 1** below.

Table 1. Geographic coordinates of the different sampling sites.

N°	Sites	Type	Latitude	Longitude	Height
1	Mobile intervention and security company	Boreholes	10.409517	−9.315310	417m
		Wells	10.409517	−9.315310	417m
2	Sogbè market	Boreholes	10.409687	−9.315310	450m
		Wells	10.409687	−9.315310	
3	Milo river under the bridge	Milo water	10.367640	−9.296900	
4	University Julius Nyerere of Kankan	Boreholes	10.375112	−9.302122	410m
		Wells	10.367640	−9.296900	415m
5	Senkefara	Boreholes	10.403110	−9.288307	401m
		Wells	10.402395	−9.287368	
6	Slaughter Milo	Boreholes	10.374848	−9.278883	407m
		Wells	10.376617	−9.275593	404m
7	Dibida	Boreholes	10.374272	−9.294493	400m
		Wells	10.374272	−9.294493	400m
8	Prefectoral Hospital of Kankan	Boreholes	10.368855	−9.304845	421m
		Wells	10.368952	−9.300985	422m

The sampling sites were chosen based on three criteria: proximity to the market; population density and proximity to agricultural areas. These criteria will enable us to determine the actual level of pollution in our environment.

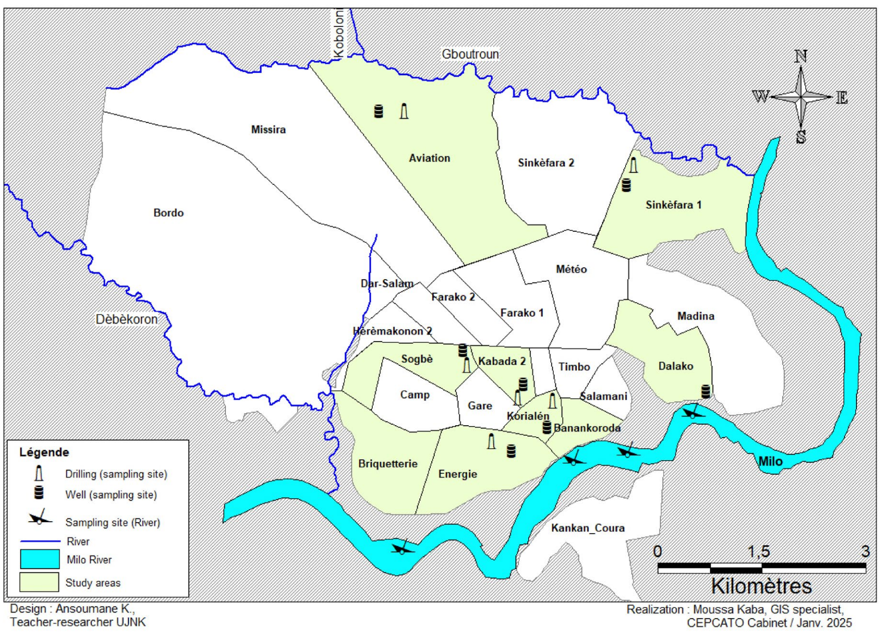

Figure 2. Geographical location of sampling sites (Map Info Software 7.5/CEPCATO Office).

2.2. Study Framework

The hydraulic laboratory of Kankan located in the energy neighborhood of the administrative region of this city served as the framework for these physicochemical analysis (temperature, pH, electrical conductivity, turbidity, dissolved oxygen, residual chlorine, ammoniacal nitrogen, total hardness, organic matter, alkalimetric title and complete alkalimetric title, sulfates, chlorides, nitrites, nitrates, phosphates). **Figure 3** presents all the equipment used for this analysis.

Figure 3. Analytical equipment.

2.3. Methods of Analysis

Determination of Physicochemical Parameters

The analysis was carried out *in situ* and in the laboratory. The values obtained were compared to WHO (World Health Organization) standards.

a) Nitrate: 1 - 30 mg/L, Reagent: Tablet, Code: 265.

Protocol:

For 10 mL of distilled water into a bottle with a white cap (this is the blank of the reaction). In another bottle, introduce 10 mL of sample into which 1 tablet of nitratest (reagent used to measure nitrate ions in the sample) has been added, then agitate the mixture until it is completely homogeneous. After preparing the sample, proceed to determine the concentration of these ions in the sample. To do this, first place the bottle containing distilled water in the aperture of the Palintest 7100 spectrophotometer to calibrate it; then a quantity of the sample was introduced into another bottle in order to have in the aperture of the Palintest 7100 spectrophotometer to calibrate it; subsequently, a quantity of the sample was introduced into another bottle to place in the device's aperture for analysis. Finally, press the "test" button on the device and wait for 5 minutes; the value displayed on the device's screen represents the result in mg/L of the Nitrate ions contained in the sample.

b) Nitrite : LR: 0.01 - 0.3 mg/L, Reagent: (PP), Code: 272.

Protocol:

This measurement was performed using distilled water and a NitriVer 3 Powder pack. To do this, a blank test was first carried out with 10 mL of distilled water, which was then placed into a flask and positioned in the opening of the spectrophotometer [4]. Then, this flask of distilled water was removed and a NitriVer 3 Powder pack was added, and the mixture was stirred for a few minutes. After this time, the flask was placed back into the device's opening, the "test" button was pressed, and we waited 20 minutes; the value displayed on the device's screen represents the result, in mg/L of the concentration of Nitrite ions in the sample.

c) Total iron: 0.02 - 1 mg/L, Reagent: Tablet, Code: 220.

Protocol:

Measure 10 mL of the sample in a flask and place it in the opening of the DR-MD-610 device. Then, to perform the blank test, press the "zero" button on the device. After this test, remove the flask and add 1 crushed IRON-LR tablet, then shake the mixture several times. Place the flask back in the opening of the device and press "test", then wait for 5 minutes and read the result in mg/L of $Fe^{2+/3+}$ ions displayed on the device's screen.

d) Phosphate HR: 1 - 80 mg/L, Reagent: Tablet, Code: 321.

Protocol:

Put 10 mL of the sample into a bottle and perform a blank test on the device (DR-MD-610). After this test, remove the bottle and add 1 tablet of phosphate HR P1 tablet, then shake the mixture several times until fully homogenized. Crush another tablet of phosphate HR P2 and add it to the mixture, then shake again. Finally, heat to achieve homogenization. Place the bottle containing this mixture into the device's opening and press the "test" button, then wait for 10 minutes and read the result in mg/L displayed on the screen, which constitutes the concentration of Phosphate ions in the sample.

e) Ammonium: 0.02 - 1 mg/L, Reagent: Tablet, Code: 60.

Protocol:

The same protocol for measuring phosphate ions was applied to determine the content of ammonium ions, with the difference that the reagents are different. Here, 1 tablet of Ammonium No. 1 and No. 2 were used and crushed successively, replacing 1 tablet of phosphate HR P1 and 1 tablet of phosphate HR P2 in the previous protocol.

3. Results and Discussions

Table 2 and Table 3 with Figure 4 presented the physical and chemical result for well water.

Table 2. Results of physical analysis of ordinary well water.

N˚	Sites	Parameters				
		pH	Cond (µs/s)	Turb (NTU)	O D(mg/L)	T ˚C
1	Wells Kabada	6.00	502	0.16	4.9	23.4
2	Wells Energy	5.75	188.2	1.61	5.8	23.8

Continued

3	Wells CMIS	5.61	37	0.80	6.1	23.9
4	Wells Dibida	6.26	464	1.80	7.00	23.9
5	Wells Sogbè	5.10	703	0.57	8.7	24.2
6	Wells Sénkéfara	6.04	80.9	0.63	5.9	24.2
	Standards	6.5 - 9.5	400	5	7	30

Table 3. Results of chemical analysis of ordinary wells waters.

N°	Sites	Parameters										
		NO_3^- mg/L	NO_2^- mg/L	NH_4^+ mg/L	PO_4^{3-} mg/L	HCO_3^- mg/L	Ca^{2+} mg/L	SO_4^{2-} mg/L	Mg^{2+} mg/L	Cl^- mg/L	Na^+ mg/L	Cl_2 mg/L
1	Wells Kabada	4	0.273	0.26	11	131.76	26.4	13	10	92.3	59.8	0.00
2	Wells Energy	11	0.057	0.6	13	43.92	14.4	16	<<	55	35.6	0.00
3	Wells CMIS	42	0.00	0.34	12	9.76	3.2	<<	0.00	81.7	53	0.00
4	Wells Dibida	44	0.022	0.06	13	185.44	42.32	23	11	42.6	27.6	0.00
5	Wells Sogbè	45	0.00	0.11	20	122	16.90	22	13	108.3	70	0.00
6	Wells Sénkéfara	56	0.65	0.10	14	9.76	22.67	25	0.00	28.4	18.39	0.01
	Standards	50	0.01	0.2	0.5	0-60	270	500	50	250	200	5

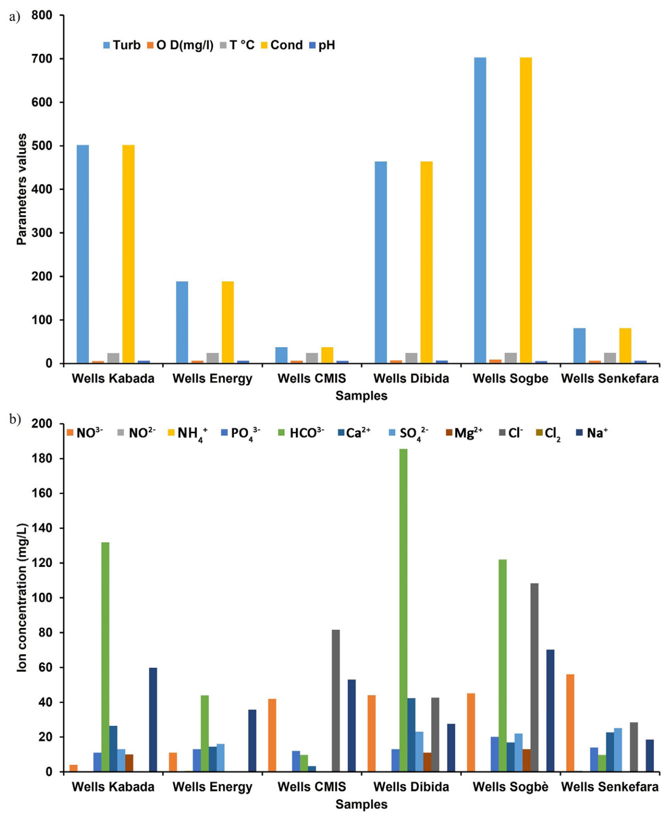

Figure 4. Diagram a) physical parameters and b) chemical parameters of ordinary wells waters.

Table 4. Results of analysis of certain metals in ordinary wells waters.

N°	Sites	Parameters				
		Fe^{2+} (mg/L)	Al^{3+} (mg/L)	Zn^{2+} (mg/L)	Cu^{2+} (mg/L)	Pb^{2+} (mg/L)
1	Wells Kabada	<0.5	<0.2	3.96	<2	<0.01
2	Wells Energie	<0.5	<0.2	4.31	<2	<0.01
3	Wells CMIS	<0.5	<0.2	<3	<2	<0.01
4	Wells Dibida	<0.5	<0.2	3.71	<2	<0.01
5	Wells Sogbè	<0.5	<0.2	4.42	<2	<0.01
6	Wells Sénkéfara	<0.5	<0.2	<3	<2	<0.01
	Standards	0.5	0.2	3	2	0.01

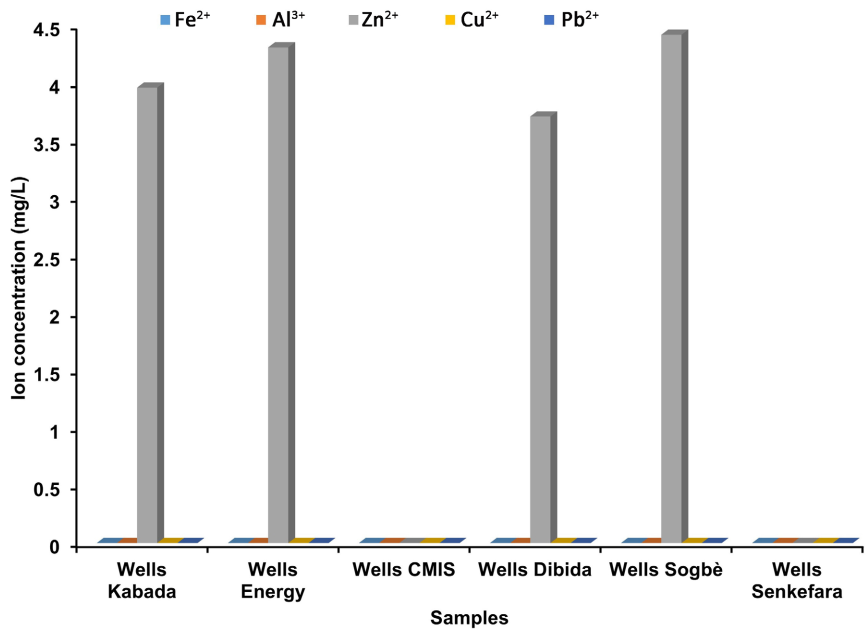

Figure 5. Diagram of the analytical results of certain metals in ordinary well waters.

It emerges from **Table 3** and **Table 4** that certain physico-chemical parameters do not meet the standards defined by the WHO [11]. Some pH values are very low compared to the average [12], while those for electrical conductivity are quite high. The concentrations of nitrite and phosphate ions are well above normal [13]. The levels of calcium (3.2 - 42.3 mg/L) and bicarbonates (9.76 - 185.44 mg/L) indicate respectively that this water ranges from soft to moderately hard and that the mineralization is variable. The calcium hardness (mg/L) of the wells in CMIS, Sénkéfara, and Energie is very low, indicating that this water is soft; however, that of the wells in Kabada, Dibida, and Sogbè is high, indicating that this water is very hard [14]. These results show that these well waters are unfit for consumption without prior treatment.

The concentrations of calcium ions (3.2 - 42.33 mg/L) in the CMIS well are low, which could indicate soft water; however, in the Dibida well sample, they are high, which means this water is hard. The concentrations of bicarbonate ions (9.76 - 185.44 mg/L) are very high in these samples, indicating the softness of these waters but also a significant presence of dissolved minerals (**Table 3**). The concentrations of calcium carbonate are high for the Kabada and Dibida wells, which indicates that these waters are hard compared to other samples where these values are acceptable (soft waters).

The concentrations of iron, aluminum, copper, lead, and zinc ions presented in **Figure 5** are within the acceptable limits according to the WHO standard [15]. This suggests an absence of significant contamination, thus these waters do not present a health risk [16]. Generally speaking, it can be said that the hardness of these samples is variable but leans much more towards hard water. The concentrations of zinc ions are above the recommended standard and may promote corrosion of plumbing. However, the other metals are compliant. Some samples show $CaCO_3$ values above 100 mg/L confirming that these waters are hard. In light of all these observations, it can be concluded that these analyzed waters do not comply with drinking water standards and are therefore unfit for human consumption [17].

The results of the metal concentrations presented in **Table 4** show that the concentrations of Iron (0.5 mg/L), Aluminum (<0.2 mg/L), Copper (<2 mg/L), and Lead (<0.01 mg/L) comply with the standards set by the WHO [18]. However, the Zinc concentration (3.41 - 4.42 mg/L) is very high compared to the WHO standard [19]. These results indicate that the water is generally soft and not polluted by these metals, but the high Zinc content in these samples may cause corrosion of water pipes [20].

Table 5. Results of the physical analysis of taps water.

N°	Sites	Parameters				
		pH	Cond. (µs/s)	Turb. (NTU)	O D. (mg/L)	T (°C)
1	SEG Kabada 2	7.10	33.6	1.37	2.9	24.9
2	SEG Energy	6.90	39.3	0.00	3.6	24.5
3	SEG Dibida	6.70	37.3	3.20	3.4	24.9
4	SEG Sogbè	6.79	37.3	0.46	3.6	25.6
5	SEG Sénkéfara	7.09	36.6	1.01	3.5	25.6
	Standards	6.5 - 9.5	400	5	7	30

Table 6. Results of the chemical analysis of taps waters.

N°	Sites	Parameters								
		NO_3^- mg/L	NO_2^- mg/L	NH_4^+ mg/L	PO_4^{3-} mg/L	SO_4^{2-} mg/L	Mg^{2+} mg/L	Cl^- mg/L	Na^+ mg/L	Cl_2 mg/L
1	SEG Kabada 2	1.4	2.20	0.23	14	11	0.00	95.9	62.1	0.04

Continued

2	SEG Energy	0.13	0.9	0.21	12	0.00	0.00	51.5	33.3	0.00
3	SEG Dibida	0.00	1.71	0.07	19	0.00	0.00	81.7	52.9	0.00
4	SEG Sogbè	0.00	0.00	0.11	16	12	0.00	64	41.4	0.03
5	SEG Sénkéfara	0.00	0.00	0.03	17	0.00	0.00	55	35.6	0.00
Standards		50	0.01	0.2	0.5	500	50	250	200	5

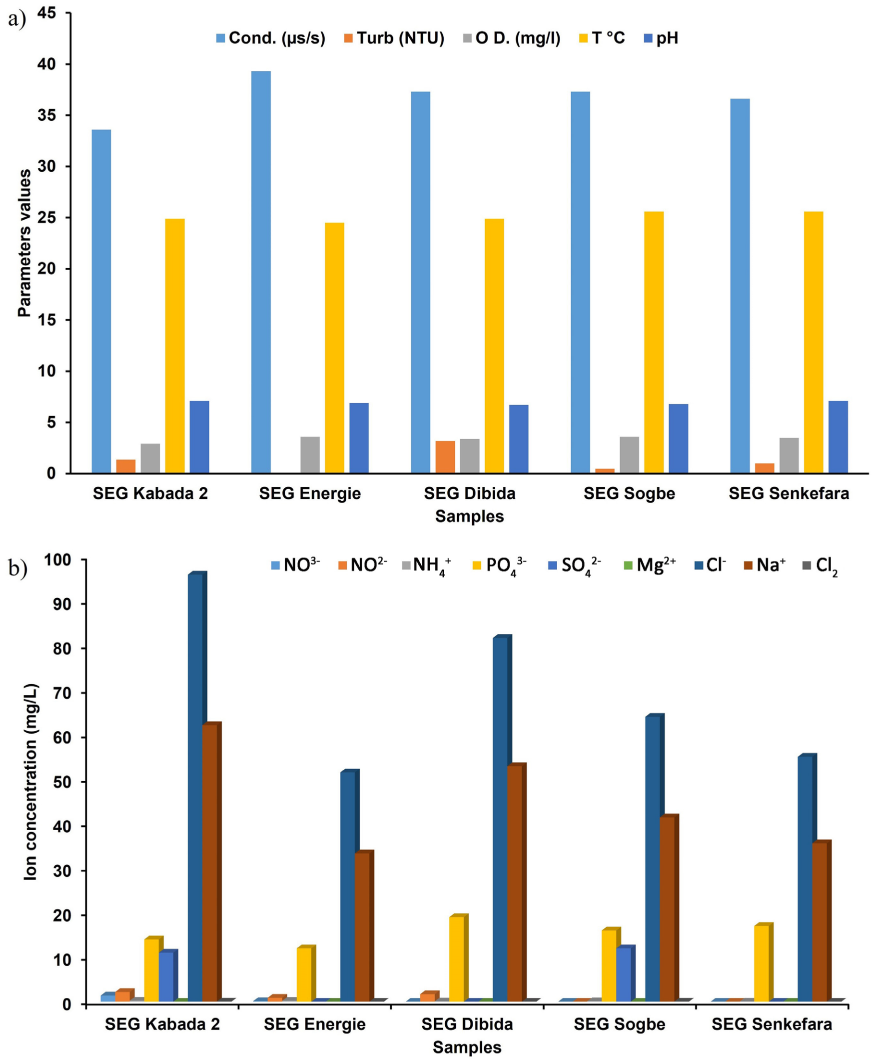

Figure 6. Diagram a) physical parameters and b) chemical parameters of tap water.

The conductivity values are very low (**Figure 6**). They indicate that this water is very poorly mineralized, which can have consequences if regularly consumed, as it contains very few essential mineral salts such as calcium, magnesium, and potassium. Water that is very poorly mineralized may tend to absorb minerals from the body (notably in the teeth and bones) that facilitate water absorption in the intestine, so it is not recommended for hydration [21]. The turbidity is generally acceptable, but the value of 3.2 NTU at the Dibida site indicates the presence of suspended matter, which may carry an increased microbial risk if not disinfected (**Table 5**).

The values of dissolved oxygen found are acceptable but slightly low compared to WHO standards [5]. This low variation may indicate water stagnation, meaning it is slightly in motion and thus promoting algae growth, poor oxygen distribution, and the accumulation of sediments or pollutants [4]. In light of WHO standards (0.01 mg/L), the nitrite values (0.9, 1.71, and 2.2 mg/L) are very high [13]. This high rate of nitrite ions may be due to uncontrolled urbanization; it can pose health problems for those who use this water. This harmful effect is particularly visible in infants (methemoglobinemia) and local population in this urban District (typhoid fever, gastrointestinal disorders such as diarrhea). This result indicates that the waters from the Kabada 2, Dibida, and Energie sites require treatment or disinfection before any consumption.

Ammonium ion levels (0.23 mg/L) are acceptable according to WHO standards (0.5 mg/L) [16], but when combined with nitrite levels, it can indicate an active degradation of water quality. This accumulation (ammonium-nitrite) can come from organic matter, fertilizers, pesticides, animal urine, etc. [22]. The pH value and levels of nitrate, chloride, sodium, and sulfate ions are very good as they fall within the WHO range [11] [16]. For phosphate ions, the levels are high (**Table 6**). Drinking water should not contain so many phosphates. This level can pose risks of eutrophication in natural environments [13].

The concentrations of magnesium ions and free chlorine are low. This low magnesium ion content indicates that these waters may bind magnesium from the body for its absorption, which can lead to a deficiency of this element in the organism [23]. Regarding free chlorine, its low value presents a risk of attack for the organism. It should not be totally absent in water; otherwise, we expose ourselves to microbiological risks as the turbidity of the water may increase. Considering the temperature values (24.5˚C to 25.6˚C), we can say that these waters are warm. This increase in temperature can encourage microbial proliferation in these waters, and therefore it must be disinfected before any use.

Table 7. Results of the physical analysis of Boreholes waters.

N˚	Sites	Parameters				
		pH	Cond. (µs/s)	Turb. (NTU)	O D. (mg/L)	T (˚C)
1	Boreholes UJNK	6.67	1.54	0.19	4.4	21.9
2	Boreholes Regional Hospital	6.44	0.16	0.24	2.9	22.7

Continued

3	Boreholes CMIS	5.27	0.16	1.69	2.2	23.7
4	Boreholes Dibida market	6.53	0.307	1.03	1.7	23.9
5	Boreholes sogbèmarket	6.67	0.224	1.34	1.8	23.9
6	Boreholes Sénkéfara market	5.61	0.073	0.00	1.7	24,3
	Standards	6.5 - 9.5	400	5	7	30

Table 8. Results of the chemical analysis of Boreholes waters.

N°	Sites	Parameters								
		NO_3^- **mg/L**	NO_2^- **mg/L**	NH_4^+ **mg/L**	PO_4^{3-} **mg/L**	SO_4^{2-} **mg/L**	Mg^{2+} **mg/L**	Cl^- **mg/L**	Na^+ **mg/L**	Cl_2 **mg/L**
1	Boreholes UJNK	56	0.37	0.12	0.00	19	5	23.07	14.94	0.00
2	Boreholes Régional Hospital	2	0.12	0.08	0.00	41	3	28.4	18.4	0.04
3	Boreholes CMIS	33	0.00	0.08	0.00	17	1	190	123.04	1.14
4	Boreholes Dibida market	88	0.06	0.11	0.00	38	12	28.4	18.4	0.3
5	Boreholes Sogbè market	82	0.00	0.40	0.00	45	9	26.6	17.24	0.00
6	Boreholes Sénkéfara market	129	0.00	0.06	0.00	14	<<	33.7	21.84	0.00
	Standards	50	0.20	0.20	0.50	500	10-50	250	200	5

The pH of the groundwater from CMIS and Sénkéfara is below the standard [5] [11], indicating slightly acidic water. This can lead to corrosion of the pipes and affect the taste of the water. The measured conductivity values are very low compared to the standard [24], suggesting poorly mineralized water with low dissolved salts or dilution by rainwater [25]. Regarding turbidity, values ranging from (0.19 to 1.69 NTU) are below (5 NTU), which is the WHO standard indicating clear water. However, the highest values could signal the presence of suspended particles. These physical results are summarized in (**Table 7**) and (**Figure 7(a)**).

The levels of dissolved oxygen are appreciable except in the case of the UJNK drilling. Low levels of dissolved oxygen may indicate organic pollution or stagnation of water, which is detrimental to aquatic life [19]. **Table 8** and **Figure 7(b)** present the chemical result for groundwater. Nitrate ion concentrations are above the standard [13] in the samples from the UJNK, Dibida market, Sogbé, and Sénkéfara drilling waters, suggesting contamination from agricultural or domestic sources. For nitrite ions, only the sample from the UJNK drilling with a concentration of (0.37 mg/L) exceeds the WHO standard of (0.20 mg/L), indicating recent organic pollution.

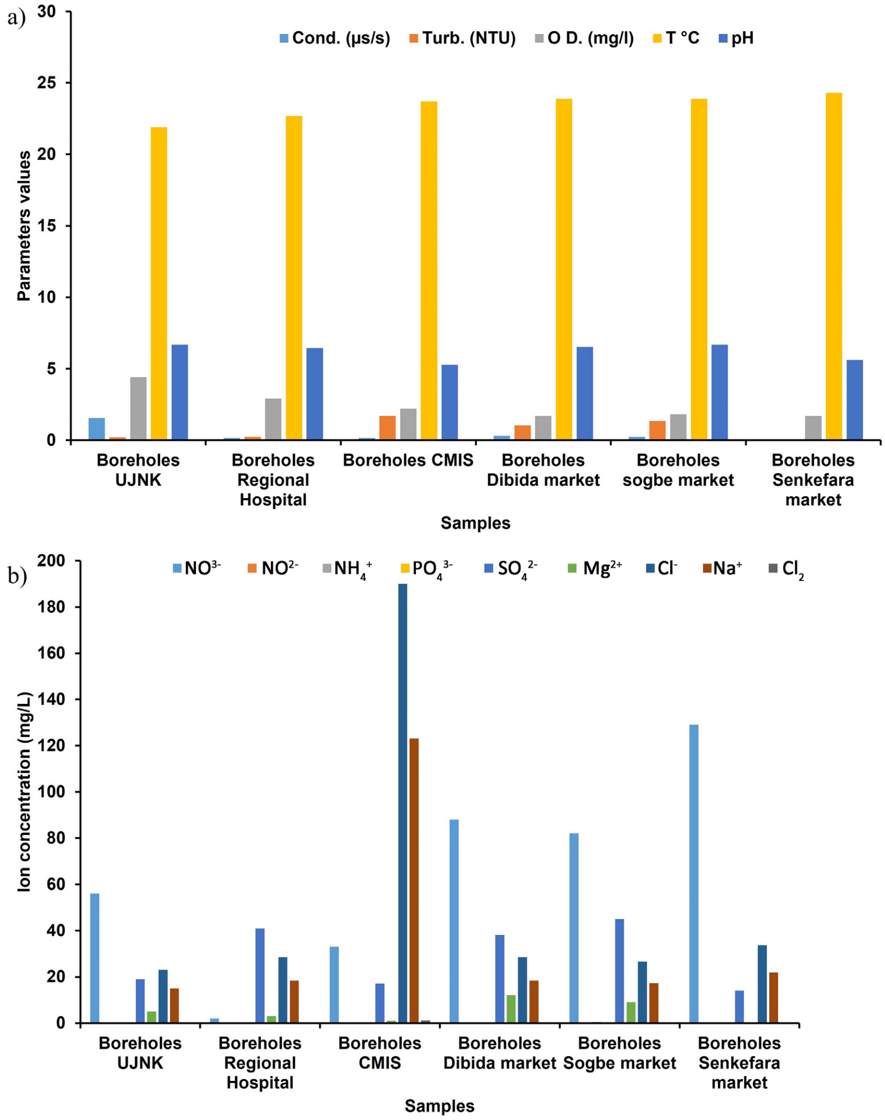

Figure 7. Diagram a) physical parameters and b) chemical parameters of groundwater.

Ammonium ions have levels all below the standard [16], which is favorable for health, but a high level of ammonium ion may indicate organic pollution. The absence of phosphate ions in the samples was noted, which indicates a favorable result for health, as their presence can promote the proliferation of algae [26]. Sulfate ions have values well below the WHO standard [7], indicating an absence of sulfate pollution. The levels of magnesium ions compared to the WHO standard (10 - 50 mg/L) are very low in most samples, suggesting fresh water.

The chloride and sodium ion levels are practically compliant with WHO standards [27], but the highest chloride ion value approaching the limit of 250 mg/L for the water from the CMIS Borehole may affect the taste of the water, while the high sodium ion level for this same Borehole may have complications for people on a low-sodium diet [28]. Most of the samples from the Borehole waters (UJNK, Marché Sogbè, and Sénkéfara) show an absence of residual chlorine, which may indicate a lack of disinfection. All temperatures are typical of surface water in tropical areas.

It follows from these results that the high levels of nitrates, nitrites, and low dissolved oxygen content lead to organic pollution of these waters which could be caused by agricultural or domestic discharges. The slightly acidic pH and low mineralization can lead to corrosion of distribution infrastructures. The absence of free chlorine in most samples indicates a lack of disinfection, increasing the microbiological risk [29]. It is necessary to implement treatment systems to reduce nitrates, nitrites, and also adjust the pH to ensure adequate disinfection of water while maintaining appropriate levels of residual chlorine. Regular analyses should then be carried out to monitor water quality and detect any variations. Finally, local authorities should implement measures to protect water sources from contamination, in particular by controlling agricultural and domestic discharges.

Table 9. Results of the analysis of certain metals in groundwater.

N°	Sites	Parameters					
		Ca^{2+} (mg/L)	Fe^{2+} (mg/L)	Al^{3+} (mg/L)	Zn^{2+} (mg/L)	Cu^{2+} (mg/L)	Pb^{2+} (mg/L)
1	Boreholes UJNK	4.8	<0.5	<0.2	3.02	1.63	<0.05
2	Boreholes Regional Hospital	4.8	<0.5	<0.2	<3	<2	<0.05
3	Boreholes CMIS	3.2	<0.5	<0.2	3.81	<2	<0.05
4	Boreholes Dibida market	9.6	<0.5	<0.2	3.72	<2	<0.05
5	Boreholes Sogbè market	12.8	<0.5	<0.2	3.88	<2	<0.05
6	Boreholes Sénkéfara market	3.2	<0.5	<0.2	3.94	<2	<0.05
	Standards	10-100	0.5	0.2	3	2	0.01

This study presents the results of physico-chemical analysis of six water samples from different sources: ordinary wells, boreholes, taps, and the Milo River (**Figure 8**). The analyzed samples contain calcium (Ca), iron (Fe), aluminum (Al), zinc (Zn), copper (Cu), and lead (Pb) ions, and the concentrations of these elements are compared to the drinking water quality standards established by the WHO. The results indicate that the calcium (Ca) levels are low, indicating soft water. These values do not present any health risks, but the water is low in minerals, thus the calcium level needs to be improved. The iron (Fe) and zinc levels are above the WHO recommendation [15].

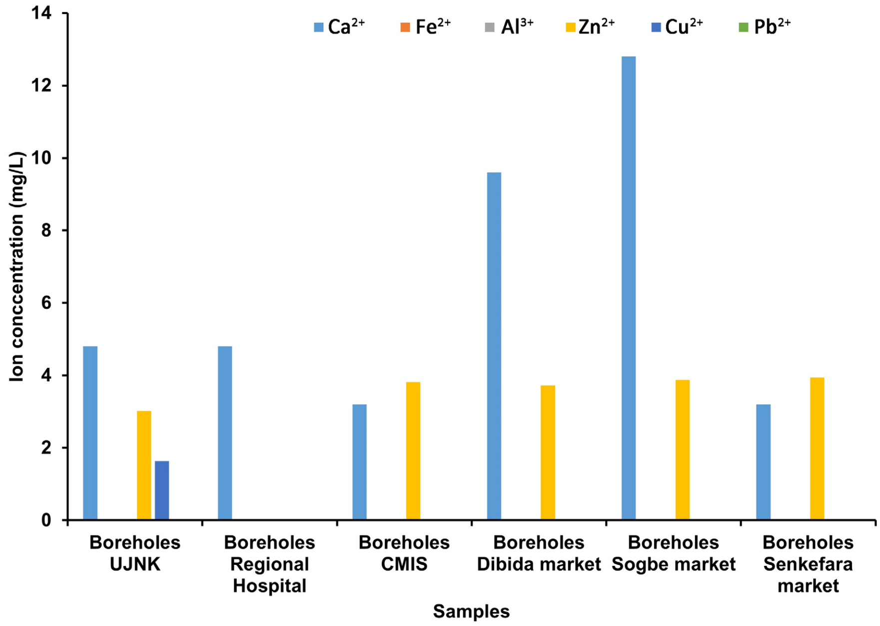

Figure 8. Diagram of analysis results of certain metals in borehole water.

A high iron content can lead to a possible metallic taste, stains on laundry or fixtures that may be due to corrosion of the piping, iron-rich soils, and high oxidation possibilities, while a high zinc content can affect taste without posing a health risk. This presence of zinc can come from the corrosion of galvanized pipes or industrial waste. For aluminum (Al) and copper (Cu), the levels are at the maximum recommended limit by the WHO, requiring monitoring. This result does not have a significant direct impact on health, but the accumulation of these elements is harmful. The presence of aluminum could come from the galvanization of aluminum objects, while that of copper would come from the oxidation of piping. Lead (Pb) is detected at <0.05 mg/L, a value above the detection threshold set by the WHO standard (0.01 mg/L) [15], therefore a potential risk cannot be excluded (**Table 9**).

It follows from these results that this water, before domestic use, must undergo treatment through aeration/filtration (activated carbon, ceramic) to eliminate harmful metals and regularly monitor the levels of these metals because their increase will be very detrimental to health.

Table 10. Results of the physical analysis of the waters of the Milo River.

N˚	Sites	Parameters				
		pH	Cond. (µs/s)	Turb. (NTU)	O D. (mg/L)	T (˚C)
1	Milo Pumping Station	7.10	24.4	22.88	4.2	25.9

Continued

2	Milo slaughter	7.05	43.7	33.9	3.4	26.6
3	Milo under the bridge	7.74	35.5	15.53	5.6	26.7
	Standards	6.5 - 8.5	750	5	7	30

Table 11. Results of the chemical analysis of the waters of the Milo River.

N°	Sites	Parameters									
		NO_3^- mg/L	NO_2^- mg/L	NH_4^+ mg/L	PO_4^{3-} mg/L	SO_4^{2-} mg/L	Mg^{2+} mg/L	Cl^- mg/L	Na^+ mg/L	Cl_2 mg/L	NO_3^- mg/L
1	Milo pumping station	0.22	0.00	0.05	16	<<	0.00	<<	31.95	20.7	0.10
2	Milo slaughter	0.26	0.00	0.11	20	<<	<<	<<	37.27	24.14	0.07
3	Milo under the bridge	0.00	0.00	0.01	0.37	<<	17.92	<<	30.17	19.54	0.00
	Standards	50	0.01	0.01	0.5	10 - 100	200	50	250	200	5

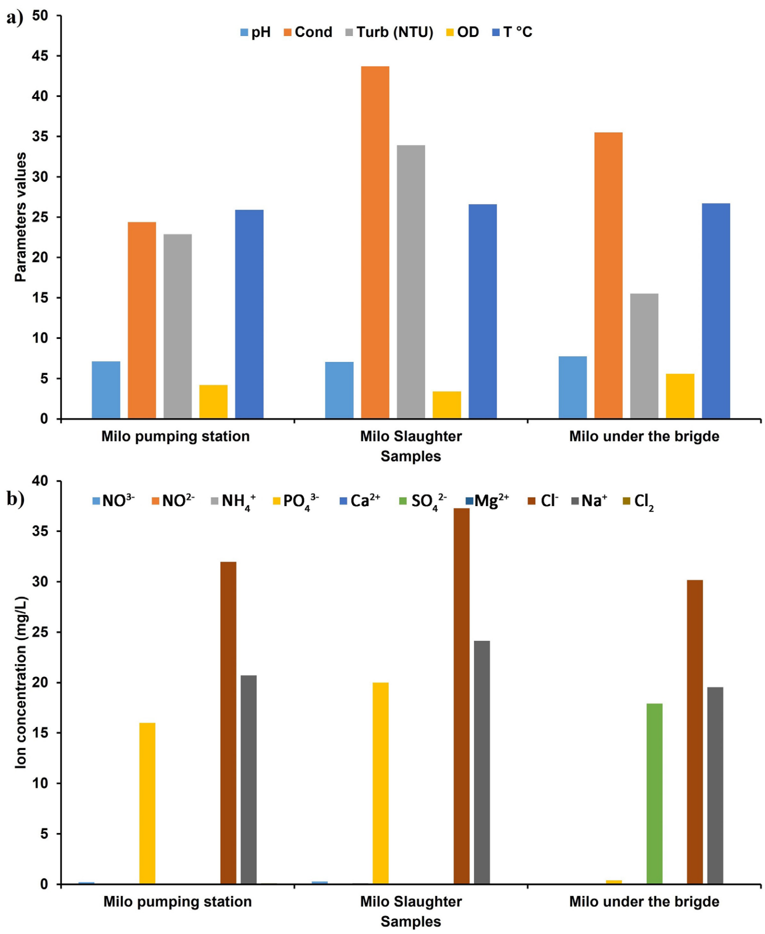

Figure 9. Diagram a) physical parameters and b) chemical parameters of the waters of the Milo river.

The results in **Table 10** and **Figure 9** show that pH values between 7.05 and 7.10 correspond to neutral water, while a pH value of 7.74 indicates that the water is slightly basic. The conductivity values indicate low mineralization, meaning a lack of calcium, phosphate, and magnesium, which can lead to digestive disorders, malabsorption (celiac disease, Crohn's disease), renal or hepatic insufficiency, and hormonal disorders (dysfunction of parathyroid hormone (PTH)), thyroid or sexual hormones in populations that consume it [23].

This low mineralization can still cause diseases in children such as rickets (bone deformity, growth retardation, pain) and problems of osteomalacia (diffuse bone pain, fatigue, muscle weakness); long-term osteoporosis (bone fragility, increased fracture risk, dental problems, cramps, muscle spasms related to electrolyte imbalances, neurological disorders in adults [23]. The COD (chemical oxygen demand) values obtained are below the limit value of 10 mg/L but accepted by the WHO [19]. COD is the consumption of oxygen by powerful chemical oxidants to oxidize the organic and mineral substances in water. It is one of the most commonly used methods to assess the overall load of organic pollutants in water. This low level of dissolved oxygen indicates that the water is probably eutrophic or stagnant in some cases, suggesting a likely decrease in biodiversity. It is worth noting that temperature and dissolved oxygen are negatively correlated. This means that the higher the temperature, the less oxygen is available.

The turbidity value of 15.53 NTU shows that the water under the Milo bridge is less turbid, while values of 22.88 NTU and 33.9 NTU indicate that the water from Milo pumping station and Milo slaughterhouse is quite cloudy, which suggests the likely presence of suspended matter and thus organic or specific pollution. The TSS refers to solid, insoluble materials that are visible to the naked eye and are present in suspension in water. This includes clays, sands, silts, plankton, and other aquatic microorganisms. The quantity of TSS varies according to the season and the water flow regime; they result from soil erosion and leaching during rainy weather, especially when precipitation is intense and in flood situations.

Biodegradable TSS significantly contributes to the oxygen demand and leads to a decrease in the concentration of dissolved oxygen in the aquatic environment. These materials affect water transparency and reduce light penetration, thereby affecting photosynthesis [17].

Value peaks are observed during the rainy season in the Stations and are likely a result of the presence of discharges around the wells. These discharges are formed by the natural fermentation of leachate. This turbid water would explain the low dissolved oxygen levels observed (**Table 10**). Phosphorus in the natural environment is found in the form of phosphates (calcium, iron, and aluminum) in volcanic and sedimentary rocks. Its transfer into water occurs through soil and rock erosion. Plants absorb the solubilized phosphates for photosynthesis [30]. It is transferred along the food chain through the consumption of plants by animals. Phosphorus is again solubilized through the decomposition of dead matter by microorganisms [31].

Nitrate ions are present in very low concentrations and completely absent in some places, while nitrite ions are absent in all samples, which is favorable for water quality. The concentrations of ammonium and phosphate ions are very high compared to the WHO standard [11], indicating respectively a slight nitrogen pollution in some cases (feces, organic decomposition) and risks of eutrophication in the case of Milo Pumping Station and Milo slaughter. The value of ion sulfate (17.92 mg/L) indicates the presence of mineral or industrial pollution at the site of the river Milo under bridge (**Table 11**).

The combined results of this study show that surface water (Milo water, ordinary wells) is the most polluted because it is exposed to human activities, compared to groundwater (boreholes and taps) which is less polluted.

4. Conclusion

This present study aims to evaluate the quality of water from: boreholes, ordinary wells, taps, and the Milo River in the urban municipality of Kankan. To do this, in July 2024, a sample collection campaign was conducted at nine sites in the locality during the rainy season. The results for parameters such as temperature, pH (5.10 - 5.75), electrical conductivity (464 - 703 µs), turbidity (15.53 - 22.88 NTU), and dissolved oxygen (DO) in the waters of ordinary wells, boreholes, and the Milo River do not comply with WHO standards, thus these waters require prior treatment before use. The analysis of ions such as nitrites (0.02 - 2.20 mg/L) for ordinary wells, boreholes, and taps; phosphate ions (11 - 20 mg/L) and zinc (3.71 - 4.42 mg/L) for ordinary wells, Drillings and Milo river; iron ions (0.5 mg/L) for the Milo river; ammonium ions (0.26 - 0.6 mg/L) for standard drillings and wells; lead (0.05 mg/L) and nitrate ions (56 - 129 mg/L) for the drillings were measured using the colorimetric method. These results also indicate that most of these waters are polluted due to their content of these various ions. The statistical analysis of the data for certain chemical parameters (concentration of nitrite and phosphate ions) was conducted using Stata 15 software, and the correlation test between the parameters yielded very significant values ($r = 0.80$; $p < 0.05$). These results add to those obtained above and further confirm that these waters are polluted. Taken together, these results demonstrate that the waters at these different sites are unsuitable for any use by the populations living there. The local authorities should implement measures to protect water sources from contamination, in particular by controlling agricultural and domestic discharges.

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Conflicts of Interest

All authors certify that they have no affiliation or involvement in any organization or entity having a financial or non-financial interest in the subject matter discussed in this manuscript.

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