Comparative study of the physicochemical quality of groundwater in Sokorodji and Sogoniko

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DOI: https://doi.org/10.56293/IJASR.2022.5540

IJASR 2023
VOLUME 6
ISSUE 4 JULY – AUGUST **ISSN: 2581-7876**

Abstract: Water is a vital substance for life, the human organism contains an average 70%. This study aimed to analyze the physicochemical quality of water from boreholes and wells collected in two neighborhoods of Bamako (Sokorodji and Sogoniko). The water samples were taken at forty water points in use, including 10 boreholes and 10 wells for each site. The physicochemical parameters including the pH, conductivity, color, turbidity, hardness, alkalinity, ferrous ions, chlorides, bicarbonates, nitrates, nitrites, fluorides, sulphates, calcium, magnesium, sodium and potassium were carried out. Based on the results, a majority of physiochemical characteristics of the drinking water were in favor of a good hygiene. In other sides, many others important parameters provided alerts about the consumption of these water.

For instance, the levels of these parameters indicated that all the wells of Sogoniko (100%) are non- standards with the standards and those of Sokorodji at 90%. As for the boreholes, the rate of non- standards was 70% for Sogoniko against 60% for Sokorodji. The menace is stronger in Sogoniko's water points than Sokorodji's ones. Also, it appears the water from boreholes was safer than those from wells in the both. The data constitute one more alert for the Malian authorities about drinking water for local populations of Bamako.

Keywords: Boreholes, wells, physicochemical parameters, Bamako.

1. INTRODUCTION

Water is a natural resource that exists in three forms (liquid, solid and gas); it can be on the surface or underground. In the human body it represents on average 70% of the body mass (Emblanch & Jourdren, 2022). The water needs of the populations vary considerably not only according to the situation of the city, but also according to the level of development and the activities: food, personal hygiene, dishes, etc. (Hugonin, 2011). It is a part of our natural environment like the air we breathe (Hayat & Naima, 2017). Access to drinking water by populations is a priority for populations in less developed countries. Water circulates constantly on the earth (Stephen et al 2017), it evaporates from the oceans and returns there in the form of precipitation (rain, snow, or hail). The water vapors group together, form clouds which, pushed by the wind, meet cold air masses and give rise to rain and snow which infiltrate the ground and reach the groundwater, rivers, forming a cycle called the water cycle. More than 75 to 90% of the world's population uses groundwater (Yasmine & Rym, 2021). Groundwater is: Groundwater including groundwater containing water at shallow depths, they traditionally supply wells and springs with drinking water (Kahoul and Touhani 2014), free aquifers in direct contact with the atmosphere via a water-saturated zone, captive aquifers between two impermeable geological layers that confine water under pressure (Arkema 2020, Arjen, 2010). Sources generally determine the qualities of groundwater (Sanogo, 2021). Fresh water is a rare commodity, 73% are used in agriculture and industry and only 6% are intended for drinking water. In addition, 40% of the world's food is produced by irrigated areas. According to WHO, having water available in sufficient quantity and quality contributes to the maintenance of health because it can be a source of disease due to its contamination by household, industrial and agricultural wastes, by excreta and various organic wastes (Belghiti et al, 2013). The water from the borehole is purified by a long route through the ground ((Gouaid et al 2017) and the possibilities of pollution are reduced if the extraction of water is done by means of a pump (Mwanza et al., 2019) Groundwater pollution is any physical, chemical, biological or bacteriological degradation of its natural qualities, caused by the environment and human activity, agricultural, household and industrial wastes (Jason, 2018; Soncy et al., 2015). It must undergo various physicochemical and bacteriological analyzes which will define its quality for human consumption (Trépanier, 2018).

It is known that many physicochemical parameters are involved in the drinking water quality. For instance, the pH of water is determined by the balance between calcium (Ca^{2+}), sodium (Na+), magnesium (Mg^{2+}) and potassium (K^{+}) cations and chloride, fluorine and sulphate anions. The turbidity, the conductivity is also linked to the presence of the metals already mentioned. The carbonic acid, alkalinity content, hardness, ferric ions are also elements of the quality of drinking water according to international standards (Kristin et al., 2015). Excess nitrites oxidize hemoglobin, which reduces the transport capacity of red blood cells. If nitrates are recommended for their beneficial effects, particularly against infections, carcinomas and cardiovascular diseases, they are easily transformed into nitrites which could form compounds as nitrosamines which are carcinogenic in the stomach. Alkalinity has a beneficial effect on health because it reduces the acidity of the internal environment. Several ions promote the alkalinity of water, these are bicarbonate, carbonate and hydroxide ions. Magnesium is involved in several biological reactions, energy recovery, signal transmission in muscle contraction and relaxation, magnesium also contributes to electrolyte balance in the dentition (Mwanza et al., 2019). The use of groundwater for consumption requires regular monitoring and quality control (Ghazali and Zaid, 2013).

A large proportion of Bamako's local population (especially those from Sokorodji and Sogoniko) use drinking water from wells and boreholes. However, these waters are not regularly monitored. The purpose of this study is to compare the physicochemical quality of drinking water collected from wells and boreholes of Sokorodji and Sogoniko. It is part of the quality control of groundwater consumed by the local populations.

2. MATERIALS & METHODS:

2.1. Materials:

The study material consisted of water samples collected from boreholes and wells between July and August 2022 in two quarters of Bamako: Sokorodji and Sogoniko. Samples were taken from 10 boreholes and 10 wells in each of the two sites, for a total of 40 samples.

2.2. Methods

2.2.1. Presentation of the study area:

Sokorodji and Sogoniko are popular quarters of commune VI with respectively an area of 217 and 353hectares (Figure 1). Sokorodji with its estimated inhabitants at 12415 is located at 120 36' North latitude and -70 56' West longitude. The population of Sogoniko is a commercial zone of Bamako located at 120 36' North latitude and - 7 0 57' West longitude with its approximately population of 22816.

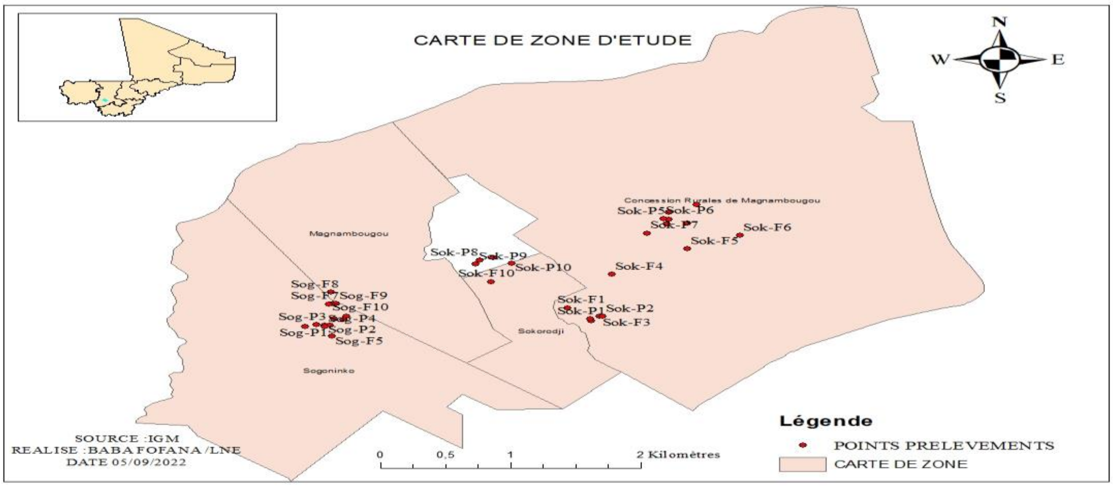

Figure 1: Map of the study area

2.2.2. Identification of sampling points

This operation consists of identifying the site and the sampler, the date and time of sampling, the individual or company requesting the request, the reason for the analysis request.

Table 1. Sampling points and their geographical coordinates in two sites

Sites	Sokorodji			Sogoniko		
Water point type	Water point identifier	Latitude	Longitude	Water point identifier	Latitude	Longitude
Boreholes equipped	Sok-B_1	12.60778	-7.94631	Sog-B_1	12.60595	-7.96411
	Sok-B_2	12.6063	-7.94465	Sog-B_2	12.60689	-7.96196
	Sok-B_3	12.60681	-7.94405	Sog-B_3	12.60655	-7.96218
	Sok-B_4	12.61152	-7.94315	Sog-B_4	12.60657	-7.96283
	Sok-B_5	12.61438	-7.93781	Sog-B_5	12.60464	-7.96302
	Sok-B_6	12.6159	-7.93408	Sog-B_6	12.60574	-7.96487
	Sok-B_7	12.61848	-7.93911	Sog-B_7	12.6083	-7.9629
	Sok-B_8	12.61932	-7.9371	Sog-B_8	12.60958	-7.96307
	Sok-B_9	12.61347	-7.95158	Sog-B_9	12.60832	-7.96266
	Sok-B_{10}	12.61073	-7.95169	Sog-B_{10}	12.60824	-7.96322
Wells	Sok-W_1	12.60649	-7.94468	Sog-W_1	12.60589	-7.96348
	Sok-W_2	12.60677	-7.94383	Sog-W2	12.60573	-7.96349
	Sok-W_3	12.61727	-7.93781	Sog-W_3	12.60591	-7.96315
	Sok-W_4	12.61717	-7.93922	Sog-W_4	12.60573	-7.96353
	Sok-W_5	12.61772	-7.93914	Sog-W_5	12.60572	-7.96357
	Sok-W_6	12.61779	-7.9395	Sog-W_6	12.60621	-7.96283
	Sok-W_7	12.61616	-7.94063	Sog-W_7	12.59969	-7.96553
	Sok-W_8	12.61316	-7.95254	Sog-W_8	12.60024	-7.96561
	Sok-W_9	12.61272	-7.95278	Sog-W_9	12.59961	-7.96486
	Sok-W_{10}	12.61276	-7.95024	Sog-W_{10}	12.59993	-7.96534

** Sok = Sokorodji; Sog = Sogoniko; B = Boreholes; W= wells.*

2.2.3. Sampling

Taking a water sample is a delicate operation to which great care must be taken. It conditions the analytical results and the interpretation that will be given. The sample must be homogeneous, representative and without modifying the physicochemical characteristics of the water. It is advisable to label each vial very carefully, making it possible to gather useful information for the laboratory as well as reserved observations during operations. Previously sterile one and a half liter (1.5 L) bottles were used for the samples. Taking water from the borehole, the bottle is rinsed three times with water to be analyzed, then filled. For well water, the sample is taken using a scoop fitted with a rope, rinse the bottle three times with the sample and then fill it.

2.2.4. Determination of physicochemical parameters

All these physicochemical parameters were carried out according to the used methods of national laboratory of water in Mali reported by Sanogo (2021).

The conductivity is the conductance of a column of water between two metal electrodes with a surface area of 1 cm^2 and separated from each other by 1 cm. The WTW brand LF 197 conductivity meter was used to measure the conductivity.

The HACH brand DR 6000 colorimeter was used to determine the color of the water.

The turbidity of water is due to the presence of suspended solids composed of clay, silt, and organic particles. It was measured by the Palin 7100 turbidimeter.

The METROHM brand ion chromatograph was used to determine the content of chloride (Cl^-), sulphate (SO_4^{2-}), nitrate (NO^{3-}), nitrite (NO^{2-}), and fluoride (F^-) ions.

The LAMBDA 25 spectrophotometer was used to determine the content of Fe^{2+} ions in the water samples. The JENWAY brand flame photometer was used to determine the content of sodium and potassium in the water.

The complete alkalinity, the total hardness and the ions (Magnesium, Calcium, Bicarbonates,) are determined by automated titration using the METROHM brand Tiamo.

TAC alkalinity: Alkalinity is determined using 0.02N sulfuric acid. 50 mL of water samples were taken using a graduated cylinder, then placed on the rack of the machine. The dosage is carried out according to the pH. The total hardness or TH: After determining the alkalinity, the machine automatically moves on to determining the total hardness. The 50 mL water samples are dosed with the EDTA solution in the presence of 15 mL of the buffer solution. The result is expressed in mg/L of $CaCO_3$ and in mg/L for the calcium and magnesium ions contained in the water.

3. RESULTS

3.1. Percentage of compliant and non-compliant water samples according to the sites

The Figure 2 summarizes the number of water samples within and outside the standards for boreholes and wells based on the investigated parameters.

The analysis of the samples by site indicated in Figure 2 shows that all the wells of Sogoniko (100%) are non-standards with the standards and those of Sokorodji at 90%. As for the boreholes, the rate of non- standards was 70% for Sogoniko and 60% for Sokorodji.

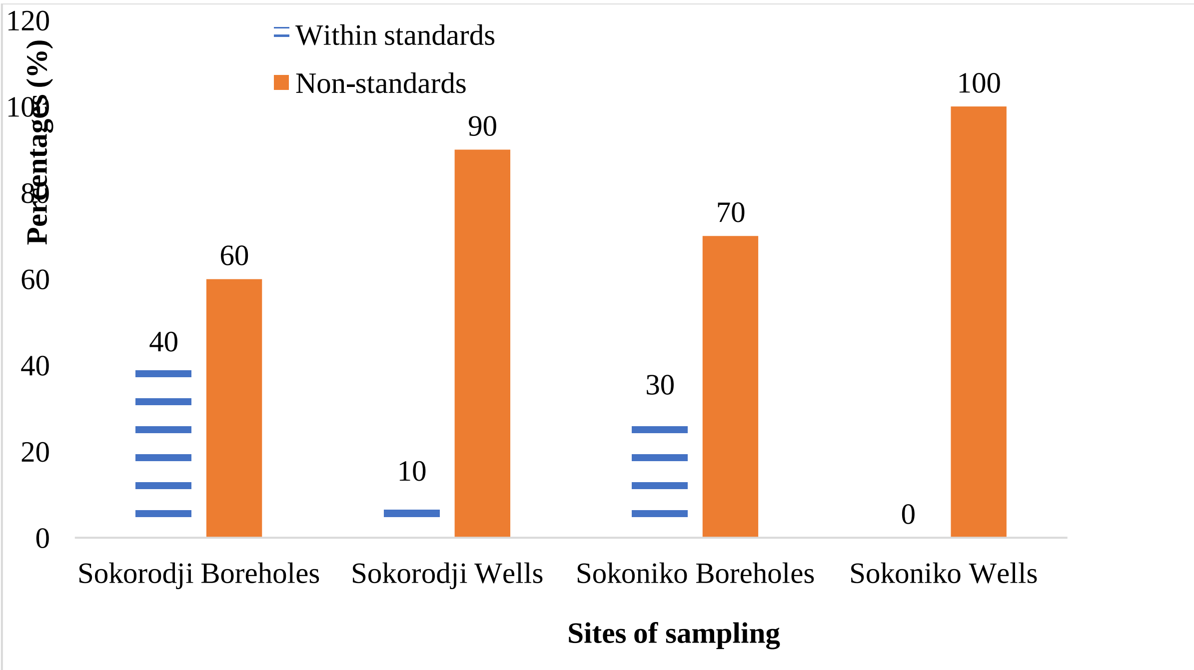

Figure 2: Percentages of standards and non-standards samples

3.2. Number of samples according to non-standards physicochemical parameters

The Table 2 describes the physicochemical parameters outside the standards

Table 2. Number of physicochemical parameters outside the standards

Physicochemical parameters	Types of groundwater	Number of water point	Total of water point
pH	Boreholes	3	8
	Wells	5	
NO_2^-	Boreholes	2	7
	Wells	5	
NO_3^-	Boreholes	8	22
	Wells	14	
TAC	Boreholes	7	12
	Wells	5	
Ca^{2+}	Wells	3	3
Mg^{2+}	Boreholes	1	1
Fe^{2+}	Boreholes	1	1

The analysis of Table 2 shows that the many parameters are not in accordance with the standards: the pH of the samples of 8 wells: W_2, W_4 and W_5 of Sokorodji and W_1 W_2, W_3, W_4 and W_5 of Sogoniko. The nitrites of the samples W_9 and W_{10} from Sokorodji as well as samples B_9, B_{10}, W_4, W_9 and W_{10} from Sogoniko. Twenty-two of 40 water points (55%) had a highest amount of nitrates (NO_3^-) and 7 of 40 (17,50%) for the nitrites (NO_2^-). The highest amount of nitrates and nitrites were mainly recorded in drinking water from well. The magnesium, calcium and ferric ions have less than 10% of unsafe water samples.

3.3. Physicochemical characteristics of water samples

Some investigated physicochemical parameters which present unsafe values of water samples from boreholes and wells are mentioned in Tables 3 & 4, respectively. These Tables 3 & 4 let show that some water points present hazardous values about their contents in nitrites, nitrates, magnesium, in addition to their pH and alkalinity.

Table 3. Some investigated physicochemical parameters of water samples from boreholes

Water point	Sokorodji			Sogoniko		
	NO_3^- (mg/L)	Mg^{2+} (mg/L)	TAC (mg/L)	NO_2^- (mg/L)	NO_3^- (mg/L)	TAC (mg/L)
B_1	50,80	5,95	192,46	0 ,671	85,34	202,52
B_2	6,19	110,18	114,91	0,110	81,68	129,53
B_3	39,93	4,72	194,82	0,000	46,38	151,79
B_4	58,48	8,25	83,77	0,000	48,89	73,74
B_5	0,82	0,14	53,90	0,000	5,26	265,62
B_6	1,51	5,76	196,48	0,194	41,51	137,02
B_7	58,89	3,02	39,2	0,000	216,46	166,48
B_8	92,83	1,30	172,3	0,000	16,46	28,25
B_9	18,39	13,21	182,7	0,334	17,84	185,99
B_{10}	33,43	6,41	91,18	0 ,113	96,07	168,14
Norms	≤ 50	≤ 100	≤ 150	≤ 0,02	≤ 50	≤ 150

** B_1 to B_{10}: Number of boreholes; Numbers in bold are non-standard*

These data reveals that 4 of 10 boreholes (40%) for Sokorodji and the same for Sogoniko are unsafe based on their nitrate contents (> 50 mg/L). Only 1% of boreholes show a high level of magnesium (> 100 mg/L) for Sokorodji. In other hand, if boreholes of Sokorodji are totally safe about nitrites content (< 0,02), it appears that 20% of them are unsafe for consumption at Sogoniko. As for the alkalinity, Sogoniko possessed the highest hazardous values (50%) recorded in boreholes against 20% for Sokorodji.

Table 4. Some investigated physicochemical parameters of water samples from wells

Water point	Sokorodji				Sogoniko				
	pH	NO_2^- (mg/L)	NO_3^- (mg/L)	TAC (mg/L)	pH	NO_2^- (mg/L)	NO_3^- (mg/L)	TAC (mg/L)	Ca^{2+} (mg/L)
W_1	5.96	1.438	25.50	99.70	4.56	0.089	147.19	201.24	25.84
W_2	5.16	0.000	53.26	60.26	5.18	1.910	253.97	237.43	44.62
W_3	6.09	0.101	76.91	45.42	4.57	0.953	306.76	65.30	29.20
W_4	5.48	0.102	97.28	60.88	5.15	**0.188**	210.76	362.84	43.66
W_5	5.30	0.000	94.19	54.70	5.67	0.181	285.26	275.93	80.40
W_6	6.38	0.000	107.20	63.72	4.45	0.083	49.32	54.89	49.32
W_7	6.59	0.167	66.65	36.47	7.14	0.096	71.97	125.96	71.97
W_8	6.52	2.333	76.25	161.57	5.67	2.297	57.02	58.40	57.02
W_9	6.62	2.809	52.44	95.64	6.83	0.106	95.42	113.41	95.42
W_{10}	6.68	44.219	701.66	480.22	6.13	0.491	39.53	48.01	39.53
Norms	5.5≤ pH≤8	**≤ 0.02**	≤ 50	≤150	**5.5≤pH≤8**	**≤0.02**	**≤50**	**≤150**	**≤400**

* *W_1 to W_{10}: Number of wells; Numbers in bold are non-standard*

For the first time, abnormal pH were noted from wells of Sokorodji (30%) and Sogoniko (50%). The abnormality observed from wells with nitrates (NO_3^-) was important than one recorded from boreholes. It varied from 50% for Sogoniko to 90% for Sokorodji. In opposite, a low rate of abnormal alkalinity was registered: 20% to 40% for Sokorodji and Sogoniko, respectively.

4. DISCUSSION

During this groundwater study of Sokorodji and Sogoniko, 40 water samples were analyzed and compared. The results showed that 40% of the boreholes and 10% of the wells of Sokorodji and 30% of the boreholes of Sogoniko have all the physicochemical parameters within the standards. A large majority of the investigated physicochemical parameters (color, turbidity, conductivity, chloride ions, fluorine, sulphates, magnesium, carbonic acid, hardness, sodium and potassium ions) were within the standards in the water samples from the both sites. However, the levels of others parameters (nitrites, nitrates, pH, alkalinity, calcium and magnesium) revealed that the safety of these drinking water from boreholes and wells are threatened.

The pH of the water samples analyzed varied between 4.45 to 7.48 for the borehole waters and 4.45 to 7.14 for the well waters of the two quarters. These pH values are abnormal for wells with 30% and 50%, respectively Sokorodji and Sogoniko. All samples with non-standards pH provide us with information on the types of ions mainly present, thus in samples from wells where the pH is acidic the anions are higher. The values obtained are close to the results of Sanogo (2021) who conducted a similar study on certain wells and boreholes in Mopti. This acidity is due to the siliceous and lateritic terrain of Bamako. Water with a pH of 7.2 to 7.8 is ideal for maintaining good health. Consuming liquids that are too acidic or too basic can upset this delicate balance, and lead to the development and growth of bacteria, viruses, fungi, yeasts and parasites. Also, a low rate of abnormal alkalinity was registered: 20% to 40% for Sokorodji and Sogoniko, respectively.

The nitrites content of the Sokorodji and Sogoniko samples ranged from 0.000 mg/L to 0.334 mg/L for borehole water and from 0.000 mg/L to 44.219 mg/L for well water. The majority of our samples are in accordance with the nitrite norms (≤ 0.02 mg/L). But 20% for boreholes and 30% for wells of Sogoniko and boreholes of Sokorodji are out the norms. These recorded values are consistent with the results of Mwanza et al. (2019). But they are different from Bouraima *et al* (2015). As for the nitrates (NO_3^-), the abnormality observed from wells with nitrates (NO_3^-) was important than one recorded from boreholes. It varied from 50% for Sogoniko to 90% for Sokorodji. The different results do not converge with those found by Bengaly (2016) who conducted a similar study on groundwater in Bamako and registered a low rate of non-standards. These high rates of non-standards could be due to the proximity of water point sources in an urban environment to the toilets or the gutters as reported by Sanogo (2021); Trépanier (2018). The literature reports that nitrates are not really toxic. It is their transformation into nitrites and nitrosated compounds (nitrosamines and nitrosamides) that could cause characteristic disorders. The nitrites formed in this way combine with blood hemoglobin to reduce oxygen-carrying capacity. Generally, with adults, current levels of nitrates and nitrites in water do not appear to be acutely toxic. However, in the long term, nitrosated compounds produced by the combination of nitrites with basic protein compounds are suspected to cause cancer (Bengaly, 2016). This presence of high-content substances could be linked to many factors, including surface water pollution, the nature of the soil.

CONCLUSION

A comparison study between boreholes and wells of two quarters of Bamako was carried out. The obtained data show that the majority of the investigated physicochemical parameters were within the standards of National Laboratory of Water of Mali. But others the levels of others parameters (nitrites, nitrates, pH, alkalinity, calcium and magnesium) revealed that these drinking water from boreholes and wells need a regular control and treatment to be safe for local populations' consumption and household works. Finally, the data show that water from boreholes is better than those from wells.

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