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Physicochemical and microbiological analyses of spring water from a rural area in the Western of Skikda (Algeria).

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ABSTRACT

This study investigates the physicochemical and bacteriological quality of spring water from five sources in the wilaya of Skikda, Algeria, focusing on areas in the communes of Zitouna and Kanoua. The physicochemical analyses were conducted using electrochemical and volumetric methods, while bacteriological analyses involved membrane filtration techniques. The sampling covered various parameters including pH, temperature, electrical conductivity, turbidity, total dissolved solids (TDS), alkalinity, hardness, and concentrations of calcium, magnesium, chloride, iron, copper, zinc, nitrate, nitrite, ammonium, phosphate, and sulfate.

The results show that all physicochemical parameters generally meet Algerian and international standards, indicating good water quality. pH values ranged from 6.5 to 7, with temperatures below 25°C, and electrical conductivity, turbidity, and TDS levels within acceptable limits. However, total alkalinity was absent, and while most sites had calcium and magnesium concentrations within standard limits, some exceeded acceptable levels. Bacteriological analyses revealed that Sites S1, S3, and S5 complied with Algerian standards for total coliforms, fecal coliforms, fecal streptococci, and *Escherichia coli*, indicating safe drinking water. In contrast, Sites S2 and S4 exceeded acceptable levels for total and fecal coliforms, suggesting significant contamination issues. Overall, the study underscores the importance of regular monitoring and targeted interventions to address water quality issues, particularly in sites with higher contamination levels. Implementing effective water treatment and management practices is essential to ensure consistent compliance with safety standards and protect public health.

KEYWORDS

Bacteriological analyses, Kanoua, Physicochemical parameters, Rural area, Zitouna.

INTRODUCTION

Pollution of drinking water presents a significant global challenge and poses a grave risk to human health. Contamination can occur at the source, during distribution, or even within households, potentially carrying various pathogens (WHO, 2017 ; Bedada et al. 2018). This issue is particularly severe in impoverished societies, largely due to inadequate awareness and implementation of sanitation measures at multiple levels (Baye et al. 2021). The significance of clean and safe water cannot be overstated . Access to drinking water is a fundamental right (Appiah-Effah et al. 2019) and is essential for health and well-being (UNDESA, 2011 ; Shaheed et al. 2014).

Water is a natural element of paramount importance, playing a crucially indispensable role for all living beings; it is the principal component of living matter (Motuma and Mulissa (2008). Spring water is distinguished by its balanced chemical composition, rich in minerals such as calcium, magnesium, potassium, and bicarbonate (Smedley and Kinniburgh (2002). These minerals give spring water unique taste properties and health benefits, contributing to the body's electrolyte balance and the health of bones and teeth.

The consumption of spring water offers numerous health advantages (Vallance, and Gorman, 2017 ; Liu and Jones, 2018 ;Gordon and Preece, 2019). In addition to providing essential minerals, it is naturally free of common contaminants such as pesticides, industrial chemicals, and pathogenic bacteria (Smith and Jones, 2018 ; Levine and Patel, 2019). Its purity and mineral composition make it an ideal hydrating option to support overall well-being and promote healthy skin. Water quality is discerned through its physicochemical and microbiological characteristics (Miller and Brown, 2018 ; Gordon and Myers, 2019).

Drinking water is more frequently contaminated in rural areas (41%) compared to urban areas (12%), with the highest contamination rates found in Africa (53%) and South-East Asia (35%) (Bain et al. 2014). Additionally, approximately 525,000 children under the age of five die each year from diarrheal diseases, the majority of which are related to water, sanitation, and hygiene (WHO, 2017). Pathogens such as Salmonella, Vibrio cholerae, Shigella, E. coli , , Hepatovirus A, and Hepatovirus E are known to be transmitted through contaminated drinking water, causing severe to fatal illnesses (WHO, 2017).

In Algeria, the primary source of meeting water demand is groundwater due to its relatively easy exploitation. Potable groundwater originates from two sources: shallow aquifers and deep aquifers (Rezig et al. 2021). Water pollution remains an international issue caused in part by chemical alterations that water undergoes (concentration, ion exchange, reduction) capable of

partially changing its chemical properties, and also by thermal or microbiological changes from point and non-point sources (Carpenter et al. 2011 ; WHO, 2011 ; UNEP, 2016). Microbiological pollution is a major cause of water quality degradation and can cause serious illnesses, particularly in developing countries (WHO, 2014 ; Gupta and Kar, 2016 ; Biryar and Najmaldin, 2024).

Zitouna and Kanoua are two areas rich in natural water sources, used by the population for drinking, cooking, and washing. These sources must possess good physical, chemical, and bacteriological properties and comply with drinking water standards to ensure they pose no health risks to consumers. Therefore, our work aims to study the physicochemical and bacteriological quality of five natural sources in the Zitouna and Kanoua regions, Western area of Skikda wilaya, North-Estern of Algeria, and assess if these drinking waters comply with Algerian standards.

MATERIALS AND METHODS

1. Description of the Study Area:

The wilaya of Skikda is established during the administrative reorganization of 1974. It comprises thirteen daïras, encompassing thirty-eight communes. It is bordered to the north by the Mediterranean Sea, to the south by the Wilaya of Constantine and partially by the Wilaya of Mila, to the east by the Wilaya of Annaba and Guelma, and to the west by the Wilaya of Jijel.

Zitouna is located in the wilaya of Skikda, in the northeastern part of Algeria. More specifically, the wilaya of Skikda is situated on the Mediterranean coast, and the daïra of Zitouna extends along this coast, with direct access to the Mediterranean Sea. It is bordered by other daïras within the wilaya of Skikda, as well as by neighboring wilayas. Zitouna is located in the Collo forest massif, 4 km from Mount Goufi, in the western part of the wilaya of Skikda, directly south of Cape Bougaroun, at an altitude of 593 meters, nestled between the sea and the mountains amidst a vast cork oak forest of 25,000 hectares. Due to its position, Zitouna is 86 km by road from Skikda and 14 km from Collo. The territory of the commune covers an area of 34.32 km². The commune of Zitouna is bordered to the east by the commune of Cheraïa, to the west by the commune of OuledAttia, to the north by the commune of Kanoua, and to the south by the commune of BeniZid.

Kanoua is a commune in the daïra of Zitouna, located 14 km from the daïra of Zitouna, which is part of the wilaya of Skikda in Algeria. Kanoua is situated on the Mediterranean coast, in northeastern Algeria. It is bordered by the Mediterranean Sea to the east, providing direct

access to the coast. Other communes in the wilaya of Skikda also surround the commune of Kanoua: OuladAtia to the north, Zitouna to the west, and Cheraiaa to the south.

2. Study Framework

The bacteriological analyses were conducted at the central laboratory of Algeria water, located 6 km from the wilaya of Skikda, and physicochemical analyses were carried out at Sonatrach of Skikda.

3. Sampling Selection of Sampling Stations

Our study is focused on the physicochemical and bacteriological analysis of spring water from various sources, we selected five springs, all intended for human consumption. Four springs are located in the commune of Zitouna (Douiouar, Tiboura, Bourrihane, Massouya) and one spring is located in the commune of Kanoua (Sdimate). (Tab. 1 and Fig. 1).

Table 1. Different sources of samples.

Samples	Site	Location
S1	SDIMAT	KANOUA
S2	DOUIOUAR	ZITOUNA
S3	BOURRIHANE	
S4	MESSOUYA	
S5	TIBOURA	

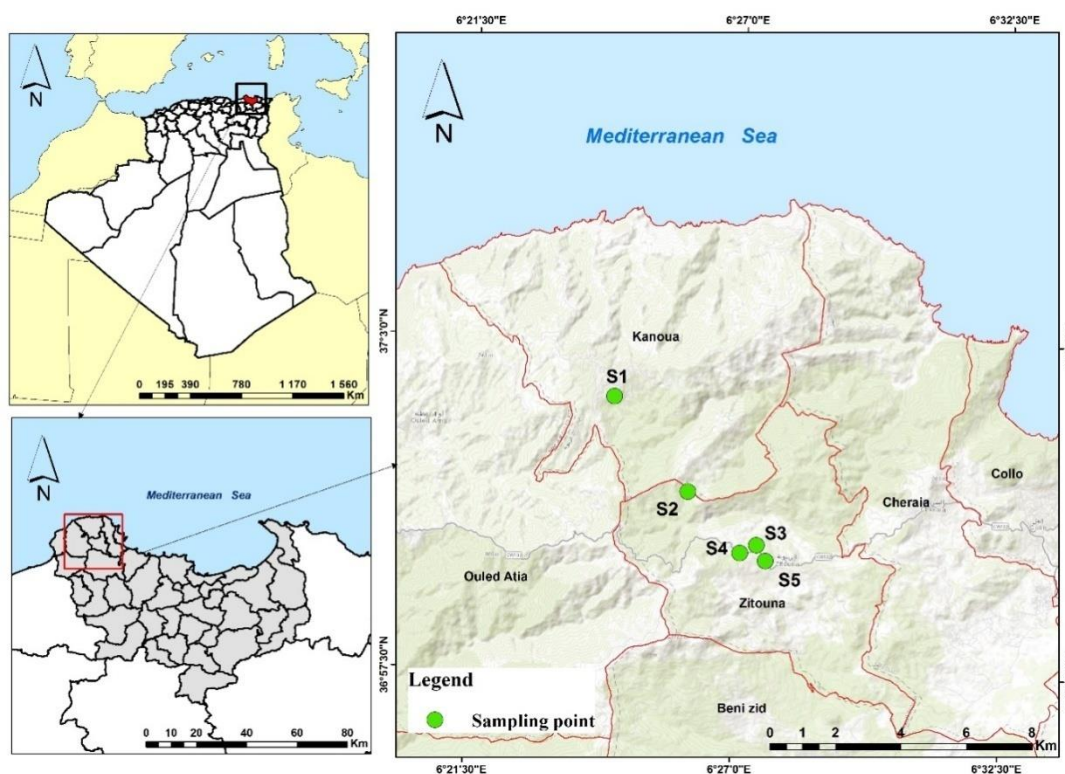


Figure 1. Location of sampling sites in Study area.

4. Sampling Techniques

Water samples necessary for physico-chemical analysis were collected in well-cleaned plastic bottles. For bacteriological analysis, the samples were taken in glass vials previously washed with distilled water and then sterilized in an autoclave. The samples must be labeled with the source name, date, and time of collection.

4.1. Transport of Samples

The carefully labeled samples are placed in a cooler with a temperature between 4 to 6 °C, then transported to the laboratory for analysis. The time between sample collection and analysis should not exceed 24 hours (WHO, 2017).

4.2. Physicochemical parameters

For the physicochemical parameters, we used the electrochemical method to measure the physical parameters; pH, temperature, electrical conductivity, and TDS were measured immediately using a multiparameter device. For the chemical parameters, we used the volumetric method for TAC, TA, THT, Cu, and Zn, whereas the other parameters were measured using spectrometry.

4.3. Bacteriological analyses

This method involves filtering the water sample through a 0.45µm filter membrane. This membrane is incubated at 44°C for 24 hours on a tergitol 7 medium for the detection of fecal coliforms and incubated at 37°C for 48 hours for the detection of total coliforms. For the detection of streptococci, the filter membrane is incubated on a Slanetz culture medium at 37°C for 24 hours.

RESULTS AND DISCUSSION

1. Physicochemical parameters

According to the findings mentioned in the table 02, we showed that pH values range from 6.5 to 7. All sites meet the Algerian standard range of 6.5-9, among them Globally, WHO consider pH values between 6.5 and 8.5 acceptable. These results indicate that the water is neither too acidic nor too basic these finding are similar to Boudjema et al.2016 in Algeria. and Kumar et al . 2019 in India. For temperatures, all sites are within the acceptable limit of 25°C, consistent with international standards, which typically recommend temperatures below 25°C to prevent microbial growth and ensure consumer comfort (Fleischmann et al. 2018; Benhamou et al. 2020). All sites are well within the Algerian standard of 2800 µs/cm. Compared to other studies in Algeria (Mouhouche et al. 2005), and in North America (Smith *et al.* 2017), these values are quite low, indicating good water quality with low ion concentration. All sites are

within the Algerian standard limit of 5 NTU, indicating low levels of suspended particles which were compared with studies carried out by Chabane et al. 2018 in Algeria and Brown et al. 2019 in Australia. This is consistent with WHO guidelines, where values typically remain below 5 NTU. All sites are within the acceptable limit of 1500 mg/l, indicating low concentrations of dissolved substances (TDS). These values are similar to those found in other studies in Algeria (Mellal et al. 2021) and other countries (Harrison et al. 2020), with low to moderate mineral content in water. TA is 0 mg/l of CaCO₃ at all sites. The absence of alkalinity suggests the water has little buffering capacity, making it susceptible to pH changes. This is not uncommon in regions with low mineral content in water (Tahar et al. 2019; Costa et al. 2021). TAC values range from 40 mg/l to 145 mg/l of CaCO₃. Sites S1, S2, S3, and S5 are within or close to the standard range of 50-100 mg /l., Site S4 exceeds the upper limit, indicating higher levels of acid-neutralizing capacity. These values are consistent with those found in other parts of Algeria and other countries with similar geological conditions (Sánchez et al. 2018; Gharbi et al. 2022). THT ranges from 62 mg/l to 210 mg/l of CaCO₃. All sites are within the standard limit of 500 mg/l, indicating that the water is not excessively hard. Similar hardness levels are observed in other studies in Algeria and globally in regions with moderate water hardness (Benouadah et al. 2017; Jackson et al. 2019).

Calcium concentrations range from 20 mg/l to 124 mg/l. All sites are within the acceptable limit of 200 mg/l. These values are comparable to those found in other studies in Algeria and globally, indicating moderate levels of calcium (Wang et al. 2020; Zouari et al. 2021). Magnesium concentrations range from 22 mg/l to 86 mg/l. Site S2 and S4 exceed the standard limit of 50 mg/l. High magnesium levels can contribute to water hardness. Similar issues are observed in other regions in Algeria and other countries, often related to local geological conditions (Wang et al. 2020; Zouari et al. 2021). Chloride concentrations range from 26 mg/l to 116 mg/l. All sites are within the acceptable limit of 300 mg/l. These levels are typical for drinking water in Algeria and other countries, indicating low to moderate salinity (Boudjema et al. 2016; Brown et al. 2019). Iron concentrations range from 0.03 mg/l to 0.16 mg/l. All sites are within the acceptable limit of 0.3 mg/l. Similar levels are found in other studies in Algeria and globally, indicating no significant iron contamination (Smith et al. 2017; El Hadi et al. 2018). Copper concentrations range from 0.01 mg/l to 0.15 mg/l. All sites are well within the acceptable limit of 1 mg/l. These levels are consistent with those found in other regions (Smith et al. 2017; El Hadi et al. 2018). Zinc concentrations range from 0.03 mg/l to 0.07 mg/l. All sites are within the acceptable limit of 3 mg/l. These values are consistent with other studies in Algeria and other countries (Smith et al. 2017; El Hadi et al. 2018).

Nitrate concentrations range from 0.2 mg/l to 0.62 mg/l. All sites are well within the acceptable limit of 50 mg/l. These low nitrate levels are similar to those found in other regions of Algeria and other countries with low agricultural runoff (Hoffmann et al. 2018; Benhamou et al. 2020). Nitrite concentrations range from 0.006 mg/l to 0.01 mg/l. All sites are within the acceptable limit of 0.1 mg/l. These values are consistent with those found in other studies in Algeria and globally (Hoffmann et al. 2018 ; Benhamou et al. 2020). Ammonium concentrations range from 0 mg/l to 0.16 mg/l. All sites are within the acceptable limit of 0.5 mg/l. Similar levels are found in other studies in Algeria and globally, indicating minimal organic contamination(Hoffmann et al. 2018 ; Benhamou et al. 2020). Phosphate concentrations range from 0.16 mg/l to 0.41 mg/l. All sites are within the acceptable limit of 0.5 mg/l. These values are comparable to those found in other regions with minimal agricultural runoff (Hoffmann et al. 2018 ;Benhamou et al. 2020). Sulfate concentrations range from 0 mg/l to 37 mg/l. All sites are well within the acceptable limit of 400 mg/l. Similar sulfate levels are found in other studies in Algeria and globally (Hoffmann et al. 2018 ; Benhamou et al. 2020).

Table 02. Results of physicochemical parameters.

Parameters	Sites	S1	S2	S3	S4	S5	Algerian standards
pH		6.5	6.6	6.7	7	6.9	6.5-9
Temperature (° C)		24	23.5	23.2	23.1	23.3	25
Electrical conductivity (µs/cm)		191	100	163	466	236	2800
Turbidity (NTU)		0.37	0.17	1.9	1.04	1.46	5
TDS (mg/l)		92	48	80	233	115	1500
TA (mg/l of CaCO ₃)		0	0	0	0	0	5
TAC (mg/l of CaCO ₃)		54	45	40	145	63	50-100
THT (mg/l of CaCO ₃)		70	106	62	210	86	500
Calcium (mg/l)		48	50	20	124	60	200
Magnésium (mg/l)		22	56	42	86	26	50
Chlorure (mg/l)		60	26	40	116	60	300
Fer (mg/l)		0.03	0.03	0.04	0.07	0.16	0.3
Cuivre (mg/l)		0.15	0.01	0.05	0.03	0.02	1
Zinc (mg/l)		0.06	0.06	0.05	0.03	0.07	3
Nitrates (mg/l)		0.2	0.36	0.34	0.62	0.59	50
Nitrites (mg/l)		0.01	0.01	0.006	0.008	0.006	0.1
Ammonium (mg/l)		0	0	0.01	0.16	0	0.5
Phosphate (mg/l)		0.29	0.41	0.28	0.16	0.38	0.5
Sulfate (mg/l)		0.55	0	19.14	37	11.72	400

2. Bacteriological analyses

From the results obtained in the table 03, we showed that:

Total Coliforms: Sites S1, S3, and S5 meet the Algerian standard of 0 UFC/100ml, indicating no detectable total coliforms, which is a good indicator of overall water quality. Site S2 significantly exceeds the standard with >100 UFC/100ml, indicating a high level of contamination. This could suggest issues with water source protection or treatment processes. Site S4 is above the standard with 15 UFC/100ml, suggesting moderate contamination, potentially due to local sources of pollution or inadequate treatment.

Fecal Coliforms: Sites S1, S3, and S5 meet the Algerian standard of 0 UFC/100ml, indicating that these sites are free from fecal coliform contamination, which is crucial for assessing the presence of fecal pollution. Site S2, with >100 UFC/100ml, indicates severe fecal contamination, which poses significant health risks and suggests issues with sanitation or waste management. Site S4, with 15 UFC/100ml, indicates some level of fecal contamination, though less severe than Site S2, suggesting localized contamination sources.

Fecal Streptococci: All sites meet the Algerian standard of 0 UFC/100ml, indicating no presence of fecal streptococci, which is a good sign for water safety and indicates the absence of fecal pollution.

Escherichia coli: All sites meet the Algerian standard of 0 UFC/100ml, showing no detectable E. coli, a key indicator of fecal contamination and a major pathogen of concern for drinking water.

The Algerian standards for total coliforms, fecal coliforms, fecal streptococci, and E. coli are all set to 0 UFC/100ml, which is a stringent requirement to ensure safe drinking water. Sites S1, S3, and S5 comply with these standards, suggesting they are safe for consumption. Sites S2 and S4 exceed the standards for total and fecal coliforms, indicating a need for immediate action to address the contamination sources and improve water safety. Similar studies in Algeria have reported issues with total and fecal coliform contamination in both rural and urban areas (Boudjema and Boukhemis, 2016; Mellal and Hadeff, 2020). This is often attributed to inadequate water treatment infrastructure, poor sanitation, and environmental pollution. The contamination observed at Sites S2 and S4 aligns with these findings, emphasizing the need for improved water treatment and management practices in affected areas. Water quality standards also require 0 UFC/100ml for total coliforms, fecal coliforms, and E. coli to ensure safe drinking water. The results for S1, S3, and S5 are consistent with international standards, indicating good water quality (Smith and Johnson, 2017; Hoffmann and Müller, 2018; Fleischmann and Greger, 2019). The high levels of total and fecal coliforms at Site S2 are a concern and are consistent with findings in other regions facing similar challenges with water pollution and sanitation.

These results suggest the need for effective interventions and monitoring to address contamination sources.

Table 03. Results of bacteriological analyses.

Sites	Germs Total coliforms (UFC/100ml)	Fecal coliforms (UFC/100ml)	Fecal streptococci (UFC/100ml)	<i>Escherichia coli</i> (UFC/100ml)
S1	0	0	0	0
S2	>100	>100	0	0
S3	0	0	0	0
S4	15	15	0	0
S5	0	0	0	0
Algerian standards	0	0	0	0

Conclusion

The water quality parameters across all sites generally meet the Algerian standards and international guidelines, indicating good overall water quality. Comparisons with other studies from Algeria and around the world reveal consistency in these findings, highlighting effective water management and treatment practices. The few deviations, particularly in magnesium concentrations and local contamination issues. The bacteriological analysis reveals that Sites S1, S3, and S5 meet the Algerian and international standards for safe drinking water, while Sites S2 and S4 show significant contamination. These findings highlight the need for targeted actions to address water quality issues and improve overall safety. Addressing the contamination sources, implementing regular monitoring, and infrastructure improvements are crucial steps to ensure that all sites consistently meet water quality standards.

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