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Comparative Characterization of the Quality Indicators of Selected Spring Waters in Mountainous Adjara

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ABSTRACT

The aim of the study was to assess the organoleptic, physicochemical, and sanitary-hygienic characteristics of spring waters from three locations in mountainous Adjara (Gulebi, Buturauli, and Kvemo Vashlovani villages). The study included the determination of key field parameters, ionic and elemental composition, nutrient concentrations, and bacteriological indicators.

The results revealed significant differences in water quality characteristics among the studied sites. The spring water from Gulebi village is characterized by moderate mineralization, slightly acidic reaction, and elevated iron content; its hydrochemical type is Ca–Mg–SO_4. The water from Buturauli village has low mineralization; however, increased nitrite concentrations and the presence of Escherichia coli were detected, indicating fecal contamination. Its hydrochemical type is HCO_3–Ca. The spring water from Kvemo Vashlovani village is distinguished by low mineralization, stable physicochemical parameters, and bacteriological purity; its hydrochemical type is also HCO_3–Ca.

The findings indicate that water quality is strongly influenced by both geological conditions and anthropogenic factors. Among the investigated springs, the water from Kvemo Vashlovani exhibited the highest quality and fully met drinking water standards. The water from Buturauli was found to be microbiologically contaminated and requires appropriate treatment and disinfection, whereas the water from Gulebi is suitable for drinking only after preliminary treatment.

Keywords: spring water, water quality, physicochemical parameters, bacteriological analysis, mountainous Adjara.

Relevance of the Research

Spring waters of mountainous regions represent an important natural resource for providing the population with drinking water. Water quality determines both its suitability for drinking and the potential risks associated with its use. Therefore, a comprehensive assessment of spring water is essential for environmental monitoring and the sustainable management of safe drinking water resources. The present study is relevant because it provides a basis for evaluating the quality of spring waters in the highland areas of Adjara and supports their sustainable and purposeful use.

Research Objective

The objective of this study was to conduct a comprehensive assessment and comparative analysis of the organoleptic, physicochemical, and sanitary-hygienic characteristics of water from three springs located in the highland region of Adjara. The objects of the study were spring waters from the villages of **Gulebi** (Keda Municipality), **Buturauli** (Shuakhevi Municipality), and **Kvemo Vashlovani** (Khulo Municipality), located in the highland region of Adjara, Georgia.

Methods Used in the Study. The following methods were employed in the research: field measurements [7], titrimetric analysis, photometric analysis [4, 5], and inductively coupled plasma atomic emission spectrometry (ICP-AES) [6].

Material and Technical Base. The research was conducted using the facilities and laboratory infrastructure of the **Institute of Agri and Membrane Technologies of Batumi Shota Rustaveli State University (BSU).**

I. PHYSICAL AND GEOGRAPHICAL CHARACTERISTICS OF THE STUDY WATER SOURCE LOCATIONS

Gulebi Village is located in the mountainous section of the Acharistsqali River Valley, on the southern slope of the Meskheti Range, at an elevation of approximately 200 m above sea level.

The area is characterized by narrow valleys, steep slopes, and climatic conditions that promote the formation of permanent springs and the accumulation of moisture in the soil. Slope erosion and localized landslide processes are observed within the territory [1].

Buturauli Village is situated on the left bank of the Acharistsqali River at an elevation of 650–800 m above sea level. The relief is characterized by a highly dissected mountainous landscape, steep slopes, and deep erosional ravines. Springs in Buturauli are associated with fractured rock formations, groundwater discharge zones, and seepage waters emerging along slopes. The area is affected by landslides, soil erosion, and water contamination caused by surface runoff.

Kvemo Vashlovani Village is located at an elevation of 700–900 m above sea level. The relief is characterized by high mountains, broad slopes, and river valleys. The area is rich in mountain springs, small rivers, and underground water flows. Although slope erosion is a relevant issue in Vashlovani, anthropogenic pressure is relatively lower than in the lower-altitude zones [2, 3].

II. COMPREHENSIVE ASSESSMENT OF SPRING WATERS
II.1. Organoleptic Characteristics of the Waters

The spring water from **Gulebi Village** is characterized by a yellowish coloration and a distinct odor. Its metallic taste and the formation of a rust-colored precipitate after standing indicate an elevated concentration of iron compounds (Table 1). This is also reflected in its reduced transparency, which is affected by the presence of suspended particles. The spring water from **Buturauli Village** exhibits a slight yellowish coloration and mild turbidity, while no noticeable odor was detected. Among the studied samples, the spring water from **Kvemo Vashlovani Village** demonstrated the most favorable organoleptic characteristics. It is colorless, odorless, and transparent, with no visible foreign impurities.

Table 1. Organoleptic Characteristics of Spring Waters

Parameter	Location	Characteristic
Color	Gulebi Village	Yellowish
	Buturauli Village	Yellowish
	Kvemo Vashlovani Village	Colorless
Odor	Gulebi Village	Distinctive odor
	Buturauli Village	Odorless
	Kvemo Vashlovani Village	Odorless
Taste	Gulebi Village	Metallic taste, characteristic of iron
	Buturauli Village	Not detected
	Kvemo Vashlovani Village	Not detected
Appearance	Gulebi Village	Formation of a rust-colored precipitate after standing
	Buturauli Village	Slightly turbid
	Kvemo Vashlovani Village	Clear, free from visible impurities
Transparency	Gulebi Village	Partially opaque
	Buturauli Village	Partially opaque
	Kvemo Vashlovani Village	Transparent

II.2. Results of Field Measurements

The spring water from **Gulebi Village** exhibited a temperature ranging from 11.68 to 12.2°C, indicating a relatively warm spring (Table 2). The pH value ranged from 5.8 to 6.0, reflecting slightly acidic conditions. Electrical conductivity was the highest among the studied springs (415 µS/cm), suggesting a greater concentration of dissolved ions. Accordingly, the total dissolved solids (TDS) content was 210 mg/L.

The spring water from **Buturauli Village** had a temperature of 4.51°C, characteristic of a cold, high-altitude spring. The pH ranged from 7.8 to 8.0, indicating slightly alkaline conditions. Electrical conductivity was relatively low (95 µS/cm), and the TDS value was 57 mg/L.

The spring water from **Kvemo Vashlovani Village** showed a temperature of 9.07°C. The pH ranged from 7.9 to 8.1, also indicating slightly alkaline conditions. Electrical conductivity was relatively low (92 µS/cm), while the TDS concentration was 75 mg/L.

Table 2. Physicochemical Parameters of Spring Waters (Field Measurements)

Location	Physical and Chemical Parameters			
	Temperature, °C	pH	Electrical Conductivity µS/Sm	TDS, mg/L
Gulebi	11.68-12.2	5.8-6.0	415	210
Buturauli	4,51	7,8-8	95	57
Kvemo Vashlovani	9,07	7,9-8,1	92	75

II.3. Physicochemical Characteristics of the Spring Waters

The spring water from **Gulebi Village** is slightly acidic, with a total hardness of 6.4 meq/L. The concentrations of calcium and magnesium indicate moderate mineralization (Table 3). The bicarbonate content is low, while the chloride concentration is very low. The oxidizability value of 1.36 mg O_2/L indicates that the water is relatively free of oxidizable organic compounds. The spring water from **Buturauli Village** is slightly alkaline, with a hardness of 1.4 meq/L. Based on the concentrations of calcium and magnesium, it can be classified as a low-mineralized water. The bicarbonate concentration is approximately 2.5 times higher than that of the Gulebi spring water. The chloride content is very low. The oxidizability value of 8.72 mg O_2/L suggests contamination by oxidizable organic substances. The spring water from **Kvemo Vashlovani Village** exhibits a slightly alkaline reaction, with a hardness of 2.2 meq/L. Based on its calcium and magnesium concentrations, it is also classified as a low-mineralized water source. Its bicarbonate content provides a good buffering capacity against changes in pH and environmental impacts. The chloride concentration is low. The oxidizability value is 1.36 mg O_2/L, indicating good water quality with respect to oxidizable organic matter.

Table 3. Physicochemical Parameters of Spring Waters (Laboratory Determinations)

Location	pH	Total Hardness meq/L	Ca mg/L	Mg mg/L	HCO3- mg/L	Cl- mg/L	Oxidizability mg O_2/L
Gulebi	6,4	6,4	72,144	34,05	30,5	4,95	1,36
Buturauli	7,85	1,4	20,04	4,864	85,4	7,9208	8,72

Kvemo Vashlovani	8,15	2,2	32,064	7,296	103,7	5,9406	1,36
Standard Limits	6.5-8.5	7-10	140	85	250-400	250	<5

II.4. SANITARY AND HYGIENIC STATUS OF THE SPRING WATERS

In the spring water from **Gulebi Village**, **ammonium (NH_4^+)** and **nitrite (NO_2^-)** were not detected (Table 4). The **phosphate concentration** was very low (**0.015 mg/L**), indicating a low nutrient load in the water. The **sulfate concentration** was within the permissible range, although its relatively higher value may be associated with the natural mineralization of the water. In the spring water from **Buturauli Village**, the **ammonium concentration (0.156 mg/L)** was elevated compared to the other studied springs. The **nitrite concentration (0.59 mg/L)** exceeded the permissible limit **(0.2 mg/L)**, indicating recent organic contamination or an incomplete nitrification process. The **phosphate concentration** remained within the acceptable range, while **sulfates were not detected.** In the spring water from **Kvemo Vashlovani Village**, the concentrations of **ammonium (0.008 mg/L)** and **phosphates (0.0103 mg/L)** were very low, indicating a low nutrient load. **Nitrites and sulfates were not detected**, reflecting favorable sanitary and hygienic water quality.

Table 4. Concentrations of Chemical and Nutrient Pollutants (mg/L)

Location	NH_4^+	NO_2^-	PO_4^{3-}	SO_4^{2-}
Gulebi	-	-	0,015	195,13
Buturauli	0,156	0.59	0,080	-
Kvemo Vashlovani	0,008	-	0,0103	-
Standard Limits, mg/L	0.5	0.2	3.5	250

In the spring waters from **Gulebi** and **Kvemo Vashlovani**, neither **total coliform bacteria** nor **Escherichia coli** were detected in **300 mL** water samples (Table 5). This indicates the absence of fecal contamination and confirms the satisfactory sanitary-hygienic quality of these water sources. In contrast, both **total coliform bacteria and Escherichia coli** were detected in **300 mL** of water from the **Buturauli** spring. This finding indicates **fecal contamination** of the water and reflects a deterioration in its sanitary-hygienic condition, suggesting potential risks to human health if the water is consumed without appropriate treatment.

Table 5. Sanitary-Bacteriological Indicators of Spring Waters

Location	Total Coliform Bacteria	Escherichia coli (E. coli)
Gulebi	Not detected in 300 mL	Not detected in 300 mL
Buturauli	Detected in 300 mL	Detected in 300 mL
Kvemo Vashlovani	Not detected in 300 mL	Not detected in 300 mL
Standard Limits	Not permitted in 300 mL	Not permitted in 300 mL

III. MULTI-ELEMENT ANALYSIS OF THE SPRING WATERS

The spring water from **Gulebi Village** is characterized by moderate mineralization, based on its calcium and magnesium content. The concentrations of potassium and sodium are low (Table

6). Overall, this water can be classified as a moderately mineralized calcium–magnesium type spring water.

The spring water from **Buturauli Village** contains relatively lower concentrations of calcium and magnesium, indicating a lower degree of mineralization. The levels of potassium and sodium remain within acceptable limits. The phosphorus concentration (0.026 mg/L) is higher than in the other studied springs, although it still remains within permissible limits.

The spring water from **Kvemo Vashlovani Village** is characterized by the lowest concentrations of macroelements among the analyzed samples, indicating weak mineralization. The phosphorus concentration is negligible, confirming the low nutrient load of the water.

Table 6. Macroelement Concentrations (mg/L)

Location	K	Ca	Mg	Na	P
Gulebi	0.82	72.14	34.05	3.69	0.005
Buturauli	0.985	20.04	4.86	3.14	0.026
Kvemo Vashlovani	0.527	32.06	7.30	1.04	0.0034
MPC, (mg/L)	20	140	40–50	200	0.01–0.05

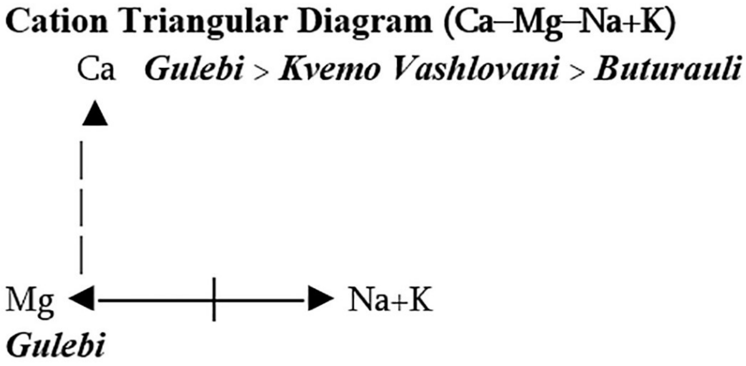
Iron showed its highest concentration in **Gulebi Village (0.983 mg/L).** An above-norm concentration of **silicon** was detected in **Buturauli (15.6 mg/L).** The **aluminum concentration in Gulebi (13.5 mg/L)** exceeds the permissible limit (Table 7). The concentration of **boron** was very low in all samples. Elevated levels of **cobalt and copper** were observed in the Buturauli spring water compared to the other sites. A relatively high value of **manganese** was also recorded in Gulebi. The concentrations of **nickel and zinc** did not exceed the permissible limits in any of the studied samples.

Table 7. Microelement Concentrations (mg/L)

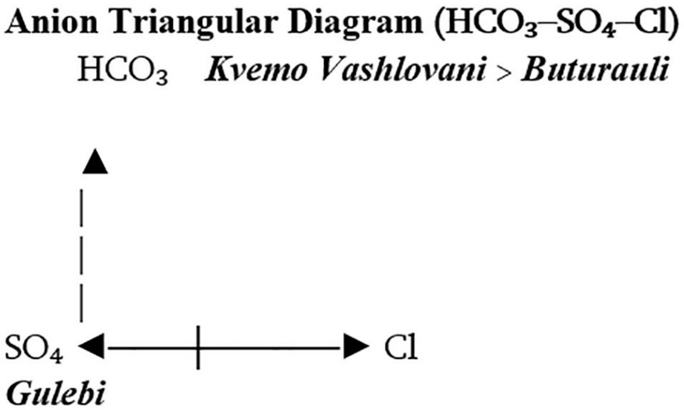
Location	Fe	Si	B	Al	Co	Cu	Mn	Ni	Zn
Gulebi	0.983	8.05	0.0018	13.5	0.0161	0.0692	0.177	0.0018	1.08
Buturauli	0.92	15.6	0.0014	3.25	0.0630	0.934	0.0274	0.0160	-
Kvemo Vashlovani	0.0325	4.16	0.0009	0.0326	-	-	-	-	-
MPC, (mg/L)	0.3	10	0.5-1.0	0.5	0.1	1.0-2.0	0.05-0.1	0.02-0.1	3.0-5.0

IV. HYDROCHEMICAL TYPE AND SANITARY-HYGIENIC STATUS OF SPRING WATERS

The spring water from **Gulebi Village** is classified as Ca–Mg–SO_4 hydrochemical type. Its status is considered conditionally unsatisfactory for drinking purposes due to elevated iron and sulfate concentrations, pH of 6.4, high hardness, and a metallic taste. The water may be used for drinking purposes only after appropriate pre-treatment. The spring water from **Buturauli Village** belongs to the HCO_3–Ca hydrochemical type. It is characterized as sanitarily contaminated, as both E. coli and total coliform bacteria were detected. In addition, the concentration of NO_2^- exceeds the permissible limit, and the oxidizability value is high. Therefore, the water is unsuitable for drinking without disinfection. The spring water from **Kvemo Vashlovani Village** is also classified as HCO_3–Ca hydrochemical type. It is characterized as clean and suitable for drinking, with low mineralization, moderate hardness, pH within acceptable limits, low concentrations of heavy metals, and no detected bacteriological contamination. Overall, this water demonstrates good sanitary-hygienic and hydrochemical quality.



Interpretation: Gulebi, Kvemo Vashlovani, and Buturauli → Ca-dominant.
Gulebi → Mg-dominant.



Interpretation: Kvemo Vashlovani and Buturauli → HCO_3^--dominant.
Gulebi → SO_4^{2-}-dominant.

CONCLUSION

The organoleptic quality of spring waters in highland Adjara shows significant variation, with the best quality observed in the less anthropogenically impacted area of **Kvemo Vashlovani Village**.The spring water from **Gulebi Village** is classified as Ca–Mg–SO_4 type. It is characterized by strong sulfate mineralization and high hardness. Its use for drinking is recommended only after appropriate treatment. The spring water from **Buturauli Village** is of HCO_3–Ca type and has low mineralization and hardness; however, the presence of bacteriological contamination and high oxidizability indicates organic pollution. Therefore, it is unsuitable for drinking without disinfection. The spring water from **Kvemo Vashlovani Village** is also of HCO_3–Ca type. It is a clean water source with low mineralization and good sanitary-chemical quality, making it suitable for drinking.

REFERENCES

1. *Autonomous Republic of Adjara (2016). Strategic Development Plan for 2016–2021. Batumi. https://api.ajara.gov.ge/storage/files/doc/acdb5711834a4d0e86f1f4f04e46.pdf*
2. *Mikava, T. (2023). Study of the chemical composition of groundwater in Western Georgia for microcomponent determination. Proceedings of GTU, No. 1(527), 64–74. https://shromebi.gtu.ge/admin/uploads/shroma%20N1(527)/07-miqava-dasavleti.pdf*
3. *Ministry of Environmental Protection and Natural Resources of Georgia (2017). Order No. 42 – Methodological guidelines for classification of groundwater reserves and prognostic resources. https://faolex.fao.org/docs/pdf/geo174852.pdf*
4. *International Organization for Standardization (ISO) (2014–2023). ISO 5667-1: Water quality — Sampling – Part 1. https://www.iso.org/standard/84099.html*
5. *ISO 9308-1 (2014). Water quality — Enumeration of Escherichia coli and coliform bacteria. https://short-link.me/17j9T*
6. *Shimadzu Corporation (n.d.). ICP Atomic Emission Spectrometer Application Note ICPETM-9820. https://www.shimadzu.com/an/sites/shimadzu.com.an/files/pim/pim_document_file/applications/application_note/14064/an_04-ad-0238-en.pdf*
7. *World Health Organization (WHO) (2022). Guidelines for Drinking-water Quality. https://www.who.int/publications/i/item/9789241549950*