

Groundwater quality and public health risks in rural North Eastern Romania: An in-situ assessment and comparative analysis

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Article info

Received 6/1/2026; received in revised form 24/1/2026; accepted 11/3/2026

DOI: [10.60923/issn.2281-4485/23137](https://doi.org/10.60923/issn.2281-4485/23137)

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Abstract

The current study assessed the physicochemical quality of groundwater from wells in a rural region of northeastern Romania, where local communities depend exclusively on this resource for drinking water. Eighty wells were analyzed *in situ* for total dissolved solids (TDS), dissolved oxygen, oxygen saturation, salinity, conductivity, redox potential (ORP), and pH. For comparative purposes, similar measurements were conducted on urban water supplies in the cities of Iași and Botoșani, as well as on 14 commercial bottled water brands. The findings revealed critical water quality issues in rural wells, including frequent exceedances of microbiological and chemical thresholds, particularly for nitrates and coliform bacteria. Spatial mapping showed strong variation across parameters, with elevated salinity and low oxygenation most prominent in lowland areas. Bottled water analysis showed a wide range of mineral compositions, influencing their appropriateness for daily consumption. Still waters such as Aqua Carpatica Still and Wonder Still displayed low sodium, calcium, and magnesium concentrations, making them suitable for specific dietary needs. In contrast, highly mineralized waters like Aqua Carpatica Sparkling exceeded World Health Organization (WHO) recommended limits for TDS and salinity. The study also highlighted the insufficient monitoring by local authorities and the lack of comprehensive labelling on bottled water, both of which hinder informed decision-making by consumers. The results emphasize the urgent need for standardized groundwater surveillance, public health initiatives, and improved transparency in bottled water labelling. These findings provide a foundation for future policy actions targeting safe and equitable access to drinking water in rural communities.

Keywords: *groundwater; drinking water quality; total dissolved solids; dissolved oxygen; wells water analysis; physicochemical contaminants.*

Introduction

Groundwater is a water source crucial for human consumption and sustains a broad range of uses, including irrigation, agriculture, and industrial processes (Abanyie et al., 2023; Krishnamoorthy and Lakshmanan, 2024; Merritt and Power, 2022; Qureshi et al., 2021; Wang et al., 2023). Given its importance, numerous studies have investigated groundwater quality (Abanyie et al., 2023; Krishnamoorthy and Lakshmanan, 2024; Merritt and Power, 2022; Wang et al., 2023), and European Union legislation emphasizes both chemical integrity and quantitative hydrologic balance of these freshwater reserves (Iefremova et al., 2019). The WHO also provides standards for assessing groundwater quality, tailored to specific physicochemical parameter (Panahi et al., 2020). Groundwater quality is influenced by both natural and anthropogenic processes. Activities such as agriculture, domestic waste disposal, and industrial operations significantly alter the physical, chemical, and biological components of groundwater ecosystems (Panahi et al., 2020; Qureshi et al., 2021). Under specific pH and redox conditions, groundwater may naturally contain dissolved minerals at concentrations exceeding health thresholds. However, anthropogenic sources, such as excessive fertilizers, can further increase contamination levels (El Alfy et al., 2015). Salinity in groundwater commonly reflects the geologic nature of the aquifer; for instance, igneous rocks, being relatively insoluble, yield lower concentrations of dissolved minerals (Qureshi et al., 2021). A key indicator of groundwater quality is TDS, which reflects both natural inputs and anthropogenic influences, such as mining, pollution, agriculture, and inefficient wastewater treatment (Garcia et al., 2024; Weber-Scannell and Duffy, 2007). TDS encompasses mineral salts and organic molecules which, while necessary at moderate concentrations, become harmful in excess, particularly when heavy metals and synthetic organic pollutants are in high concentrations (World Health Organization, 2022). Monitoring TDS is vital for understanding impacts on human health, agricultural suitability, industrial use, and ecosystem integrity (WHO, 1996). Other standard chemical parameters routinely assessed in groundwater surveys are pH, salinity, conductivity, dissolved oxygen, oxygen saturation, and redox potential. Sustainable groundwater quality programs depend heavily on the active involvement of local communities (Chilima et al., 2001; Rasool et al., 2024). The stakeholders play a critical role throughout all implementation phases, from site assess-

ment and well placement to routine monitoring and the creation of protected buffer zones. According to WHO guidelines, community involvement enhances oversight, facilitates maintenance, and ensures timely response to emerging issues. Long-term success is further supported by public hygiene and sanitation initiatives (World Health Organization, 2022). In Romania, hundreds of thousands of people rely on groundwater drawn from wells for drinking, household, and agricultural use. Unfortunately, these water sources are frequently contaminated by nitrites, pesticides, and bacteria, often due to poor waste and agricultural management practices (Roba et al., 2021). While national legislation, which is aligned with EU directives, mandates quarterly monitoring of public fountains by local authorities, funding limitations hinder compliance, particularly in rural areas (Chilima et al., 2001; Weber-Scannell and Duffy, 2007). The current survey aimed to assess the groundwater quality used as the main drinking water source in a rural area situated in the northeast of Romania. A suite of physicochemical parameters was analyzed, such as TDS, pH, salinity, conductivity, dissolved oxygen, oxygen saturation, and redox potential in 80 wells. For comparative purposes, similar analyses were conducted on municipal water sources from the Cities of Iași and Botoșani, as well as on selected brands of bottled still and sparkling water. TDS, while naturally present in water, is also elevated through human activity, including mining, pollution, agriculture, and inadequate wastewater management (Weber-Scannell and Duffy, 2007). U.S. water regulations require periodic TDS monitoring to track levels of various anthropogenic substances. TDS composition varies by geologic substrate, atmosphere input, and hydrologic balance (i.e., precipitation versus evaporation). Globally, river water salinity averages about 120 mg L⁻¹, with bicarbonates being the dominant anions (Weber-Scannell and Duffy, 2007). Sulphates follow closely, with average levels of 20 mg L⁻¹, while the main cations are calcium (21 mg L⁻¹), sodium, and silicon (9 mg L⁻¹). Water with TDS levels above 1000 mg L⁻¹ (or 1000 ppm) is typically considered unpalatable or potentially harmful. Changes in TDS values often reflect industrial effluents, shifts in hydrologic balance (e.g., droughts, excessive water use), or surface water salinization. Elevated TDS can affect aquatic ecosystems by increasing salinity, altering ion composition, and increasing the concentration of toxic ions. These changes reduce biodiversity by excluding less tolerant species or inducing sublethal effects across their life stages (Weber-Scannell & Duffy, 2007). For

instance, concentrations between 270 – 1170 mg L⁻¹ have been shown to eliminate macrophytes such as *Ceratophyllum demersum* and *Typha spp.* (Weber-Scannell and Duffy, 2007). Shifts in ionic composition can also change community structure. Derry et al. (2003) found that *Brachionus plicatilis* and *Cletocamptus spp.* dominate chloride-rich waters, whereas *Leptodiptomus sicilis* and *Diptomus nevadensis* are more prevalent in sulphurous or carbonate-dominated systems (Derry et al., 2003). Osmotic stress from high salinity can reduce species richness, especially if specific ions reach toxic levels. For example, Stekoll et al. (2009) reported that elevated Ca²⁺ concentrations inhibit salmonid egg hatching (Stekoll et al., 2009), while Erickson et al. (1996) showed that copper toxicity increases with potassium chloride but decreases in the presence of calcium and sodium chloride (Erickson et al., 1996). Similarly, Stoss et al. (1977) demonstrated that fish sperm motility is suppressed by low concentrations of potassium salts, specifically 19.2 mg L⁻¹ KCl or 106.2 mg L⁻¹ K₂CO₃ (Stoss et al., 1977).

Materials and Methods

Study area

The current survey was conducted in Stroiești village, Lunca commune, Botoșani County, located in north-eastern Romania. A total of 80 wells (Fig. 1), comprising the main source of drinking water for the local population, were surveyed. The local geology is domi-

nated by Sarmatian formations, including clay and marl, with shallow deposits of dusty clays, clay-sandy layers, and alluvial-eolian sediments. The region experiences a temperate-continental climate, which influences hydrological dynamics across surface lentic and lotic ecosystems. These water bodies typically show high flow volumes during spring snowmelt or after intense rainfall events in summer and autumn. In contrast, most rivers are dry during winter and exhibit reduced flow in summer. Only around 8% of the atmospheric precipitation, primarily from rainfall and snow, contributes to river and stream recharge. The dominant soil type in the area is leached Chernozem, which develops on clay or marl substrates. The upper soil layers typically consist of 60% chernozem mixed with clay (Florica Breșug, 2016). Agriculture and livestock rearing remain the primary economic activities, sustaining the rural population in this region.

Methods

Total Dissolved Solids was used as the primary indicator of water quality in the current study. TDS is a parameter standardized by the U.S. Environmental Protection Agency (US-EPA), which provides a reference scale for typical values across various geographic settings (Florica Breșug, 2016). In addition to TDS, other physicochemical parameters were measured, such as dissolved oxygen, oxygen saturation, salinity, conductivity, Oxidation-Reduction Potential (ORP) and pH. The same parameters were also recor-

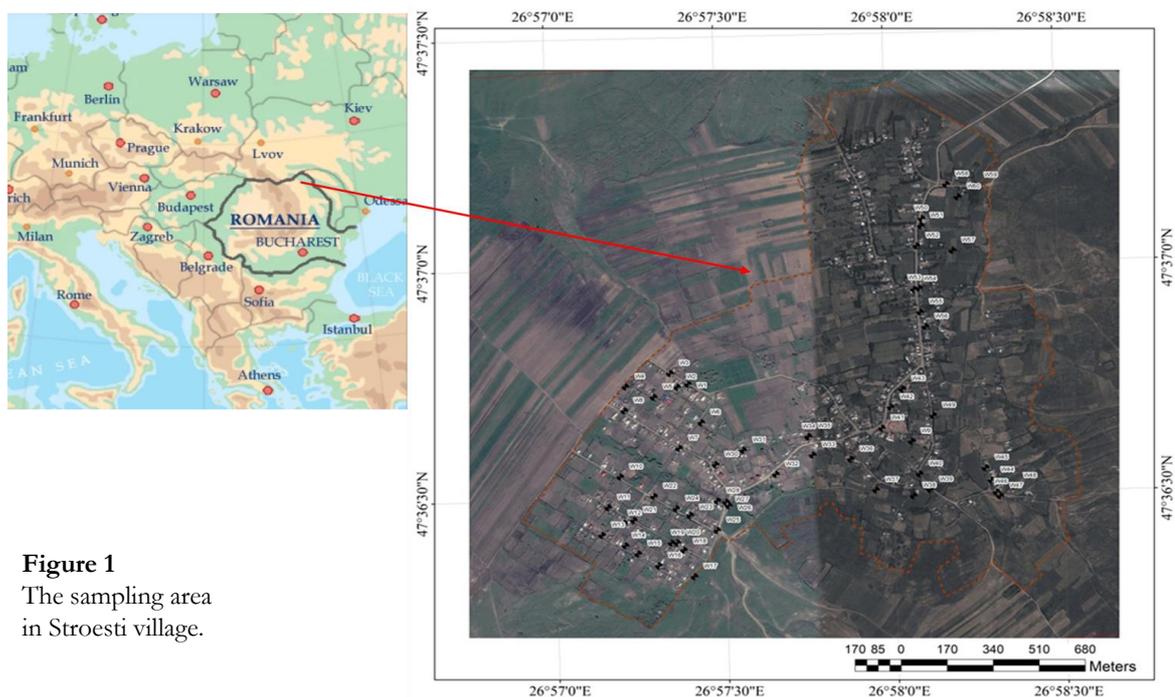


Figure 1
The sampling area
in Stroiești village.

ded for urban surface waters in the cities of Iași and Botoșani, as well as for several commercial still and sparkling bottled water brands. All field measurements were conducted with HI 9828 multiparameter instrument (HANNA Instruments). The device was calibrated in the laboratory 24 hours prior to sampling, using certified reference materials to ensure measurement accuracy. Each well was assigned a unique identifier to ensure complete spatial coverage of the study area. Water samples were analysed immediately on site, with ten replicate measurements per well to ensure consistency. The geographic position of each well was recorded with Garmin GPSMAP 62, and these coordinates were used to generate spatial maps for each parameter

using Inverse Distance Weighting (IDW) interpolation in ArcGIS 10.2. Sampling was carried out continuously over a 14-hour period in January 2015, in order to provide consistent and representative measurements for spatial analysis and cross-comparisons. According to the U.S. EPA's Secondary Drinking Water Regulations, water with TDS concentrations above 500 mg L⁻¹ is not recommended for human consumption. Moreover, concentrations ranging from 1,500 to 2,600 mg L⁻¹ render the water unsuitable for agricultural use or irrigation purposes (Fig. 2). Since the present study did not involve human participants or animal subjects, approval from an institutional ethics committee was not required.

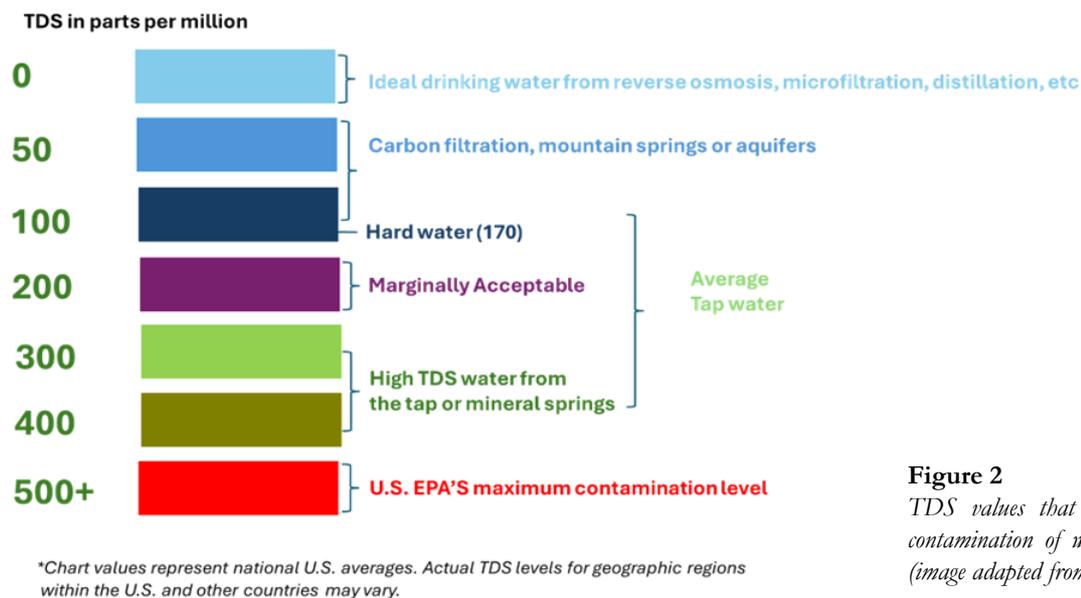


Figure 2

TDS values that set normal levels and contamination of waters in different areas (image adapted from (Stoss et al., 1977)).

Results and Discussions

For an accurate assessment of groundwater quality, it is essential to evaluate a range of relevant physicochemical parameters, including temperature, total hardness, pH, chlorides, dissolved oxygen, total alkalinity, and total dissolved solids (Kumar et al., 2022). The concentration and composition of these parameters in natural waters are influenced by local geological formations, patterns of atmospheric precipitation, and hydrological balance, specifically the interplay between evaporation and precipitation. Additionally, the porosity of soils plays a critical role in determining groundwater chemistry, as it affects both infiltration and contaminant transport. Previous studies have shown that porous soils tend to enhance groundwater quality in comparison to non-porous substrates. Factors such as soil particle size and the thickness of soil layers must

also be considered in this context (Abanyie et al., 2023). In this study, the physicochemical measurements obtained from the surveyed wells were spatially extrapolated to visualize both the degree of contamination and the variability across the sampled region.

a) Dissolved Oxygen and Oxygen Saturation. The first parameter analysed was dissolved oxygen (DO) (Fig. 3). Across the study area, DO concentrations ranged from 0.05 to 12 mg L⁻¹. Low oxygen concentrations are typically indicative of microbial activity, associated with the degradation of organic matter in groundwater. The lowest values were recorded in the lowland areas, shown in blue on the map. This pattern may be explained by the infiltration of organic-rich substances from the surrounding hill regions, which subsequently accumulate in the lower-lying zones, resulting in increased microbial oxygen consumption

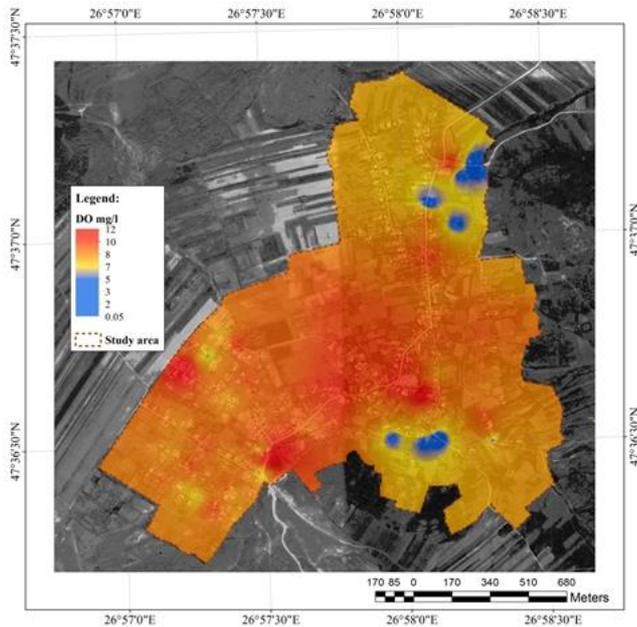


Figure 3. The level of dissolved oxygen (DO mg L^{-1}) concentration in the study area.

and reduced oxygen availability. Oxygen saturation in water (Fig. 4) varied between 0.45 – 88%. The lowest values were observed in the same wells in which a low level of dissolved oxygen was recorded. Lowland area remained the most affected and strongly overlapped with the households where livestock is reared intensively. All the analysed wells were covered with a lid, with variable water volumes and depths. According to

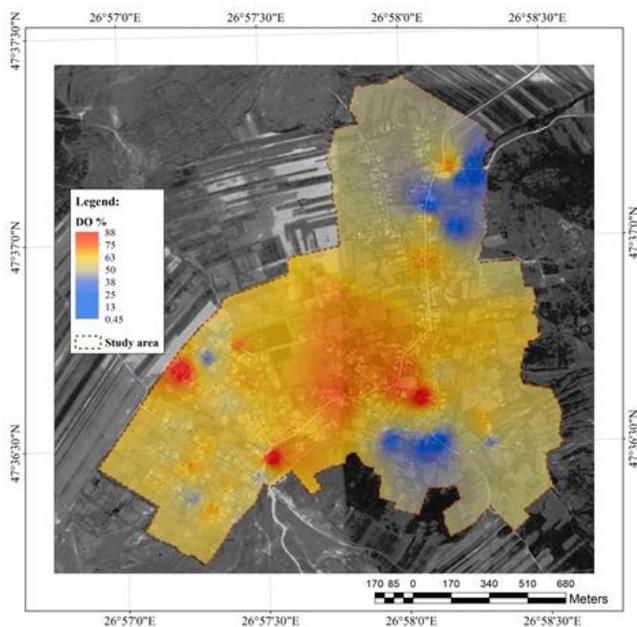


Figure 4. The level of oxygen saturation (%) of the water in the study area.

the Environmental Protection Division of the British Columbia Ministry of Environment (British Columbia Ministry of Environment and Climate Change Strategy., 2020), elevated dissolved oxygen (DO) concentrations in groundwater are generally favourable for human consumption. However, this beneficial effect is partially offset by the tendency of metal oxides, such as those of iron, manganese, and lead, to precipitate under high-oxygen conditions. Dissolved oxygen inhibits the release of these metals from sediments into groundwater and promotes the biochemical oxidation of ammonium into nitrates, thereby enhancing the self-purification capacity of the aquifer. Drinking water quality guidelines for dissolved oxygen varies by regions. In British Columbia, the recommended minimum DO concentration is 5 mg L^{-1} for potable water (Alberta Environment, 1977). In the State of Washington, the recommended range is between 8.0 and 9.5 mg L^{-1} , while Alaska stipulates a minimum of 4 mg L^{-1} (Alaska, 1979). In the current study, the areas highlighted in blue on the map indicate zones where oxygen concentrations were below recommended thresholds, potentially posing health risks to local populations who rely on these wells for drinking water. Dissolved oxygen concentrations in groundwater were found to be inversely correlated with water temperature (Figure 5), which ranged between $+1^\circ\text{C}$ and $+12^\circ\text{C}$. While surface waters typically experience pronounced diurnal temperature fluctuations, groundwater temperatures in wells remain relatively stable throughout the day.

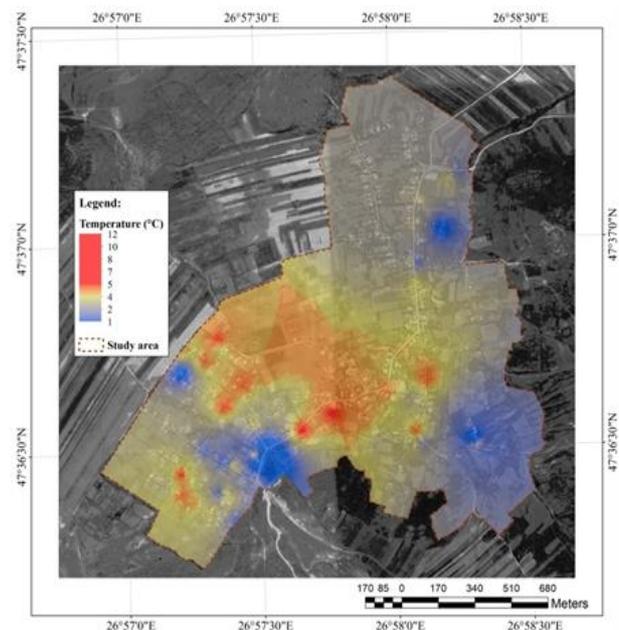


Figure 5. The level of water temperature ($^\circ\text{C}$) in the study area.

DOI: 10.60923/issn.2281-4485/23137

According to USEPA (the US Environmental Protection Agency), the dissolved oxygen levels vary in water with temperature as follows: 0 °C -14,6 mg L⁻¹; 1 °C -14,19 mg L⁻¹; 2 °C -13,81 mg L⁻¹; 3 °C -13,44 mg L⁻¹; 4 °C -13,09 mg L⁻¹; 5 °C -12,75 mg L⁻¹; 6 °C -12,43 mg L⁻¹; 7 °C -12,12 mg L⁻¹; 8 °C -11,83 mg L⁻¹; 9 °C -11,55 mg L⁻¹; 10 °C -11,27 mg L⁻¹; 11 °C -11,01 mg L⁻¹; 12 °C -10,76 mg L⁻¹; 13 °C -10,52 mg L⁻¹; 14 °C -10,29 mg L⁻¹; 15 °C -10,07 mg L⁻¹; 20 °C -9,07 mg L⁻¹; 22 °C -8,72 mg L⁻¹; 24 °C -8,4 mg L⁻¹; 26 °C -8,09 mg L⁻¹; 28 °C -7,81 mg L⁻¹.

b) Oxidation-reduction potential and temperature. The oxidation-reduction potential of groundwater (Fig. 6) belonged to two distinct areas with reducing conditions, with values as low as -3 mV and -26 mV (indicated in blue). In contrast, most wells displayed strong oxidizing

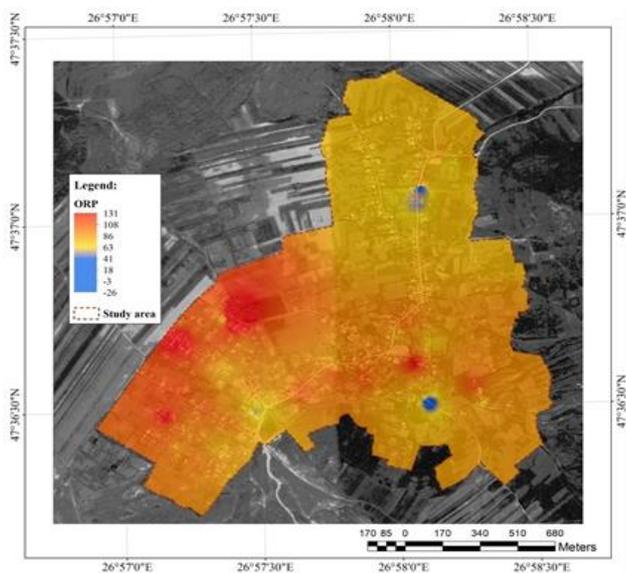


Figure 6. The oxidation-reduction potential of water in the study area.

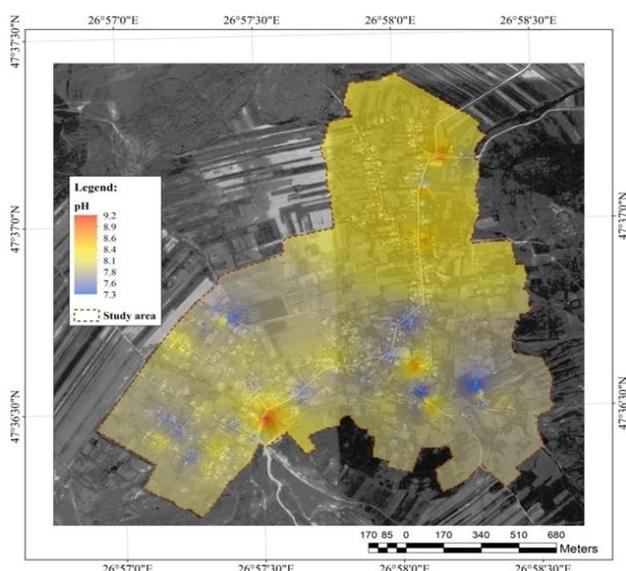


Figure 7. Water pH in the study area.

character, with maximum recorded values reaching +131 mV. These patterns are likely due to the oxidation of organic substances and the subsequent formation of inorganic oxides within the aquifer matrix. ORP analysis provided insight into the redox status of water and is a valuable indicator of the ability to inhibit microbial growth and support disinfection processes. This metric is especially relevant in evaluating the efficacy of water treatment techniques such as chlorination and ozonation in achieving safe drinking water standards (Suslow, 2004). According to water quality guidelines, safe and microbiologically stable drinking water should exhibit ORP values between +200 and +400 mV. Values within this range typically suggest the absence of biologically active contaminants. On the other hand, water with negative ORP values (e.g., -100 to -300 mV) is often associated with antioxidant properties and has been proposed to confer certain health benefits due to its reducing character.

c) Salinity and pH. Salinity is intimately related to conductivity and TDS. Salinity may include hundreds of different ions, which are present in the most significant amounts: chlorine, sodium, nitrates, calcium, magnesium, bicarbonates, and sulphates. Bromine, boron, and iron ions are rarely encountered. In the study area, the salinity reached high values, ranging from 0.3 to 3.1, with the lowest recorded in the hill area and the highest in the flat terrain (Fig. 8).

d) TDS and conductivity. Changes in TDS concentrations in groundwater habitats are usually due to industrial effluents, changes in water balance (i.e. rainfalls, overexploitation or prolonged drought), as

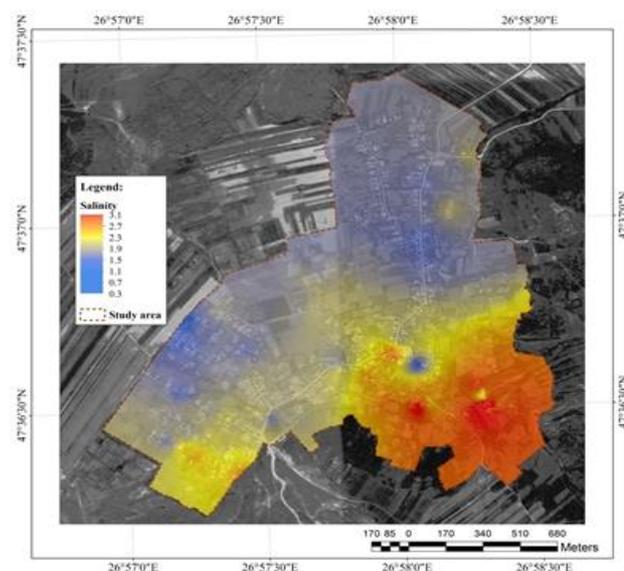


Figure 8. Water salinity in the study area.

well as surface water salinization. The total amount of dissolved solids in groundwater increases the toxicity due increasing salinity, changes in ionic composition of water, as well as of the concentration of specific toxic ions. Increasing salinity in groundwater has a negative impact on aquatic biodiversity, by excluding less tolerant species or deleterious impact on various development stages of tolerant species (Weber-Scannell and Duffy, 2007). Another pressing environmental concern in Botoșani County is the limited involvement of local authorities in monitoring groundwater quality and conducting public health assessments. This region presents a unique opportunity for investigating the potential he-

alth effects associated with elevated salinity and total dissolved solids, particularly because the local population is relatively stable and relies exclusively on well water for daily consumption. In 2012, under the framework of the European project Preventing the Blue Death, a total of 117 well water samples were collected and analysed (Table 1). Of these, 68 samples were deemed inadequate for human consumption, indicating significant water quality issues in the region. Additionally, 457 microbiological tests were conducted, and 167 of them failed to meet safety standards, underscoring the urgent need for additional monitoring and corrective interventions to ensure safe drinking water for the local population.

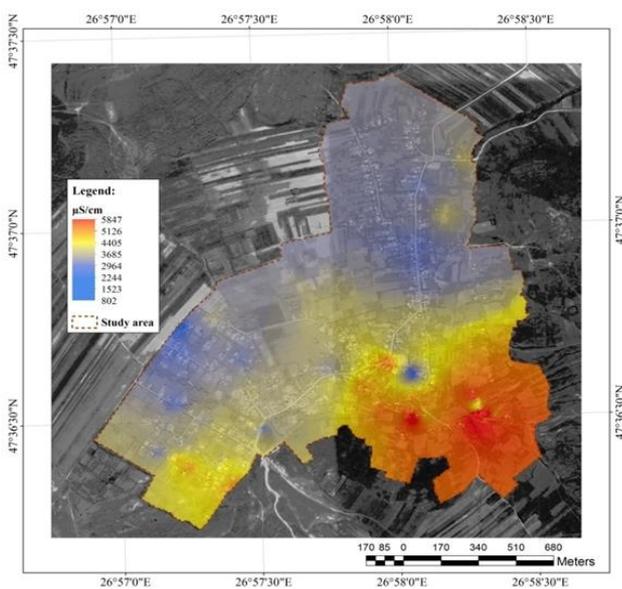


Figure 9. Water conductivity in the resource in the study area.

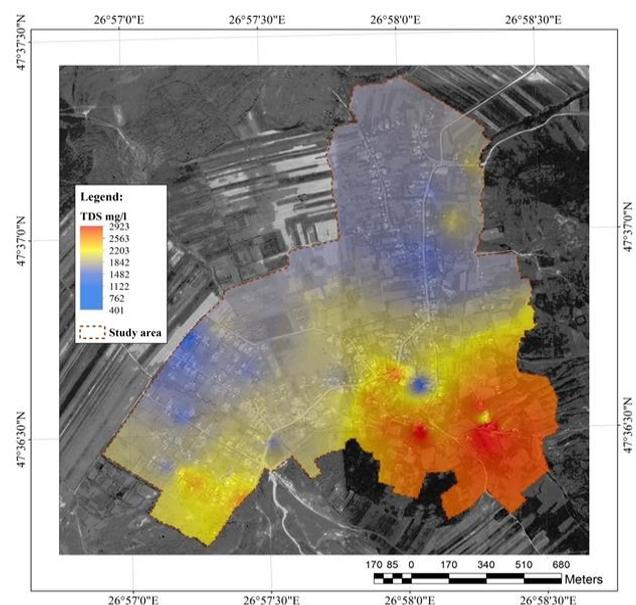


Figure 10. Total dissolved solids in the water resource in the study area.

Year	Wells Analyzed	Non-Compliant Samples	Microbiological Determinations	Non-Compliant Microbiological Determinations
2012	117	68	457	167
2013	105	58	356	127
2014	107	67	353	146

Table 1. Summary of Water Samples Analysed (2012-2014).

The microbiological analyses were conducted in accordance with international standards and targeted key parameters relevant to waterborne health risks. Specifically, assessments included the total number of colonies at 37°C (as per SREN ISO 6222/2004), coliform bacteria and *Escherichia coli* (both following SREN ISO 9308-1/2009), and enterococci (SREN ISO 7899-2/2009). These evaluations aimed to identify microbiological hazards and verify the compliance of groundwater sources with established drinking water

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safety standards. Complementing the microbiological assessments, a series of chemical analyses were also performed to provide a comprehensive overview of groundwater quality (Table 2). These included measurements of ammonium (SR ISO 7150-1/2001), nitrite (SREN 26777 C 91/2006), nitrate (SR ISO 7890-3/2000), oxidation potential (SREN ISO 8467/2001), pH (SR ISO 10533/2009), total hardness (SR ISO 6059/2008), and turbidity (SR EN ISO 7027/1999). Altogether, these parameters offered a robust diagno-

stic framework for evaluating the physicochemical integrity of drinking water and ensuring its alignment with national and international quality standards. Furthermore, in May 2012, two additional water samples were collected from the Lunca area in Botoşani County as part of the same European initiative. These samples contributed to a broader regional monitoring effort, aimed at enhancing drinking water quality and identifying actionable solutions to mitigate public health risks.

Parameter	Standard Used
Number of Colonies at 37°C	SREN ISO 6222/2004
coliform Bacteria	SREN ISO 9308-1/2009
Escherichia coli	SREN ISO 9308-1/2009
Enterococci	SREN ISO 7899-2/2009
Ammonium	SR ISO 7150-1/2001
Nitrites	SREN 26777 C 91/2006
Nitrates	SR ISO 7890-3/2000
Oxidability	SREN ISO 8467/2001
pH	SR ISO 10533/2009
Hardness	SR ISO 6059/2008
Turbidity	SR EN ISO 7027/1999

Table 2.

Microbiological and chemical determinations conducted on drinking water.

Between 2012 and 2014, a series of water quality assessments were conducted in Baznoasa, Zlatunoaia, and Lunca villages (Botoşani County). The results revealed both encouraging aspects and significant concerns regarding the safety of drinking water. In 2012, supplementary analyses were performed on water samples from wells located in Baznoasa and at the Cultural Centre in Lunca. The microbiological parameters from the Baznoasa well revealed considerable contamination: coliform bacteria (20 CFU 100 mL⁻¹), *E. coli* (18 CFU 100 mL⁻¹), and enterococci (950 CFU 100 mL⁻¹) all exceeded the maximum admissible limit of 0 CFU 100 mL⁻¹. Furthermore, the nitrate concentration reached 98.6 mg L⁻¹, nearly double the allowable threshold of 50 mg L⁻¹. In contrast, other parameters such as the total colony count at 37°C (20 CFU mL⁻¹), ammonium (below detection limit), nitrite (0.036 mg L⁻¹), oxidizability (1.27 mg L⁻¹), and pH (7.18) remained within the acceptable range. A similar situation was recorded at the well in Lunca, where coliform bacteria (500 CFU 100 mL⁻¹), *E. coli* (250 CFU 100 mL⁻¹), and enterococci (700 CFU 100 mL⁻¹) were all significantly above legal limits. Nitrate levels (58.6 mg L⁻¹) also exceeded the recommended maximum. However, the other indicators, colony count at 37°C

(65 CFU mL⁻¹), ammonium (below detection limit), nitrite (0.044 mg L⁻¹), oxidation potential (3.16 mg L⁻¹), and pH (7.38), remained compliant with drinking water standards. In 2013, samples collected from the well at the Zlatunoaia Junior High School revealed high microbial contamination: coliform bacteria (1.7×10^1 CFU 100 mL⁻¹), *E. coli* (2.5×10^1 CFU 100 mL⁻¹), and enterococci (9 CFU 100 mL⁻¹), all exceeding permissible limits. Nitrate concentration reached 179 mg L⁻¹, over three times the maximum allowed concentration. Nevertheless, hardness (51 °dH) and turbidity (1.67 NTU) were within standard ranges. Conversely, at the Baznoasa Primary School well, microbiological parameters (coliforms, *E. coli*, enterococci) were within acceptable limits. However, nitrate concentrations remained problematic, reaching 284 mg L⁻¹, well above safe thresholds. Hardness (77 °dH) and turbidity (1.63 NTU) were again within permissible limits. By 2014, water quality at the drilled well in Lunca showed marked improvements. All microbiological indicators complied with regulatory standards. Chemical parameters, namely ammonium (0.3 mg L⁻¹), nitrite (0.08 mg L⁻¹), nitrate (0.74 mg L⁻¹), and turbidity (2.53 NTU), were also within acceptable limits, suggesting effective mitigation or natural attenuation of previous contaminants.

DOI: 10.60923/issn.2281-4485/23137

Table 3. Water analysis results in Baznoasa, Zlatunoaia, Lunca – Botosani (2012-2014).

Year	Sample	Parameter	Result	Admissible Value	Compliance
2012 – “Preventing Blue Death” Project	Police Well Baznoasa	Number of Colonies (37°C)	20 cfu mL ⁻¹	-	✓
		Coliform Bacteria	20 cfu 100 mL ⁻¹	0 cfu 100 mL ⁻¹	✗
		Escherichia coli	18 cfu 100 mL ⁻¹	0 cfu 100 mL ⁻¹	✗
		Enterococci	950 cfu 100 mL ⁻¹	0 cfu 100 mL ⁻¹	✗
		Ammonium	0 mg L ⁻¹	≤ 0.5 mg L ⁻¹	✓
		Nitrites	0.036 mg L ⁻¹	≤ 0.5 mg L ⁻¹	✓
		Nitrates	98.6 mg L ⁻¹	≤ 50 mg L ⁻¹	✗
		Oxidability	1.27 mg L ⁻¹	≤ 5 mg L ⁻¹	✓
	pH	7.18	6.5 - 9.5	✓	
	Cultural Center Well – Lunca	Number of Colonies (37°C)	65 cfu mL ⁻¹	-	✓
		Coliform Bacteria	500 cfu 100 mL ⁻¹	0 cfu 100 mL ⁻¹	✗
		Escherichia coli	250 cfu 100 mL ⁻¹	0 cfu 100 mL ⁻¹	✗
		Enterococci	700 cfu 100 mL ⁻¹	0 cfu 100 mL ⁻¹	✗
		Ammonium	0 mg L ⁻¹	≤ 0.5 mg L ⁻¹	✓
Nitrites		0.044 mg L ⁻¹	≤ 0.5 mg L ⁻¹	✓	
Nitrates		58.6 mg L ⁻¹	≤ 50 mg L ⁻¹	✗	
Oxidability		3.16 mg L ⁻¹	≤ 5 mg L ⁻¹	✓	
pH	7.38	6.5 - 9.5	✓		
2013 – Lunca- Botosani Area	Well at Zlatunoaia Secondary School	Coliform Bacteria	1.7 × 10 ⁶ cfu 100 mL ⁻¹	0 cfu 100 mL ⁻¹	✗
		Escherichia coli	2.5 × 10 ⁶ cfu 100 mL ⁻¹	0 cfu 100 mL ⁻¹	✗
		Enterococci	9 cfu 100 mL ⁻¹	0 cfu 100 mL ⁻¹	✗
		Nitrates	179 mg L ⁻¹	≤ 50 mg L ⁻¹	✗
		Hardness	51 °dH	≥ 50 °dH	✓
	Well at Baznoasa Primary School	Turbidity	1.67 NTU	≤ 5 NTU	✓
		Coliform Bacteria	0 cfu 100 mL ⁻¹	0 cfu 100 mL ⁻¹	✓
		Escherichia coli	0 cfu 100 mL ⁻¹	0 cfu 100 mL ⁻¹	✓
		Enterococci	0 cfu 100 mL ⁻¹	0 cfu 100 mL ⁻¹	✓
		Nitrates	284 mg L ⁻¹	≤ 50 mg L ⁻¹	✗
2014 – “Preventing Blue Death” Project	Drilled Well, Lunca Village	Hardness	77 °dH	≥ 50 °dH	✓
		Turbidity	1.63 NTU	≤ 5 NTU	✓
		Coliform Bacteria	0 cfu 100 mL ⁻¹	0 cfu 100 mL ⁻¹	✓
		Escherichia coli	0 cfu 100 mL ⁻¹	0 cfu 100 mL ⁻¹	✓
		Enterococci	0 cfu 100 mL ⁻¹	0 cfu 100 mL ⁻¹	✓
		Ammonium	0.3 mg L ⁻¹	≤ 0.5 mg L ⁻¹	✓
		Nitrites	0.08 mg L ⁻¹	≤ 0.5 mg	✓
		Nitrates	0.74 mg L ⁻¹	≤ 50 mg L ⁻¹	✓
Turbidity	2.53 NTU	≤ 5 NTU	✓		

✓ Value within the permissible limits according to applicable standards

✗ Value exceeding the permissible limits (non compliant)

According to the results provided by the Botosani Public Health Directorate between 2012 and 2014, groundwater contamination with nitrites and microbiological organisms posing health risks was identified in several wells located in Stroiești village. However, these analyses were sporadic and insufficient for robust monitoring of an area where the local population depends entirely on well water for daily consumption. The low

number of official records confirms the relevance and necessity of our in-situ measurements, which provided more comprehensive and spatially resolved data. To further contextualize the findings, the current survey included a comparative analysis of chemical parameters from local wells with those of commercially available bottled waters. A total of 14 bottled water brands, both still and sparkling, were analysed. Table 4 summarizes

Table 4. Values of some elements and physicochemical parameters in water sold in stores

Brand	Na	Mg	Ca	K	pH	HCO ₃	Dry residue at 180°C	Sulphate	CO ₂ minimum	Chloride
	(mg L ⁻¹)					(mg L ⁻¹)				
AQUA CARPATICA still natural mineral water	0.78	14.3	44.9		7.7	199.5				
AQUA CARPATICA natural sparkling mineral water	5.3	78.1	286			1281			2500	
CARPATICA still natural mineral water	0.82	1.328	64.34	0.501	7.76	201.3	202	21.23	300	
CARPATICA natural sparkling mineral water	22.39	41.68	117.4	5.371	6.65	543	475		300	10.64
PERLA HARGHITEI still natural mineral water	8.22	10.6	109	1.67		457		17.5		17
PERLA HARGHITEI natural sparkling mineral water	61.92	40.91	112.9	10.57		732		2.83	3500	14.77
BUCOVINA still natural mineral water	2.88	2.63	9.56	1.18	7.05	48.8	74			
BUCOVINA natural sparkling mineral water	26.72	76.73	264.5	4.32	5.3	1189	951			
VALEA IZVOARELOR still natural mineral water	92.5	9.42	47.42		7.56	306.1	474			93.9
VALEA IZVOARELOR natural sparkling mineral water	93	9.66	47.02		5	306.1	464.5			93.6
BORSEC still natural mineral water	2.54	29.5	58		7.42	312	275			
WONDER still natural mineral water	0.74	3.45	17.2	0.53		71.8	81.4			
KAUFLAND still natural mineral water	70.7	41.3	197		7	901	924		250	16.1
PERLA COVASNEI natural sparkling mineral water	85.82	19.91	35.66	2.59	5.76		453		2500	16.31

the chemical composition data as reported by manufacturers. Notably, no producer provided complete information on all relevant parameters, and some elemental concentrations were entirely omitted. The mineral composition of bottled waters is a critical factor in assessing their safety and suitability for long-term human consumption, as well as in identifying potential health risks. Key parameters examined included sodium, magnesium, calcium, potassium, bicarbonates, dry residue at 180°C, sulphates, carbon dioxide, and chlorides. Sodium concentrations showed considerable variation among brands. Still water products such as Aqua Carpatica (0.78 mg L⁻¹), Wonder Still (0.74 mg L⁻¹), and Carpatica Still (0.82 mg L⁻¹) had very low sodium levels, making them appropriate for individuals on low-sodium diets, including those with hypertension

or cardiovascular conditions. In contrast, sparkling waters such as Valea Izvoarelor (93 mg L⁻¹) and Perla Covasnei (85.82 mg L⁻¹) contained elevated sodium levels, which may not be suitable for sodium-sensitive individuals. Magnesium levels, essential for neuromuscular and enzymatic function, also varied widely. Aqua Carpatica Sparkling (78.1 mg L⁻¹) and Bucovina Sparkling (76.73 mg L⁻¹) were rich in magnesium and may support individuals with deficiencies. Still waters like Wonder (3.45 mg L⁻¹) and Bucovina Still (2.63 mg L⁻¹) had significantly lower magnesium levels. Calcium, important for bone metabolism, was highest in Aqua Carpatica Sparkling (286 mg L⁻¹), Bucovina Sparkling (264.5 mg L⁻¹), and Kaufland Still (197 mg L⁻¹). These brands may serve as valuable calcium sources. In contrast, Bucovina Still (9.56 mg L⁻¹), Wonder Still

Table 5. Values of physicochemical parameters measured in the laboratory in water sold in stores.

Brand	DO (mg L ⁻¹)	pH	Conductivity (μS cm ⁻¹)	TDS (mg L ⁻¹)	Salinity (g L ⁻¹)	ORP (mV)	DO (%)
WATER NETWORK BOTOSANI	8,64	8,05	393	197	0,91	46,2	76,1
WATER NETWORK IASI	8,01	7,75	566	283	0,27	193,2	73,2
AQUA CARPATICA still natural mineral water	7,08	7,91	309	155	0,15	80,1	68,4
AQUA CARPATICA natural sparkling mineral water	2,74	5,70	1603	802	0,81	141,3	17,6
CARPATICA still natural mineral water	5,93	7,95	339	169	0,16	46,9	59,3
CARPATICA natural sparkling mineral water	1,49	5,62	1049	524	0,52	13,9	27,4
PERLA HARGHITEI still natural mineral water	5,52	7,10	610	305	0,30	70,9	48,4
PERLA HARGHITEI natural sparkling mineral water	1,14	5,58	988	494	0,49	130,3	18,6
BUCOVINA still natural mineral water	4,35	7,63	100	50	0,05	41,6	42,6
BUCOVINA natural sparkling mineral water	1,57	5,60	1394	700	0,70	122,1	8,4
VALEA IZVOARELOR natural sparkling mineral water	2,03	5,26	833	417	0,41	138,8	4,4
VALEA IZVOARELOR decarbonated natural mineral water	1,93	6,55	837	418	0,41	71,3	18,1
BORSEC still natural mineral water	3,58	7,30	497	249	0,24	50,3	34,1
WONDER still natural mineral water	4,32	7,78	132	66	0,06	34,8	45,9
KAUFLAND still natural mineral water	3,70	6,26	1257	628	0,63	87,9	40,4
PERLA COVASNEI natural sparkling mineral water	1,35	5,34	571	285	0,28	131,4	13,1

(17.2 mg L⁻¹), and Perla Covasnei Sparkling (35.66 mg L⁻¹) had lower calcium content. Bicarbonate concentration is indicative of the water's buffering capacity and its potential effect on gastrointestinal health. High bicarbonate levels were recorded in Aqua Carpatica Sparkling (1281 mg L⁻¹) and Bucovina Sparkling (1189 mg L⁻¹), which may assist in neutralizing stomach acid and promoting digestion. The pH values ranged from 5.0 (acidic; Valea Izvoarelor Sparkling) to 7.7 (slightly alkaline; Aqua Carpatica Still), with sparkling waters generally showing lower pH due to CO₂ content. Dry residue at 180°C, representing total dissolved mineral content, was highest in Kaufland Still (924 mg L⁻¹) and Aqua Carpatica Sparkling (1281 mg L⁻¹), indicating high mineralization. Sulphate concentrations, beneficial in moderation for digestive health, were present in various

(amounts, e.g., 21.23 mg L⁻¹ in Aqua Carpatica Still, and were negligible in others. Some brands, such as Perla Harghitei Still and Borsec Still, offered a balanced mineral profile, making them suitable for regular, daily hydration. In contrast, highly mineralized sparkling waters, such as Bucovina and Aqua Carpatica, may be more appropriate for therapeutic use but less ideal for consumers with specific dietary restrictions. In conclusion, bottled water brands comprise a broad spectrum of mineral compositions, each catering to different consumer health needs and preferences. When selecting bottled water, it is important for consumers to consider individual health conditions, particularly with respect to sodium, calcium, and magnesium intake, as well as pH and overall mineralization. Improved labeling transparency would further support informed choi-

ces regarding long-term water consumption. Dissolved oxygen (DO) serves as a key indicator of water quality. The highest DO concentrations were recorded in municipal water networks of Botoșani (8.64 mg L⁻¹) and Iași (8.01 mg L⁻¹), suggesting excellent oxygenation and favourable conditions for human consumption. In contrast, significantly lower values were observed in sparkling mineral waters such as Valea Izvoarelor (2.03 mg L⁻¹) and Perla Harghitei (1.14 mg L⁻¹), indicating poor oxygenation and potentially compromised water quality. The pH of most still waters fell within the optimal range of 6.5 to 8.5, as observed in samples such as Water Network Botoșani (8.1), Aqua Carpatica Still (7.91), and Carpatica Still (7.95). Carbonated waters displayed lower pH values due to the presence of dissolved CO₂, with Aqua Carpatica Sparkling (5.7) and Valea Izvoarelor Sparkling (5.26) being notably acidic. Electrical conductivity, which reflects the concentration of dissolved ionic species, varied considerably across samples. Aqua Carpatica Sparkling (1603 μS cm⁻¹) and Kaufland Still (1257 μS cm⁻¹) demonstrated elevated conductivity, indicative of high mineralization. In contrast, Bucovina Still water exhibited a much lower conductivity (100 μS cm⁻¹), aligning with the characteristics of low-salinity water suitable for regular consumption. TDS exceeded the WHO-recommended upper limit of 500 mg L⁻¹ in Aqua Carpatica Sparkling (802 mg L⁻¹) and Kaufland Still (628 mg L⁻¹), potentially affecting palatability and long-term suitability for consumption. Lower TDS values were recorded in Water Network Botoșani (197 mg L⁻¹) and Aqua Carpatica Still (155 mg L⁻¹), which are within acceptable limits for daily use. Salinity levels ranged from 0.05 to 0.91. Very low salinity was recorded in Bucovina Still (0.05) and Wonder Still (0.06), while Aqua Carpatica Sparkling showed relatively high salinity (0.81), which may impact taste and consumer preference. ORP, a measure of chemical stability and disinfection potential, showed marked variation. Elevated ORP values were observed in Water Network Iași (193.2 mV) and Valea Izvoarelor Sparkling (138.8 mV), possibly reflecting higher oxidative conditions, which can influence chemical reactivity and perceived water quality. Dissolved oxygen saturation (DO%) was highest in Water Network Botoșani (76.1%) and Iași (73.2%), further supporting their classification as high-quality sources. Conversely, sparkling waters such as Valea Izvoarelor (4.4%) and Bucovina Sparkling (8.4%) had low DO%, suggesting limited oxygenation and suboptimal quality. In conclusion, still water sources such as Water Network Botoșani, Water Network Iași,

and Aqua Carpatica Still demonstrated favourable physicochemical profiles and are best suited for regular consumption. In contrast, some carbonated waters, particularly Aqua Carpatica Sparkling and Kaufland Still, showed elevated TDS and salinity levels, rendering them less appropriate for frequent use without further treatment or medical consideration.

Conclusions

The current study identified several critical concerns regarding water quality in the rural areas of Botoșani County, particularly the community's reliance on unmonitored well water. The limited involvement of local authorities in systematic assessments of water quality and population health significantly amplified the risks associated with groundwater consumption. The findings reinforced the urgent need for standardized, periodic monitoring programs to ensure the provision of safe drinking water in rural settings. Comparative analyses of bottled water revealed considerable variability in mineral composition, which directly influenced their appropriateness for human consumption. Brands such as Aqua Carpatica Still, Wonder Still, and Bucovina Still are characterized by low sodium, calcium, and magnesium concentrations and were found to be suitable for regular intake, especially for individuals with specific dietary requirements. Conversely, waters with high mineral content, including Aqua Carpatica Sparkling and Kaufland Still, may offer therapeutic benefits but are less appropriate for frequent consumption due to elevated TDS and salinity levels. Among the physicochemical indicators assessed, dissolved oxygen and pH emerged as key determinants of water quality. Still waters generally exhibited more favourable values, with higher oxygenation and near-neutral pH. Variability in conductivity and salinity further highlighted the heterogeneity of the samples and underscored the importance of tailoring drinking water choices to individual health needs. The current study also emphasized the importance of transparent and comprehensive labelling of bottled water. The lack of complete information on key physicochemical parameters hinders consumers from making informed decisions. Improved labelling practices would enhance public awareness and contribute to safer and more personalized hydration choices. In summary, the current survey underscores the need for enhanced water quality monitoring, increased institutional engagement, and greater public education in rural areas. It also highlights the necessity for clearer regulation of bottled water labelling. The results offer valuable guidance for

policymakers, public health professionals, and consumers, advocating for strengthened efforts to secure safe and accessible drinking water for all. Moreover, the expected long-term decline in groundwater levels due to climate change, recently projected for northeastern Romania, further amplifies the urgency of implementing sustainable water management policies and improving rural water security (Sfîcă et al., 2022).

Author Contributions: Conceptualization, G.-I.P., O.-A.P., O.M.R., R.V., M.N. and S.A.S.; methodology, G.-I.P., M.N. and S.A.S.; data curation, G.I.P., M.N. F.B., and S.A.S.; writing-original draft preparation, G.I.P., O.A.P., O.M.R., R.V., M.N. and S.A.S.; writing-review and editing, B.D., F.B., O.F., A.I.C., O.P.; visualization, G.-I.P., M.N. and S.A.S.; supervision, G.-I.P., M.N. and S.A.S. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding. OP was supported by National Core Program-Romanian Ministry of Research and Innovation, Romania, Project SIA-PRO 2302010, contract nr. 7N from 03.01.2023.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The data are available in the article.

Conflicts of Interest: The authors declare no conflicts of interest.

Abbreviations: The following abbreviations are used in this manuscript:

°dH	degree of German hardness
CFU	colony-forming unit
DO	dissolved oxygen
EPA	Environmental Protection Agency
NTU	Nephelometric Turbidity Unit
ORP	oxidation-reduction potential
TDS	total dissolved solids
TH	total hardness
WHO	World Health Organization

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