
In-situ Assessment of Rural Physico-Chemical Groundwater Quality from the North-East of Romania

[Gabriel Ionut Plavan](#) , [Oana Plavan](#) ^{*} , [Bojan Đurin](#) , [Oana Mare Roșca](#) , [Fehmi Boufahja](#) , [Osman Fetoshi](#) , [Alexandru Iulian Crăciun](#) , [Mircea Nicusor Nicoara](#) , [Stefan Strungaru](#) , [Octavian Pacioglu](#) , [Viorica Rarinca](#) ^{*}

Posted Date: 25 February 2025

doi: 10.20944/preprints202502.1971.v1

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



Preprints.org is a free multidisciplinary platform providing preprint service that is dedicated to making early versions of research outputs permanently available and citable. Preprints posted at Preprints.org appear in Web of Science, Crossref, Google Scholar, Scilit, Europe PMC.

Copyright: This open access article is published under a Creative Commons CC BY 4.0 license, which permit the free download, distribution, and reuse, provided that the author and preprint are cited in any reuse.

Article

In-situ Assessment of Rural Physic-Chemical Groundwater Quality from the North-East of Romania

Gabriel-Ionuț Plavan ^{1,2}, Oana-Alexandra Plavan ^{3,*}, Bojan Đurin ⁴, Oana Mare Rosca ⁵, Fehmi Boufahja ⁶, Osman Fetoshi ⁷, Alexandru-Iulian Crăciun ⁸, Mircea Nicoară ¹, Stefan-Adrian Strungaru ¹, Octavian Pacioglu ⁹ and Viorica Rarinca ^{1,9,10,11,*}

¹ "Alexandru Ioan Cuza" University of Iasi, Romania, Faculty of Biology

² VASILE BACAUANU Scientific Research and Student Practice Station Stefanesti

³ Department of Environmental Engineering and Management, "Cristofor Simionescu" Faculty of Chemical Engineering and Environmental Protection, "Gheorghe Asachi" Technical University of Iași

⁴ Department of Civil Engineering, University North, 42000 Varaždin, Croatia

⁵ Technical University of Cluj-Napoca, Faculty of Science, 76 Victoriei Street, 430122, Baia Mare, Romania

⁶ Laboratoire de Biosurveillance de l'Environnement, Faculté des Sciences de Bizerte, 7021 Zarzouna, Tunisia

⁷ Food Science and Biotechnology, UBT-Higher Education Institution, 10000 Prishtina, Kosovo

⁸ SC Realitis SA, Romania

National Institute of Research and Development for Biological Sciences, Bucharest, Romania ⁹

Apollonia University, Pacurari Street 11, 700511 Iași, Romania

¹⁰ "Alexandru Ioan Cuza" University of Iași, Faculty of Geography and Geology, Doctoral School of Geosciences, Carol I Avenue, No. 20A, 700505 Iași, Romania

¹¹

* Correspondence: oana.plavan@tuiasi.ro (O.-A.P.) ; rarinca_viorica@yahoo.com (V.R.)

Abstract: The current survey aimed to analyse the water quality from wells in a rural area situated in the north-east of Romania, comprising the main water source for human consumption in the area. 80 wells were analysed for total dissolved solids, which was used as the main indicator of water quality and followed by measurements of dissolved oxygen and saturation, salinity, conductivity, redox potential and pH. For comparison, the values of these parameters were also measured in the water from the public network of the cities of Iasi and Botosani, as well as in various brands of bottled water. The results highlighted important water quality issues in rural areas, especially in terms of microbiological contamination and high nitrate levels, urging the need for future measures to improve the local infrastructure and water treatment systems. These findings contribute to a better understanding of the challenges related to ensuring drinking water in rural communities and provide a basis for developing effective public policies in water resources management.

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

1. Introduction

Groundwater habitats play important roles in human consumption. Numerous studies were focused on groundwater quality [1–4] given the important role played by this subterranean aquatic source in human consumption, irrigation, agriculture, and industrial activities [1,5]. European Union legislation on groundwater protection aims to achieve adequate chemical quality and optimal quantitative balance [6]. The World Health Organization (hereafter WHO) has different standards for assessing groundwater quality, given the types of physic-chemical parameters of interest. [7].

Groundwater quality is affected by numerous factors, either natural or human induced. Various human activities, such as agriculture, domestic activities, and industrial operations can impact the physical, chemical, and biological characteristics of groundwater ecosystems [5,7]. Groundwater is a resource for domestic and public use worldwide. Under certain pH and redox conditions, natural pollutants in the groundwater comprise dissolved minerals above certain thresholds. Moreover, the heavy use of fertilizers to boost agricultural productivity can increase groundwater contamination [8]. Groundwater habitats contain salts and the presence of soluble salts in high concentrations normally reflects the geology of the aquifer. Groundwater in igneous rocks dissolves minimal amounts of mineral because of their relative insolubility [5]. One routine parameter measured in groundwater quality surveys is the Total Dissolved Solids (hereafter TDS). This parameter is influenced by both natural and human activities, such as mining, pollution, agriculture, and improper wastewater treatments [9,10]. TDS includes the sum of mineral salts and organic molecules, which are essential for organisms in moderate amounts, but become harmful, such as the case of heavy metals and organic pollutants, at high concentrations [11]. TDS analysis is very important if to understand the impact on human health, industrial applications, irrigation and agriculture, as well as at ecosystem levels [12]. Other parameters, such as pH, salinity, conductivity, dissolved oxygen, saturated oxygen, and redox potential are also routinely measured in groundwater quality assessments.

Successful and sustainable programs focused on ensuring groundwater quality for human consumption rely on the active engagement and direct participation of local stakeholders [13,14]. Their involvement should span all stages of implementation, from conducting initial assessments and selecting suitable locations for wells and water intakes to establish protected zones. In WHO guidelines, it is mentioned the fact that local communities play a key role in monitoring and overseeing water supplies, identifying and reporting issues, performing maintenance, and implementing corrective measures. Additionally, promoting complementary initiatives, such as hygiene and sanitation practices, is essential for the long-term effectiveness of these programs [11].

Millions of people in Romania use groundwater from wells for drinking, agriculture or household needs. These water sources are often polluted with nitrites, pesticides, or bacteria. These contaminants are caused by improper management of waste or agricultural waste deposits [15]. In Romania, national drinking water legislation was adopted according to the European Union directives. This regulation stipulates that public fountains should be monitored once every four months by local authorities. Unfortunately, in most villages, there is no budget for such actions [9,13].

The current survey aimed to assess the groundwater quality of the primary source of drinking water in a village situated in northeastern Romania. Therefore several physicochemical parameters were analysed as follows: TDS, pH, salinity, conductivity, dissolved oxygen, saturated oxygen, and oxidation-reduction reaction from 80 wells, comprising the primary source of drinking water for the local population. Measurements of the same parameters were made for current water in the Municipality of Iasi and Botosani and for various bottled sparkling and still water brands.

Total dissolved solids are naturally present in water, but also due to anthropogenic activities such as mining, pollution, agriculture, and wastewater treatment [9]. They represent the total amount of mineral salts and organic molecules, which in moderate concentrations are required for organisms, but in high concentrations become contaminants, such as heavy metals and organic pollutants. The United States (US) legislation provides periodic measurement and monitoring of this parameter in water for inorganic salts, organic matter and other substances dissolved. The concentration and composition of TDS in natural waters varies depending on the geological substrate, atmospheric precipitation and water balance (evaporation-precipitation). The worldwide average of river salinity is approximately 120 mg L⁻¹ and most anions present in natural waters are bicarbonates [9]. The next most common anion is sulphate, with an average concentration of about 20 mg L⁻¹. The most common cations are calcium (21 mg L⁻¹), sodium, and silicon (9 mg L⁻¹). Waters with a TDS concentration of more than 1000 mg L⁻¹ (equivalent to 1000 ppm) are considered “unpleasant” or unhealthy.

Changes in TDS concentrations in natural waters are usually due to industrial effluents, changes in water balance (by rainfall or heavy use of water or prolonged drought), and surface water salinization. The total amount of dissolved solids in the water produces toxicity by increasing salinity, changes in the ionic composition of the water, or the increase in concentration of specific toxic ions. Increased salinity in water negatively impacts aquatic biodiversity by excluding less tolerant species or producing chronic effects in various biological stages of tolerant species [9]. It was reported that, for TDS values between 270 mg L⁻¹ to 1170 mg L⁻¹ of the macrophytes *Ceratophyllum demersum* and *Typha sp.* disappear [9]. Changes in the ionic composition of water may exclude certain species in favour of others. For example, Derry et al., 2003 showed that the rotifer *Brachionus plicatilis* and the copepod *Cletocamptus sp.* dominate Cl⁻ dominated habitats, in comparison to the species *Leptodiptomus sicillis* and *Diptomus nevadensis* that dominate in more sulfurous and carbonate waters [16]. The diversity of aquatic organisms decreases when osmotic tolerance is exceeded due increasing salinity. Concentrations of specific ions that are too high can become toxic in certain stages of body development. For example, Stekoll et al., 2009 identified that Ca²⁺ is the primary inhibitor of hatching salmonids when it significantly increases in concentration during fertilization [17]. Erickson et al., 1996 demonstrated that copper toxicity increased in water once with the addition of potassium chloride, whereas calcium and sodium chloride adversely affected copper toxicity in water [18]. Stoss et al., 1977 showed that fish sperm activity in water was inhibited when small amounts of potassium chloride (19.2 mg L⁻¹) or potassium carbonate (106.2 mg L⁻¹) were added [19].

2. Materials and Methods

2.1. Study Area

The study area was the Stroesti village, Lunca commune, Botosani County, situated in North-Eastern Romania. A total of 80 wells (Figure 1), comprising the primary source of drinking water for the local population, were analysed. The area primarily comprises clay and marl Sarmatian rocks with surface profiles that include dusty clays, clay-sandy formations, and alluvial-eolian deposits. The temperate-continental climate characteristics affect rivers, streams, puddles, and ponds, which have large volumes in the spring when the snow melts or in the summer and fall during intense rain. All rivers had no flow in winter and relatively little flow in summer.

Rivers and streams are nourished by approximately 8% of atmospheric precipitation, which includes snow and rain. The region's typical soils belong to the leached chernozems category. These soils were composed of parent rock clays or marl, with 60% chernozem and clay in the top layer [20]. Agriculture and animal husbandry have always been the main occupations, as they ensure the existence of a native population.

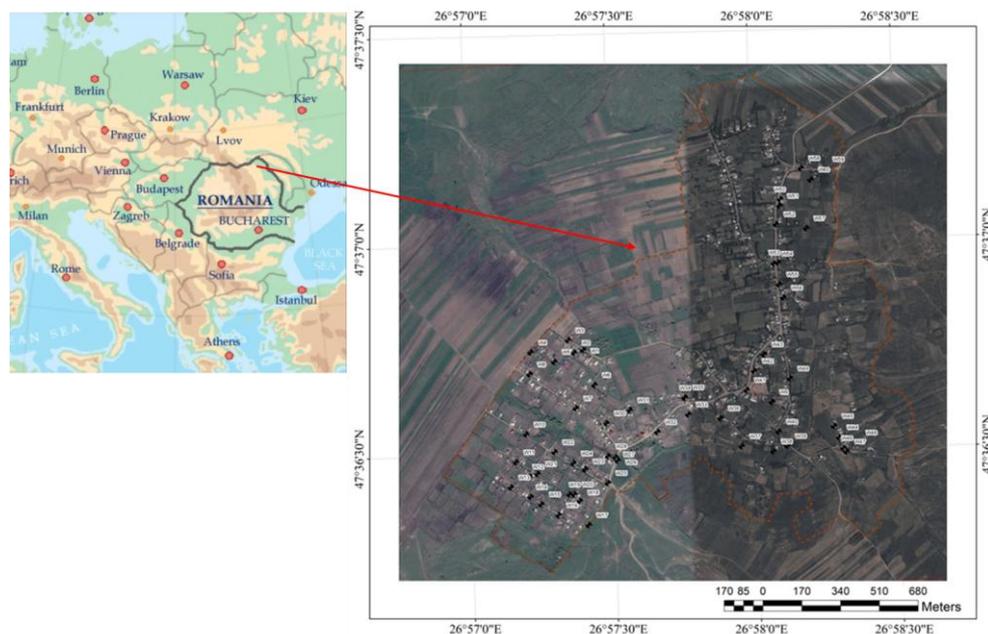


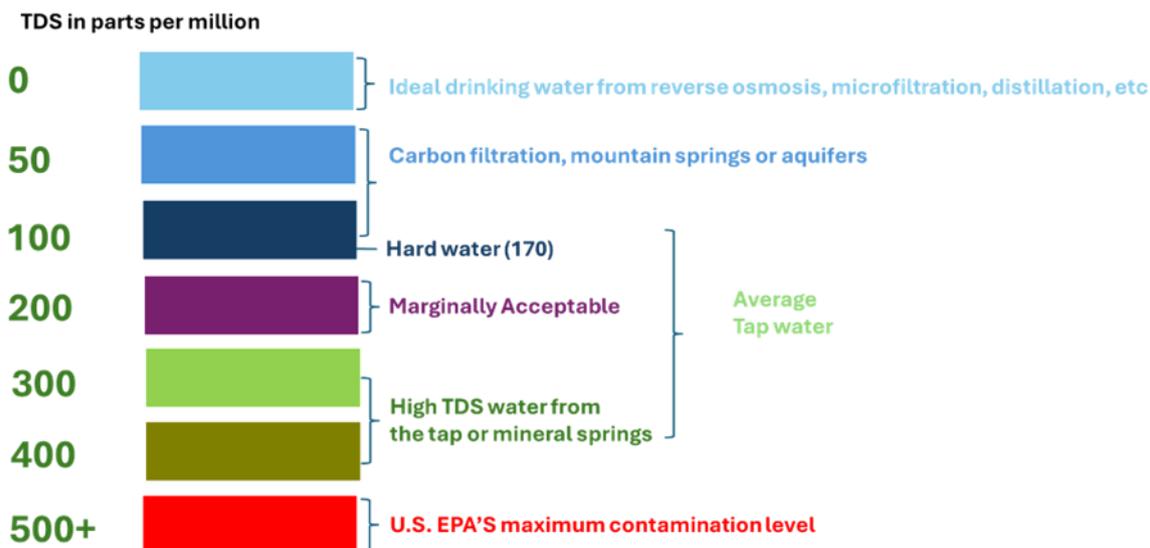
Figure 1. The sampling area in Stroesti village.

2.2. Methods

TDS was used as the main indicator of water quality. This parameter is normalized by US-EPA (American Environmental Protection Agency) as a scale of typical values for waters in different geographic regions [20]. In addition to this parameter, we analysed dissolved oxygen, oxygen saturation, salinity, conductivity, oxidation-reduction reaction, and pH. Measurements of the very same parameters were made for the urban streams flowing through the City of Iasi and Botosani and for various bottled sparkling and still water brands. Water physicochemical parameters were instantly measured from each well using a HI 9828 multiparameter device produced by HANNA Instruments.

Before use, the multiparameters were calibrated in the laboratory 24 h prior measurements with valid certified reference materials. Each well was numbered so that the entire surface of interest was covered. The water from each well was analysed instantly ten times. For each well, GPS coordinates were obtained with Garmin GPSMAP 62. The coordinates were used to create maps in ArcGis 10.2 based on Inverse Distance Weight interpolation for each parameter. The measurements were made continuously for 14 hours, to ensure correct interpolation and validate comparisons, in January 2015.

The second drinking water guidelines of EPA mention that TDS values above 500 mg L^{-1} reflect water not recommended for human consumption, and above 1500 to 2600 $1,500$ to $2,600 \text{ mg L}^{-1}$ is not suitable for agriculture or irrigations (Figure 2).



*Chart values represent national U.S. averages. Actual TDS levels for geographic regions within the U.S. and other countries may vary.

Figure 2. TDS values that set normal levels and contamination of waters in different areas (image adapted from [19]).

3. Results and Discussions

For a proper assessment of groundwater quality it is essential to measure the relevant physicochemical parameters, such as temperature, total hardness (TH), pH, chlorides, dissolved oxygen, total alkalinity, and total dissolved solids (TDS), respectively [21]. The concentration and composition of physicochemical parameters in natural waters vary due local geology, atmospheric precipitation, and water balance (i.e. evaporation-precipitation). In addition, the soil porosity also influences groundwater chemistry, and the contamination level depends on that too. Previous studies reported that porous soils improve water quality compared with non-porous soils, and the particle size and thickness of soil layers should also be considered [1].

The measurements of physicochemical parameters of the groundwater from wells were further geographically extrapolated to map the degree of contamination, as well as the amplitude variation in the surveyed region.

a) Dissolved oxygen and oxygen saturation

The first parameter analysed in the well water was the dissolved oxygen (Figure 3). In the study area, it varied between 0.05 and 12 mg L⁻¹. Low oxygen levels usually reflect the local microbial degradation activity of organic substances in water. The lowest levels were observed in the plain area (blue). Substances infiltration into the hill area and their accumulation in the lowland area could explain this.

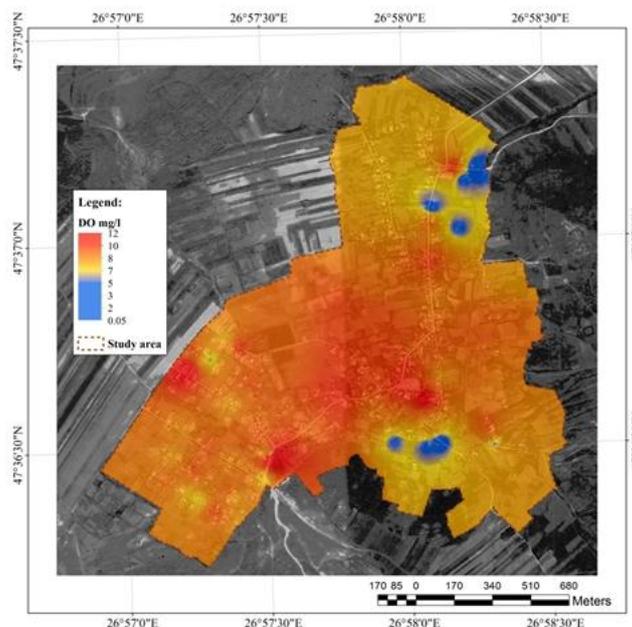


Figure 3. The level of dissolved oxygen (DO mg L⁻¹) concentration in the study area.

Oxygen saturation in water (Figure 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 watervolume and depth.

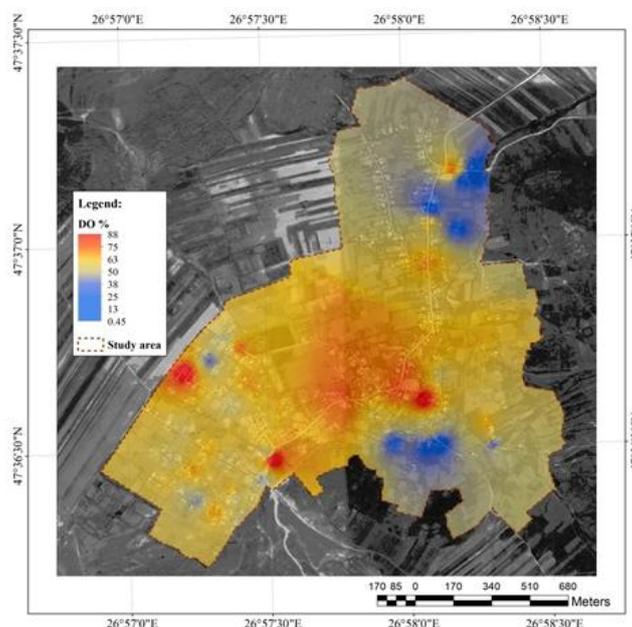


Figure 4. The level of oxygen saturation (%) of the water in the study area.

According to the Environmental Protection Division of the British Columbia Environmental Ministry [22], high levels of oxygen in groundwater recommends it for human consumption, but its beneficial effect is counterbalanced by the precipitation of metal oxides.

Dissolved oxygen prevents chemical reactions of lead, iron, and manganese released from sediments into the groundwater and facilitates the biochemical reduction of ammonium to nitrates, hence increasing the self-purification capacity. The norms for dissolved oxygen concentration in

drinking water for British Columbia are minimum of 5 mg L⁻¹ for drinking water (Alberta Environment, 1977), >8.0->9.5 (State of Washington, 1982), and a minimum of 4 mg L⁻¹ (Alaska, 1979).

In the current survey, the blue areas indicate potential hazard for the local population who consume water from these wells.

The dissolved oxygen levels in groundwater is reversely correlated to temperature (Figure 5). Water temperature ranged from +1 +12°C. It varies significantly over 24 hours in surface waters, but in wells the temperature is relatively constant (<http://water.epa.gov/type/rsl/monitoring/vms52.cfm>).

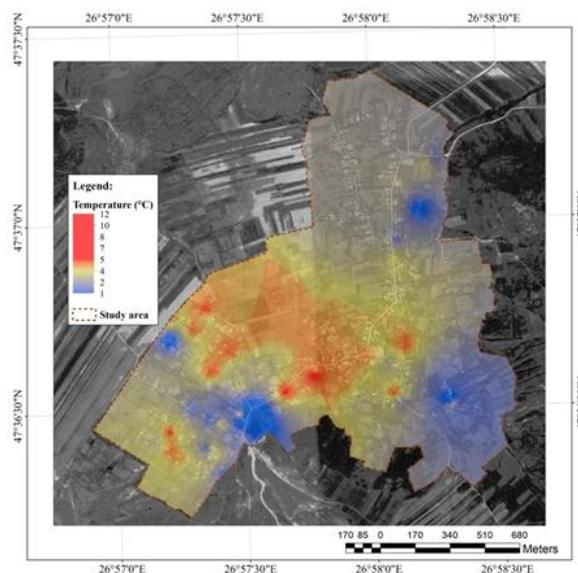


Figure 5. The level of water temperature(°C) in the study area.

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

Regarding water ORP (Figure 6), there were observed two areas where the groundwater had reduction character, marked in blue (-3 și -26); otherwise, the character was strongly oxidant, reaching maximum value of +131. The explanation is in the oxidation of organic substances and the formation of inorganic oxides. ORP analysis can assess the ability of water to disinfect and eliminate harmful microorganisms. This is important when ensuring that water treatment processes, such as chlorination or ozonation, are effective in maintaining safe drinking water standards [23].

Drinking water should have an ORP between 200 and 400 mV to indicate safety and the absence of biologically active contaminants. Water with negative (e.g. 100 to -300 mV) is considered beneficial for health RP - antioxidant effects.



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

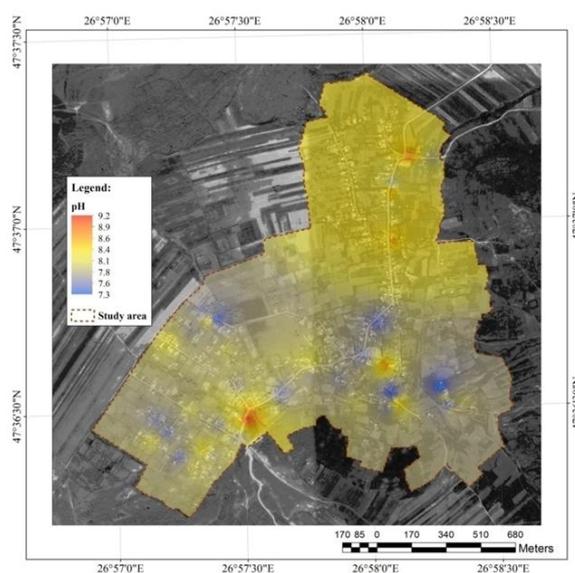


Figure 7. Water pH in the study area.

c) Salinity and pH

Salinity is strongly 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 sulfates. 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 (Figure 8).

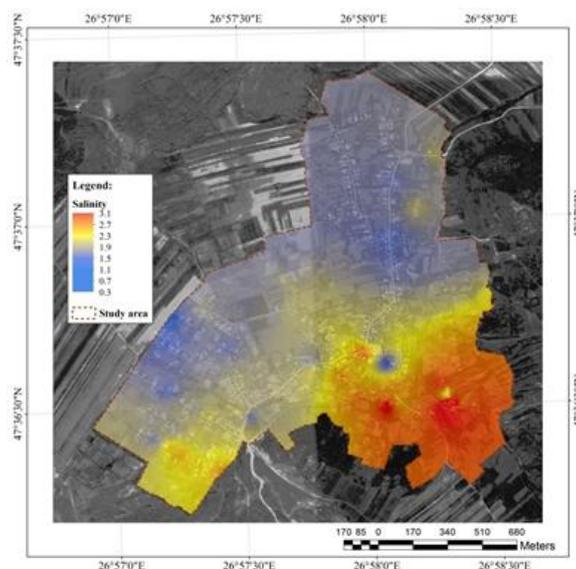


Figure 8. Water salinity in the study area.

d) TDS and conductivity

Changes in TDS concentrations in groundwater habitats are usually due industrial effluents, changes in water balance (i.e. rainfalls, overexploitation or prolonged drought), as 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 the deleterious impact on various development stages of tolerant species [9].

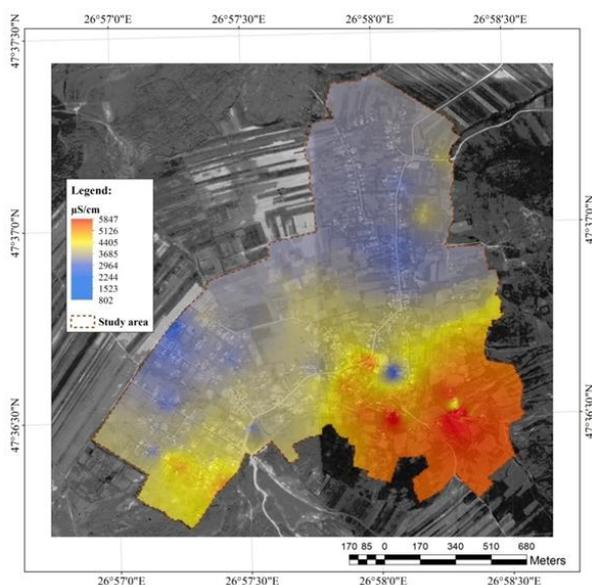


Figure 9. Water conductivity in the resource in the study area.

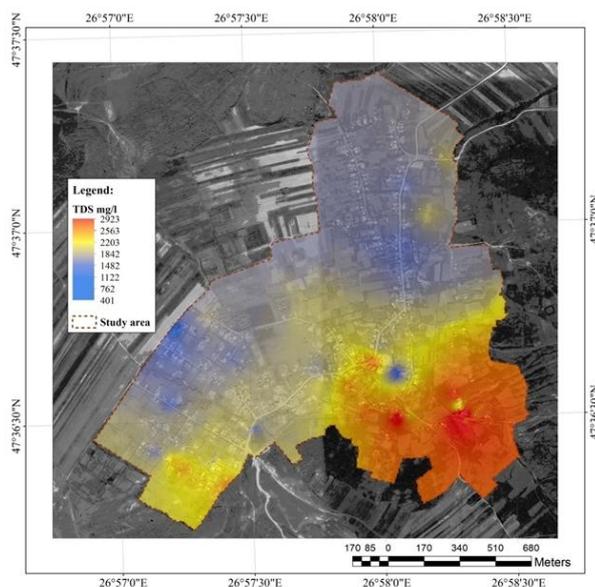


Figure 10. Total dissolved solids in the water resource in the study area.

Another environmental issue that arises in the current context is the lack of involvement of local authorities in Botosani County in monitoring water quality and population health surveys. This area is perfect for studying the effects of high salinity and TDS of water on human health, given that the local population is stable and consumes just well water.

In 2012, as part of the European project “Preventing the Blue Death”, 117 water samples from wells were collected and analysed (Table 2). 68 samples were assessed as inadequate, indicating potential water quality issues. In addition, 457 microbiological measurements were done, out of which 167 were classified as insufficient, highlighting the need for supplementary measures to improve the safety standards of drinking water.

Table 2. Summary of Water Samples Analyzed (2012-2014).

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

The microbiological measurements were done out according to international standards and were focused on essential parameters, such as the total number of colonies at 37°C (according to SREN ISO 6222/2004), coliform bacteria (according to SREN ISO 9308-1/2009), *Escherichia coli* (according to SREN ISO 9308-1/2009) and enterococci (according to SREN ISO 7899-2/2009). These analyses aimed to assess the microbiological risks and to ensure the safety standards compliance of drinking water supplies.

In addition to microbiological measurements, chemical analyses were also performed to assess the water quality (Table 3). These analyses comprised the measurements of ammonium (according to SR ISO 7150-1/2001), nitrite (according to SREN 26777 C 91/2006), nitrate (according to SR ISO 7890-3/2000), oxidizability (according to SREN ISO 8467/2001), pH (according to SR ISO 10533/2009), hardness (according to SR ISO 6059/2008) and turbidity (according to SR EN ISO 7027/1999). These parameters provide a comprehensive diagnostic of the physicochemical characteristics of groundwater and ensure their compliance to quality standards.

Also, in May 2012, two water samples were collected from the Lunca area, Botosani County, within the same project. The samples were part of a more significant effort to monitor and improve

the quality of drinking water in the region, contributing to the identification of solutions to prevent risks to public health.

Table 3. Microbiological and chemical Determinations Conducted on Drinking Water.

Parameter	Standard Used
Number of Colonies at 37°C	SREN ISO 6222/2004
coliform Bacteria	SREN ISO 9308-1/2009
<i>Escherichia coli</i>	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

Between 2012 and 2014, water analyses were done in Baznoasa, Zlatunoaia and Lunca in Botosani County. The results of these analyses highlighted both positive aspects and significant problems regarding drinking water quality.

In 2012, supplementary samples were analysed from the wells in Baznoasa and Cultural Centre in Lunca. In the samples from Baznoasa well, the microbiological parameters indicated the presence of significant contamination of coliform bacteria (20 cfu/100 mL), *Escherichia coli* (18 cfu/100 mL), and enterococci (950 cfu/100 mL) exceeded the permissible values, which are 0 cfu/100 mL for all three indicators. Also, the nitrate concentrations (i.e. 98.6 mg L⁻¹) exceeded the maximum allowed limit of 50 mg L⁻¹. In contrast, other parameters, such as the colony count at 37°C (i.e. 20 cfu/mL), ammonium (i.e. beyond detection limits mg L⁻¹), nitrite (i.e. 0.036 mg L⁻¹), oxidizability (i.e. 1.27 mg L⁻¹) and pH (i.e.7.18), were within the permissible limits.

At the well from Lunca, the situation was similar: coliform bacteria (i.e.500 cfu/100 mL), *Escherichia coli* (i.e. 250 cfu/100 mL) and enterococci (i.e. 700 cfu/100 mL) exceeded the maximum allowed values. Nitrates (58.6 mg L⁻¹) were also above 50 mg L⁻¹ limit. However, other parameters, such as the colony count at 37°C (i.e. 65 cfu m L⁻¹), ammonium (below detection limit), nitrite (i.e. 0.044 mg L⁻¹), oxidizability (i.e. 3.16 mg L⁻¹) and pH (i.e. 7.38) complied with the standards.

In 2013, analyses of samples from the well of the Zlatunoaia Junior High School showed the presence of coliform bacteria (i.e. 1.7 × 10⁶ cfu/100 mL), *Escherichia coli* (i.e.2.5 × 10⁶ cfu/100 mL) and enterococci (i.e. 9 cfu/100 mL), all exceeding maximum allowed values. The nitrate concentration (i.e. 179 mg L⁻¹) was almost four times higher than the maximum limit of 50 mg L⁻¹. However, the hardness (i.e. 51 °dH) and turbidity (i.e. 1.67 NTU) were within the permissible limits. At the well of the Primary School in Baznoasa, the microbiological parameters (i.e. coliform bacteria, *Escherichia coli*, and enterococci) were compliant, but nitrates (i.e. 284 mg L⁻¹) exceeded the permissible limit again. Hardness (i.e. 77 °dH) and turbidity (i.e. 1.63 NTU) were also within normal limits.

In 2014, the analyses carried out at the drilled well in Lunca showed significant improvements of water quality. All microbiological indicators (i.e. coliform bacteria, *Escherichia coli*, and enterococci) were compliant, and chemical parameters, such as ammonium (i.e. 0.3 mg L⁻¹), nitrites (i.e. 0.08 mg L⁻¹), nitrates (i.e. 0.74 mg L⁻¹) and turbidity (i.e. 2.53 NTU), were within the permissible limits.

Table 4. 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	-	✓	
		Coliform Bacteria	20 cfu 100m L ⁻¹	0 cfu 100m L ⁻¹	✗	
		<i>Escherichia coli</i>	18 cfu 100m L ⁻¹	0 cfu 100m L ⁻¹	✗	
		Enterococci	950 cfu 100m L ⁻¹	0 cfu 100m L ⁻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 100m L ⁻¹	0 cfu 100m L ⁻¹	✗
			<i>Escherichia coli</i>	250 cfu 100m L ⁻¹	0 cfu 100m L ⁻¹	✗
			Enterococci	700 cfu 100m L ⁻¹	0 cfu 100m L ⁻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 100m L ⁻¹	0 cfu 100m L ⁻¹	✗
		<i>Escherichia coli</i>	2.5 × 10 ⁶ cfu 100m L ⁻¹	0 cfu 100m L ⁻¹	✗	
		Enterococci	9 cfu 100m L ⁻¹	0 cfu 100m L ⁻¹	✗	
		Nitrates	179 mg L ⁻¹	≤ 50 mg L ⁻¹	✗	
		Hardness	51 °dH	≥ 50 °dH	✓	
		Turbidity	1.67 NTU	≤ 5 NTU	✓	
		Well at Baznoasa Primary School	Coliform Bacteria	0 cfu 100m L ⁻¹	0 cfu 100m L ⁻¹	✓
	<i>Escherichia coli</i>		0 cfu 100m L ⁻¹	0 cfu 100m L ⁻¹	✓	
	Enterococci		0 cfu 100m L ⁻¹	0 cfu 100m L ⁻¹	✓	
	Nitrates		284 mg L ⁻¹	≤ 50 mg L ⁻¹	✗	
	Hardness		77 °dH	≥ 50 °dH	✓	
	Turbidity		1.63 NTU	≤ 5 NTU	✓	

2014 – “Preventing Blue Death” Project	Drilled Well, Lunca Village	Coliform	0 cfu	0 cfu 100m	✓
		Bacteria	100m L ⁻¹	L ⁻¹	
		<i>Escherichia coli</i>	0 cfu	0 cfu 100m	✓
			100m L ⁻¹	L ⁻¹	
		Enterococci	0 cfu	0 cfu 100m	✓
			100m L ⁻¹	L ⁻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	✓		

Thus, according to the results of the analyses from the Botosani Public Health Directorate carried out between 2012 and 2014, the contamination with nitrites and microbiological organisms detrimental for human health was found in the groundwater from several wells situated in the illage of Stroiesti. These analyses are insufficient for a proper monitoring of the area where the local population depends on the water resources from wells. The low values recorded bt Botosani Public Health Directorate confirmed our *in-situ* measurements.

The current survey was completed with comparisons of the values obtained in local wells to those from various brands and types of water sold in stores. Thus, 14 types of water sold were analysed. Table 5 presents the chemical composition provided by the manufacturers. No manufacturer offered complete information about all the analysed parameters and for some elements present in water.

The mineral composition of bottled waters plays a crucial role in assessing their suitability for human consumption and potential health hazards. The table highlights key parameters, such as sodium, magnesium, calcium, potassium, bicarbonates, dry residue at 180°C, sulphates, carbon dioxide, and chloride for various still and sparkling mineral water brands.

Sodium levels vary significantly across the analysed brands. Waters such as Aqua Carpatica still (i.e. 0.78 mg L⁻¹), Wonder still (i.e.0.74 mg L⁻¹), and Carpatica still (i.e.0.82 mg L⁻¹) had very low sodium concentrations, making them suitable for individuals adhering to low-sodium diets, such as those with hypertension or cardiovascular diseases. On the other hand, sparkling waters like Valea Izvoarelor sparkling (i.e. 93 mg L⁻¹) and Perla Covasnei sparkling (i.e. 85.82 mg L⁻¹) contained higher sodium levels, which could be contraindicated for individuals with sodium-sensitive conditions.

Magnesium, an essential mineral for muscle and nerve function, was found in varying amounts. Brands such as Aqua Carpatica sparkling (i.e. 78.1 mg L⁻¹) and Bucovina sparkling (i.e. 76.73 mg L⁻¹) were rich in magnesium and may provide additional health benefits, particularly for individuals with magnesium deficiencies. Conversely, waters like Wonder Still (i.e. 3.45 mg L⁻¹) and Bucovina Still (i.e. 2.63 mg L⁻¹) exhibited low magnesium concentrations, making them less significant as a magnesium source.

Calcium levels, which are important for bone health, were notably high in some sparkling waters, such as Aqua Carpatica sparkling (i.e. 286 mg L⁻¹) and Bucovina sparkling (i.e. 264.5 mg L⁻¹), as well as in still water brands like Kaufland still (i.e. 197 mg L⁻¹). These waters may contribute significantly to dietary calcium intake. In contrast, waters such as Bucovina still (i.e. 9.56 mg L⁻¹), Wonder still (i.e. 17.2 mg L⁻¹) and Perla Covasnei sparkling (i.e. 35.66 mg L⁻¹) have considerably lower calcium levels.

The bicarbonate content is a key indicator of the buffering capacity and ability to neutralize stomach acidity. High bicarbonate levels are observed in Aqua Carpatica sparkling (i.e. 1281 mg L⁻¹) and Bucovina sparkling (i.e. 1189 mg L⁻¹), which may benefit digestion and metabolic health. The pH values range from 5.0 (acidic, Valea Izvoarelor sparkling) to 7.7 (slightly alkaline, Aqua Carpatica still), indicating varying acidity across brands. Still waters tend to have more neutral pH values, while sparkling waters are more acidic due to dissolved CO₂.

The dry residue at 180°C reflects the total mineralization of the water. High values are recorded for Kaufland still (i.e. 924 mg L⁻¹) and Aqua Carpatica sparkling (i.e. 1281 mg L⁻¹), indicating significant mineral content. Sulphates, known for their role in digestion and detoxification, are present in moderate amounts in some brands, such as Aqua Carpatica Still (i.e. 21.23 mg L⁻¹), but are negligible in others.

Waters like Perla Harghitei still and Borsec still combine moderate mineralization with balanced calcium and magnesium levels, making them suitable for daily consumption. On the other hand, sparkling waters with high sodium, magnesium, and bicarbonate levels, such as Bucovina sparkling and Aqua Carpatica sparkling, may be beneficial for specific therapeutic purposes but less suitable for individuals with dietary restrictions.

In conclusion, the mineral content of bottled waters varied, catering to different health needs and preferences. When selecting bottled water, consumers should consider their health requirements, particularly regarding sodium, calcium, and magnesium intake, as well as the water's pH and mineralization levels.

Table 5. Values of some elements and physicochemical parameters in water sold in stores.

Brand	Na (mg L ⁻¹)	Mg (mg L ⁻¹)	Ca (mg L ⁻¹)	K (mg L ⁻¹)	pH	HC O ₃	Dry residue at 180°C	Sulphate	CO ₂ mini mum	Chloride
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	7.7	201. 6 3	202	21.23	300	
CARPATICA natural sparkling mineral water	22.39	41.68	117.4	5.371	6.6	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	7.0	48.8 5	74			
BUCOVINA natural sparkling mineral water	26.72	76.73	264.5	4.32	5.31	1189	951			
VALEA IZVOARELOR still natural mineral water	92.5	9.42	47.42		7.5	306. 6 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		7.4	312 2	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	5.7 6	453	2500	16.31

Dissolved oxygen is an indicator of water quality. The highest values were found in Water Network Botosani (i.e. 8.64 mg L⁻¹) and Water Network Iasi (i.e. 8.01 mg L⁻¹), indicating good oxygenation. Conversely, lower values, such as those observed in Valea Izvoarelor Natural sparkling mineral water (i.e. 2.03 mg L⁻¹) and Perla Harghitei Natural sparkling mineral water (i.e. 1.14 mg L⁻¹), suggest lower quality, potentially unsuitable for consumption.

pH falls within the optimal range of 6.5–8.5 for most still waters, such as Water Network Botosani (8.1), Aqua Carpatica Still natural mineral water (7.91), and Carpatica Still natural mineral water (7.95). Carbonated waters, such as Aqua Carpatica Natural sparkling mineral water (5.7) and Valea Izvoarelor Natural sparkling mineral water (5.26), show lower pH levels due to their CO₂ content, characteristic of this type of water.

The conductivity, which reflects the concentration of dissolved salts, varies significantly across samples. Aqua Carpatica Natural sparkling mineral water (i.e. 1603 μS cm⁻¹) and Kaufland Still natural mineral water (i.e. 1257 μS cm⁻¹) exhibit high values, indicating significant mineral content. In contrast, Bucovina Still natural mineral water (i.e. 100 μS cm⁻¹) indicated low-salt water, suitable for frequent consumption.

TDS exceeded the allowed upper limit of 500 mg L⁻¹ in Aqua Carpatica Natural sparkling mineral water (i.e. 802 mg L⁻¹) and Kaufland Still natural mineral water (i.e. 628 mg L⁻¹), potentially affecting taste and suitability for regular consumption. Waters with lower TDS, such as Water Network Botosani (i.e. 197 mg L⁻¹) and Aqua Carpatica Still natural mineral water (i.e. 155 mg L⁻¹), are more appropriate for drinking.

Salinity ranged from 0.05 to 0.91, with low values, such as those from Bucovina Still natural mineral water (0.05) and Wonder Still natural mineral water (0.06), making them suitable for frequent consumption. Waters with higher salinity, such as Aqua Carpatica Natural sparkling mineral water (0.81), may negatively affect taste and usability.

Oxidation-reduction potential, an indicator of chemical stability, varies significantly, with higher values in Water Network Iasi (193.2 mV) and Valea Izvoarelor Natural sparkling mineral water (138.8 mV), potentially indicating chemical instability that could affect perceived water quality.

Dissolved oxygen percentage (DO%) was high in Water Network Botosani (76.1%) and Water Network Iasi (73.2%), suggesting superior quality. On the other hand, lower values, such as those in Valea Izvoarelor Natural sparkling mineral water (4.4%) and Bucovina Natural sparkling mineral water (8.4%), reflected insufficient oxygenation, which may affect water characteristics.

In conclusion, the still waters such as Water Network Botosani, Water Network Iasi, and Aqua Carpatica Still natural mineral water stood out with optimal parameters, making them most suitable for regular consumption. Conversely, the carbonated waters, particularly Aqua Carpatica Natural sparkling mineral water and Kaufland Still natural mineral water, displayed high TDS and salinity levels, making them less suitable for frequent consumption without additional treatment.

Table 6. 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	ORP	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 HARGHITAI still natural mineral water	5,52	7,10	610	305	0,30	70,9	48,4
PERLA HARGHITAI 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

4. Conclusions

The current survey highlighted critical issues related to water quality in rural areas of Botosani County, particularly the reliance on well water, which often lacks adequate monitoring and control. Local authorities limited involvement in survey for assessing water quality and population health exacerbated the risks associated with well water consumption. The results of the current research reinforced the need for standardized and regular monitoring to ensure safe drinking water for rural communities.

Comparative analyses of bottled water revealed wide variability in mineral contents, which influences further their suitability for human consumption. Bottled waters with low sodium, calcium, and magnesium levels, such as Aqua Carpatica Still, Wonder Still, and Bucovina Still, were ideal for regular use and specific dietary needs. In contrast, waters with high mineral content, including Aqua Carpatica Sparkling and Kaufland Still, offered therapeutic benefits but were less suitable for frequent consumption due elevated TDS and salinity levels.

Dissolved oxygen and pH values were crucial indicators of water quality, with still waters generally exhibiting better oxygenation and neutral pH levels compared to sparkling waters. Conductivity and salinity further underscored the diverse chemical profiles of water samples, emphasizing the importance for selecting appropriate sources for daily hydration based on individual health requirements.

The study also underscores the necessity for comprehensive labelling of bottled water. The absence of complete information about all analysed parameters limit the consumer ability to make informed choices. Enhanced transparency in labelling would thus facilitate better public understanding of health implications associated with water consumption.

In conclusion, the current study underscored the critical need for improved water quality monitoring and public awareness in rural areas, alongside better regulation and labelling of bottled water. The findings provided valuable insights for policymakers, public health officials, and consumers, advocating for enhanced efforts to ensure safe and accessible drinking water.

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.” Please turn to the CRediT taxonomy for the term explanation. Authorship must be limited to those who have contributed substantially to the work reported.

Funding: This research received no external funding.

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

References

1. Abanyie, S.K.; Apea, O.B.; Abagale, S.A.; Amuah, E.E.Y.; Sunkari, E.D. Sources and Factors Influencing Groundwater Quality and Associated Health Implications: A Review. *Emerg. Contam.* **2023**, *9*.
2. Merritt, P.; Power, C. Assessing the Long-Term Evolution of Mine Water Quality in Abandoned Underground Mine Workings Using First-Flush Based Models. *Sci. Total Environ.* **2022**, *846*, doi:10.1016/j.scitotenv.2022.157390.
3. Krishnamoorthy, L.; Lakshmanan, V.R. Groundwater Quality Assessment Using Machine Learning Models: A Comprehensive Study on the Industrial Corridor of a Semi-Arid Region. *Environ. Sci. Pollut. Res.* **2024**, doi:10.1007/s11356-024-34119-7.
4. Wang, Y.; Yuan, S.; Shi, J.; Ma, T.; Xie, X.; Deng, Y.; Du, Y.; Gan, Y.; Guo, Z.; Dong, Y.; et al. Groundwater Quality and Health: Making the Invisible Visible. *Environ. Sci. Technol.* **2023**, *57*.

5. Qureshi, S.S.; Channa, A.; Memon, S.A.; Khan, Q.; Jamali, G.A.; Panhwar, A.; Saleh, T.A. Assessment of Physicochemical Characteristics in Groundwater Quality Parameters. *Environ. Technol. Innov.* **2021**, *24*, doi:10.1016/j.eti.2021.101877.
6. Iefremova, I.; Lomakina, I.; Obiiukh, N. Groundwater Protection as an Essential Component of Water Management in the European Union in the Light of Modern Integration Processes: Legal Aspects of the Problem. *Eur. J. Sustain. Dev.* **2019**, *8*, 354, doi:10.14207/ejsd.2019.v8n3p354.
7. Panahi, M.; Sadhasivam, N.; Pourghasemi, H.R.; Rezaie, F.; Lee, S. Spatial Prediction of Groundwater Potential Mapping Based on Convolutional Neural Network (CNN) and Support Vector Regression (SVR). *J. Hydrol.* **2020**, *588*, doi:10.1016/j.jhydrol.2020.125033.
8. El Alfy, M.; Lashin, A.; Al-Arifi, N.; Al-Bassam, A. Groundwater Characteristics and Pollution Assessment Using Integrated Hydrochemical Investigations GIS and Multivariate Geostatistical Techniques in Arid Areas. *Water Resour. Manag.* **2015**, *29*, doi:10.1007/s11269-015-1136-2.
9. Weber-Scannell, P.K.; Duffy, L.K. Effects of Total Dissolved Solids on Aquatic Organisms: A Review of Literature and Recommendation for Salmonid Species. *Am. J. Environ. Sci.* **2007**, *3*.
10. Garcia, J.; Heo, J.; Kim, C. Machine Learning Algorithms for Water Quality Management Using Total Dissolved Solids (TDS) Data Analysis. *Water (Switzerland)* **2024**, *16*, doi:10.3390/w16182639.
11. WHO *Guidelines for Drinking-Water Quality: Fourth Edition Incorporating the First and Second Addenda*; **2022**;
12. WHO *Guidelines for Drinking Water Quality, Vol 2, 2nd Ed. World Heal. Organization, Geneva* **1996**, *2*, 132–388.
13. Chilima, G.; Nkhoma, B.; Chavula, G.; Mulwafu, W. Community Based Management Approach in the Management of Water Resources By Different Organisations in the Lake Chilwa Basin, Malawi. *Basis* **2001**, 1–13.
14. Rasool, A.; Saeed, S.; Ahmad, S.; Iqbal, A.; Ali, A. Empowering Community Participation for Sustainable Rural Water Supply: Navigating Water Scarcity in Karak District Pakistan. *Groundw. Sustain. Dev.* **2024**, *26*, 101269, doi:https://doi.org/10.1016/j.gsd.2024.101269.
15. Roba, C.; Bălc, R.; Creța, F.; Andreica, D.; Pădurean, A.; Pogăcean, P.; Chertes, T.; Moldovan, F.; Mocan, B.; Roșu, C. Assessment of Groundwater Quality in Nw of Romania and Its Suitability for Drinking and Agricultural Purposes. *Environ. Eng. Manag. J.* **2021**, *20*, doi:10.30638/eemj.2021.043.
16. Derry, A.M.; Prepas, E.E.; Hebert, P.D.N. A Comparison of Zooplankton Communities in Saline Lakewater with Variable Anion Composition. *Hydrobiologia* **2003**, *505*, doi:10.1023/B:HYDR.0000007414.12566.19.
17. Stekoll, M.S.; Smoker, W.W.; Failor-Rounds, B.J.; Wang, I.A.; Joyce, V.J. Response of the Early Developmental Stages of Hatchery Reared Salmonids to Major Ions in a Simulated Mine Effluent. *Aquaculture* **2009**, *298*, doi:10.1016/j.aquaculture.2009.10.017.
18. Erickson, R.J.; Benoit, D.A.; Mattson, V.R.; Nelson, H.P.; Leonard, E.N. The Effects of Water Chemistry on the Toxicity of Copper to Fathead Minnows. *Environ. Toxicol. Chem.* **1996**, *15*, doi:10.1897/1551-5028(1996)015<0181:TEOWCO>2.3.CO;2.
19. Stoss, V.J.; Büyükhhatipoglu, S.; Holtz, W. Der Einfluß Bestimmter Elektrolyte Auf Die Bewegungsauslösung Bei Spermatozoen Der Regenbogenforelle (*Salmo Gairdneri*). *Reprod. Domest. Anim.* **1977**, *12*, doi:10.1111/j.1439-0531.1977.tb00170.x.
20. Florica Breșug, V.M. Pagine Monografice. Comuna Lunca, Județul Botoșani. **2016**.
21. Kumar, S.; Veerwal, B.; Sharma, D.; Verma, B.K. Review on Physicochemical Parameters of Water Concerning Their Effect on Biotic Population. *Indian Hydrobiol.* **2022**, *21*, 15–24.
22. British Columbia Ministry of Environment and Climate Change Strategy. *B.C. Source Drinking Water Quality Guidelines: Guideline Summary.*; **2020**; ISBN 9780772671622.
23. Suslow, T. V *Oxidation-Reduction Potential (ORP) for Water Disinfection Monitoring, Control, and Documentation*; **2004**;

Disclaimer/Publisher's Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.