ASSESSMENT OF DRINKING WATER QUALITY FROM THE PUBLIC WATER SUPPLY SYSTEM: CIOC-MAIDAN VILLAGE, COMRAT DISTRICT

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Abstract. In the Republic of Moldova, artesian wells are used intensively in rural areas, being a main source of drinking water supply for the population in the area. To a large extent, the quality of water from artesian wells does not meet the limit values for drinking. Therefore, the present study aimed to evaluate the quality of drinking water from a physico-chemical and microbiological point of view from the 12 artesian wells in the outskirts of Cioc-Maidan village, Comrat district. Thus, 13 physico-chemical parameters and 3 microbiological parameters were determined to characterize the drinking water. The laboratory results were compared with the permissible limit values of the national legal framework on drinking water quality (Law 182/2019). According to the results obtained, it was found in all artesian wells, an excess of ammonium (NH_4^+) of approximately 5 times the permissible limit (0.5 mg/l). This indicator is often detected in artesian wells in the Republic of Moldova, indicating pollution of both natural and artificial origin, thus modifying the taste and smell of the water. All water sources are characterized by a very low total hardness (< 3.7 °dH), which denotes that the local geology of the aquifer is devoid of calcium and magnesium rocks. From a microbiological point of view, no bacteria were detected. The conclusions showed that most of the water quality parameters determined fall within the national drinking water quality standards, with the exception of ammonium and total hardness. The geomorphological context, the depth of the captured levels and the geological nature of the soil formations are all factors that influence the quality of drinking water distributed to the inhabitants of the region.

Keywords: artesian well, drinking water, water quality parameter, permissible limit value.

Rezumat. Evaluarea calității apei potabile din sistemul public de alimentare cu apă: satul Cioc-Maidan, raionul Comrat. În Republica Moldova, sondele arteziene sunt folosite intens în zonele rurale, fiind o sursă principală de alimentare cu apă potabilă a populației din zonă. În mare măsură, calitatea apelor din sondele arteziene nu corespund valorilor limită pentru potabilitate. Prin urmare, prezentul studiu a avut ca scop evaluarea calității apei potabile din punct de vedere fizico-chimic și microbiologic din cele 12 sonde arteziene din extravilanul satului Cioc-Maidan, raionul Comrat. Astfel, pentru caracterizarea apei potabile au fost determinați 13 parametri fizico-chimici și 3 parametri microbiologici. Rezultatele de laborator au fost comparate cu valorile limită admisibile a cadrului național legal privind calitatea apei potabile (Legea 182/2019). Conform rezultatelor obținute, s-a constatat în toate sondele arteziene, o depășire a amoniului (NH_4^+) de aproximativ de 5 ori față de limita admisibilă (0,5 mg/l). Acest indicator este des depistat în sondele arteziene din Republica Moldova, indicând atât o poluare de origine naturală cât și artificială, astfel modificând gustul și mirosul apei. Toate sursele de apă se caracterizează printr-o duritate totală foarte joasă (< 3,7 °dH), ceea ce denotă că rocile acviferului sunt sărace în calciu și magneziu. Din punct de vedere microbiologic, bacteriile nu au fost depistate. Concluziile au arătat că majoritatea parametrilor de calitate a apei determinați se încadrează în standardele naționale de calitate a apei potabile, cu excepția amoniului și durității totale. Contextul geomorfologic, adâncimea nivelurilor captate și natura geologică a formațiunilor de sol, sunt principalii factori care influențează calitatea apei potabile distribuită locuitorilor din regiune.

Cuvinte cheie: sondă arteziană, apă potabilă, parametru de calitate a apei, valoare limită admisibilă.

INTRODUCTION

Problems related to the quality of drinking water represent an important element for the well-being and development of a modern society. Providing clean and safe water for its inhabitants is a crucial aspect, while ensuring a low rate of disease in the human population, thus minimizing the risk of various water-related diseases.

The increase in pollution and the rapid depletion of surface water resources have led to the implementation of mandatory water quality assessments worldwide (CHAUDHARI et al, 2024). Groundwater is a critical component of human development as it is the primary source of drinking water in many countries around the world. The scarcity of surface water resources makes people dependent on groundwater for their regular water supply (MENGSTIE et al., 2023). Groundwater is the largest freshwater resource and is needed for many domestic, industrial and agricultural activities, especially in rural areas (LIANG et al., 2022).

In the last decade, the Republic of Moldova's dependence on groundwater has increased considerably, due to climate change and anthropogenic activities. The drying up of freshwater bodies and their pollution has led to the excessive use of groundwater for various necessary purposes.Thus, groundwater is used at a higher rate than it can be recharged.In the Republic of Moldova, the main sources of drinking water for the population in urban areas are surface (the Dniester and Prut rivers) and deep (artesian wells), and for the population in rural areas - mine wells and artesian wells. The population in rural areas is currently supplied with water from 922 aqueducts, of which 488 do not comply with sanitary standards, including the lack of a sanitary protection zone and the lack of water treatment facilities (CARP & FRIPTULEAC, 2020).

In the current conditions of the Republic of Moldova, the issue of the quality of the water consumed by the population and its impact on human health represents one of the main environmental challenges (PRODAN et al., 2024). Of the total number of inhabitants, about 57% do not have access to good quality drinking water. The quality of water from local supply sources (74.6%), central supply sources (68.2%) and distribution networks (37.7%) does not meet the hygienic requirements for drinking water (CIOBANU & MEȘINA, 2023). Under these conditions, morbidity from diseases caused by water pollution has doubled. About 80% of diseases related to unsatisfactory environmental quality are caused by excessive pollution of drinking water and only 20% - by other environmental factors (OSTROFEȚ et al., 2011).

According to the results carried out by the laboratories of the National Agency for Public Health, it is revealed that for the period 2015-2019, there is an improvement in the quality of water from centralized underground and surface sources in terms of chemical parameters. Thus, the share of water samples from centralized underground sources (2331 artesian wells), which do not comply with the sanitary regulations in force, decreased by 2% (from 71.5% to 69.5%) during the estimated period. However, it is necessary to note that the share of non-conformity of water quality, in chemical parameters, from the mentioned sources, remains at a fairly high level, the average for the years 2015-2019 being 69.0%. For waters from centralized deep sources, the most frequent non-conformities are attested to the content of fluorine (on average 29.0%) and boron (on average 16.0%) (CARP & FRIPTULEAC, 2020).

According to the national report for 2022 (***. SUPRAVEGHEREA DE STAT A SĂNĂTĂȚII PUBLICE ÎN REPUBLICA MOLDOVA, 2022), the National Agency for Public Health found that the share of drinking water samples not complying with the sanitary norms taken was in the reference year 2022 - 57.8%, in 2021 - 60%, in 2020 - 58%. Also, the share of samples not complying with sanitary norms according to microbiological parameters was 31% in 2022, and 31% in 2021.

Various researchers around the world have conducted studies to assess the quality of drinking water. The physical, chemical, biological and organoleptic properties of water are the parameters used to describe its quality and determine the capacity of water for a variety of uses, including the protection of human health and the aquatic ecosystem. Most of these properties are influenced by constituents that are either dissolved or suspended in water, and water quality can be influenced by both natural processes and human activities (LUVHIMBI et al., 2022). The chemical composition of groundwater is influenced by the minerals and gases that react with water in its relatively slow passage through the rocks and sediments of the Earth's crust. Thus, the purpose of this study was to evaluate the quality of groundwater from artesian wells, the only source of drinking water supply in the area, according to physicochemical and microbiological quality parameters. The results are extremely useful for local public authorities, economic agents and decision-makers, in achieving the objectives of adequate planning and sustainable development of groundwater resources.

MATERIALS AND METHODS

The study area is located in the outskirts of the village of Cioc-Maidan, Comrat district, located at latitude 46.3640, longitude 28.8219 and altitude 192 meters above sea level (Fig. 1). The commune of Cioc-Maidan, consisting of a single village of the same name, is located about 60 km east of the Prut and 90 km west of the Dniester, in the northern part of the Bugeac plain, and about 140 km north of the Danube. To the east, 3 km from the village flows the Lunguța stream, and to the west, 6 km flows the Lunga stream, both tributaries of the Ialpug river (DUMINICA, 2018).

In this study, to assess the quality of groundwater, 12 groundwater samples from artesian wells were taken, which are located in the outskirts of the locality, supplying the population in the area with drinking water. Agricultural lands and forest plots are located in the well protection areas.

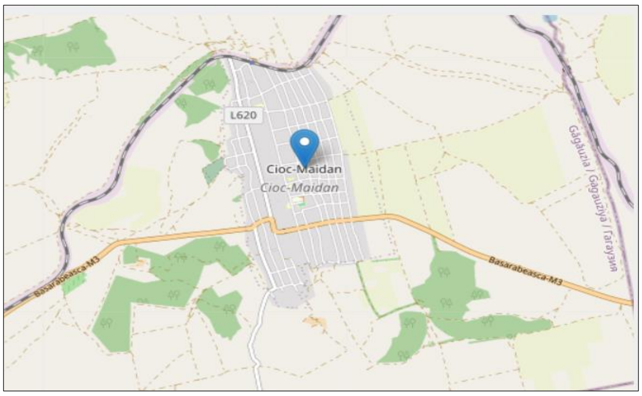

Figure 1. Study area (original).

The samples were taken in September 2024, according to the requirements of the SM ISO 5667-11:2010 standard. For the assessment of physico-chemical parameters, 1500 ml of water were sampled, and for the microbiological analysis of water, 500 ml were sampled, in sterile recipients. The following water quality parameters were analysed: pH, electrical conductivity, mineralization (TDS), turbidity, chlorides (Cl^-), ammonium (NH_4^+), nitrites (NO_2^-), nitrates (NO_3^-), sulfates (SO_4^{2-}), total hardness, sodium (Na^+), total iron (Fe_{tot}), fluorides (F), coliform bacteria, *Escherichia coli*, enterococci. The samples were analyzed in the laboratory according to standardized methods (Table 1), and the results obtained were evaluated based on the admissible limit values in the Law 182/2019 (LAW No. 182 OF 19-12-2019 ON THE QUALITY OF DRINKING WATER, 2020).

Table 1. Quality parameters analyzed in water samples.

	Quality parameter	Unit of measurement	Analysis method	Equipment used
1.	Turbidity	NTU	SM EN ISO 7027-1:2017	Hanna HI 98703 Portable Turbidimeter
2.	Hydrogen ion concentration (pH)	units pH	SM SR EN ISO 10523:2014	Consort C3010 Multiparameter, Belgium and BOECO MSH 140 Stirrer, Germany
3.	Electrical conductivity	µS/cm	SM SR EN 27888:2005	Consort C3010 Multiparameter, Belgium and BOECO MSH 140 Stirrer, Germany
4.	Mineralization (TDS)	mg/l	SM SR EN 27888:2005	Consort C3010 Multiparameter, Belgium and BOECO MSH 140 Stirrer, Germany
5.	Chloride (Cl^-)	mg/l	SM SR ISO 9297:2012	Automatic burette, class A, 25 ml
6.	Ammonium (NH_4^+)	mg/l	PS-NH4-05, ed. 1/2024	Agilent Cary 60 spectrophotometer, USA
7.	Nitrite (NO_2^-)	mg/l	SM SR EN 26777:2006/C91:2012	Agilent Cary 60 spectrophotometer, USA
8.	Nitrate (NO_3^-)	mg/l	PS-NO3-06, ed. 1/2024	Agilent Cary 60 spectrophotometer, USA
9.	Total hardness	mmol/l	PS-Dt-04, ed. 1/2024	Automatic burette, class A, 25 ml
10.	Sulfates (SO_4^{2-})	mg/l	PS-SO4-02, ed. 1/2021	Agilent Cary 60 spectrophotometer, USA
11.	Fluoride (F)	mg/l	GOST 4386-89	Agilent Cary 60 spectrophotometer, USA
12.	Total iron (Fe_{total})	mg/l	GOST 4011-72	Agilent Cary 60 spectrophotometer, USA
13.	Sodium (Na^+)	mg/l	SM ISO 9964-3:2013	Analytic Jena AAS
14.	Coliform bacteria	UFC/100 ml	SM EN ISO 9308-1:2017	Filtration system, incubator, agar medium
15.	*Escherichia coli*	UFC/100 ml	SM EN ISO 9308-1:2017	Filtration system, incubator, agar medium
16.	Enterococci	UFC/100 ml	SM EN ISO 7899-2:2016	Filter system, incubator, m-Enterococcus Agar medium

The laboratory tests were performed within the accredited laboratory "Laboratorul Investigații de Mediu" S.R.L., which has the status of a legal entity under private law, and is legally responsible for its laboratory activities in accordance with the requirements of the reference document SM EN ISO/IEC 17025:2018.

RESULTS AND DISCUSSION

Groundwater quality assessment is becoming increasingly important as the availability of good quality water becomes a significant challenge for humanity. The quality of life is constantly associated with the quality of the water we consume every day.

Groundwater systems are dynamic and can continuously adapt to short- and long-term changes in climate, groundwater withdrawal, and land use. The balance between charging and discharging aquifers controls groundwater levels. The chemical character of any groundwater influences its quality and use. Thus, quality is a function of physical, chemical and biological parameters and can be subjective as it depends on a particular intended use. (JASROTIA et al., 2018). In addition, it is important to understand the change in quality due to the interaction of water with rocks present in the aquifer or any source of anthropogenic influence.

The investigations carried out in this study show the current situation of groundwater quality, therefore the obtained database contributes to informing the population of the given locality. The laboratory results obtained on the physicochemical and microbiological properties are presented in the table below (Table 2), which were compared with national regulations on drinking water quality.

Table 2. Laboratory results on water quality.

Quality parameter / unit of measurement PLV*	Sampling location / well number											
	1	***2***	***3***	***4***	***5***	***6***	***7***	***8***	***9***	***10***	***11***	***12***
1. Turbidity, NTU **< 5**	0.13	0.13	0.20	0.14	0.14	0.15	0.13	0.14	0.18	0.17	0.14	0.15
2. pH, units pH **6.5 – 9.5**	7.98	7.94	7.99	8.15	8.15	8.15	7.30	7.20	8.06	8.05	7.88	7.90
3. Electrical conductivity, µS/cm **< 2500**	778	752	749	792	737	790	760	783	755	749	713	707
4. TDS, mg/l **< 1500**	468	446	446	470	438	469	456	463	453	446	425	419
5. Cl^-, mg/l **< 250**	25.71	27.45	27.10	25.71	26.75	34.74	28.84	32.49	32.66	31.96	24.32	21.89
6. NH_4^-, mg/l **< 0.5**	3.26	2.36	2.34	2.59	2.59	2.37	2.38	2.35	2.34	2.47	2.53	2.57
7. NO_2^-, mg/l **< 0.5**	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002
8. NO_3^-, mg/l **< 50**	< 0.1	< 0.1	0.18	0.19	0.18	0.10	0.11	< 0.1	< 0.1	0.10	< 0.1	< 0.1
9. SO_4^{2-}, mg/l **< 250**	72.6	71.5	67.8	67.5	67.8	80.8	81.7	80.0	65.8	61.4	61.3	61.3
10. Total hardness, °dH **> 5**	3.7	3.3	3.4	2.0	2.0	1.4	1.9	1.7	2.0	2.1	3.0	3.2
11. F, mg/l **< 1.5**	0.54	0.54	0.53	0.53	0.44	0.44	0.44	0.54	0.55	0.88	0.52	0.51
12. Fe_{total}, mg/l **< 0.2**	0.07	0.07	0.07	0.06	0.06	0.06	0.05	0.05	0.05	0.05	0.05	0.05
13. Na^+, mg/l **< 200**	159.7	159.7	152.3	159.7	159.7	144.8	159.7	159.7	152.3	159.7	152.3	144.8
14. Coliform bact., UFC/100 ml **0**	0	0	0	0	0	0	0	0	0	0	0	0
15. E. Coli, UFC/100 ml **0**	0	0	0	0	0	0	0	0	0	0	0	0
16. Enterococci, UFC/100 ml **0**	0	0	0	0	0	0	0	0	0	0	0	0

* Permissible limit value according to Law 182/2019

Water pH is an important parameter in evaluating the acid-base balance of water (HUNG et al., 2020). pH can be determined by the rock with which the water comes into contact, anthropogenic activities, but also by temperature fluctuations (RACARIU et al., 2018). The pH range of safe drinking water according to Law 182/2019 is 6.5 – 9.5. Groundwater pH values ranging from 7.20 to 8.15 indicate that the conditions of underground aquifers range from neutral to slightly alkaline. In general, the samples studied correspond to the permissible limit values for drinking water. The pH of drinking water does not have immediate direct effects on human health, but it has some indirect effects on health, by modifying other water quality parameters, such as metal solubility and pathogen survival (KIM et al., 2011).

Turbidity in drinking water is due to the presence of particles (impurities) of organic or inorganic nature in the water, particles that are in suspension and do not sediment over time. Turbidity is the result of invisible particles measured in nephelometric turbidity units (NTU). Turbidity in water can be due to a wide variety of suspended materials, which range in size from colloidal to coarse dispersions, depending on the degree of turbulence (PRAKASH & SOMASHEKAR, 2006). The level of turbidity, an important physical contaminant, was within the permissible limit of up to 5 NTU (permissible value). Thus, the turbidity of water from artesian wells was on average 0.15 NTU, the waters are transparent without mechanical particles. Low turbidity in water samples is a positive indicator, which is related to the quality of drinking water.

Mineralization is an important parameter for determining the quality of water used for various purposes. Water has the ability to dissolve a wide range of minerals or inorganic and organic salts, such as potassium, calcium, sodium, bicarbonates, chlorides, magnesium, sulfates, etc. Water with a high TDS value indicates that the water is highly mineralized. The limit for TDS of drinking water for the Republic of Moldova is 1500 mg/l. The TDS values ranged from 419 mg/l to 470 mg/l. Therefore, the waters are not highly mineralized, the determined values are admissible for drinking.

Increasing the ion concentration increases the electrical conductivity of water. In general, the solid materials of dissolved solids in water determines electrical conductivity, which is an important factor in measuring water quality because it provides data on the amount of dissolved salts in the water (LEWOYEHU, 2021). Since water conductivity is correlated with water mineralization, the same picture is confirmed. Thus, the electrical conductivity in the analyzed water samples was within the permissible limits for drinking water, on average 755 µS/cm.

Chloride levels in water sources do not pose any significant risk to users, except for imparting a taste to the water for sources with chloride levels above 300 mg/l (EDOKPAYI et al., 2018). Chloride concentration serves as an indicator of organic pollution (MURHEKAR, 2011). The chloride concentration in all tested samples did not vary significantly from one another. The chloride level was within the permissible limit of 250 mg/l, with an average concentration of 28.3 mg/l.

Of the three forms of nitrogen (ammonium, nitrite and nitrate), exceedances were found for ammonium. While nitrate (NO_3^-) is the most abundant nitrogen-based groundwater pollutant, elevated groundwater ammonium (NH_4^+) similarly deserves attention due to its toxicity to the ecosystem and human health (LIANG et al., 2022). Ammonium is present in groundwater naturally as a result of anaerobic degradation of organic matter and artificially as a result of the disposal of organic waste (BÖHLKE et al., 2006). From the results of laboratory tests conducted on various groundwater sources (PRODAN et al., 2024), high levels of ammonium are frequently detected in the groundwater of the Republic of Moldova. Ammonium values (2.34 – 3.26 mg/l) found in groundwater sources exceed the limit value of 0.5 mg/l. The significant presence of ammonium in groundwater can occur naturally from underground organic areas, but we do not exclude the fact that anthropogenic pollution also contributes to the pollution of aquifers.

Sulfate is an abundant ion in the Earth's crust, and its concentration in water varies depending on the numerous minerals ($BaSO_4$, $MgSO_4$*7H_2O, $CaSO_4$*2H_2O) persisting in the aquifer. Sulfates are anions that are naturally found in almost all types of water (LEWOYEHU, 2021). According to the national standard, sulfates should be 250 mg/l as a threshold level. According to the results obtained, no exceedances were found in the groundwater sources, the average value being 70.0 mg/l. Thus, the aquifer does not contain much gypsum rocks, iron sulfides and other sulfur compounds.

Total hardness is the sum of the mineral salts dissolved in water, calcium (Ca^{2+}) and magnesium (Mg^{2+}), represented in equivalent amounts of calcium carbonate, carbonates, bicarbonates and sulfates. The main natural sources of water hardness are sedimentary rocks, infiltration and runoff from the soil. Water from artesian wells is characterized by low hardness (1.3 – 3.7 °dH), values being lower than the permissible limit of > 5 °dH. Low values of total hardness suggest minimal mineral dissolution from the aquifer geology, characterized by a small amount of carbonate rocks.

The sodium concentration depends greatly on the type of sediments present in the aquifer. The obtained values of sodium in groundwater on average of 150.0 mg/l suggest the presence and degradation of sodium-bearing rocks, compared to the insufficient presence of calcium and magnesium rocks. The results showed that the artesian wells correspond to the permissible limit of 200 mg/l, but there is an imbalance between calcium, magnesium and sodium cations ($Na^+ > Ca^{2+} > Mg^{2+}$). Therefore, sodium is the most abundant member of the alkali metal group of the groundwaters studied, representing a risk to human health.

Groundwater is contaminated with fluoride due to geological factors, namely the weathering of minerals and the decomposition of certain minerals in the ground. The high fluoride content in groundwater causes severe damage to the teeth and bones of the human system, resulting in dental fluorosis and skeletal fluorosis (TOURE et al., 2017). Fluoride is one of the main trace elements in groundwater, generally found as a natural constituent (AGHAZADEH et al., 2017). The fluoride concentration in the researched water sources ranged from 0.44 mg/l to 0.88 mg/l, the permissible limit being 1.5 mg/l.

Variations in the results of iron concentration in groundwater were not observed, the average iron value being 0.05 mg/l. Therefore, iron compounds do not predominate in the aquifer rocks.

Microbial contamination indicators are important water quality parameters, as exposure to microbes in drinking water could involve serious public health problems through waterborne diseases (AKPATAKU et al., 2020). The factors that influence the type and the number of bacteria in water are: temperature, light, organic matter, acidity, salinity, protozoa, precipitation and storage conditions (PRAKASH & SOMASHEKAR, 2006). However, the water sources are not contaminated with bacteria. From a microbiological point of view, the groundwater is clean and does not pose a health risk to the population in the area. The lack of microorganisms in the analyzed samples indicates that the conditions around the artesian wells are hygienic and adequately maintained. Based on the results of the 3 microbiological indicators, the groundwater corresponds to the limit values for drinking water.

CONCLUSION

This study was conducted to assess the quality of groundwater in Cioc-Maidan locality, Comrat district, where groundwater is an important water resource for the inhabitants. According to laboratory results, groundwater sources do not meet the permissible limit values for ammonium and total hardness quality parameters. Also, the dominance of the sodium cation compared to the calcium and magnesium cations also makes the water a risk to human health. Thus, the water from artesian wells does not meet the requirements for drinking water.

The complete picture of the physicochemical and microbiological characteristics of groundwater is presented in this study, which can be used as a basic tool for improving water quality for drinking purposes, namely through treatment. The concentrations of pollutants detected serve as a tool for the appropriate choice of water treatment facilities. By having a clear view of groundwater quality, local public authorities can more effectively plan the exploitation and maintenance of these resources, which constitute a national heritage of great importance. At the same time, preventive actions must be taken on non-point sources of agricultural pollution in the study area.

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