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Anthropogenic influence on the water resource quality in the village of Bălăneşti, Nisporeni district

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Abstract. Water is one of the fundamental elements of life, and, at the same time, the factor that defines social-economic development. That is why the current state of water resources is a pressing and current problem of contemporary society. The evaluation of the anthropogenic impact on some water sources in the village of Bălănești, Nisporeni district, highlighted the real state of the surface and underground waters in this area by determining some physico-chemical quality indices; establishing the correlation of the content of some main ions (Ca^{2+}, Mg^{2+}, Cl^-, SO_4^{2-}, HCO_3^-) with the content of nitrates as well as determining the degree of pollution of the Nârnova River.

Keywords: surface water, groundwater, quality index, pollution index.

Impactul antropic asupra calității unor resurse de apă în satul Bălănești, raionul Nisporeni

Rezumat. Apa este unul dintre elementele fundamentale ale vieţii, şi, în acelaş timp, factorul care definește dezvoltarea social - economică. De aceea starea actuală a resurselor de apă este o problemă stringentă și actuală a societății contemporane. Evaluarea impactului antropic asupra unor surse de apă din satul Bălănești, raionul Nisporeni, au scos în evidență starea reală a apelor de suprafață și subterane din această zonă prin determinarea unor indici fizico-chimici de calitate; stabilirea corelației conținutului unor ioni principali (Ca^{2+}, Mg^{2+}, Cl^-, SO_4^{2-}, HCO_3^-) cu conținutul nitraților precum și determinarea gradului de poluare a râului Nârnova.

Cuvinte-cheie: ape de suprafață, ape subterane, indice de calitate, indice de poluare.

1. Introduction

Water represents the most important element in the natural environment, without which life on earth is inadmissible, and at the same time, a natural resource that defines the socio-economic development factor. The demand for water has grown enormously, with the rapid increase of the population on Earth, because of the progress in social-economic activities, with the acceleration in the urbanization process and with the increase in comfort of the modern life.

Republic of Moldova depends a lot on surface water, especially on water captured from the Nistru River. This makes Moldova's water resource balance highly dependent on the external water flow. Annually, Moldova uses approximately 800 million m^3 of water, of which 85% is obtained from surface water resources. The Republic is sourced by two main sources of water: the Nistru River, which provides almost 90% of water consumption from surface waters, and also the Prut River [1].

The drinking water supply of localities in rural areas is ensured from three important sources: underground water, which accounts for 65% of the total volume of consumed water, surface water - 34.8% of the volume of consumed water, reservoirs and springs - 0.2% [2].

The quality of drinking water is a current topic of major importance, in the assessment of the anthropogenic impact on the health of the population [3]. The attention given to this theme is directly proportional to the degree of influence of the various factors, that define drinking water and the assessment of the health status of the population and the environment in general. Ensuring the population with drinking water in quantity and quality, is one of the priority tasks of the state, in order to improve the health indicators and the well-being of the population of the Republic of Moldova.

The aim of this study is to evaluate the ecological state of some underground and surface water sources in Bălănești, by determining the quality and physico-chemical parameters, the correlation between the content of the cations and nitrate anions, the determination of the surface water pollution index and the coefficient of irrigation. It is the first important study carried out in this area.

2. Materials and Methods

The water quality index is a tool for transmitting information to the public, water users, scientific researchers, managers, engineers, etc. about water quality. In the assessment of the surface water quality index (ICAcc, %), which is applied to assess water quality according to the requirements specified in Government Decision no. 890 of 12.11.2013 [4], the national standard SM 354: 2021 [5] was used.

The surface water quality index includes a 100% scale based on quality classes (I-V) according to the concentration of substances specified in the Regulation on environmental quality requirements for surface waters [6].

Different physico-chemical methods were used to estimate the degree of water pollution and perform the analysis of the collected samples:

- The quantitative titrimetric method is used to determine carbonic and total alkalinity (neutralization); carbonic and total (complexonometric) hardness; calcium (complexonometric); chemical oxygen demand (redox), content of Cl- ions (exchange).

- The gravimetric method is applied to determine the fixed residue (mineralization). The spectrophotometric method is used to determine nitrites NO_2^-, nitrates NO_3^-, sulfates SO_4^{2-}, Na^+, K^+ ions. The instrumental method applied to the determination of the pH value.

Table 1. List of collected samples

1.- Well nr.I, the right bank of river Nârnova	6.- Well III,the left bank of river Nârnova
2. – Well II, the right bank of river Nârnova	7. - Rriver Nârnova; upstream
3.- Well III, the right bank of river Nârnova	8. - River Nârnova; centre of village
4.- Well I, the left bank of river Nârnova	9. - River Nârnova; downstream
5.- Well II, the left bank of river Nârnova	

3. Results and Discussion

The analysis of the water collected from different sources, to determine the quality indices (hardness, mineralization, pH) and the physico-chemical indices of the main ions in the composition of the waters, was carried out in two stages, between the years 2020-2021 and the years 2022-2023. The list of collected samples are indicated in Table 1.

Characteristic of the physico-chemical quality parameters of natural waters.

Table 2. Average values of physico-chemical parameters of groundwater and surface water in the study area during 2023

Sample nr.	$Na^+ + K^+$ mg/L	Ca^{2+} mg/L	Mg^{2+} mg/L	NH_4^+ mg/L	NO_2^- mg/L	Cl^- mg/L	SO_4^{2-} mg/L	NO_3^- mg/L	HCO_3^- mg/L
1.	41,3	97,5	74,2	0	0	50,9	143,32	25,5	477,1
2.	326,5	281,9	132,5	0	0	199,8	1101	338,4	521,3
3.	176	241,8	92,5	0	0	150,2	598,2	99,1	538,7
4.	42,5	125,3	85,3	0	0	50,9	85	28,4	501,7
5.	79	107,6	56,9	0	0	72,3	163	121,3	571
6.	37	119,5	57,6	0	0	50,9	87	23,4	526
7.	90,5	109,64	65,5	0	0	86,4	139	146,1	521
8.	171	125,54	70,9	0	1,37	128,92	405	73,3	525
9.	377	200,5	139,5	2,87	1,4	178,6	841	2,5	661

The results obtained are indicated in Tables 2 and 3.

Table 3. Average values of groundwater and surface water quality indices in the studied area during 2023

Sample nr.	pH	General hardness		Mineralization
		me/dm^3	°dH	mg/dm^3
1.	8,06	10,8	30,28	664
2.	7,13	25,03	70,1	2672
3.	7,01	19,64	56,08	1642
4.	7,27	13,21	37,01	623
5.	7,29	10	28	939
6 .	7,58	10,61	29,72	617

The comparative study of groundwater.

Nitrate ion concentration values during the years 2021-2023 did not vary significantly, which indicates that the pollution is of an anthropogenic nature (Figure 1).

According to the data of the analyzes carried out, it was found that in three wells the concentration of nitrates exceeds the maximum permissible concentration by 2-9 times (CMA of NO_3^- ions 50 mg/dm^3).

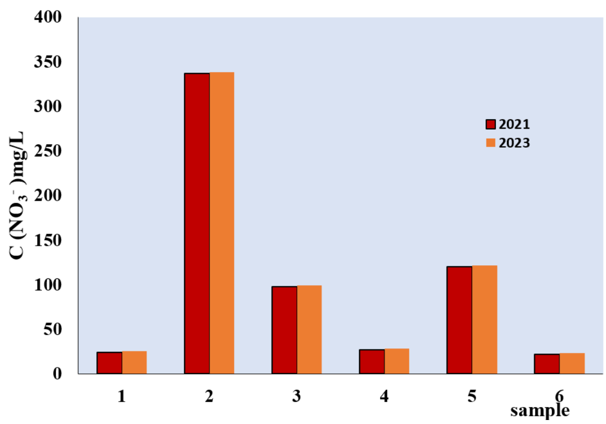

Figure 1. Variation of the concentration of nitrate ions in the analyzed water samples, collected from 6 wells in the years 2021-2023.

During the year 2021, the values of mineralization in the waters of the wells varied within the limits of 626-2680 mg/dm^3. Water from wells number 2 and 3 has increased mineralization, exceeding the CMA for drinking water. It is obvious that the dynamics of mineralization and the main ions depend on natural factors, but the variation of the ratio between ions can also be influenced by the human factor. The value of mineralization is determined by the content of the main cations (Ca^{2+} with a range of 94-280 mg/dm^3; Mg^{2+}46 -170 mg/dm^3) and anions (Cl^- 49-200 mg/dm^3, SO_4^{2-} 86-556 mg/dm^3, HCO_3^- 475-573 mg/dm^3). The water of the Nârnova river is of hydrogen carbonate type, Ca group.

There is a balanced dependence between mineralization values and main ions (Figures 2 and 3).

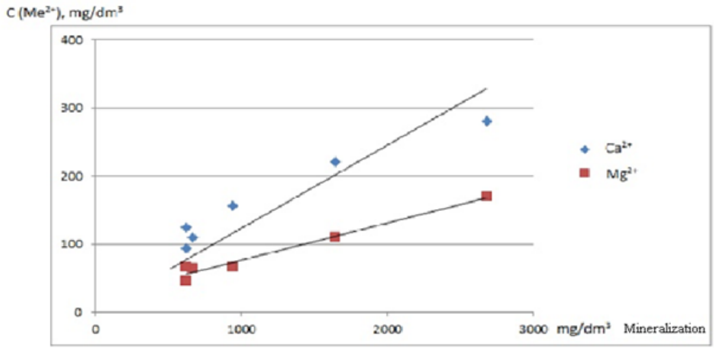

Figure 2. Dependence of the content of Ca^{2+} and Mg^{2+} cations on the mineralization values of the investigated waters.

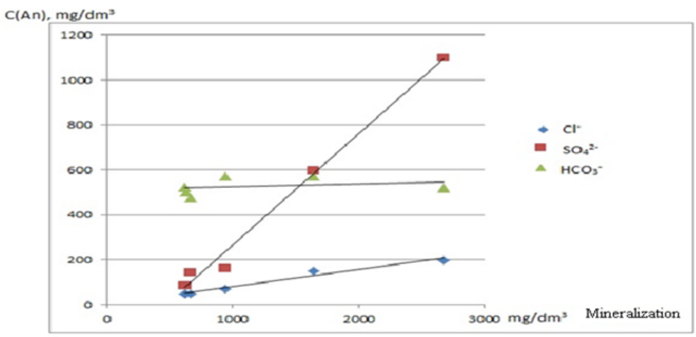

Figure 3. Dependence of the content of HCO_3^-, SO_4^{2-}, Cl^- anions on the mineralization values of the analyzed waters.

The waters from wells 1,4,5,6 under study from the territory of Bălănești, according to the regulations in force, correspond to class II which is of good quality (Tables 2 and 3).

Chemical oxygen demand COD in the waters of the Nârnova river

The chemical oxygen demand (COD) value is widely used in aquatic ecosystem investigations. The given quantity indirectly characterizes the content of organic and mineral substances in water, oxidized by one of the strong oxidants such as $KMnO_4$ or $K_2Cr_2O_7$, under certain conditions. COD can be expressed by the amount of oxygen required for the oxidation of organic substances in a certain volume of water. Average values of COD-Mn during the study period (May and July 2021-2023) ranged from 8,65 mg O_2/dm^3 to 24,4 mg O_2/dm^3 (Figure 4).

Depending on the season and the water sampling points, the COD-Mn values vary significantly, indicating that the most polluted waters with organic substances are those discharged from the territory of the town (downstream) and reach the maximum value of 24 mgO_2/dm^3 and less polluted are the waters upstream of the locality (8,65-15,7 mgO_2/dm^3). The direct influence of the human factor on water pollution is obvious. Taking into account the COD-Mn value and according to the Regulation on the quality requirements for surface waters [7], the upstream water quality corresponds to the III[a] quality class (moderately polluted); and the downstream water - quality class IV (polluted).

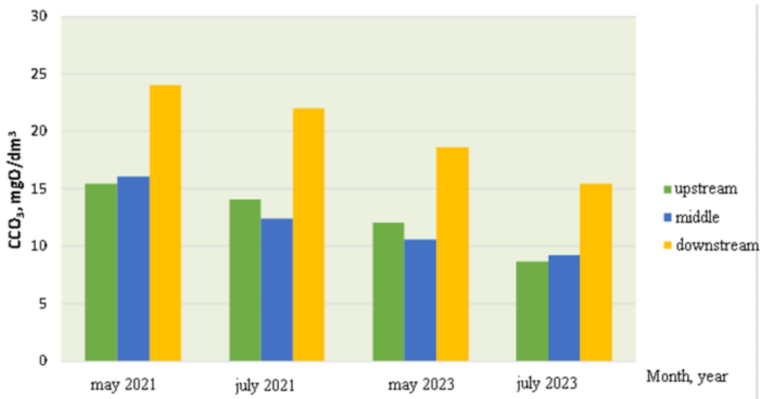

Figure 4. COD-Mn values in the waters of the Nârnova river during the years 2021 and 2023.

Water pollution index in the Nârnova river.

The Pollution Index was used to assess the ecological state of the water in Nârnova, which was determined using the 5 classes of surface water quality (IPAcc) in accordance with the National Normative. The IPAcc assessment frames the selection of the set of water quality parameters. The calculation was made based on the following parameters: pH, mineralization, hardness, COD-Mn, co-concentration of Ca^{2+}, Mg^{2+}, Cl^-, SO_4^{2-}, HCO_3^-, NO_3^- ions. The intermediate values of the quality level (VNC, %) between quality classes of the water for a specific amount of physico-chemical parameters were calculated according to [8].

The evaluation of water quality is recommended after the stoppage (IPAcc, %) according to [8]. The values of the pollution index (IPAcc), ecological status and quality level of the investigated waters are presented in Table 4.

Table 4. The water pollution index of Nârnova river, year 2021.

Methods of analysing the samples	IPAcc, %	Quality level	Environmental status
In upstream	60,5	III	Moderately polluted
Middle	40,2	IV	Polluted
In downstream	37,9	IV	Polluted

Recent data indicate that the flowing waters of this stream, which traverses the village downstream, are polluted by the unauthorized waste from the population in this area.

Determination of water irrigation coefficients in Bălănești village, Nisporeni district.

A series of irrigation indices, calculated based on the chemical parameters of the water, were used to evaluate the quality of the irrigation water.

SAR index – Sodium absorption capacity, [SAR].

The SAR index is used to estimate the water quality for irrigation purposes. The determination of the coefficient is carried out according to the ratios between the milliequivalents of Na^+, Ca^{2+} and Mg^{2+}.

$$SAR = \frac{rNa^+}{\sqrt{\frac{rCa^{2+}\,rMg^{2+}}{2}}}$$

In general, the higher the SAR, the less suitable the water is for irrigation. The water with a high SAR value, before use, will require the use of specialized soil additives in order to avoid the long-term effect of sodium on soil quality.

If irrigation water has a high SAR and is used over many years, sodium can replace calcium and magnesium in the soil. Sodium is an element that disperses the soil and leads to the loss of its structure. It will also increase soil compaction, a fact that will have a negative effect on plant growth and expenses for mechanized works.

According to the value of the SAR coefficient, the waters used in irrigation can be classified as:

- if SAR<10 – excellent;
- if SAR 10-18 – good;

- if SAR 18-26 – satisfactory;
- if SAR >26 – unsatisfactory [9].

The calculated data regarding the SAR index values is indicated in Table 5.

Stebler coefficient or Irrigation coefficient [Ka] [10].

This coefficient is used to evaluate the probability of a secondary salinization of the soil, triggered by the poor quality of the water used for irrigation. The Stebler method involves the calculation of alkaline characteristics in the form of irrigation coefficients, K (in me/L):

$$K1 = \frac{288}{5\,\mathrm{rCl}^-}, \quad \text{at } \mathrm{rNa}^+ < \mathrm{rCl}^-$$

$$K2 = \frac{288}{\mathrm{rNa}^+ + 4\,\mathrm{rCl}^-}, \quad \text{at } \mathrm{rCl}^- + \mathrm{SO}_4^{2+} > \mathrm{rNa}^+ > \mathrm{rCl}^-$$

$$K3 = \frac{288}{\mathrm{rNa}^+ + 5\,\mathrm{rCl}^- + 9\,\mathrm{rSO}_4^{2-}}, \quad \text{at } \mathrm{rNa}^+ > \mathrm{rCl}^- + \mathrm{SO}_4^{2-}$$

Stebler:

- K>18 – good;
- K 18-6 – satisfactory;
- K 6-1,2 – unsatisfactory;
- K <1.2 – bad [10].

The calculated data regarding the values of the STEBLER index are indicated in Table 5.

Magnesium Adsorption Ratio (MAR).

The magnesium content of water is considered one of the most important qualitative criteria in determining the quality of irrigated water. The magnesium content is calculated by the following formula: MAR = [Mg^{2+} / (Mg^{2+}+ Ca^{2+})] /100 (Concentrations are in meq/l). Water is suitable for irrigation at MAR <50% and unsuitable at MAR>50%, as it will damage the soil [11].

The irrigation coefficients calculated for the taken water samples are presented in Table 5.

According to the SAR coefficient, all the waters analyzed are good for irrigation, and according to the Stebler coefficient, 56% correspond to the ”good” qualification, and 44% - to the ”satisfactory” qualification, according to the MAR qualification, 33% of the waters sampled cannot be used for irrigation, because they can damage the quality of the soil.

Table 5. Quality of surface water according to irrigation coefficients.

Nr	SAR	Rating	Stebler	Rating	MAR	Rating
1	0,76	Excellent	39,2	Good	56	Not satisfactory
2	3,75	Excellent	7,9	Satisf.	50	Good
3	2,4	Excellent	11,8	Satisf.	40	Good
4	0,9	Excellent	38,97	Good	38	Good
5	1,32	Excellent	25,3	Good	41	Good
6	0,7	Excellent	40	Good	51	Good
7	1,6	Excellent	21,4	Good	48	Good
8	2,76	Excellent	13,2	Satisfactory	57	Not satisfactory
9	5,6	Excellent	7,9	Satisfactory	72	Not satisfactory

4. Conclusions

The water from 50% of the wells under study cannot be used for human consumption, they are classified as polluted water, because the concentration of nitrates exceeds the permissible norm of 2-9 CMA.

Consequently, according to the chemical parameters (hardness, sulfates, nitrates, pollution index), the waters of the Nârnova river correspond to quality class III - IV.

As a result of the research conducted according to the SAR coefficient, all analyzed waters are good for irrigation, and according to the Stebler coefficient, 56% correspond to the "good" qualification, and 44% - to the "satisfactory" qualification, and only according to the MAR qualification, 33% of the sampled waters cannot be used for irrigation, because they can damage the quality of the soil.

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