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EVALUATION OF THE CHEMICAL QUALITY OF ARTIFICIAL LAKES MOFTIN, ADRIAN, VÂRȘOLȚ AND CĂLINEȘTI OAȘ (IN NORTH-WEST ROMANIA)

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Abstract: The research carried out on artificial lakes Vârșolț, Moftin, Adrian and Călinești Oaș, located in North-West Romania targeted the water chemical analysis. Based on the achieved results we can estimate the possibility for these lakes to provide resources in order to support stable bird population starting from the premises that the ecosystems in balanced are characterized by high diversity, quantitatively and qualitatively stable. From the list of water physical-chemical indicators, we stopped only to those which are at the grounds of the analysis of the lakes natural resources, thus being able to appreciate the nutritional potential. It resulted after this analysis that the analysed lakes, even having an aspect close to natural with vegetation borders on significant areas, do not ensure quality and diversified chemical natural resource for the bird population due to the chemical quality of the water which is a modest one. The natural resource of these lakes may lead to bio-accumulation of toxic substances in various species of these artificial ecosystems, which this research proved.

Keywords: quality of the water, biodiversity, natural resources

INTRODUCTION

The evaluation of the water chemical quality for the four investigated artificial lakes was carried out as the doctoral research of the author Duță, her thesis having as one objective to identify the influences on the bird population caused by the chemical estate of these artificial aquatic ecosystems. In addition, we wanted to compare the data we achieved with public data on the chemical status of the water for these artificial aquatic ecosystems so we could have a real (current) image on them.

We selected from the list of physical-chemical indicators of the water only those which are at the grounds for the evaluation of the natural resources of the lakes (and which influence the structure of the bird population). These allow to appreciate the nutritive potential of the water and to ensure the development of the plankton biomass. Concretely, we analysed the regime of the oxygen and contents in nutriments, expressed by the concentration of N and P. In addition, we also made some pH determinations to see some deviations from normality. The results were interpreted according to the Disposition 161/2006 on the elements and standards of chemical and physical-chemical quality of the water in order to establish the ecological status of the groundwater.

The water samples were taken from the lakes under study, during each season, in years 2015 and 2016 (April 15-16, 2015, August 10-11, 2015, November 21-22, 2015, February 9-10, 2016), and were processed in the Laboratory of Chemistry of the "Vasile Goldiș" Western University of Arad, Satu Mare Branch.

Based on these measurements, I wanted to have an image of the possibility for these ecosystems orientation towards and ecologically stable status. Considering the current image of the analysed lakes, the image is likely to the natural aquatic ecosystems. The study of the bird population on these artificial lakes relies also on the chemical quality of the water in order to confirm the ornithological research.

MATERIALS AND METHODS

Study Area

The lakes under study are artificial water basins in the North-West of Romania, belonging to the Someș-Tisa basin. Lakes Moftin, Adrian and Călinești Oaș are in the County of Satu Mare, and Lake Vârșolț in Sălaj County. Lakes Călinești and Adrian are supplied with water from the River Tur, and Vârșolț and Moftin from River Crasna. All four lakes have a common destination, pisciculture. Lakes Călinești and Vârșolț are also sources for drinking water. The only lake which has as secondary destination the hydropower plant dam is Lake Călinești.

Table 1.

General Characterisation of the Lakes (own source)

Indicator	Lakes:				
	Călinești	**Adrian**	**Motiș**	**Vârșolț**	**Moftin**
1. Lake destination					
- Source for drinkable water	+			+	
- Micro- hydropower plant	+				
- Pisciculture	+	+	+	+	+
- Abandoned			Partially		

Correspondence:

Indicator	Lakes:				
	Călinești	**Adrian**	**Motiș**	**Vârșolț**	**Moftin**
2. Way of organisation of the lakes					
- singular	+			+	
- complex of lakes		+	+		+
3. Lakes geographical location:					
- on Tur river	+	+			
- on Someș river					
- on the Sălaj Valley			+		
- on Crasna river				+	+
4. Water supply for the lakes					
- from the rivers, as dam lake	+			+	
- side basins on the rivers		+	+		+
- former gravel pits					
- not functional branches					
5. Water depth in the lakes					
- low (< 3 m)		+	+		+
- median (3-5 m)					
- high (> 5 m)	+			+	
6. Quality of the lake water – considering its drinkability					
- very good	+			+	
- good		+			
- satisfactory			+		+
7. Fluctuations of the water level in the lake:					
- constant					
- summer decrease (drought)	+	+		+	+
- drainage of the lake water			+		
8. The degree of clogging of the lake					
- not clogged		+			
- partially clogged	+			+	+
- clogged			+		
9. Vegetation weight					
- weak		+			
- average	+			+	+
- consistent			+		
10. Degree of eutrophication					
- without eutrophication	+	+			
- partial eutrophication				+	+
- total eutrophication			+		
11. Natural resources of the lakes					
- forest / shrubs	+		+	+	+
- reed, rush, variegated horsetail, sedge	+		+	+	+
- drinkable water	+			+	
- fish	+	+	+	+	+
- aquatic birds	+	+	+	+	+
- common ground birds	+	+	+	+	+
- amphibians (frogs)			+		+
- reptiles (turtle)			+		
- aquatic mammals (otter, beaver, muskrat)	+		+	+	
12. Ornithological facilities provided by lakes					
- nesting places for birds	+		+	+	+
- food for ichthyophagous birds	+	+	+	+	+
- food for phytophagous birds	+		+	+	+
- stopping place in migration				+	+
13. Location related to the migration routes					
- main migration route					+
- small distance from the main migration route	+	+			
- large distance from the main migration route			+		+

Methodologies used in the research

a) *Hydrological and hydro-biological methodologies for the investigation on the types of the lakes of accumulation*: Ujvari, 1972, Papadopol, 1978, general sheet on the lake issued by us (based on the elements taken from various literature sources).

b) *Methodology on the analysis of the general quality of the lakes water*: Roșu and Domșa, 2014, Framework Directive Water 2000/60/EC; Directive

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on environmental quality standards in the field of water policy 2008/105/EC; Minister's Disposition 1146/2002 on the approval of the Normative on the referential objective for the classification of the groundwaters; SR - ISO and EN, and standard regulations for establishing some physical, chemical and biological indicator for the quality of the water; Gomoiu et al., 2009.

c) *Methodology on the study of the anthropic impact on the water and ichthyofauna me*: Ardelean, 2013; Munteanu, 1982; Munteanu and Mătieș, 1983.

Selected Methods for carrying out the research

Table 2.

A. WATER SAMPLES	
1. Establishing the sampling points for the water samples and the rhythmicity of the procedure	- SR ISO 5667:2004. Water quality. Sampling. Guidelines for preservation and handling of the water samples
B. PHYSICAL INDICATORS OF THE WATER	
2. Establishing the water temperature (°C)	- Measuring the water temperature with special thermometers in a liquid environment
C. CHEMICAL INDICATORS	
3. Establishing the concentration of Hydrogen ions (pH)	- SR ISO 10532-1997. Establishing the pH concentration
4. Establishing the biochemical consume of oxygen at 5 days (CBO_5)	- SR EN 1899 – 1:2000. Quality of the water. Establishing the biochemical consume of oxygen after *n* days (CBO*n*). Part I. Method by dilution and sowing with the contribution of allylthiourea
5. Establishing the chemical consume of oxygen (CCO_{Cr}) (mgO_2/l)	- STAS 6954-82. Establishing the chemical consume of oxygen. The method with potassium dichromate (CCO-Cr)
6. Determination of the dry filterable residue at 105°C	- STAS 9187:84. The gravimetric method of determination
7. Determination of the suspended matter content	- SR EN 872:2005. Method of filtering by glass fibre filters
8. Determination of ammonium contents (mg NH_4^+/l)	- SR ISO 7150-1:2001. Quality of the water. Determination of the ammonium contents. Part I. Manual spectrometric method
9. Determination of total nitrogen (mg/l)	- SR EN 12260:2004. Spectrometric method - Chemiluminescence - method for determining total nitrogen
10. Determination of nitrates (mg NO_3/l)	- SR EN 7890-3:2000. Spectrometric method of determining the nitrates
11. Determination of nitrites (mg NO_2/l)	- SR EN 26777:2002. Spectrometric method of determining the nitrites
12. Determination of phosphorus	- SR EN 6878:2005. Spectrometric method of determining the phosphorus
13. Interpretation of the obtained results	- According to the regulations specified in the utilised determination methods

RESULTS AND DISCUSSIONS

The active reaction of water (pH)

When ranging between normal margins for life (6.50 – 8.50), the water provides good conditions, including for fish. When pH records values beyond the normal margins, perturbations of the biological processes in the water or the accumulation of toxic intermediates based on nitrogen and phosphorus (*Ardelean*, 2013).

Analysing the pH values, it results that lakes Călinești, Adrian, Moftin and Vârșolț water active reaction is performed, generally, within the normal margins (6.50 – 8.50), ranging in the category of neutral waters, and mostly among the low alkaline type, due to the discharge of domestic water or animal waste. The summer season (August 2015) showed some deviations from the normal values for Lake Călinești, so, during summer 2015, an increase in the alkalinity was recorded (pH – 9.42) in the area where domestic water and animal waste enter the lake water, and also an increase in the acidity (pH – 5.97) in the area where the river Tur water flows in the lake carrying partially purified industrial water from the Cleaning Station of Negrești Oaș.

Consequently, considering the pH, the lake's water researched by us are, with few exceptions, good for their flora and fauna, including for fish and birds populations.

The biochemical requirement for oxygen (CBO_5)

It represents the quantity of oxygen consumed by bacteria and microorganisms in a certain timeframe for the biochemical decomposition of the biodegradable substances contained by the water.

CBO_5 is a chemical indicator varying depending on the conditions provided by the lake and the season, as it can also be seen in table 7.

Table 3.

Minimum and Maximum CBO_5 Values in the Artificial Accumulation Lakes Water Studied during 2015 - 2016

Lake	Minimum CBO_5 (mg O_2/l)	Maximum CBO_5 (mg O_2/l)	Dominant Quality Rank	CBO_5 Increases/ Decreases by seasons (Ranks)
1. Călinești Oaș	4.03	15.84	IV	February 2016 – rank II
2. Adrian	7.37	35.05	IV	August 2015 – rank V
3. Moftin	13.37	121.00	V, IV	-
4. Vârșolț	4.05	12.88	IV	February 2016 – rank II

All studied lakes have high levels of CBO_5, Călinești, Adrian and Vârșolț have rank IV quality of the water for this indicator, and Lake Moftin has quality rank V. Moreover, CBO_5 has lower levels during winter (February 2016).

Consequently, all lakes studied by us have water of law quality (ranks IV and V) for this indicator, meaning that there are unsatisfactory quantities of dissolved oxygen in the water causing severe issues to the aerobic bodies, especially to oxyphile fish (*Ardelean*, 2013). This is why, when temperatures are higher than 30 - 35°C, during summertime, dead fish appear at the surface of the studied lakes, suffocated by the lack of oxygen, due to the decrease of the dissolved oxygen concentration at the lake bottom (below 4 mg/l).

The chemical consume of oxygen (CCO-Cr)

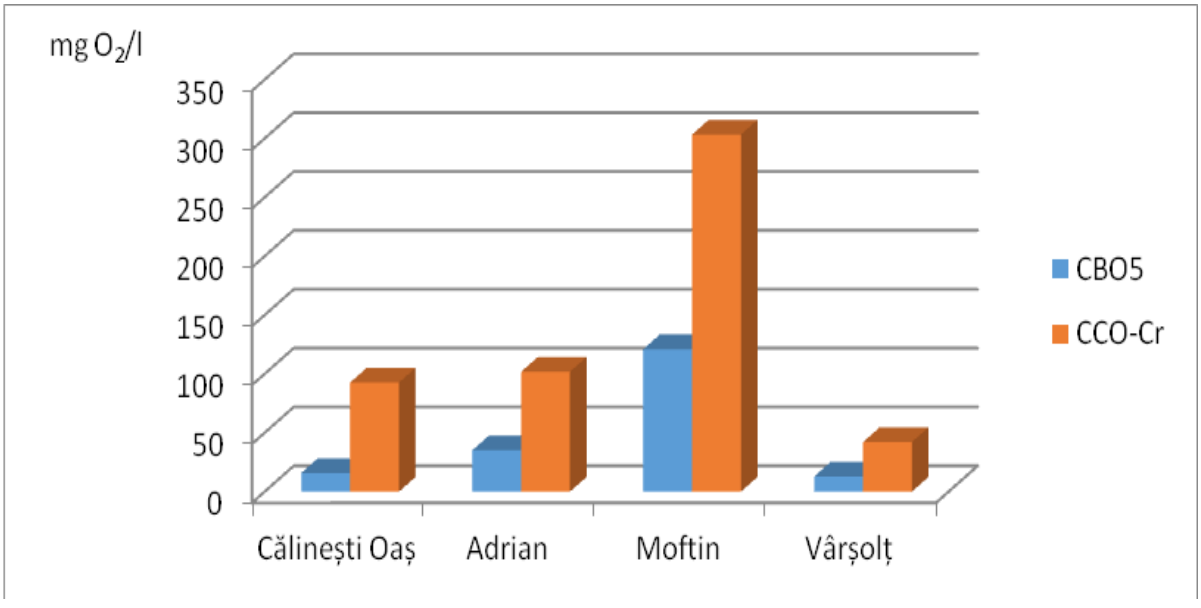
It is the quantity of oxygen required for the oxidation of the organic substances without involving bacteria. The values of this indicator in the studied lake's water are presented in table 4.

Table 4.

The Minimum and Maximum Values for CCO-Cr and the Dominant Quality Ranks in the Water of the Artificial Accumulated Lakes, Studied during 2015 - 2016

Lake	Minimum CCO-Cr (mg O_2/l)	Maximum CCO-Cr (mg O_2/l)	Dominant quality rank for the lake water	Comments
1. Călinești Oaș	11.52	42.27	II, III	In February 2016 – it decreases to rank II of stage
2. Adrian	21.12	101.80	III	-
3. Moftin	38.40	303.36	V	In February 2016 – it decreases to rank III of quality
4. Vârșolț	11.70	42.10	II, III	-

The CCO-Cr absolute values are higher than those for CBO_5, and the ranks for water quality have wider equivalence ranges.



Graph 1. Maximum values for CBO_5 and CCO-Cr in the Studied Artificial Accumulated Lakes Water during 2015 - 2016

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For this indicator, the waters in the lakes Călinești Oaș and Vârșolț are closer to clean natural waters, being ranked II as quality, needing small additional oxygen quantities for the oxidation of the organic substances in the water. The water in the lake Adrian is rank III as quality, and Lake Moftin in rank V of quality, as its water has a high deficit of oxygen dissolved in the water. The CCO-Cr values for the lake Moftin water show that a lot of organic substances were discharged in it, substances which have to be mineralised and come from uncontrolled discharge of the domestic water from the households in the localities without cleaning stations or with cleaning stations with outdated capacities or with malfunctions (there are risks of bioaccumulation due to the functioning of the detritophages mechanisms).

The two analysed indicators of the oxygen consume are complementary, disputing over the same lake water resources, and their high values show a vicious oxygen regime. The ratio between the two indicators of the oxygen consume at the level of their maximum values is presented in graph 1. It results from this graph that both indicators are directly correlated, but CCO-Cr records higher values.

The regime of the oxygen in the water is important also for the nutrients oxidation by which the (N and P) biogenic substances are generated there. Their lack in the water inhibits firstly the plant's growth and development. Without biogenic substances in the water, the structure of the proteins and nucleic acids could not be achieved, and no chlorophyll would be formed. N and P are the main nutritive elements for the plants.

The excess of not decomposed nutrients endanger both human and most animals' lives. In addition, the nutrients regime, their concentrations are the most important indices for the eutrophication processes, especially the total nitrogen and phosphorus.

Nitrogen compounds

They have been studied as the nitrogen is the most representative chemical element in the used waters. There were analysed: ammonium, total nitrogen, nitrates and nitrites, the presence of which in the water influences the quality of the water considering its drinkability, its usefulness for the living beings. The accumulation of nitrates and nitrites in the water above the admitted quota increases the water toxicity, affecting the fish population, by their accumulation. Consequently, the maximum admitted level of nitrates in the water is of 10mg/l. Their presence in the water above this level is dangerous causing serious damages and sickness in animals. The situation of these indicators in the water of the studied lakes is presented in table 5.

The ammonium is within normal ranges in the water of the lakes Adrian and Vârșolț. Therefore, their water is in the 1st rank of quality for this indicator. The water in the Lake Moftin – which takes large quantities of organic substances from around it – belongs to the last quality rank for this indicator (rank V).

A relatively good situation is for the water of the studied lakes for the indicator of total nitrogen. Their water is ranged in the rank II of average quality.

The nitrates are found in the water of the studied lakes in concentrations ranging from 1.26 to 9.22 mg/l, which mean that the water of the lakes which are water supply for the population (Călinești and Vârșolț) are in the ranges for drinkability. The water of the lakes Moftin, Vârșolț and Călinești are for this indicator in the III and IV classes of average quality, which shows that there is discharge of some agricultural fertilizers and animal waste from the neighbouring areas in the studied lakes. Only the Lake Adrian water was less affected by the agricultural fertilizers so its water is of better quality according to the nitrates indicator (class II of quality).

However, the nitrates have the capacity to turn into nitrites, products with extremely high toxicity (above 30 times higher than the nitrates).

Table 5.

Values of the Nitrogen and its Compounds, and of the Phosphorus in the Water of the Studied Accumulation Artificial Lakes, during 2015 - 2016

Lake	Sampling date (dd/mm/yyyy)	Values of the indicators and their ranging in the quality class									
		Ammonium		N total		Nitrates (NO_3)		Nitrites (NO_2)		Phosphorus	
		mg NH_4^+/l	Quality rank	mg/l	Quality rank	mg/l	Quality rank	mg/l	Quality rank	mg/l	Quality rank
1. Călinești Oaș	15.04.2015	0.315 0.022 0.040	I I I	1.021 2.015 1.893	I II II	2.03 4.56 3.43	I III III	0.612 0.602 0.495	V V V	- - -	- - -
	10.08.2015	0.066 0.038 0.034	I I I	2.06 1.97 1.73	II II II	2.10 5.03 3.08	II III III	0.614 0.424 0.583	V V V	0.238 0.211 0.216	II II II
	25.11.2015	0.275 0.260 0.335	I I I	1.50 2.13 1.92	I II II	5.49 8.06 7.08	III IV IV	0.181 0.128 0.118	IV IV IV	0.161 0.148 0.154	II I II

Lake	Sampling date (dd/mm/yyyy)	Values of the indicators and their ranging in the quality class									
		Ammonium		N total		Nitrates (NO_3)		Nitrites (NO_2)		Phosphorus	
		mg NH_4^+/l	Quality rank	mg/l	Quality rank	mg/l	Quality rank	mg/l	Quality rank	mg/l	Quality rank
	09.02.2016	0.316 0.082 0.001	I I I	1.23 1.91 1.42	I II I	4.93 3.97 6.11	III III IV	0.288 0.032 0.111	IV IV IV	0.073 0.004 0.065	I I I
2. Adrian	15.04.2015	0.060 0.067	I I	1.216 1.925	I II	2.02 2.89	II II	0.495 0.522	V V	- -	- -
	10.08.2015	0.513 0.679	II II	3.26 3.97	II II	3.03 3.24	III IV	0.71 0.912	V V	0.229 0.317	I II
	25.11.2015	0.481 0.385	II I	1.04 0.80	I I	1.53 1.82	I II	0.21 0.306	IV V	0.143 0.124	I I
	09.02.2016	0.001 0.001	I I	0.32 0.62	I II	1.26 2.17	II II	0.414 0.189	V IV	0.076 0.085	I I
3. Moftin	15.04.2015	3.412 1.285	V IV	5.89 2.41	II II	8.12 4.27	IV III	1.140 0.913	V V	- -	- -
	10.08.2015	0.21	I	1.61	II	1.512	II	0.442	V	0.391	II
	25.11.2015	11.1 10.7	V V	9.40 8.74	III II	2.96 1.49	II II	0.386 0.298	V IV	0.213	II
	09.02.2016	4.64 5.04	V V	5.03 5.22	II II	5.40 5.48	III III	0.268 0.213 0.741	IV IV V	0.059 0.147	I I
4. Vârșolț	15.04.2015	0.038 0.413	I II	2.11 3.91	II II	2.95 3.26	II III	0.835	V	-	-
	10.08.2015	0.016 0.084	I I	1.91 2.14	II II	3.62 4.09	III III	0.518 0.483	V V	0.284 0.125	II I
	25.11.2015	0.358 0.412	I II	2.21 2.04	II II	7.85 8.21	IV IV	0.870 0.744	V V	- 0.128	- I
	09.02.2016	0.065 0.041	I I	1.42 1.24	I I	4.21 3.73	III III	0.301 0.269	V IV	0.047 0.040	I I

The nitrites record values between 0.032 and 0.948 mg/l in the water of the studied lakes but, due to their particular toxicity, these waters belong to IV and V quality ranks. These concentrations show that all studied lakes concentrate high quantities of organic substances discharged by the rivers supplying the lakes and that the aquatic life forms are affected by high toxicity due to this concentration.

Total mineral phosphorus

It is indispensable for life, being the carrier to the plants of the energy taken from the sun. It is also a major nutrient, triggering the eutrophication (blossoming) of the waters. However, the high concentration of total P is toxic and easy to accumulate for the animals, being dangerous even if it is below 1 mg/l.

For the studied lakes, the concentration of total phosphorus records low values ranging from 0.004 to 0.419 mg/l. These values range the water of the respective lakes in the category of the mesotrophic waters, respectively in rank I of quality for this indicator. Only, during summer the water of the lakes Călinești Oaș and Moftin is ranged in the rank II of quality due to the discharge of some agricultural fertilizers, domestic waters and dejection products.

PARTIAL CONCLUSIONS

After consulting the data from S.H. Someș-Tisa and A.B.A. Satu Mare (Someș-Tisa) for 2015 on the chemical quality of the water, it is stated that it is good for the rivers and moderate for lakes, as it also results from table 6. An important note is required, namely that, among the lakes monitored by these institutions,

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only two can be found in my research, i.e. the lakes Călinești Oaș and Vârșolț.

Table 6.

Ecological and Chemical Status of the Water in 2015 (according to S.H. Someş -Tisa)

Status of the water	Rivers		Natural Lakes		Accumulation Lakes	
	No. of water bodies	Ratio (%)	No. of water bodies	Ratio (%)	No. of water bodies	Ratio (%)
I. Ecological:						
-Very good	-	-	-	-	-	-
- Good	35	60.30	-	-	4	40.00
- Moderate	21	36.20	3	100.00	6	60.00
- Weak	-	-	-	-	-	-
- Bad	2	3.40	-	-	-	-
II. Chemical						
- Very good	-	-	-	-	-	-
- Good	51	87.0	3	100.00	-	-
- Moderate	-	-	-	-	10	100.00
- Weak	-	-	-	-	-	-
- Bad	6	10.30	-	-	-	-

CONCLUSION

The chemical analysis of the water quality of the studied lakes in North-West Romania emphasises insufficient amounts of dissolved oxygen in the water (according to CBO_5 the water is of IV and V quality; by CCO-Cr, II-III ranks and V rank for the water in the lake Moftin), and the accumulation of some significant quantities of nitrates (water of III and IV quality ranks) and of nitrites (water of IV and V quality ranks) creates an environment with issues for the existence of the aquatic fauna in the lakes, in particular for the fish populations. Thus, the chemical state of the water for the ecosystems under study shows as being a weak one, my research highlighting that the water has lower quality overall. In such types of water, the mechanisms of discomposure of the detritophages, which are stimulated, may cause bio-accumulation of toxic substances in various species of these ecosystems.

Comparing our results with the public data, we may state that, during the own research, the chemical quality of the water in the four lakes was not moderate, it is modest (weak). Under such circumstances, we cannot state that the artificial aquatic ecosystems are close to a state of ecological balance.

AUTHORS CONTRIBUTIONS

Conceptualization, Duță. C. S. and Hermenean A.; methodology, Duță C. S:, Hermenean A., Ardelean A.; data collection Duță C. S:, Ardelean D. P., Turcuș V.; data validation, Duță C. S:, Ardelean D. P., Turcuș V.; data processing Duță C. S:, Ardelean D. P., Turcuș V.; writing— original draft preparation, Duță C. S. and Turcuș V.; writing—review and editing, Hermenean A.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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