Assessment of Physico-chemical Characteristics and Eutrophic Parameters of Valea Mare and Turceni Storage Lakes

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In this study, it is described the assessment of physico-chemical characteristics and the parameters of eutrophication of Valea Mare and Turceni Storage Lakes during January 2013 - November 2015. Monitoring was conducted by taking samples from the middle lake (photic zone). It was observed the seasonal and multiannual variation of physico-chemical indicators of water quality. Based on the analyzes performed, it was assessed the ecological potential and water quality characterization of lakes monitored in terms of eutrophication parameters. According the results obtained, it can be concluded that both storage lakes have a moderate ecological potential. Water quality index calculation for each year in the period 2013-2015 led to the conclusion that both storage lakes have good water quality.

Key words: storage Lakes, monitoring, physico-chemical parameters, eutrophication

Water reservoirs are characterized by a higher content of organic substances, nutrients and planktonic biomass, which may have negative effects on the organoleptic and physical indicators such as taste, odor, color, turbidity, and *p*H. In terms of water treatment, storages have a favorable effect on water quality by reducing the content of suspensions, ensuring low and relatively constant temperatures, eliminating the danger of frost. Due to considerably lower hydrodynamic energy of water lakes, it creates favorable conditions for settling of suspended matter. During warmer months, intense solar radiation that reaches the water surface has as results increases the temperature of the top layer. It facilitates thermal stratification of the lake, in case of greater depths of 5 m, which involves the establishment of composition gradients. Bottom water layer, which is not directly exposed to sunlight, has a lower temperature.

Due to absence of mixing, the transfer of oxygen to the bottom of the water is less intensive and, therefore, the dissolved oxygen concentration in the area is small or even zero. Characteristic for this area are anaerobic processes that produce NH_3, H_2S, Fe^{2+}, Mn^{2+}, and oxidisable organic matter. In autumn, the top layer becomes coler as the air temperature decreases, and therefore it will be more dense. The top layer sinks and causes mixing of the lake layers and natural contamination is removed. This natural process leads to undesirable consequences in case of anthropogenic pollution when deep lakes are used as a source of water supply [1].

A common phenomenon of lakes is eutrophication due to discharge of large amounts of nitrates and phosphates from industry, wastes from treatment plants that are not adequately equipped. In all cases waters loaded with fertilizers based on nitrogen, phosphorus and detergents determine increasing of aquatic vegetation (micro- and macrophyte) which has negative effects to water quality. In tnis case, water will be enriched with natural substances, and putrefaction of them often causes mortalit of fish and other aquatic organisms [2].

Eutrophication causes high consumption of oxygen in aquatic and terrestrial environments due to nitrogen and phosphate products. This phenomenon results in a destruction of plankton in aquatic areas with different consequences on wildlife. It has to be notes that the air immissions of nitrogen compounds and phosphates also contribute to this effect. For surface waters these disturbances take place in trophic levels of ecosystems, leading to destabilization of the regulatory mechanisms of species distributions. This phenomenon is often illustrated by the explosive growth of limited number of species. In parallel, biochemical cycle of water is disrupted as a result of these algal excessive developments by appearing of anaerobic processes.

Thus, it is very important to determine the physical, chemical and biological properties of the lakes [3-5]. This is imposed by the Water Framework Directive. According to this Directive all the member states of European Union are obliged to assess and to report the ecological status of lakes exceeding a surface area 0.5 km^2 [6-8]. The ecological status is established by biological, chemical and physical characteristics of the water bodies and their variation from reference values [9, 10].

The purpose of this research paper is to assess the water quality and ecological status of Valea Mare and Turceni Storage Lakes through a series of standardized methods for analyzing physico-chemical quality indicators.

Experimental part

Valea Mare Storage Lake reservoir is arranged on the Motru river located in the mountains, with an average depth of 17.5 m and an area of 0.37 km^2. The dam has a length of 360 m, a width of 6 m and a height of 47 m. The storage is part of hydropower Cerna-Motru-Tismana-Jiu reservoir, taking part in the derivation of water flows from Cerna to Jiu reservoirs. Turceni Storage Lake is located in the village Turceni on the Jiu river at upstream confluence Jilt. It was built to produce electricity and to diminish flood wave in case of floods.

Water samples were taken monthly by standardized methods from middle section (photic zone) of the lake studied during the period January 2013 - November 2015. Physico-chemical parameters s uch as: pH the turbidity, water temperature, dissolved oxygen, COD, alkalinity, hardness, $N\text{-}NH^{4+}$, $N\text{-}NO_2^-$, $N\text{-}NO_3^-$, $P\text{-}PO_4^{3-}$ were monitored.

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The methods used for measuring of mentioned parameters were standardized [11].

A multiparameter for water quality analysis, 3320 Multi type was used to determine *p*H, turbidity and water temperature. Dissolved oxygen and COD (chemical oxygen demand) indicators were determined by analysis and control of water quality standard volumetric methods. The alkalinity was determined by titration with 0.1N HCl in the presence of phenolphthalein, and hardness by titration with EDTA. Molecular absorption spectrometric methods were applied to determine the level of nutrients. Thus, the method with salicylate and hypochlorite ions in the presence of sodium nitroprusside was used to determine the concentration of $N\text{-}NH_4^+$, the method with 4-amino-benzene- sulphonamide was involved to establish the level of $N\text{-}NO_2^-$, 2,6-dimethylphenol method was used to determine the level of $N\text{-}NO_3^-$, and ammonium molybdate method was applied to determine the level of $P\text{-}PO_4^{3-}$. Measurements were conducted by measuring the absorbance at the wavelength stated in the working method by using a UV absorption spectrophotometer - V.I.S. type CINTRA 101 GBC.

Results and discussions

The average values of quality water parameters were calculated based on measurements performed monthly, and the results recorded in spring, summer, autumn, and winter in period 2013-2015 for Valea Mare Lake in the middle section (photic zone) samplimg sections are presented in tabels 1-3.

The average values recorded in spring, summer, autumn, winter for period 2013-2015 for Turceni Lake in middle (photic) sampling section are shown in tables 4-6.

The thermal regime of the studied Lakes, shown in figure 1 is strictly influenced by the air temperature, in the sense that it varies with the air temperature by printing the same rate of increase or decrease. This phenomenon is affected by the lower heat capacity of water.

The water *p*H has an indirect role in the development of toxicity of the present compounds in water, as well as the nitrogen intermediates. The results recorded in the period 2013-2015, expressed by seasonal average values (tables 1-6) indicate that water Lakes monitored is classified as neutral-weak alkaline water. *p*H ranges between 7.13-7.8 for Valea Mare Lake and between 7.58-8.29 for Turceni Lake.

The variation of water turbidity in the period 2013-2015

Table 1

VALUES RECORDED IN 2013 FOR MIDDLE SAMPLING SECTION OF VALEA MARE STORAGE LAKE

No.	Physico-chemical indicators	Spring average values	Summer average values	Autumn average values	Winter average values
		(Sr-2013)	(S-2013)	(A-2013)	(W-2013)
1.	pH (pH units)	7.56	7.34	7.3	7.46
2.	Turbidity (NTU)	0.64	0.51	0.91	0.9
3.	Temperature (°C)	8	14	10	3
4.	Dissolved oxygen (mg O_2/L)	11.2	9.3	10.84	12.66
5.	COD-Cr (mg/L)	8.12	6.24	7.56	5.60
6.	Alkalinity (mmoles/L)	0.83	0.75	0.68	0.74
7.	Hardness (° d)	3.51	2.99	3.36	3.14
8.	$N\text{-}NH_4^+$ (mg/L)	0.033	0.029	0.027	0.025
9.	$N\text{-}NO_2^-$ (mg/L)	0.003	0.002	0.004	0.003
10.	$N\text{-}NO_3^-$ (mg/L)	0.7	0.61	0.46	0.66
11.	$P\text{-}PO_4^{2-}$ (mg/L)	0.011	0.010	0.011	0.021

Table 2

VALUES RECORDED IN 2014 FOR MIDDLE SAMPLING SECTION OF VALEA MARE STORAGE LAKE

No.	Physico-chemical indicators	Spring average values	Summer average values	Autumn average values	Winter average values
		(Sr-2014)	(S-2014)	(A-2014)	(W-2014)
1.	pH (pH units)	7.5	7.31	7.33	7.36
2.	Turbidity (NTU)	1.95	3.93	7.92	5.21
3.	Temperature (°C)	10	18	15	6
4.	Dissolved oxygen (mg O_2/L)	11.28	9.8	10	10.12
5.	COD-Cr (mg/L)	9.15	7.85	7.21	8.46
6.	Alkalinity (mmoles/L)	0.65	0.66	0.81	0.79
7.	Hardness (° d)	3.97	4.03	4.94	4.29
8.	$N\text{-}NH_4^+$ (mg/L)	0.015	0.021	0.028	0.019
9.	$N\text{-}NO_2^-$ (mg/L)	0.002	0.004	0.008	0.003
10.	$N\text{-}NO_3^-$ (mg/L)	0.55	0.4	0.55	0.49
11.	$P\text{-}PO_4^{2-}$ (mg/L)	0.009	0.007	0.006	0.008

Table 3

VALUES RECORDED IN 2015 FOR MIDDLE SAMPLING SECTION OF VALEA MARE STORAGE LAKE

No.	Physico-chemical indicators	Spring average values	Summer average values	Autumn average values	Winter average values
		(Sr-2015)	(S-2015)	(A-2015)	(W-2015)
1.	pH (pH units)	7.8	7.17	7.21	7.13
2.	Turbidity (NTU)	2.94	3.63	5.24	6.57
3.	Temperature (°C)	13	23	16	2
4.	Dissolved oxygen (mg O_2/L)	9.2	9.3	9.7	12.67
5.	COD-Cr (mg/L)	7.13	6.9	7.44	6.59
6.	Alkalinity (mmoles/L)	0.81	0.67	0.69	0.58
7.	Hardness (° d)	5.19	4.79	5.19	4.39
8.	$N\text{-}NH_4^+$ (mg/L)	0.064	0.014	0.017	0.016
9.	$N\text{-}NO_2^-$ (mg/L)	0.051	0.004	0.006	0.008
10.	$N\text{-}NO_3^-$ (mg/L)	0.98	0.30	0.26	0.38
11.	$P - PO_4^{3-}$ (mg/L)	0.046	0.005	0.007	0.009

Table 4

VALUES RECORDED IN 2013 FOR MIDDLE SAMPLING SECTION OF TURCENI STORAGE LAKE

No.	Physico-chemical indicators	Spring average values	Summer average values	Autumn average values	Winter average values
		(Sr-2013)	(S-2013)	(A-2013)	(W-2013)
1.	pH (pH units)	7.8	8.29	7.63	7.69
2.	Turbidity (NTU)	2.14	0.54	0.64	0.72
3.	Temperature (°C)	19	26	17	5
4.	Dissolved oxygen (mg O_2/L)	9.3	7.2	9.2	8.9
5.	COD-Cr (mg/L)	10.04	9.49	7.54	10.25
6.	Alkalinity (mmoles/L)	1.56	1.39	1.28	1.22
7.	Hardness (° d)	6.06	4.71	5.37	5.2
8.	$N\text{-}NH_4^+$ (mg/L)	0.140	0.069	0.050	0.052
9.	$N\text{-}NO_2^-$ (mg/L)	0.05	0.049	0.05	0.048
10.	$N\text{-}NO_3^-$ (mg/L)	1.12	1.06	1.0	1.1
11.	$P - PO_4^{3-}$ (mg/L)	0.057	0.050	0.047	0.046

Table 5

VALUES RECORDED IN 2014 FOR MIDDLE SAMPLING SECTION OF TURCENI STORAGE LAKE

No.	Physico-chemical indicators	Spring average values	Summer average values	Autumn average values	Winter average values
		(Sr-2014)	(S-2014)	(A-2014)	(W-2014)
1.	pH (pH units)	7.95	7.75	7.75	7.6
2.	Turbidity (NTU)	3.38	4.69	8.14	10.2
3.	Temperature (°C)	22	28	19	10
4.	Dissolved oxygen (mg O_2/L)	9.2	8.25	8.2	10.8
5.	COD-Cr (mg/L)	7.65	8.54	8.29	6.96
6.	Alkalinity (mmoles/L)	1.435	1.405	1.57	1.63
7.	Hardness (° d)	6.01	5.12	5.23	5.3
8.	$N\text{-}NH_4^+$ (mg/L)	0.111	0.131	0.168	0.08
9.	$N\text{-}NO_2^-$ (mg/L)	0.045	0.04	0.047	0.035
10.	$N\text{-}NO_3^-$ (mg/L)	1.075	1.095	1.3	0.87
11.	$P - PO_4^{3-}$ (mg/L)	0.061	0.049	0.066	0.081

(fig. 2) shows that Turceni Lake turbidity is higher than Valea Mare Lake turbidity and presents an increasing variation during the monitoring period ending in summer 2015 with peak of 16.18 NTU.

Dissolved oxygen is the most important quality parameter of one lake because it is vital to aquatic ecosystems. The evolution of the dissolved oxygen has a sinuous curve depending on the season, as can be seen from figure 3.

Values of dissolved oxygen content that are considered optimum for aquatic life have been recorded in autumn, winter and spring, for the entire period in both Lakes studied (figs. 3, 4). During 2013-2015, the average dissolved oxygen content for Valea Mare Lake ranged from 9.2 to 12.67 mgO_2/L, and for Turceni Lake between 7.2 to 11.1 mg O_2/L. For the entire period, dissolved oxygen shows the same seasonal variation with warming of water masses. It was observed an increasing of the amount of dissolved oxygen in autumn and winter which was determined by increasing of its solubility with decreasing of temperature. The lowest

Table 6

VALUES RECORDED IN 2015 FOR MIDDLE SAMPLING SECTION OF TURCENI STORAGE LAKE

No.	Physico-chemical indicators	Spring average values	Summer average values	Autumn average values	Winter average values
		(Sr-2015)	(S-2015)	(A-2015)	(W-2015)
1.	pH (pH units)	7.62	7.58	7.84	7.59
2.	Turbidity (NTU)	15.49	16.18	13.26	12.85
3.	Temperature (°C)	23	30	12	8
4.	Dissolved oxygen (mg O_2/L)	9.2	7.7	11.1	8.9
5.	COD-Cr (mg/L)	11.23	14.04	12.48	11.56
6.	Alkalinity (mmoles/L)	1.40	1.64	1.55	1.58
7.	Hardness (° d)	3.35	3.17	2.14	4.21
8.	$N\text{-}NH_4^+$ (mg/L)	0.064	0.095	0.042	0.057
9.	$N\text{-}NO_2^-$ (mg/L)	0.035	0.037	0.077	0.069
10.	$N\text{-}NO_3^-$ (mg/L)	0.87	0.98	0.92	0.88
11.	$P\text{-}PO_4^{3-}$ (mg/L)	0.057	0.07	0.064	0.073

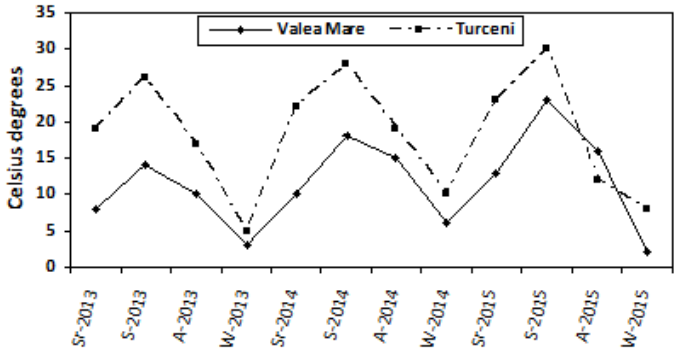

Fig. 1. Temperature variation in period 2013-2015

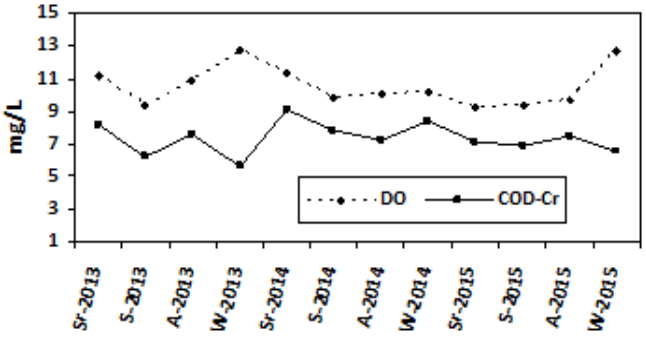

Fig. 3. Variation of DO and COD-Cr for Valea Mare Lake

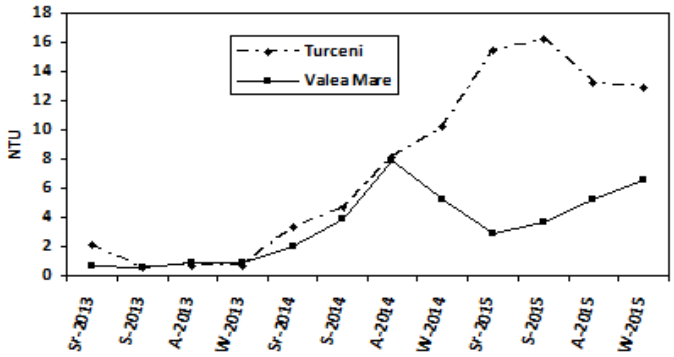

Fig. 2. Turbidity variation in period 2013-2015

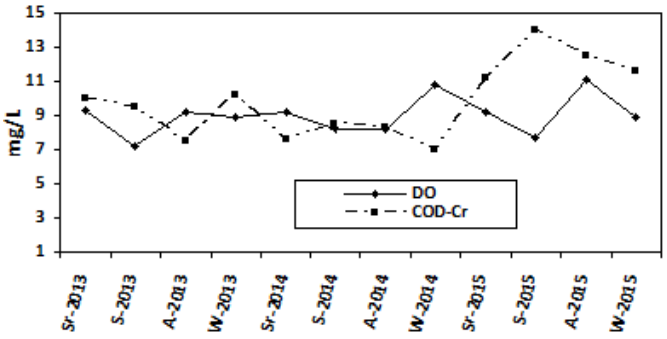

Fig. 4. Variation of DO and COD-Cr for Turceni Lake

values of dissolved oxygen have been recorded in summer. Temperature and dissolved oxygen parameters are in an inverse relationship. Evolution of COD-Cr parameter values with seasons (figs. 3 and4) shows the high influence of temperature and dissolved oxygen to the organic matter decomposition process.

Valea Mare Lake alkalinity varied during the three years between 0.58 to 0.83 mmol/L, and for Turceni Lake between 1.22-1.64 mmol/L. Average hardness variation was similar for the two Lakes, namely, for Valea Mare Lake hardness content was between 2.99 - 5.19 °d, and for Turceni Lake it ranged between 2.14 - 6.06 °d.

Parameters characteristics for water eutrophication (N-ammonium, N-nitrite, N-nitrate, P-phosphate) registered for the two lakes had different seasonal variations. Thus, the results obtained, the indicator N-nitrite for Turceni Lake (fig. 5) is in the range 0.035-0.077 mgN/L with the peak recorded in autumn 2015, and in the range 0.002-0.051 mgN/L for Valea Mare Lake (fig. 6).

By comparing the seasonal variation of N-ammonium average values over the three years of study, it was observed that these values are between 0.042 and 0.168 mgN/L for Turceni Lake (fig. 5) and between 0.014-0.064 mgN/L for Valea Mare Lake (fig. 6). It was found a high level of load of about three times higher for nutrients such as N-ammonium for Turceni Lake than for Valea Mare Lake.

The P-phosphate content values are in the limits 0.046-0.081 mgP/L for Lake Turceni (fig. 5) and 0.005-0.046 mgP/L for Valea Mare Lake (fig. 6) also indicating a high loading for Turceni Lake. The values of the three parameters such as N-ammonium, N-nitrite, and P-phosphate are very high in the spring of 2015, for Valea Mare Lake, in comparison to the rest of the monitoring period. The results and variation of N- nitrate indicator (fig. 7) show that between the average seasonal values of Turceni Lake (0.87- 1.3 mgN/L) and those of Valea Mare Lake (0.26-0.98 mgN L) for the three years are significant differences in the sense of an increased level of loading of Turceni Lake. Similar content presents Valea Mare Lake only in the spring of 2015.

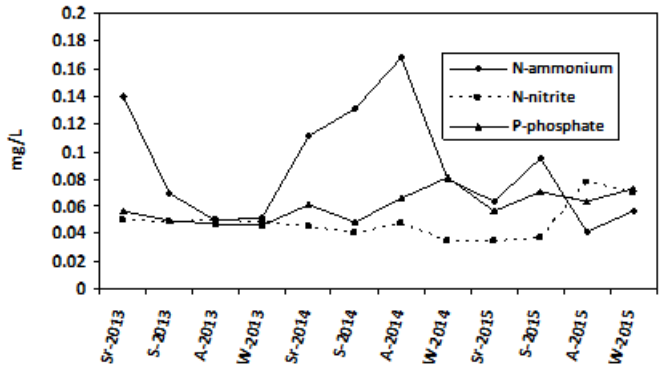

Fig. 5. Variation of $N\text{-}NH_4^+$, $N\text{-}NO_2^-$, $P\text{-}PO_4^{3-}$ in period 2013-2015 for Turceni Lake

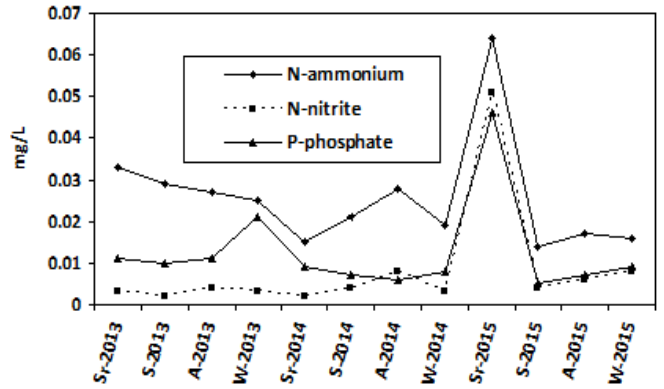

Fig. 6. Variation of $N\text{-}NH_4^+$, $N\text{-}NO_2^-$, $P\text{-}PO_4^{3-}$ in period 2013-2015 for Valea Mare Lake

To assess the ecological potential of Valea Mare and Turceni Storage lakes in terms of eutrophication parameters, there were considered annual mean of $N\text{-}NO_3^-$ and $P\text{-}PO_4^{3-}$ for 2013-2015 and limit values of these parameters (table 7).

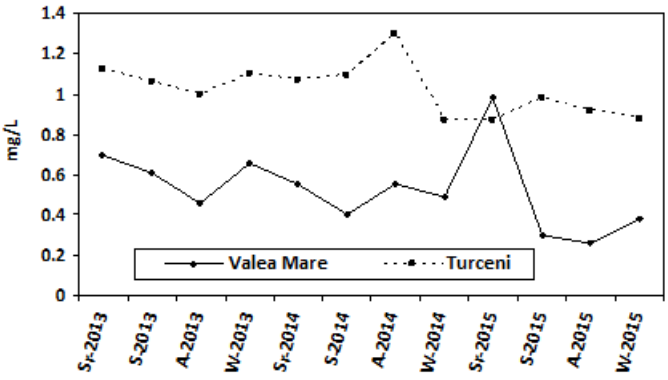

Fig. 7. Variation of average values of N-nitrate content for Valea mare and Turceni Lakes

The average value of $N\text{-}NO_3^-$ indicator recorded in 2013 for the Valea Mare Lake is characteristic moderate ecological potential (MoEP). The annual average values of $N\text{-}NO_3^-$ indicator for the period 2014-2015 indicate that Valea Mare Lake has good ecological potential (GEP). In terms of the $P\text{-}PO_4^{3-}$ annual average values for the whole period 2013-2015 correspond to maximum ecological potential (MEP). The Turceni Storage Lake shows for 2013, a value of $N\text{-}NO_3^-$ indicator characteristics for good ecological potential (GEP), and in 2014-2015 the values of $N\text{-}NO_3^-$ indicator are characteristics for moderate ecological potential (MoEP). Regarding the $P\text{-}PO_4^{3-}$, in 2014-2015 the average annual values correspond to moderate ecological potential (MoEP). Ecological status is given by *the worst indicator*. Thus, terms of parameters measured both two lakes monitored can be classified as moderate ecological potential (MoEP).

By the results regarding the physico-chemical characterization of Valea Mare and Turceni Storage lakes,

Table 7

ANNUAL AVERAGE AND LIMIT VALUES FOR ECOLOGICAL POTENTIAL ASSESSMENT FOR VALEA MARE AND TURCENI STORAGE AND TURCENI LAKES

Lake/ Typological Category	Annual average values $N\text{-}NO_3^-$ (mgN/L)			Limit values $N\text{-}NO_3^-$ (mgN/L)		Annual average values $P\text{-}PO_4^{3-}$ (mgP/L)			Limit values $P\text{-}PO_4^{3-}$ (mgP/L)	
	2013	2014	2015	MEP	GEP	2013	2014	2015	MEP	GEP
Valea Mare ROLA08	1.07	0.49	0.48	0.40	0.80	0.013	0.0075	0.016	0.02	0.03
Turceni ROLA08	0.60	1.085	0.91	0.40	0.80	0.05	0.064	0.066	0.02	0.03

MEP- maximum ecological potential; GEP- good ecological potential

Table 8

VARIATION OF PHYSICO-CHEMICAL PARAMETERS AND THEIR INTERPRETATION IN FUNCTION OF WQI for VALEA MARE STORAGE LAKE

No	Parameter	Annual average values			Quality Index Parameter		
		2013	2014	2015	2013	2014	2015
1.	pH	7.41	7.37	7.32	88	88	88
2.	turbidity	0.74	4.75	4.59	99	88	88
3.	temperature	8.75	12.25	13.5	56	36	34
4.	$N\text{-}NO_3^-$	1.07	0.49	0.48	97	97	97
5.	$P\text{-}PO_4^{3-}$	0.013	0.0075	0.016	100	100	100
Overall water quality index: 91-100: excellent quality; 71-90: good quality; 51-70: moderate quality; 26-50: bad quality; 0-25: poor quality					88 –good quality	82 – good quality	81 – good quality

Table 9

VARIATION OF PHYSICO-CHEMICAL PARAMETERS AND THEIR INTERPRETATION IN FUNCTION OF WQI for TURCENI STORAGE LAKE

No	Parameter	Annual average values			Quality Index Parameter		
		2013	2014	2015	2013	2014	2015
1.	pH	7.85	7.76	7.65	88	88	88
2.	turbidity	1.01	6.60	14.44	96	84	69
3.	temperature	16.75	19.75	18.25	29	24	26
4.	$N\text{-}NO_3^-$	0.60	1.085	0.91	97	96	97
5.	$P - PO_4^{2-}$	0.05	0.064	0.066	100	100	100
Overall water quality index: 91-100: excellent quality; 71-90: good quality; 51-70: moderate quality; 26-50: bad quality; 0-25: poor quality					82 - good quality	82 – good quality	77 – good quality

it can be observed that all five physico-chemical lakes parameters, including $N\text{-}NO_3^-$ and $P\text{-}PO_4^{3-}$ indicate the level of eutrophication. This was exxpressed by water quality index method (WQI). The results for WQI of Valea Mare and Turceni Storage Lakes are shown in tables 8 and 9.

Conclusions

The purpose of the present study was to assess the physicochemical characteristics of Valea Mare and Turceni Storage Lakes during January 2013 - November 2015 by taking samples from the middle lake (photic zone). Monitoring was carried out by measuring the parameters: *p*H, turbidity, water temperature, dissolved oxygen, COD, alkalinity, hardness, $N\text{-}NH^{4+}$, $N\text{-}NO^{2-}$, $N\text{-}NO^{3-}$, $P\text{-}PO_4^{3-}$. It was aimed to analyze seasonal and multiannual variation of values recorded for physico-chemical indicators of water quality and the correlations between them. Ecological potential of Valea Mare and Turceni Storage Lakes was assess by taking account of annual average values of parameters that indicate the level of eutrophication such as $N\text{-}NO_3^-$, $P\text{-}PO_4^{3-}$ for 2013-2015 in relation to the limit values. Considering that ecological status is given by *the worst indicator*, the analysis of values for parameters evaluated in case of monitored lakes indicates that both lakes have moderate ecological potential (MoEP). Interpretation of the results by calculating the physico-chemical water quality index (WQI) per year in period 2013-2015 led to the conclusion that both lakes can be classified as good water quality.

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Manuscript received: 15.02.2016