STUDY FOR EVALUATING THE WATER QUALITY OF THE JIU RIVER IN GORJ COUNTY

DELIA NICA-BADEA*, *Constantin Brancusi University Targu – Jiu, Romania*
ANIELA BALACESCU, *Constantin Brancusi University Targu – Jiu, Romania*

* Corresponding author: nicabadeadelia@yahoo.com

Abstract: This paper presents a study conducted in the autumn season 2018, whose main objective was to assess the water quality of the Jiu River in the administrative territory of Gorj County. Based on the physico-chemical parameters determined in three sampling points on the direction of river flow, we analyzed the data and established the water quality class from an ecological point of view by reference to elements and physico-chemical quality standards according to O 161/2006. From the perspective of ecological status, most parameters fall into quality class I for all three water segments, except: P-PO4 class IV. The WQI values calculated for each parameters vary depending on the analyzed segment and fall into different quality classes: Excellent (DO, BOD, Nitrate, Phosphates, pH); Good (TDS; BOD –SJ3); Bad (Temperature); Very Bad (Turbidity). The general WQI varies very little, respectively: 79, 78, 77, falling within the Good quality range, decreasing towards the southern segment of the Jiu River. The assessment of the quality of water bodies described in this study, reveals that the Jiu River is a clean body of water, a fact which has also been confirmed by national and European authorities in the periodic in recent reports.

Keywords*: Jiu River, Water quality parameters, Ecological status, Water Quality Index*

1. INTRODUCTİON

The importance of water conservation has led to the monitoring and evaluation of watercourses at regional, national and European level [1]. Water quality is currently one of the most important issues in water resources management. Assessing water quality for various purposes: domestic, irrigation, conservation and industrial, is an important strategy aimed at food safety, maintaining and promoting human health, supporting the global economy [2].

In common terms, water quality can be classified into three broad categories: physical, chemical, and biological, which in turn each contain a number of parameters. According to national legislation [3], for the characterization and assessment of water quality, at national legislation a set of five indicators was established: *thermal regime and acidification*; *oxygen regime*; *nutrients*; *salinity*; *other relevant chemical indicators*. To determine the ecological status of water bodies according to Order 161/2006 on the classification of surface waters, five quality classes for rivers have been defined: high ecological status (Class I) coded blue, good ecological status (Class II), coded green; moderate ecological status (Class III), coded yellow; poor ecological status (Class IV), encoded by orange and bad status (Class V), encoded by red. The acceptable value for each quality class is the maximum value of the parameters for that class [3].

The Water Quality Index (WQI) has been proposed since 1965 to define the state of water quality in a river [4], and after 1970, the proposed WQI models are based on the weight of a set of individual parameters taken into account [5- 9].

The surface water body in Romania in the year 2018 is appreciated from the point of view of the environmental indicators as moderate 45% and high 55% [10]. The Jiu River is the main watercourse that crosses the territory of Gorj County together with the main rivers that have upper basins in the high mountain area have high average annual flows, provide natural water supply or are

water supply sources for cities and rural communities. The water quality in the Gorj Rivers is periodically monitored by Romanian Waters Agency, Jiu Water Basin Administration. A number of studies on the analysis of water quality parameters in the Jiu River have been reported recently, but WQI evaluation studies have not been reported, except for the Dolj County segment. The objective of this study was evaluation water quality potential for Jiu River - Gorj County taking into account the average values of each quality parameter, which were recorded at three monitoring stations, assessment of ecological status and range of water quality.

2. MATERIALS AND METHODS

The first stage of water quality assessment study was establishing the three collection points for water samples from the Jiu River, the segment related to Gorj County: upstream confluence with Sadu River (SJ1); downstream accumulation Targu -Jiu (JS2); Jiu locality Balteni (SJ3), Figure 1.

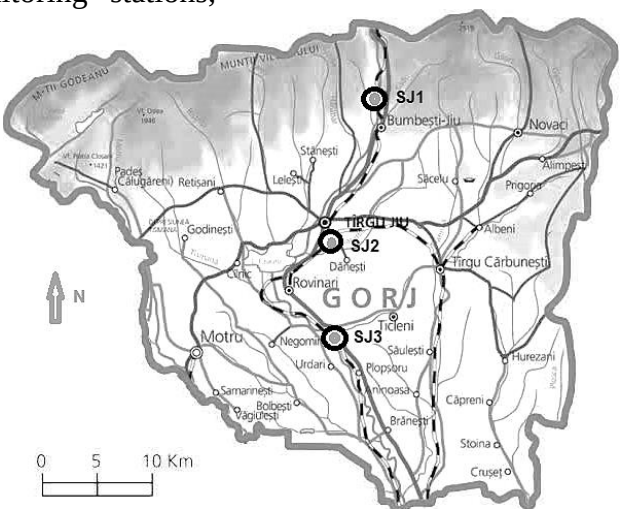

Figure 1. Location of the sampling sections

Water samples were collected during the autumn months of 2018 applying the standards in force regarding the internal sampling procedures rivers and streams [11-13]. Analysis of physico-chemical indicators selected were performed according to Romanian standard methods, approved internationally (SR ISO and/or SR EN), using reference materials, high purity chemical reagents. Determinations were performed with the following standard methods: Gorj County thermometry (T); potentiometric (pH); Turbidimetric (Turb); incubation, Winkler titration (BOD); titrimetric (DO); gravimetric (TDS); UV-VIS spectrophotometry (N-NO_3, P-PO_4). The parameters determined in the laboratory Archive Water Management System Gorj were used as indicators for assessing the status of the water body in relation to national regulations [3] (Order 161) and for calculating the water quality index (WQI) for the Jiu River. For this study, the water quality index formula / model (1) was applied [5]:

$$WQI = 1/100\left(\sum_{i=1}^{9} q_i w_i\right)^2 \quad (1)$$

where i – the quality parameter; qi – the registered value; wi – the rank of implication of the parameter in the computation formula.

According to the PathFinder Science Network [14], WQI index includes following steps:1) Selected water quality parameters: water temperature, pH,

turbidity, total solids; dissolved oxygen five days, biochemical oxygen demand, phosphates, nitrates, total phosphorus; 2)For each of the i parameters determined obtain the value of Q by using the WQI Worksheet [14], Figure 2. After which the Qi value will be assigned a given weight Wi, and the quality index is calculated by the formula WQI (1). According to Field Manual for Water Quality Monitoring [5], calculating NSF Water Quality Index was performed online [15].

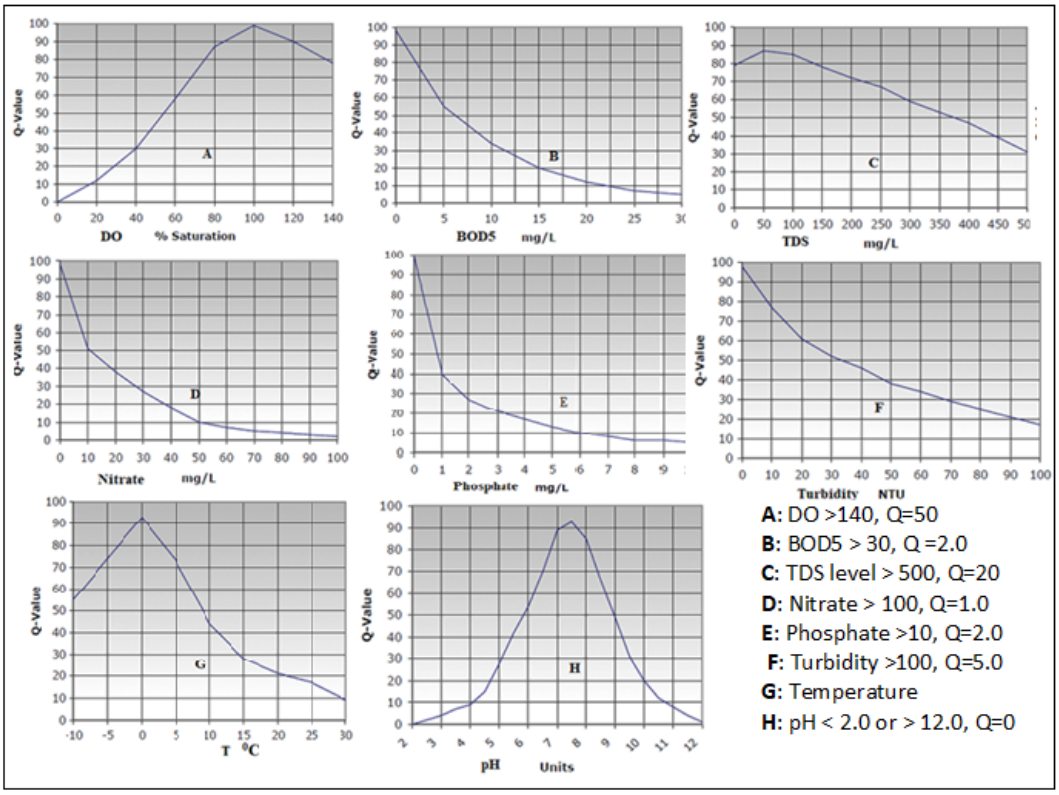

Figure 2. WQI Worksheet: Q_i = F (wi) **[**14**]**

3. RESULTS AND DISCUSSIONS

The results of the physico-chemical parametric analysis presented in Table 1 may constitute the database that allows the evaluation of the quality class that the surface waters used for surface water quality classification in order to establish the ecological status of water bodies [3]; calculation water quality index and water quality status [5].

Tabel 1. Physico-chemical indicators for Jiu River

Indicator	**UM**	**Analysis method**	**Sampling section**		
			SJ1	SJ2	SJ3
Turbidity	(mg/L)	SR 27888 /1997	33.0	21.0	21.0
T	(º C)	SR EN1622:2007	17.00	19.00	25.00
DO	(mgO2/L)	SR EN 1899 -2 / 2002	9/1	11.0	7,9
Oxygen saturation	(%)	-	97.0	98.3	97.4
BOD5	(mg/L)	DIN 38409 /1992	1.3	1.8	2.0
pH at 21.1ºC	(u pH)	SR ISO 10523/2012	7.07	7.81	7.74
$N\text{-}NO_3^-$	(mg N/L)	SR ISO 7890-3/2000	0.620	0.65	0.950
$P - PO_4^{3-}$	(mg P/L)	SR EN ISO 6878/2005	0.050	0.079	0.052
TDS	(mg/L)/	STAS 9187/1984	125.2	151.3	136.0

Source. Data processed by the Water Management System Gorj

In order to evaluate the water quality of the Jiu River on the Gorj segment, we performed a comparative analysis of the characteristic quality parameters for the three sampling sectors (SJ1, SJ2, SJ3) Table 1 and the ecological quality class according to elements, chemical and physical standards of quality in the freshwater quality.

3.1. Assessment of ecological status

Thermal regime and acidifying

The temperature of water bodies has a direct influence on the biodiversity of aquatic species, the concentration of dissolved oxygen, the processes of chemical and biological substance, stratification and density. It is observed that the water temperature of the Jiu River shows an increase in value. from 17 ºC at point SJ1 to about 25 ºC at point SJ3. This increase due to the influence of air temperature is specific to the autumn days for the mountain area (upstream Sadu), passing through the area of Targu-Jiu Municipality to the plain area (Balteni).

The concentration of the hydrogen ion represented by the pH of the water shows values that fall within the range provided by the quality norms I (6.5-8.5), having a neutral or slightly basic character, which varies between 7.07 at the entrance to Sadu (SJ1), with a maximum of 7.81 downstream of the municipality of Targu-Jiu (SJ2) and 7.74 in the southern extremity of the analyzed segment (SJ3). This variation is justified by the potential impact of industrial and domestic wastewater in the areas through which it flows. The southern area (SJ3) is characterized by the existence of the lignite quarrying industry and the operation of lignite power plants (Rovinari, Turceni).

Oxygen regime

It was found that the daily and annual regime of soluble gases dissolved in river waters is determined by water temperature, photosynthesis intensity, river energy sources, as well as pollution sources. Within the oxygen regime quality class, three indicators were analyzed:

- dissolved oxygen (DO) which varies inversely with water temperature, the amount of micro-organisms and oxidizable substances;
- biochemical oxygen demand (BOD5), which is a function of the amount and capacity of biochemical decomposition of organic substances in water;

According to the data in Table 1, it can be seen that the minimum value of dissolved oxygen (DO) of 7.9 mg / L (segment SJ3) is above the limit of quality class II (7 mg / L), while the values of 9.1 mg / L for the SJ1 segment and 11.0 mg / L for the SJ2 segment have values higher than the permitted limit for ecological quality class I (9 mg / L). This confirms the inverse correlation between water temperature and DO value presented in the literature [16] and the slight depreciation of ecological quality by going through an environment with anthropogenic influences. And the percentage values of the parameter saturation in oxygen values between 97% and 98.3% in water class I quality (90-110): Epilimnion - stratified water.

Based on the values of the indicator (BOD5) there is an increasing variation of the concentration from the northern part of the entrance segment (SJ1) to the southern part (SJ3), between 1.3-2.1mg / L, which determines the classification in ecological quality class I (3mg / L), reflecting a decrease as a function of the quantity and capacity of biochemical decomposition of organic substances in water on the river segment from north to south, within the same class.

Nutrients

The nutrient assessment was focused on highlighting the level of $N\text{-}NO_3$; $P\text{-}PO_4$. Although their toxicity is considered low, their presence in water can be considered an indicator of anthropogenic pollution.

Nitrate level $N\text{-}NO_3$ - shows an increase from SJ1 (0.620 mg / L) to SJ3 (0.950 mg / L), values that fall below the maximum level of quality class I (1mg / L). TN has the same increasing variation in the direction of water flow: 0.81mg / L for SJ1 to 1.26 mg / L for SJ2, falling within the limit of quality class I (1.5 mg / L). The increasing variation of these parameters in the direction of flow suggests the possibility of sewage discharges (Targu-Jiu, Rovinari) or wastewater from livestock farms (Bumbești-Jiu) that take place between analysis sections.

The level of $P\text{-}PO_4$ varies sinusoidally with a maximum downstream of Targu-Jiu (SJ2) of 0.079 mg / L, enclosing the area in quality class IV for all the three sections. The same trend can be seen at the parameter Total P with a maximum also downstream of Targu-Jiu (SJ2) of 0.082 mg / L, class IV (max.1.2mg / L), respectively class III for SJ1 and SJ3 (max.0.0752 mg / L. The increase in phosphorus content is usually a consequence of improper storage of animal waste and the use of phosphate fertilizers.

Salinity

The salinity regime is reflected in the total concentration of suspended materials. The frequency of maximum values is usually found in winter and less in autumn.

The TDS distribution has a sinusoidal variation with a maximum at SJ2 (151.3 mg / L), a distribution that can be explained by the fact that this water sample collection point is located downstream of the two accumulation dams in the Targu-Jiu area, which could change the level of this parameter. The value of the fixed residue in the water body indicates a relatively high level of erosion in the water body. Also, the determined chloride concentration also shows a sinusoidal variation with a maximum at SJ2 of 7.12 mg / L, being well below the maximum value of quality class I (25 mg / L).

3.2. Assessment of Water quality based on Water quality Index

According to Field Manual for Water Quality Monitoring, (formula 1), the water Quality Index for the Jiu river is based of following physical-chemical and biologic parameters selected by table 1:

- Physical parameters: temperature, turbidity, total solid;
- Chemical parameters: pH, total phosphate, nitrates.
- Biologic parameters: Oxygen saturation (%), BOD.

The result of applying the calculation program [5], water quality evaluation is based on calculated water quality index to: each selected parameter of the three sampling sections; Overall WQI and Range Quality, presented in table 2.

In order to evaluate the water quality of the Jiu River on the Gorj segment, we performed a comparative analysis of the characteristic quality parameters for the three sampling sectors (SJ1, SJ2, SJ3) Table 1 and the ecological quality class according to elements, chemical and physical standards of quality in the freshwater quality.

3.1. Assessment of ecological status

Thermal regime and acidifying

The temperature of water bodies has a direct influence on the biodiversity of aquatic species, the concentration of dissolved oxygen, the processes of chemical and biological substance, stratification and density. It is observed that the water temperature of the Jiu River shows an increase in value. from 17 ºC at point SJ1 to about 25 ºC at point SJ3. This increase due to the influence of air temperature is specific to the autumn days for the mountain area (upstream Sadu), passing through the area of Targu-Jiu Municipality to the plain area (Balteni).

The concentration of the hydrogen ion represented by the pH of the water shows

values that fall within the range provided by the quality norms I (6.5-8.5), having a neutral or slightly basic character, which varies between 7.07 at the entrance to Sadu (SJ1), with a maximum of 7.81 downstream of the municipality of Târgu-Jiu (SJ2) and 7.74 in the southern extremity of the analyzed segment (SJ3). This variation is justified by the potential impact of industrial and domestic wastewater in the areas through which it flows. The southern area (SJ3) is characterized by the existence of the lignite quarrying industry and the operation of lignite power plants (Rovinari, Turceni).

Oxygen regime

It was found that the daily and annual regime of soluble gases dissolved in river waters is determined by water temperature, photosynthesis intensity, river energy sources, as well as pollution sources. Within the oxygen regime quality class, three indicators were analyzed:

- dissolved oxygen (DO) which varies inversely with water temperature, the number of micro-organisms and oxidizable substances;
- biochemical oxygen demand (BOD5), which is a function of the amount and capacity of biochemical decomposition of organic substances in water;

According to the data in Table 1, it can be seen that the minimum value of dissolved oxygen (DO) of 7.9 mg / L (segment SJ3) is above the limit of quality class II (7 mg / L), while the values of 9.1 mg / L for the SJ1 segment and 11.0 mg / L for the SJ2 segment have values higher than the permitted limit for ecological quality class I (9 mg / L). This confirms the inverse correlation between water temperature and DO value presented in the literature [16] and the slight depreciation of ecological quality by going through an environment with anthropogenic influences. And the percentage values of the parameter saturation in oxygen values between 97% and 98.3% in water class I quality (90-110): Epilimnion - stratified water.

Based on the values of the indicator (BOD5) there is an increasing variation of the concentration from the northern part of the entrance segment (SJ1) to the southern part (SJ3), between 1.3-2.1mg / L, which determines the classification in ecological quality class I (3mg / L), reflecting a decrease as a function of the quantity and capacity of biochemical decomposition of organic substances in water on the river segment from north to south, within the same class.

Nutrients

The nutrient assessment was focused on highlighting the level of $N\text{-}NO_3$; $P\text{-}PO_4$. Although their toxicity is considered low, their presence in water can be considered an indicator of anthropogenic pollution.

Nitrate level $N\text{-}NO_3$ - shows an increase from SJ1 (0.620 mg / L) to SJ3 (0.950 mg / L), values that fall below the maximum level of quality class I (1mg / L). TN has the same increasing variation in the direction of water flow: 0.81mg / L for SJ1 to 1.26 mg / L for SJ2, falling within the limit of quality class I (1.5 mg / L). The increasing variation of these parameters in the direction of flow suggests the possibility of sewage discharges (Târgu-Jiu, Rovinari) or wastewater from livestock farms (Bumbești-Jiu) that take place between analysis sections.

The level of $P\text{-}PO_4$ varies sinusoidally with a maximum downstream of Targu-Jiu (SJ2) of 0.079 mg / L, enclosing the area in quality class IV for all the three sections. The same trend can be seen at the parameter Total P with a maximum also downstream of Targu-Jiu (SJ2) of 0.082 mg / L, class IV (max.1.2mg / L), respectively class III for SJ1 and SJ3 (max.0.0752 mg / L. The increase in phosphorus content is usually a consequence of improper storage of animal waste and the use of phosphate fertilizers.

Salinity

The salinity regime is reflected in the total concentration of suspended materials. The frequency of maximum values is usually found in winter and less in autumn.

The TDS distribution has a sinusoidal variation with a maximum at SJ2 (151.3 mg / L), a distribution that can be explained by the fact that this water sample collection point is located downstream of the two accumulation dams in the Târgu-Jiu area, which could change the level of this parameter. The value of the fixed residue in the water body indicates a relatively high level of erosion in the water body. Also, the determined chloride concentration also shows a sinusoidal variation with a maximum at SJ2 of 7.12 mg / L, being well below the maximum value of quality class I (25 mg / L).

3.2. Assessment of Water quality based on Water quality Index

According to Field Manual for Water Quality Monitoring, (formula 1), the water Quality Index for the Jiu River is based of following physical-chemical and biologic parameters selected by table 1:

- Physical parameters: temperature, turbidity, total solid;
- Chemical parameters: pH, total phosphate, nitrates.
- Biologic parameters: Oxygen saturation (%), BOD.

The result of applying the calculation program [5], water quality evaluation is based on calculated water quality index to: each selected parameter of the three sampling sections; Overall WQI and Range Quality, presented in table 2.

Table 2. Water quality evaluation based on WQI calculated for the Jiu River

Factor	Weight	Value JS1	WQI SJ1	Value SJ2	WQI SJ2	Value SJ3	WQI SJ3
DO %	0.17	97	99	98.3	99	97.4	99
pH (u pH)	0.11	7.07	89	7.81	90	7.74	91
BOD5 (mg/L)	0.11	1,3	92	1.8	84	2.0	80
Temperature (º C)	0.10	17.00	27	19.00	24	25.00	16
Phosphate (mg/L)	0.10	0.050	98	0.079	97	0.052	98
Nitrates (mg/L)	0.10	0.62	96	0.65	96	0.95	96
Turbidity (NTU)	0.08	99	18	63	32	63	32
Total Solids (mg/L)	0.07	125.2	81	151.3	79	136.0	80
Overall WQI			79		78		77
Range Quality [a]			Good		Good		Good

[a] B.Oram, 2010, Water Quality Index [5].

Legend. Range Quality: 90-100 Excellent; 70-89 Good; 50-69 Medium; 25-49 Bad; 0-24 Very bad.

The individual values of the quality index (WQI) obtained for each selected parameter, as well as the general values (summative) for the three collection points of water samples allow us to observe how the water quality of the Jiu River evolves on the investigated section in Gorj County.

A) The individual values of the calculated WQI have a value distribution on the three analysis points SJ1-SJ3, for the selected parameters, as follows: a) equal or close: DO (99 Excellent); Nitrate (96 Excellent); Total Phosphate (98, 97, 98: Excellent); b) ascending: pH (89, 90, 91: Excellent); Turbidity (18, 32, 32: Bad, Very bad); c) BOD descending (92, 84, 80: Excellent, Good); Temperature (27, 24,16: very Bad) c) different: Total solid (81,79,80: Good).

B) Overall WQI varies very little (Range Quality: Good), decreasing from the point of exit from the Jiu and entering the territory of Gorj County, upstream of the confluence with the river Sadu (SJ1: 79), passing through the intermediate point of the route - downstream from the municipality of Târgu - Jiu (SJ2: 78), towards the terminal-downstream point of Bâlteni locality (SJ3: 77). The decreasing variation of the water quality of the Middle Jiu continues on the territory of Dolj County, fact confirmed by a recent paper (2017) which aims at three evaluation points of WQI; Răcari (P1: 67.67), Podari (P2: 64.27), Gângiova (P3: 63.19) [17].

This continuous decrease of the water quality of the Jiu River in the direction of flow is explicable taking into account the anthropogenic pressures to which the water course is subjected by significant punctual and diffuse sources on the territory of the two counties. Situation of anthropogenic pressures: Urban pollution sources / human agglomerations; industrial and agricultural pollution and the level Discharges of organic substances and nutrients into the water resources in Jiu River basin, highlighted in National Administration, Craiova Branch, Report (2017) [18].

4. CONCLUSIONS

The physico-chemical parameters of water have undergone a series of anthropogenic influences from point and diffuse sources of pollution caused by urban / human agglomerations / localities and industrial and agricultural pollution.

The calculation of the WQI water quality index provides the possibility to make a temporal and spatial comparison of a water body and establishes the quality class for each parameter or in general and the water use capacity in different areas or purposes. According to Quality scale for WQI [5], Overall WQI calculated for the Jiu River indicates a Good quality class, slightly decreasing towards the southern area of Gorj County, a decrease that is accentuated in the Dolj County area until it empties into the Danube.

The assessment of the quality of water bodies in general, of the Jiu River in particular described in this study, reveals that the Jiu River is a clean body of water, a fact which has also been confirmed by national and European authorities in the periodic in recent reports [10].

Acknowledgments: Thanks for the collaboration of the management team of SGA Gorj (PC 10710/2017).

References

1.*** Water Framework Directive (2000/60/EC), Official Journal of the European Community, vol. L327, pp. 1–73, 2000

2. Venkatramanan, S., Chung, S.Y., Lee S.Y., Park, N., Assessment of river water quality via environmentric multivariate statistical tools and water quality index: A case study of Nakdong River Basin, Korea, CARPATH. J. EARTH. ENV., 9 (2), 2014, 125–132.

3. *** Normative regarding the classification of surface water quality in order to establish the ecological status of water bodies. Government Order No. 161/2006, Official Gazette of Romania, Part I, no. 511/ 13.06.2006.

4. Horton, R.K., An index number system for rating water quality, J. Water Pollut. Control Fed., 37(3), 1965, 300–306.

5. Oram, B., Water Quality Index Calculator, According to the book Field Manual for Water Quality Monitoring, 2010, Pennsylvania, USA, 2010. http://www .water-research.net/index.php/water-treatment/water-monitoring/

6. Tyagi, S., Sharma, B., Singh, P., Dobhal, R., Water quality assessment in terms of water quality index, Am. J. Water Resour., 1(3), 2013, 34-38.

7. Rocha, F.C., Andrade, E.A., Lopes, F.B., Water quality index calculated from biological, physical and chemical attributes, Environ. Monit. Assess., 187, 2015, 41–63.
8. Sutadian, A.D., Muttil, N., Yilmaz, A., Perera, C., Development of River Water Quality Indices - A Review, Environ. Monit. Assess., 188 (1), 2016, 58. doi: 10.1007/s10661-015-5050-0.
9. Sener, S., Sener, E., Davraz, A., Evaluation of water quality using water quality index (WQI) method and GIS in Aksu River (SW-Turkey), Sci. Total Environ., 584–585, 2017, 131–144.
10. ***European waters - assessment of status and pressurest. EEA Report No 7/2018. Luxembourg: Publications Office of the European Union, 2018 doi:10.2800/303664, https://www.eea.europa.eu/publications/state-of-water
11. *** ISO 5667-1:2007, Water quality. Sampling. Part 1: Guidance on the design of sampling programmes and sampling techniques.
12. *** ISO 5667-3:2013, Water quality. Sampling. Part 3: Preservation and handling of water samples.
13. ***ISO 5667-6:2017, Water quality. Sampling. Part 6: Guidance on sampling of rivers and streams.
14. PathFinder Science Network. Stream Monitoring. Calculating the Overall Water Quality Index. http://www.pathfinderscience.net/stream/cproto4.cfm
15. *** http://water-research.net/watrqualindex/index.htm
16. Gavrilescu, E., Buzatu, G-D., The toxicity level of the lower Jiu water Oltenia. Studii şi comunicări, Ştiinţele Naturii, 30(1), 2014, 202-207.
17. Faur, F., Nyari (Apostu), I-M., Lazăr, M., Study regarding the water quality of Jiu river in Dolj County, Res. J. Agric. Sci., 49 (4), 2017, 118-127.
18. *** 2017, Apele Române, National Administration, Craiova Branch, Report - Management Plans of the Jiu Hydrological Basin in 2016.