Water Quality Index, a Useful Tool for Evaluation of Danube River Raw Water

IULIANA PAUN[1]*, FLORENTINA LAURA CHIRIAC[1], NICOLETA MIRELA MARIN[1], LILIANA VALERIA CRUCERU[1], LUOANA FLORENTINA PASCU[1], CAROL BLAZIU LEHR[1], CORINA ENE[2]

[1]National Research and Development Institute for Industrial Ecology ECOIND, 71-73 Drumul Podu Dambovitei Str., 060652, Bucharest, Romania

[2] Petroleum-Gas University of Ploiesti, Faculty of Economic Sciences, 39 Bucharest Blvd., 100680, Ploiesti, Romania

The Danube River is the major source of drinking water supply for the cities in the southern part of Romania. The study was a descriptive-analytical one and lasted for 9 month. Samples were taken monthly between March 2016 and November 2016. Six sampling sites were selected to evaluate the spatial and temporal changes of water quality along the river. The samples were analyzed based on the standard methods for the following parameters: pH, conductivity (EC), NH_4^+, NO_3^-, Cl^-, suspended solids, PO_4^{3-}, SO_4^{2-}, metals (Fe, Cd, Cr, Pb, Ni, Hg, As, Zn, Cu, Mn). The obtained values were compared with those imposed by the Romanian environmental legislation. An efficient and simplified method to express the quality of water used for consumption is provided by the Water Quality Index (WQI). WQI reflects the quality of water in a single value by comparing data obtained from the investigation of a number of physico-chemical parameters to the existing limits. The evaluation of water quality was performed using the Water Quality Index of the Canadian Council of Ministries of the Environment (CCME WQI). Water quality indices were classified as: excellent, good, medium, bad and very bad. The results indicated the water quality classification as "good" in all six sampling selected sites.

Keywords: drinking water quality, Danube River, physico-chemical parameters, raw water, WQI

Water is the most important natural resource of the ecosystem, having an important role both as drinking supply and for economic sectors. Water sources may be mainly in the form of rivers, lakes, glaciers, rain water or ground water. The availability and quality of either surface or ground water have been deteriorated by increasing population, industrialization and urbanization.

The Danube is the second longest river of Europe (after the Volga) and is the only European river that flows from West to East. The Danube hydrological regime is characterized by the existence of significant variations of the level and flow during the year and over the time [1].

Being a relevant resource for several water uses [2], Danube River is one of the main sources of drinking water for many surrounding cities/villages (for more than 700000 inhabitants) [3]. Given that for some areas it is the only drinking water source (for example: Danube Delta area) [4], an important issue related to the drinking water quality is associated with the pollution of raw water [5].

In Romania, the role of the Danube River as local and European waste water collector makes it an important source of pollution in the Black Sea [6], as the river receives discharges from agricultural, industrial and urban sources [7, 8].

Growing concern for Danube water quality is mainly determined by the fact that it is an important source of drinking water for riparian population, in some cases without being subjected to any process of drinking water abstraction [9].

The study of the surface water as a complex multi-component system depends on the knowledge and application of facts, principles, and methods from chemistry, physics, geology, hydrology, meteorology, mathematics and other sciences for the purpose of solving the essential ecological problems. The particularity and complexity of the surface water chemical composition and of quality indicators (representing the effects of various dissolved substances such as mineral and organic matter, gases, colloids, suspended particles, and microorganisms present in water through natural or artificial processes) stress the importance of applying quality index methods for their assessment by identifying a mutual factor that emphasizes quality as a whole [10].

Traditionally, drinking water quality status is professionally communicated by comparing the individual physical, chemical and biological parameters with guideline values. The limits of those parameters that are harmful to human health have been established at national or international level (WHO, EPA, MECC) by various laws, regulations, normatives.

The water quality index aims at assessing the quality of water on the basis of one system which converts all the individual parameters and their concentrations - present in a sample - into a single value.

Numerous water quality indices (National Sanitation Foundation Water Quality Index (NSFWQI), Canadian Council of Ministers of the Environment Water Quality Index (CCMEWQI), British Columbia Water Quality Index (BCWQI), Oregon Water Quality Index (OWQI)) have been formulated all over the world, allowing to easily assess the overal water quality within a particular area promptly and efficiently [11 -15].

The Canadian Council of Ministers of the Environment Water Quality Index (CCME WQI) provides an overall measure of the suitability of water bodies to support aquatic life at selected monitoring sites in Canada. The indicator is based on applications of the Water Quality Index (WQI). Given that aquatic life can be influenced by the presence of hundreds of both natural and anthropogenic substances present in water, the WQI provides a useful tool that allows

* email: iuliana.paun@incdecoind.ro; Phone: + (40) 722.437.605

experts to translate vast amounts of water quality monitoring information into a simple overall rating [16,17].

The Danube, as the most important river in Europe, is the subject of numerous investigations of various aspects. The Danube River is the major source of drinking water supply for the cities in the South part of Romania.

The aim of the study was to analyze the surface water quality of the Danube River and its tributary Jiu River, also used as a source for drinking water, using the CCMEWQI model.

Experimental part

Sampling

In order to achieve a more accurate assessment of the Danube River water quality, the analyzed samples were taken from five sampling points located at the entrance to the drinking water treatment plant of the following cities: Drobeta Turnu Severin, Calafat, Calarasi, Braila (Gropeni, Chiscani) (fig. 1) and one sampling point located at the Jiu River, tributary of the Danube River, at the entrance to the drinking water treatment plant of the city Isalnita. The water samples were collected during three different seasons (spring, summer and autumn), between March 2016 and November 2016. Samples were collected once a month in polythene bottles. Sampling was followed by conservation, marking and transport to the laboratory.

Parameters and applied methods

The methods used for monitoring quality parameters are standardized.

The physical-chemical parameters namely pH, electrical conductivity (EC), ammonium (NH_4^+), nitrate (NO_3^-), chloride (Cl^-), fluoride (F^-), suspended matter (SM), phosphate (PO_4^{3-}), sulphate (SO_4^{2-}), metals: iron (Fe), cadmium (Cd), chromium (Cr), lead (Pb), nickel (Ni), mercury (Hg), arsenic (As), zinc (Zn), cooper (Cu), manganese (Mn) were analyzed using electrochemical, volumetric, UV-Vis spectrometry, respectively inductively coupled plasma atomic emission spectrometry (ICP-EOS) methods. All analyses were performed in accreditation system according to SR EN ISO 17025:2015 reference standard [18].

Equipment

Determinations of *p*H, fluoride, and electrical conductivity were performed by electrochemical method using a portable WTW 350i Multipara meter. For the determination of sulfate, phosphate, nitrate and ammonium ions, an UV-VIS Lambda 25 Spectrometer, type Perkin Elmer was used. The metallic elements were analyzed after treatment (digestion with ultrapure nitric acid) on an Optima 5300DV Perkin Elmer Spectrometer (ICP-EOS).

Quality control and assurance

All the reagents (Merck and Sigma) used in the determinations were of analytical purity. The quality control of the data was carried out using certified reference materials for the calibration curves, duplicate samples, and participation to Proficiency Test Schemes.

Water Quality Index

The CCME WQI relates water quality data to the various beneficial uses of water using relevant water quality guidelines as benchmarks. Each index is calculated for an individual monitoring site during a chosen reference period. Water samples collected over this period of time are analyzed for a suite of water quality parameters. The measured values of each parameter are compared to the appropriate water quality guidelines. These are called tests. The percentage of parameters and tests that fail to meet the guidelines, as well as the deviation from the guideline for tests that do not meet guidelines, are captured in three factors used in the calculation of the index. These factors are as follows: scope (F_1), frequency (F_2), and amplitude (F_3). The index yields a number between 0 and 100. A higher number indicates better water quality (1).

$$CCME\ WQI = 100 - \frac{\sqrt{(F_1^2+F_{12}^2+F_3^2)}}{1.732} \qquad (1)$$

Scope (F_1): The scope factor represents the percentage of the total number of parameters that fail to meet the water quality guidelines at any time during the reference period (2).

Frequency (F_2): The frequency factor represents the percentage of individual tests that fail to meet the water quality guidelines. (3)

$$F_1 = \left(\frac{number\ of\ failed\ parameters}{total\ number\ of\ parameters}\right) x100 \qquad (2)$$

$$F_2 = \left(\frac{number\ of\ failed\ tests}{total\ number\ of\ tests}\right) x100 \qquad (3)$$

A failed test occurs when an individual parameter value within a sample exceeds the guideline. The total number of failed tests represents the total number of failed parameter values in every sample during the reference period. The total number of tests for an individual site is calculated by multiplying the average number of parameters per sample by the total number of samples during the reference period.

Amplitude (F_3): The amplitude factor represents the average deviation of failed test values from their respective guidelines. The relative deviation of a failed test from the guideline is termed an excursion and is calculated as follows:

Fig. 1. The cities crossed by the Danube River from the entrance to the country until the Black Sea (https://commons.wikimedia.org/wiki/File:Dunarea_romaneasca.png)

-when the test value must not exceed the guideline (4);
-when the test value must not fall below the guideline (5).

$$excursion_i = \left(\frac{failed\ test\ value_i}{guideline\ value_i}\right) - 1 \qquad (4)$$

$$excursion_i = \left(\frac{guideline\ value_i}{failed\ test\ value_i}\right) - 1 \qquad (5)$$

The collective amount by which individual tests are out of compliance is calculated as follows where ***nse*** is the normalized sum of the excursions from the guidelines (6). The F_3 factor is then calculated by a formula that scales the ***nse*** to yield a range between 0 and 100 (7).

$$nse = \frac{\sum excursion_i}{total\ number\ of\ test} \qquad (6)$$

$$F_3 = \frac{nse}{(0.01nse+0.01)} \qquad (7)$$

The WQI measures the frequency and extent to which selected parameters exceed water quality guidelines at individual monitoring sites. Water quality guidelines are numerical values for physical, chemical, radiological, or biological characteristics of water that indicate that adverse effects may be occurring when exceeded. The water quality guidelines used in the calculations are those defined for the protection of aquatic life. They include national guidelines developed by the CCME, as well as provincial and site-specific guidelines developed by federal, provincial, and territorial partners. If a guideline value is exceeded at a given site, there is an increased probability of an adverse effect on aquatic life at that site [16, 17].

Therefore, five ranges have been suggested to categorize the water qualities, which are summarized in table 1 [19].

Water quality indices have proved to be a useful tool for summarizing and transmitting information generated by individual parameters and their concentrations present in a sample to managers and the general public [20].

Results and discussions

The results obtained for the analyzed parameters were compared to the maximum limits allowed (table 2) by the NTPA-013 Quality Norm that must be met by surface waters used as source for drinking water [21].

The data of these parameters presented in tables 3 to 8 are used in the calculation of CCME WQI indices for different sampling points. The values of water quality indices are ranked by comparing to the categories listed in table 1.

Generally, the values of *p*H reflect a change in the quality of the water source. In this study, the *p*H value of the Danube River water ranged from 6.8 to 7.9. For Jiu River water the value for *p*H ranged from 7.2 to 7.6. All values for pH were within the permissible range for surface waters used as source for drinking water.

Another monitored parameter was electrical conductivity which is a value that represents the concentration of soluble salts in water. For this parameter, the values for electrical conductivity were lower than MAV (1000 µS/cm) for all the sampling points.

Ammonia is an indicator of high pollution due to organic substances. The maximum concentration of ammonium in surface waters used as source for drinking water is 0.05 mg/L [21]. The variation of ammonium indicator value reveals that samples collected in March (Calafat, Calarasi, Chiscani), June (Chiscani, Gropeni), July and September (Calarasi, Chiscani, Gropeni), August (Calarasi), October (Drobeta Turnu Severin), November (Calarasi, Gropeni) exceeded the limit prescribed by the norm. The values recorded for the samples from Isalnita (Jiu River) were below the maxim limit prescribed by the norm NTPA-013.

Fluoride is a trace element typically present in water at levels from 0.1 to 1.5 mg/L. It may be added extra to water as a measure to prevent tooth decay in humans (0.7 to 1.2 mg/L). The fluoride recommended concentration is 0.07 mg/L (A1R), the fluoride mandatory value is 1.5 mg/L (A1O) for surface water used as source for drinking water. The

Table 1

CRITERIA ACCORDING TO CANADIAN COUNCIL OF MINISTERS OF THE ENVIRONMENT, WATER QUALITY INDEX (CCME WQI)

WQI Value	Rating of Water Quality
95 - 100	Excellent - Water quality meets all criteria for use as a source of drinking water
80 - 94.9	Good - Water quality rarely or narrowly violates criteria for use as a source of drinking water.
65 - 79.9	Fair - water quality sometimes violates criteria, possibly by a wide margin, for use as a source of drinking water
45 - 64.9	Marginal - water quality often violates criteria for use as a source of drinking water by a considerable margin
0 - 44.9	Poor - water quality does not meet any criteria for use as a source of drinking water

Table 2

MAXIMUM ADMISSIBLE VALUE (MAV) ACCORDING TO NTPA-013 QUALITY NORM

Determined parameter	MU	MAV*		Determined parameter	MU	MAV	
		A1R	A1O			A1R*	A1O*
pH	pH units	6.5-8.5	6.5-8.5	Hg	µg/L	0.50	1.00
EC	µS/cm	1000	1000	As	µg/L	10	50
Suspended matter (SM)	mg/L	25	25	Zn	µg/L	500	3000
Fe	µg/L	100	300	SO_4^{2-}	mg/L	150	250
Mn	µg/L	50	50	NH_4^+	mg/L	0.05	0.05
Cd	µg/L	1.00	5	NO_3^-	mg/L	25	50
Cr	µg/L	50	50	PO_4^3	mg/L	0.40	0.40
Cu	µg/L	20	50	Cl^-	mg/L	200	200
Pb	µg/L	50	50	F^-	mg/L	0.70	1.50
Ni	µg/L	50	50				

* A1O = mandatory values, A1R = recommended values

Table 3

VARIATION OF THE PHYSICO-CHEMICAL PARAMETERS ANALYZED FOR DROBETA TURNU SEVERIN

Determined parameter	MU	Month								
		III	IV	V	VI	VII	VIII	IX	X	XI
pH	pH units	7.6	7.1	7.4	7.5	7.4	7.3	7.3	7.4	7.5
EC	µS/cm	358	416	376	344	352	393	407	441	464
SM	mg/L	**64**	**28**	20	12	**40**	**36**	12	12	20
Fe	µg/L	**570**	**102**	**262**	95.7	98.1	46.9	97.4	**105**	**233**
Mn	µg/L	**238**	5.1	12	7.6	8.2	9.2	7.9	10.1	6.9
Cd	µg/L	< 0.12	< 0.12	< 0.12	< 0.12	< 0.12	< 0.12	< 0.12	< 0.12	< 0.12
Cr	µg/L	8.9	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	5.7
Cu	µg/L	10.8	3.6	5.5	2	2.3	2.8	5.7	2.6	2.5
Pb	µg/L	8.1	<0.05	0.7	0.5	<0.05	<0.05	<0.05	<0.05	1.1
Ni	µg/L	13	1.8	1.3	1	2.3	< 0.4	1.6	< 0.4	< 0.4
Hg	µg/L	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
As	µg/L	2.7	< 0.2	< 0.2	< 0.2	1.1	1.1	1.4	< 0.2	< 0.2
Zn	µg/L	48.9	8	10	5.5	8.8	17.7	5.3	5.9	9.6
SO_4^{2-}	mg/L	29.08	22.53	19.6	19.68	26.13	34.94	32.71	34.16	42.15
NH_4^+	mg/L	<0.02	<0.02	<0.02	<0.02	0.025	0.035	0.039	**0.054**	0.03
NO_3^-	mg/L	5.75	7.52	3	2.21	2.7	7.56	6.68	3.17	3.5
PO_4^{3}	mg/L	**0.419**	0.188	0.343	0.313	0.122	0.343	0.313	0.432	0.323
Cl^-	mg/L	15.65	19.01	19.38	16.9	18.37	19.97	21.34	22.15	20.3
F^-	mg/L	0.3	0.51	0.1	0.02	0.26	0.2	0.19	0.38	0.11

Table 4

VARIATION OF THE PHYSICO-CHEMICAL PARAMETERS ANALYZED FOR CALAFAT SAMPLING POINT

Determined parameter	MU	Month								
		III	IV	V	VI	VII	VIII	IX	X	XI
pH	pH units	6.8	7.3	7.3	7.5	7.5	7.6	7.5	7.8	7.4
EC	µS/cm	374	415	374	361	338	388	411	437	414
SM	mg/L	**60**	24	**28**	16	16	12	**78**	4	**40**
Fe	µg/L	**339**	**106**	**495**	93	**108**	42.3	38.4	**148**	**177**
Mn	µg/L	13.2	8	20.4	9.2	7.1	10.1	3.7	9.1	8.2
Cd	µg/L	< 0.12	< 0.12	< 0.12	< 0.12	< 0.12	< 0.12	< 0.12	< 0.12	< 0.12
Cr	µg/L	0.91	1.5	1.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	1
Cu	µg/L	3.2	2.6	3.5	1.4	1.9	2	2.4	2.8	2.3
Pb	µg/L	0.9	< 0.05	0.94	< 0.05	< 0.05	0.2	< 0.05	< 0.05	< 0.05
Ni	µg/L	2.5	5.9	1.8	< 0.4	3.3	2.5	< 0.4	<0.4	1.5
Hg	µg/L	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
As	µg/L	0.8	< 0.2	< 0.2	< 0.2	1.2	< 0.2	< 0.2	< 0.2	< 0.2
Zn	µg/L	14.4	4.5	7	15.9	3.9	11.8	2.7	4.5	8.8
SO_4^{2-}	mg/L	42.01	22.06	22.73	32.87	21.47	35.74	31.78	29.22	27.48
NH_4^+	mg/L	**0.12**	< 0.02	< 0.02	< 0.02	< 0.02	0.039	0.037	0.021	0.04
NO_3^-	mg/L	4.86	3.54	2.25	1.15	1.81	6.41	6.41	2.83	2.9
PO_4^{3}	mg/L	0.106	0.022	0.357	0.238	0.134	0.357	0.372	0.282	0.328
Cl^-	mg/L	17.14	19.38	18.64	17.64	16.16	18.6	22.03	21.41	19.68
F^-	mg/L	0.24	0.64	26	0.11	0.25	0.18	0.17	0.41	0.09

value recorded for fluoride was lower than the maximum limits, for all the sampling points.

The high concentration of chloride is considered to be an indication of pollution due to high organic waste of animal origin [22]. For this parameter, the concentrations were lower than the maximum limit (200 mg/L), for all the sampling points.

The sulfate parameter, the predominant form of sulphur in an aquatic ecosystem, is of immense importance as it affects ecosystem productivity, abundance and distribution of biota etc. Nearly all assimilation of sulphur takes place as sulphates but during decomposition of organic matter, sulphur is reduced to hydrogen sulfide which is oxidized rapidly [23]. In an aquatic environment, sulfate does not limit the growth and distribution of biota. The recommended concentration of sulfate is 150 mg/L and the mandatory concentration of sulfate is 200 mg/L. The sulfate concentrations were lower than the maximum limits prescribed by the norm, for all the sampling points.

Phosphate can be found in surface water as a result of domestic waste or of using detergent and fertilizers containing phosphorus. The maximum admissible limit of phosphate in surface water is 0.4 mg P_2O_5/L. Only the sample collected from Drobeta Turnu Severin in March 2016 exceeded that limit.

The nitrate concentrations were situated both recommended and mandatory values for all the sampling points.

Table 5
VARIATION OF THE PHYSICO-CHEMICAL PARAMETERS ANALYZED FOR CALARASI SAMPLING POINT

Determined parameter	MU	Month							
		III	IV	VI	VII	VIII	IX	X	XI
pH	pH units	7.0	7.6	7.5	7.3	7.2	7.5	7.4	7.9
EC	µS/cm	374	441	378	342	348	364	445	429
SM	mg/L	**60**	24	**40**	**72**	24	**40**	24	**36**
Fe	µg/L	**480**	76.2	**180**	**243**	61.5	18.3	54.5	**112**
Mn	µg/L	**52.8**	65	6.6	11.5	2.9	2.1	3.6	5.2
Cd	µg/L	0.2	<0.12	<0.12	<0.12	0.3	0.4	<0.12	<0.12
Cr	µg/L	<0.4	<0.4	<0.4	1.04	0.7	0.6	<0.4	<0.4
Cu	µg/L	7.0	6.7	< 0.3	6.94	3.6	4.9	3	4.1
Pb	µg/L	1.24	< 0.05	< 0.05	0.39	0.6	< 0.05	< 0.05	0.8
Ni	µg/L	3.4	< 0.4	< 0.4	4.59	1.9	< 0.4	< 0.4	< 0.4
Hg	µg/L	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
As	µg/L	<0.2	0.8	<0.2	<0.2	1.9	2.7	1.1	1.8
Zn	µg/L	11.9	6.7	2.47	29.8	16	11.3	9.9	3.6
SO_4^{2-}	mg/L	43.48	57.57	33.91	15.82	37.47	17.63	22.39	41.14
NH_4^+	mg/L	**0.06**	0.023	0.023	**0.071**	**0.069**	**0.097**	<0.02	**0.3**
NO_3^-	mg/L	2.93	5.31	2.65	0.81	3.01	0.97	1.86	1.78
PO_4^3	mg/L	0.358	0.387	0.179	0.093	0.112	0.223	0.085	0.1
Cl^-	mg/L	18.64	30.94	22.36	24.25	19.47	24.1	25.84	23.89
F^-	mg/L	0.3	0.3	0.26	0.12	0.63	0.15	0.28	0.18

Table 6
VARIATION OF THE PHYSICO-CHEMICAL PARAMETERS ANALYZED FOR CHISCANI SAMPLING POINT

Determined parameter	MU	Month								
		III	IV	V	VI	VII	VIII	IX	X	XI
pH	pH units	7.1	7.3	7.4	7.5	7.3	7.3	7.3	7.5	7.3
EC	µS/cm	398	422	413	374	369	347	422	486	524
SM	mg/L	**56**	22	**56**	**28**	**48**	16	**40**	12	20
Fe	µg/L	**117**	**404**	**250**	51.2	84.8	16.2	**160**	35.6	**109**
Mn	µg/L	5.1	32.5	8.11	3.8	4.2	1.4	12.6	3.2	5.7
Cd	µg/L	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4
Cr	µg/L	< 0.4	< 0.4	< 0.4	< 0.4	1.1	< 0.4	< 0.4	< 0.4	< 0.4
Cu	µg/L	3.7	5	4.54	2.3	4.2	3.3	8.7	2.8	2.6
Pb	µg/L	0.5	<0.05	0.5	<0.05	<0.05	<0.05	1.6	<0.05	0.4
Ni	µg/L	1.1	1.8	3.61	<0.4	<0.4	<0.4	1.3	<0.4	<0.4
Hg	µg/L	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
As	µg/L	< 0.2	1.2	0.9	< 0.2	1.4	< 0.2	1.2	3.2	1.1
Zn	µg/L	7.3	11.3	7	5.6	7.7	4.3	7.7	2.6	2.5
SO_4^{2-}	mg/L	42.2	59.6	55.07	55.52	58.39	32.66	36.1	16.61	34.18
NH_4^+	mg/L	**0.11**	<0.02	0.025	**0.12**	**0.17**	0.047	**0.11**	<0.02	**0.85**
NO_3^-	mg/L	1.45	3.98	5.75	3.26	4.1	1.01	0.86	1.45	1.63
PO_4^3	mg/L	0.312	0.283	0.119	0.127	0.076	0.164	0.125	0.283	0.343
Cl^-	mg/L	21.62	26.84	27.21	22.04	23.18	19.28	24.1	29.61	34.44
F^-	mg/L	0.27	0.24	0.21	0.3	0.21	0.21	0.28	0.28	0.27

According to NTPA-013, the recommended value for iron is 100 µg/L and the mandatory values of iron is 300 µg/L. The variation of iron indicator value reveals that samples collected in March and November (Drobeta Turnu Severin, Calafat, Calarasi, Chiscani), April and May (Drobeta Turnu Severin, Calafat, Chiscani, Gropeni), June (Calarasi), July (Calafat, Calarasi) and September (Chiscani, Gropeni), October (Drobeta Turnu Severin, Calafat), exceeded the maximum admissible limit. The values recorded for the Isalnita (Jiu River) samples exceeded the limit value only in May and June 2016.

Regarding manganese parameter, the value reveals that samples collected in March (Drobeta Turnu Severin, Calarasi) and April (Gropeni) exceed the MAV (50 µg/L).

Suspended matter is the main problem for most of the analyzed samples. The suspended matter may result from mobilization of sediments, mineral precipitates, or biomass from the water. The variation of suspended matter indicator value reveals that samples collected in March (Drobeta Turnu Severin, Calafat, Calarasi, Chiscani, Gropeni), April and August (Drobeta Turnu Severin), May (Calafat, Chiscani, Gropeni), June and November (Calarasi, Chiscani), July (Drobeta Turnu Severin, Calarasi, Chiscani, Gropeni), September (Calafat, Calarasi, Chiscani, Gropeni) were situated over the MAV. The values recorded for the samples from Isalnita (Jiu River) exceeded the limit in March, May, September, and November 2016.

In conclusion, variations and exceeding of the imposed limits of suspended matter, iron, manganese, ammonium and phosphate have been observed at the Danube River sampling points. For the surface water collected from the

Table 7
VARIATION OF THE PHYSICO-CHEMICAL PARAMETERS ANALYZED FOR GROPENI SAMPLING POINT

Determined parameter	MU	Month								
		III	IV	V	VI	VII	VIII	IX	X	XI
pH	pH units	7.2	7.4	7.5	7.4	7.4	7.4	7.4	7.3	7.3
EC	µS/cm	398	435	420	375	372	348	421	445	489
SM	mg/L	**32**	20	**48**	24	**44**	16	**36**	8	10
Fe	µg/L	58.6	**628**	**234**	27.8	26.2	32.9	**151**	49.2	17.9
Mn	µg/L	6	**50,5**	7.4	2.3	1.9	1.2	11.7	7.1	1.1
Cd	µg/L	<0.4	<0.4	<0.4	<0.4	0.4	<0.4	<0.4	<0.4	<0.4
Cr	µg/L	< 0.4	15.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	< 0.4	<0.4
Cu	µg/L	3.3	9.52	3.87	2.3	3.9	3.2	3.4	3.1	5.3
Pb	µg/L	0.2	5.8	<0.05	<0.05	<0.05	<0.05	0.6	<0.05	<0.05
Ni	µg/L	0.9	29.3	3.87	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4
Hg	µg/L	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
As	µg/L	0.4	1.3	<0.2	1.5	1.7	1.1	1.5	2.7	<0.2
Zn	µg/L	7.2	122	5.3	6.1	2.2	2.1	6.6	3.3	3.8
SO_4^{2-}	mg/L	38.69	58.2	49.73	38.54	41.26	34.6	39.62	16.91	31.21
NH_4^+	mg/L	0.05	0.03	0.026	**0.11**	**0.13**	< 0.02	**0.16**	0.028	**0.78**
NO_3^-	mg/L	4.17	3.54	3.54	3.02	3.93	1.26	2.73	2.04	2.26
PO_4^3	mg/L	0.313	0.164	0.135	0.094	0.119	0.116	0.194	0.298	**0.536**
Cl^-	mg/L	22.36	27.21	28.33	22.78	22.71	19.97	24.41	24.79	32.33
F^-	mg/L	0.27	0.31	0.19	0.28	0.23	0.24	0.21	0.24	0.21

Table 8
VARIATION OF THE PHYSICO-CHEMICAL PARAMETERS ANALYZED FOR ISALNITA SAMPLING POINT

Determined parameter	MU	Month								
		III	IV	V	VI	VII	VIII	IX	X	XI
pH	pH units	7.6	7.2	7.2	7.4	7.3	7.5	7.4	7.5	7.4
EC	µS/cm	335	279	269	246	279	382	383	369	265
SM	mg/L	**28**	20	**40**	20	12	8	**58**	8	**32**
Fe	µg/L	16.3	7.2	**840**	**313**	24.8	5.8	18.3	16.4	6.9
Mn	µg/L	17.6	5.6	42	48.9	15.4	2.6	2.1	5.1	10
Cd	µg/L	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12	<0.12
Cr	µg/L	5.2	<0.4	4	3.4	<0.4	<0.4	<0.4	<0.4	<0.4
Cu	µg/L	3.7	2.4	5.1	12.5	1.2	2	4.9	2.8	1.6
Pb	µg/L	<0.05	<0.05	1.3	3.3	<0.05	<0.05	<0.05	<0.05	<0.05
Ni	µg/L	2.2	<0.4	8.1	5.6	<0.4	<0.4	<0.4	<0.4	<0.4
Hg	µg/L	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005
As	µg/L	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	2.7	<0.6	<0.6
Zn	µg/L	8.2	6.5	14	21.4	5.7	10.9	11.3	1.7	8.8
SO_4^{2-}	mg/L	47.34	27.2	23.73	20.37	54.84	48.39	48	61.03	37.25
NH_4^+	mg/L	<0.02	<0.02	0.028	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	0.5
NO_3^-	mg/L	1.64	1.26	1.1	0.97	3.05	2.92	2.21	4.7	2.3
PO_4^3	mg/L	0.083	0.149	0.298	0.18	0.113	0.086	0.09	0.268	0.106
Cl^-	mg/L	12.67	11.93	11.18	8.08	11.02	12.4	13.8	11.77	10.5
F^-	mg/L	0.09	0.53	0.11	0.24	0.39	0.38	0.32	0.47	0.17

Jiu River, exceeding of suspended matter and iron were noticed.

The overall water quality index CCMEWQI for each sampling point was calculated based on the total values of parameters examined in tables 2 to 8. The total number of examined parameters, the total number of individual test, the number of variable not meeting the objective (MAV) and the number of tests not meeting the objectives for each sampling point are presented in table 9.

The calculated values and rating of WQI are presented in table 10.

The WQI of 85.45 for recommended values (A1R) and 86.08 for mandatory values (A1O) indicates that the quality of Danube River surface water is ranked as *good* (table 1).

The above mentioned values represent mean of the CCMEQI calculated for all investigated cities situated on Danube River (Drobeta Turnu Severin, Calafat, Calarasi, Chiscani, Gropeni). The water quality index indicates that water quality rarely or narrowly violates criteria for use as a source of drinking water.

The WQI of 90.84 for recommended values (A1R) and also for mandatory values (A1O) indicates that the surface water quality from Jiu River at Isalnita City is ranked as *good*, which means that the water quality rarely or narrowly violates criteria for use as a source of drinking water.

Table 9

TOTAL NUMBER OF PARAMETERS, TESTS AND VARIABLES

	Total number of exanimated parameters	Total number of individual test	Number of variable not meeting objective (MAV)	Number of tests not meeting objective (MAV)
Drobeta Turnu Severin				
NTPA 013 A1 R	19	171	5	12
NTPA 013 A1 O	19	171	4	7
Calafat				
NTPA 013 A1 R	19	171	3	11
NTPA 013 A1 O	19	171	4	7
Calarasi				
NTPA 013 A1 R	19	152	4	15
NTPA 013 A1 O	19	152	4	12
Chiscani Braila				
NTPA 013 A1 R	19	171	3	15
NTPA 013 A1 O	19	171	3	11
Gropeni Braila				
NTPA 013 A1 R	19	171	4	11
NTPA 013 A1 O	19	171	4	9
Isalnita				
NTPA 013 A1 R	19	171	2	6
NTPA 013 A1 O	19	171	2	6

Table 10

CCMEWQI WATER QUALITY INDEX VALUE FOR EACH SAMPLING POINT

	F1	F2	nse	F3	CCMEQI	Rank
Drobeta Turnu Severin						
NTPA 013 A1 R	26.32	7.02	0.324	24.44	80.87	Good
NTPA 013 A1 O	21.05	4.09	0.305	23.4	81.67	Good
Calafat						
NTPA 013 A1 R	15.79	6.43	0.078	7.25	89.30	Good
NTPA 013 A1 O	15.79	4.09	0.070	6.54	89.85	Good
Calarasi						
NTPA 013 A1 R	21.05	9.87	0.106	9.55	85.47	Good
NTPA 013 A1 O	21.05	7.89	0.092	8.42	86.14	Good
Chiscani Braila						
NTPA 013 A1 R	15.79	8.77	0.185	15.58	86.33	Good
NTPA 013 A1 O	15.79	6.43	0.171	14.58	87.04	Good
Gropeni Braila						
NTPA 013 A1 R	21.05	7.24	0.141	12.39	85.29	Good
NTPA 013 A1 O	21.05	5.92	0.131	11.55	85.72	Good
Danube River						
NTPA 013 A1 R					**85.45**	Good
NTPA 013 A1 O					**86.08**	Good
Isalnita						
NTPA 013 A1 R	10.53	3.51	0.128	11.33	**90.84**	Good
NTPA 013 A1 O	10.53	3.51	0.128	11.33	**90.84**	Good

Conclusions

The results of the study based on the water quality indices (CCMEWQ) calculated after characterization of samples in five sampling points along the Danube River and one sampling point of Jiu River demonstrate that both rivers correspond to a good quality class.

The parameters used for the characterization of surface water quality rarely or narrowly violates criteria for use as a source of drinking water. As a consequence, the surface water collected from Danube River at Drobeta Turnu Severin, Calafat, Calarasi, Chiscani and Gropeni and also surface water from Jiu River collected on Isalnita can be used for drinking water production.

Acknowledgment: The work has been funded by National Authority for Scientific Research and Innovation through the Program Nucleu, project code PN 16-25.02.05.

References

1.STANESCU, E., VOSNIAKOS, F., SCRADEANU, D., PAUN, I., LUCACIU, I., STANESCU, B., CRUCERU, L., VASILE, G., IANCU, V., NICULESCU, M, J. Environ. Prot. Ecol., **16**, no.4, 2015, p. 1371.

2.PETRE, J., CRUCERU, L., NICOLAU, M., VASILE, G., MITRITA, M., IANCU, V., Rev. Chim. (Bucharest), **55**, no. 4, 2004, p. 264.

3.ITICESCU C., MURARIU G., GEORGESCU L.P., BURADA A., TOPA C.M. , Rev. Chim. (Bucharest), **67**, no. 9, 2016, p. 1843.

4.GHEORGHE S., CATRANGIU A., LUCACIU I., TIRON O., COSMA C., STOICA C., DINU L., Water Sci Tech-W Sup, **15**, no. 1, 2015, p 66.

5.VASILE, G**.,** DINU, C., ENE, C., CRUCERU, L., DAMIAN, N., STANCU, A., Rev. Chim. (Bucharest), **66**, no. 1, 2015, p. 92.
6.RADU V.M,. IVANOV A.A., IONESCU P., GYORGY D., DIACU E., Rev. Chim. (Bucharest). **67**, no. 3, 2016, p. 391.
7.VOSNIAKOS, F., PETRE, J., PASCU, L., VASILE, G., NICOLAU, M., STANILOAE, D., IANCU, V., CRUCERU, L., GOLUMBEANU, M., Fre. Env. Bull., 2010, **19**, no. 1, p. 20.
8.VOSNIAKOS, F., PASCU, L., PETRE, J., CRUCERU L., VASILE, G., IANCU, V., DINU C., NICULESCU M., NICULAE A., M. NICOLAU, M. GOLUMBEANU, Fre. Env. Bull., **21** no. 2, 2012, p. 233.
9.PETRE J., GALAON T., IANCU V. I., VASILE G. G., STANESCU E., PASCU L. F., SIMION M., CRUCERU L., Rev. Chim. (Bucharest). **67**, no. 8, 2016, p. 1436**.**
10.TAKIÆ L.M., MLADENOVIÆ-RANISAVLJEVIC I., NICOLIÆ V.D., NICOLIÆ L.B., VUKOVIÆ M.V., ZIVKOVIC, N.V., Advanced technologies, **1**, no.1, 2012, p.58.
11.POONAM T., TANUSHREE B., SUKALYAN C., Int. J. Adv. Chem., **1**, no.1, 2015,
12.ABBASI S.A., Water quality indices, state of the art report, National Institute of Hidrology, scientific contribution no. INCOH/SAR-25/2002, Roorkee: INCOH, 73, 2002.
13. KANNEL P.R., LEE Y.S., KANEL S.R., KHAN S.P., Environ, Monit. Assess., **132**, 2007, p.93.
14.LUMB A, HALLIWELL D., AND SHARMA T, Environ, Monit, Assess., **113**, 2006, p. 411.
15.SHARIFI M, IAHSV, **197**, 1990, p.163.
16.*** CCME (2001). Canadian water quality guidelines for the protection of aquatic life: CCME Water QualityIndex 1.0, user's manual. In Canadian environmental quality guidelines, 1999, Canadian Council of Ministers of the Environment, Winnipeg, Manitoba. Retrieved on March 29, 2007, from http: //www.ccme.ca/assets/pdf/wqi_usermanualfctsht_e.pdf.
17.*** CCME (2005). Canadian environmental sustainability indicators. Freshwater quality indicator: Data sources and methods. Catalogue no.16-256-XIE. Retrieved on March 29, 2007, from http://www.statcan.ca/bsolc/english/bsolc?catno=16-256-XIE#formatdisp.
18.*** SR EN ISO/CEI 17025:2005. General requirements for the competence of testing and calibration laboratories.
19.HURLEY T., SADIQ R, MAZUMDER A., Water Res, **46**, 2012, p. 3544.
20.PAUN I., CRUCERU L. V., CHIRIAC F. L., NICULESCU M., VASILE G. G., MARIN N. M., International Symposium The Environment and the Industry, 2016, p. 395.
21.*** NTPA 0013 Quality Norms that must be met by surface waters used as source for drinking water, approved by HG no. 100/2002 and modified by HG no. 567/2006.
22.GOPALKRUSHNA, M.H., 2011, **1**, no. 2, p. 183.
23.WETZEL, R.G. Liminology, 1, 2000, p.3.

Manuscript received: 15.01.2017