Smart Energy and Sustainable Environment

2020, *23*(2): 93-106, https://doi.org/10.46390/j.smensuen.23220.432

CWQI INDEX AS QUALITY INDICATOR OF SURFACE WATER - AN APPROACH ON THE OLT RIVER, ROMANIA

Claudia Sandru*, Mihaela Iordache, Andreea Maria Iordache, Roxana Elena Ionete, Ramona Ionela Zgavarogea

National Research and Development Institute for Cryogenics and Isotopic Technologies – ICSI Rm. Valcea, Uzinei Street no. 4, P.O. Râureni, Box 7, 240050 Rm. Valcea, Romania

Abstract:

This work aims at assessing the pollution degree of the Olt River (Romania), based on the Canadian Water Quality (CWQI) index, by monitoring twenty twos locations along the middle and south part of the river basin for a period of four months, from March to October, during 2018. A comprehensive physico-chemical analysis involving major cations (Ca^{2+}, Mg^{2+}, Na^{+}), anions (Cl^{-}, SO_4^{2-}, $N\text{-}NO_3^{--}$) and general parameters (pH, electrical conductivity, total dissolve solids) was performed for this purpose. Results demonstrated that CWQI values classified the water in the investigated sectors of the river as fair (values between 66.08 to 79.05), marginal (56.22 to 64.63) and good (value of 85.60). This method appears to be more systematic and provide comparative evaluation of the water quality in different seasons of the year. The results showed that there is a large variations in the parameters in different sections of the river due to different anthropogenic factors. Therefore, this index may be helpful as marker for the public to better understand the quality of water, but also as tool for water quality management.

Article info:

Received 22 October 2020
Received in revised form 02 November 2020
Accepted 02 November 2020
Available online 03November 2020

Keywords*:*
Canadian water quality index, Pollution, Surface water

How to cite: Sandru, C., Iordache, M., Iordache, A.M., Ionete, R.E., Zgavarogea, R. I. (2020) - CWQI index as quality indicator of surface water - An approach on the Olt River, Romania, *Smart Energy and Sustainable Research*, *23*(2), 93-106, https://doi.org/10.46390/j.smensuen.23220.432.

1. INTRODUCTION

Water quality is one of the most important environmental concerns worldwide (Bilgin, 2018). With rapidly growing populations and industrialization among developing countries, anthropogenic activities, including industrial evacuation, city sewerage, agricultural and domestic evacuation, have increasingly led to deteriorating water quality (Liu et al., 2012; Zhai, et al., 2014). Water in nature presents a special relevance due to the multiple roles it

**Corresponding author: Claudia Sandru, E-mail: claudia.sandru@icsi.ro, ORCID: 0000-0002-5168-7290*

performs and the many areas in which it is used (Smitha et al, 2007). Above all, water is the most important and irreplaceable habitat and environmental skills of aquatic organisms. Water pollution occurs due to industrial and agricultural activities, man-made activities and erosion (Bilgin, 2018). Water materials and discharges of industrial effluents into surface waters have gradually depleted water quality in recent times (Onojake et al., 2011; Varol and Sen, 2009; Boyacioglu, 2007). Monitoring and evaluation of the quality of aquatic ecosystems is based on establishing physical, chemical and biological properties of the waters. Evolution in quality of aquatic ecosystems depends on a multitude of natural and anthropogenic factors and is the more complex as areas assessed and dimensions of the watershed are more important. Anthropogenic causes are related to agricultural and industrial activities, as well as the existence of urban areas, and sustainable (Yadav et al., 2013).

CWQI index provides scientific information and summarizes in a single number if water fits into the appropriate quality class to be used in human activities. Also, indicate any changes in the relative quality of the water. CWQI is an important indicator that can be relatively easily determined and its importance stems from the crucial role of the water resources (Onwughara et al., 2013). The Canadian Council of Ministers of the Environment Water Quality Index (CCME-CWQI) is an important technique in water quality assessment. CCME-CWQI has been used in many countries and has received a high rating due to several merits. It has been used to evaluate the water quality in rivers (de Almeida and de Oliveira, 2018; Zotou et al., 2019; Gikas, 2017; Tsaboula et al., 2019), lakes/reservoirs (Gao et al., 2016; Trikoilidou et al., 2017), surfacewater (Bilgin, 2018), groundwater (Adimalla et al., 2018; Wagh et al., 2017; Venkatramanan et al., 2016), and drinking water (Bereskie et al., 2017). The index provides a unique value, which represents the general adequacy of water quality for a specific intended purpose, such as drinking, irrigation or protection of aquatic life (Miyittah et al., 2020; Bilgin A., 2018, Terrado, 2010). CCME-CWQI model consists of three measures of variance from selected water quality objectives (scope, frequency, and amplitude). These three measures of variance combine to produce a value between 0 and 100 that represents the overall water quality. CWQI is suggested to be a helpful tool that enables the decision makers to evaluate quality of surface waters. CWQI was calculated to assess the spatial and temporal variability and identify the of water quality (Feng et al., 2016).

The present study deals with the assessment of Olt River water quality by a comprehensive analytical investigation and calculation of the water quality index.

2. MATERIALS AND METHODS

2.1. Study area

The investigation area was set on the Olt River (Romania) that flows into the Danube River near Turnu Magurele, at Islaz, and has a total length of 615 km. The middle and lower part of the Olt River catchment includes 19 lakes mainly used for electricity and irrigation systems. The average flow of the Olt River is 140 m^3s^{-1} with monthly variations from 25 to 300 m^3s^{-1}.

Water samples were collected from 22 locations, including 19 accumulation lakes, 1 point from the Olt River before flowing into the Danube River, and 2 points in the Danube River (upstream and downstream of the Olt River). The samples were taken during March and October, 2018, from 22 selected locations (Table 1).

2.2. Sample Collection and Pre-treatment

Standard methods were used for collecting and analyzing the water samples (SR EN ISO 5667-6, 2017). Water sampling was made in clean glass bottles, which were rinsed with deionized water and stored to the laboratory for up to 24 h, at 4°C, to retard the microbiological activity as well as the rates of possible physical and chemical reactions.

Table 1. Water sampling points

Code	Coordinates	Water sampling locations	Code	Coordinates	Water sampling locations
A1	N: 45°24’337 E: 24°18’255	Cornet accumulation lake, Valcea county	A12	N: 43°42’693 E: 24°46’610	Danube River - upstream the Olt River, Teleorman county
A 2	N: 45°21’312 E: 24°16’350	Lotru accumulation lake, Valcea county	A13	N: 43°44’630 E: 24°46’777	Olt River - Islaz, before flowing into the Danube River, Teleorman county
A3	N: 45°17’200 E: 24°18’365	Turnu accumulation lake, Valcea county	A14	N: 43°42’792 E: 24°53’463	Danube River - downstream the Olt River, Teleorman county
A4	N: 45°14’522 E: 24°20’855	Calimanesti accumulation lake, Valcea county	A15	N: 43°48’682 E: 24°42’318	Izbiceni accumulation lake, Olt county
A5	N: 45°10’723 E: 24°22’200	Daesti lake accumulation, Valcea county	A16	N: 43°54’772 E: 24°37’680	Rusanesti accumulation lake, Olt county
A6	N: 45°07’510 E: 24°22’382	Ramnicu Valcea accumulation lake, Valcea county	A17	N: 43°54’988; E: 24°37’463	Frunzaru accumulation lake, Olt county
A7	N: 45°00’542 E: 24°17’922	Govora accumulation lake, Valcea county	A18	N: 44°09’468 E: 24°28’415	Draganesti accumulation lake, Olt county
A8	N: 44°55’030 E: 24°14’983	Babeni accumulation lake, Valcea county	A19	N: 44°15’517 E: 24°37’680	Ipotesti accumulation lake, Olt county
A9	N: 44°51’468 E: 24°16’927	Ionesti accumulation lake, Valcea county	A20	N: 44°25’322 E: 24°20’738	Slatina accumulation lake, Olt county
A10	N: 44°46’620 E: 24°16’935	Zavideni accumulation lake, Valcea county	A21	N: 44°26’877 E: 24°19’087	Arcesti accumulation lake, Olt county
A11	N: 44°07’790 E: 24°17’888	Dragasani accumulation lake, Valcea county	A22	N:44°32’762 E: 24°20’370	Strejesti accumulation lake, Olt county

2.3. Analytical procedure

The analytical methods used in environmental monitoring have greatly evolved.

For unstable parameters such as electrical conductivity (EC) and pH were measured at the sampling site. Samples were taken to the laboratory for analysis of physico-chemical parameters like calcium, magnesium, sodium, chlorides, sulphate, nitrate, electrical conductivity (EC), pH, and total dissolved solids (TDS).

The nitrate and sulphate concentrations in samples were determined by colorimetric method, using a UV-VIS spectrophotometer type SPECORD 250. All the results, for nitrate and sulphate concentration are expressed in $mg \cdot L^{-1}$.

The chloride ions were generally determined by titrating the water samples against a standard solution of $AgNO_3$ using potassium chromate as an indicator.

The pH values were determined by electrochemical method, and the total dissolved solids were determined by gravimetric method.

The determination of Ca, Mg, and Na in water samples was carried out by flame atomic absorption spectroscopy (AAS), according to standard methods. An AAS NOVAA 300 model with Air-C_2H_2 flame type of an average fuel flow rate between 0.8-4.0 $L \cdot min^{-1}$

and the support gas flow rate between 13.5 and 17.5 $L \cdot min^{-1}$ was used for sample analysis. Hallow cathode lamps of the different metals were used as radiation sources and the analytical measurements based on time-averaged absorbance. Resonance lines at 422.7, 285.2, and 589.0 nm were employed for Ca, Mg, and Na. Lamp intensity (4-6 mA) and band pass (0.2-0.5 nm) were used. Air/acetylene flow rates were between 0.9-1.1 $L \cdot min^{-1}$ for all metals. Prior to each series of measurements, a calibration line was created for each element.

Chemicals and reagents used during the study were of spectroscopic grade; the multielement standard solution CertiPur® with a certified value of 1000 ± 3 $mg \cdot L^{-1}$, obtained from Merck (Germany) was used for the calibration curve in the quantitative analysis. Ultrapure water with a maximum resistivity of 18.2 $M\Omega \cdot cm^{-1}$, were used for sample treatment and sample dilution. The working standards and control sample were prepared daily from the intermediate standards that were earlier prepared from the stock solutions. Each determination was carried out twice and the range and median values were reported.

All the investigated calibration curves were characterized by a high correlation coefficient ($r > 0.995$) for both analytical methods.

2.4 Canadians Water Quality Index (CWQI)

Canadian water quality index (CWQI) was founded in 1995 based on water quality index, released by British Columbia University. A merit of this index is using numerous quality variables for calculating this index, though it has some limitations as well. The CWQI is calculated using the Canadian Council of Ministers of the Environment Index method. The CCME WQI is a consistent method used to assess the quality of water and was formulated by Canadian jurisdictions. This method was developed to protect aquatic life and assess water quality by applying guidelines (Bilgin, 2018). The mathematical formulation of CCME CWQI is given below:

$$\text{CWQI} = 100 - \left(\frac{\sqrt{F_1^2+F_2^3+F_3^2}}{1.732}\right) \tag{1}$$

where F1 represents the number of variables, F2 represents the percentage of individual tests that do not meet objectives (failed tests), F3 represents the amount by which failed test values do not meet their objectives (Bilgin, 2018).

Following expressions are used to determine the CWQI for our study. Three factors are combined to calculate the CWQI, F1 (Scope), F2 (Frequency) and F3 (Amplitude).

F1 (scope) is the percentage of variables that do not meet their objective at least once during the time period under consideration, relative to the total number of variables measured:

$$F_1 = \left(\frac{Number\ of\ failed\ variables}{Total\ number\ of\ variables}\right) \text{x}100 \tag{2}$$

F_2 (Frequency) represents the percentage of individual tests that do not meet objectives:

$$F_2 = \left(\frac{Number\ of\ failed\ tests}{Total\ number\ of\ tests}\right) \text{x}100 \tag{3}$$

F3 (Amplitude) represents the amount by which failed test values do not meet their objectives. F3 is calculated in three steps.

The number of times by which an individual concentration is greater than (or less than, when the objective is a minimum) the objective is termed an "excursion" and is expressed as follows: When the test value must not exceed the objective:

$$\text{excursion}_i = \left(\frac{Failed\ test\ value}{Objective}\right) - 1 \tag{4}$$

For the cases in which the test value must not fall below the objective:

$$\text{excursion}_j = \left(\frac{Objective}{Failed\ test\ value}\right) - 1 \tag{5}$$

The collective amount by which individual tests are out of compliance is calculated by summing the excursions of individual tests from their objectives and dividing by the total number of tests (both those meeting objectives and those not meeting objectives). This variable, referred to as normalized sum of excursions, or nse, is calculated as: F3 is then calculated by an asymptotic function that scales the normalized sum of the excursions from objectives (nse) to yield a range between 0 and 100.

$$\text{NSE} = \frac{\sum_{i=1}^{n} excursion_i}{number\ of\ tests} \tag{6}$$

$$F_3 = \left(\frac{nse}{0.01nse+0.01}\right) \tag{7}$$

$$\text{CWQI} = 100 - \frac{\sqrt{F_1^2+F_2^3+F_3^2}}{1.732} \tag{8}$$

The CWQI value ranges between 1 and 100, the result is further simplified by assigning it to a descriptive category as Table 2.

Table 2. Range of CCME-CWQI (Canadian Environmental Quality Guidelines, 1999, Winnipeg)

Rank	CWQI Value	Description
Excellent	95 - 100	Water quality is intact; conditions are very close to natural or desired levels
Good	80 - 94	Water quality is intact; and only one minor threat or deterioration is observed, conditions rarely differed from the natural or desirable level
Fair	65 - 79	Water quality is usually intact, but occasionally endangered or deteriorated; conditions sometimes deviate from natural or desirable levels
Marginal	45 - 64	Water quality is frequently endangered or deteriorated. Conditions often deviate from natural or desirable levels
Poor	0 - 44	Water quality is always endangered or deteriorated; conditions usually deviate from natural or desirable levels

3. RESULTS AND DISCUSSION

3.1. The physicochemical characteristics of the Olt River basin

The physico-chemical parameters such as calcium (Ca), magnesium (Mg), sodium (Na), chlorides (Cl^-), sulphate (SO_4^{2-}), nitrate ($N\text{-}NO_3^-$), electrical conductivity (EC) and total dissolved solids (TDS) of water were analysed for the water samples collected from the Olt River, and are summarized in Table 3.

Standard Limits of water quality parameters recommended by the Order No. 161/2006 (Table 3).

Table 3. Water quality in the Olt River for the year 2018

Location No.	Sample Date	pH (u.pH)	$N\text{-}NO_3^-$ (mgN/L)	TDS (mg/L)	Cl^- (mg/L)	SO_4^{2-} (mg/L)	EC ($\mu S\cdot cm^{-1}$)	Ca (mg/L)	Mg (mg/L)	Na (mg/L)
A1	March	7.67	0.16	208.00	**62.39**	14.00	283.00	29.43	3.42	12.76
	May	8.20	0.18	265.00	22.68	21.00	336.00	**51.02**	6.40	22.17
	June	8.38	0.23	271.00	23.40	19.00	344.00	45.76	5.58	**27.21**
	October	7.70	0.18	379.00	**52.86**	22.00	480.00	**59.94**	7.54	**37.88**
A2	March	7.53	0.16	211.00	22.68	13.00	288.00	33.69	3.48	14.02
	May	8.40	0.14	258.00	20.56	17.00	326.00	49.10	6.50	20.15
	June	8.34	0.27	269.00	**29.10**	12.00	340.00	43.40	5.10	**28.01**
	October	7.30	0.24	375.00	**52.11**	19.00	475.00	**61.93**	7.23	**48.28**
A3	March	7.80	0.20	207.00	18.43	19.00	267.00	29.45	3.49	11.74
	May	8.30	0.18	262.00	**26.23**	22.00	332.00	47.68	6.45	22.28
	June	8.37	0.16	244.00	19.14	16.00	308.00	43.18	5.57	**26.62**
	October	7.71	0.13	259.00	**35.00**	23.00	328.00	48.67	5.53	**32.61**
A4	March	7.75	0.20	225.00	15.59	17.00	282.00	30.70	3.54	12.64
	May	8.00	0.31	263.00	**30.50**	19.00	334.00	48.75	6.35	20.79
	June	8.36	0.13	216.00	18.40	19.00	273.00	44.77	5.65	**26.95**
	October	7.63	0.16	359.00	**40.20**	18.00	455.00	**56.80**	6.42	**32.09**
A5	March	7.67	0.17	232.00	9.92	19.00	303.00	30.67	3.73	14.16
	May	8.30	0.13	251.00	**31.20**	16.00	318.00	47.24	6.00	19.57
	June	8.30	0.12	249.00	22.00	16.00	315.00	**106.70**	4.99	**27.46**
	October	7.74	0.10	385.00	**53.60**	21.00	483.00	**64.86**	7.16	**37.99**
A6	March	7.76	0.17	236.00	14.18	15.00	291.00	29.34	3.75	14.21
	May	**8.50**	0.14	232.00	**41.13**	20.00	293.00	44.17	5.68	19.64
	June	8.29	0.13	251.00	**26.23**	22.00	317.00	**107.10**	5.66	**54.05**
	October	8.01	0.15	283.00	**58.30**	26.00	359.00	47.78	5.18	**29.72**
A7	March	7.75	0.25	229.00	19.85	20.00	283.00	30.55	3.45	12.97
	May	**9.10**	0.23	257.00	**35.45**	23.00	325.00	46.97	5.90	21.32
	June	8.32	0.07	621.00	**234.00**	26.00	786.00	**107.90**	5.64	**55.33**
	October	8.07	0.11	290.00	**45.41**	24.00	368.00	46.82	4.83	**29.77**
A8	March	7.84	0.16	340.00	**55.30**	11.00	442.00	42.84	3.91	23.59
	May	8.30	0.16	622.00	**161.00**	14.00	788.00	**108.40**	6.27	**37.86**
	June	8.43	0.07	628.00	**235.40**	29.00	794.00	**99.50**	5.22	**51.34**
	October	7.77	0.09	880.00	**303.00**	26.00	1114.00	**148.50**	4.99	**59.03**
A9	March	7.93	0.15	356.00	**66.65**	11.00	455.00	43.61	3.93	23.99
	May	8.00	0.14	635.00	**175.84**	17.00	805.00	**114.90**	6.40	**38.84**
	June	8.37	0.07	626.00	**228.32**	33.00	793.00	**100.40**	5.19	**51.57**
	October	7.75	0.08	878.00	**296.00**	32.00	1111.00	**152.40**	4.87	**59.48**
A10	March	7.82	0.12	339.00	**63.81**	16.00	427.00	39.02	4.26	23.78
	May	8.10	0.16	621.00	**180.10**	22.00	785.00	**112.60**	6.33	**37.88**
	June	8.43	0.07	625.00	**221.20**	38.00	792.00	**101.40**	5.58	**52.12**
	October	7.66	0.06	881.00	**312.70**	44.00	1115.00	**156.20**	4.82	**59.67**
A11	March	7.63	0.02	449.00	**83.66**	19.00	575.00	**57.61**	6.11	**27.03**
	May	**8.60**	0.02	541.00	**150.32**	24.00	681.00	**98.57**	6.21	**34.48**
	June	7.87	0.07	628.00	**224.10**	42.00	795.00	**101.60**	5.19	**52.43**
	October	8.08	0.07	697.00	**233.90**	40.00	881.00	**116.70**	5.27	**51.18**
A12	March	7.84	0.01	328.00	**38.28**	37.00	411.00	**52.60**	**13.94**	20.13
	May	7.80	0.01	385.00	**35.45**	30.00	487.00	**76.61**	**21.14**	22.37
	June	7.97	0.13	388.00	**66.65**	25.00	490.00	**101.20**	5.36	**51.37**
	October	7.80	0.12	341.00	**31.30**	22.00	430.00	**63.54**	**12.67**	20.18

Location No.	Sample Date	pH (u.pH)	$N\text{-}NO_3^-$ (mgN/L)	TDS (mg/L)	Cl^- (mg/L)	SO_4^{2-} (mg/L)	EC ($\mu S \cdot cm^{-1}$)	Ca (mg/L)	Mg (mg/L)	Na (mg/L)
A13	March	8.14	0.01	612.00	**153.16**	42.00	774.00	**82.45**	**14.32**	**54.65**
	May	7.20	0.01	449.00	**102.10**	46.00	569.00	**84.65**	10.28	**29.69**
	June	8.20	0.13	497.00	**158.80**	38.00	630.00	**101.10**	5.57	**40.61**
	October	8.10	0.13	420.00	**93.10**	34.00	531.00	**91.89**	8.55	**32.73**
A14	March	8.04	0.01	510.00	**103.52**	39.00	646.00	**79.58**	10.40	**39.60**
	May	8.00	0.02	363.00	**52.47**	28.00	460.00	**68.82**	11.87	19.19
	June	8.40	0.12	354.00	**58.14**	21.00	447.00	**101.70**	5.21	**54.27**
	October	8.12	0.12	338.00	**29.80**	19.00	427.00	**72.21**	**14.72**	**25.68**
A15	March	8.49	0.02	613.00	**129.05**	44.00	772.00	**91.48**	8.58	**47.76**
	May	8.40	0.17	447.00	**93.60**	31.00	565.00	**81.04**	8.60	**25.13**
	June	8.30	0.12	492.00	**156.00**	34.00	624.00	**46.41**	5.48	**54.64**
	October	7.80	0.12	390.00	**94.60**	38.00	493.00	**76.69**	7.27	**31.76**
A16	March	8.30	0.02	572.00	**144.65**	46.00	727.00	**78.17**	9.10	**48.02**
	May	8.30	0.12	443.00	**97.90**	36.00	561.00	**77.15**	7.80	**26.36**
	June	8.30	0.14	510.00	**163.10**	36.00	644.00	**45.98**	5.17	**51.15**
	October	8.40	0.14	393.00	**95.00**	42.00	497.00	**73.91**	6.54	**93.80**
A17	March	8.50	0.01	534.00	**104.94**	39.00	673.00	**84.22**	8.65	**43.24**
	May	8.50	0.12	446.00	**96.43**	43.00	564.00	**83.92**	8.00	**28.23**
	June	8.20	0.16	557.00	**174.40**	43.00	706.00	**44.34**	5.51	**54.06**
	October	8.10	0.16	418.00	**106.00**	48.00	533.00	**87.50**	7.46	**88.84**
A18	March	8.14	0.01	495.00	**110.61**	41.00	625.00	**74.52**	8.13	**39.29**
	May	8.00	0.11	502.00	**106.40**	39.00	635.00	**93.58**	9.28	**30.67**
	June	**8.70**	0.16	524.00	**167.34**	36.00	663.00	**101.50**	5.40	**45.97**
	October	8.30	0.17	417.00	**100.50**	32.00	519.00	**80.01**	6.30	**32.70**
A19	March	8.05	0.01	386.00	**79.41**	35.00	487.00	**64.69**	5.70	**26.80**
	May	8.10	0.10	488.00	**110.00**	33.00	470.00	**62.40**	5.40	**27.60**
	June	8.40	0.07	598.00	**177.27**	34.00	758.00	**99.50**	5.17	**54.64**
	October	8.40	0.07	570.00	**168.00**	38.00	624.00	**87.75**	7.45	**88.43**
A20	March	8.07	0.03	370.00	**68.07**	34.00	471.00	**63.39**	6.01	**29.46**
	May	**8.70**	0.05	476.00	**116.30**	37.00	602.00	**86.14**	6.54	**29.01**
	June	**8.89**	0.16	567.00	**171.60**	39.00	718.00	**101.70**	4.84	**50.83**
	October	**8.68**	0.16	581.00	**166.80**	42.00	730.00	**103.50**	5.45	**41.99**
A21	March	7.73	0.01	600.00	**140.40**	32.00	752.00	**88.80**	8.88	**46.30**
	May	8.40	0.01	631.00	**180.10**	30.00	799.00	**101.70**	9.62	**39.80**
	June	**8.92**	0.14	600.00	**211.30**	42.00	759.00	**100.80**	5.47	**53.02**
	October	**8.84**	0.14	593.00	**176.40**	48.00	749.00	**113.70**	5.65	**47.87**
A22	March	8.20	0.32	385.00	**69.49**	31.00	478.00	**63.07**	6.53	**35.51**
	May	**8.70**	0.14	593.00	**183.90**	42.00	751.00	**86.75**	6.18	**33.18**
	June	**8.70**	0.14	622.00	**214.14**	38.00	788.00	**107.70**	4.86	**42.14**
	October	**8.70**	0.14	593.00	**183.90**	42.00	751.00	**105.90**	5.28	**44.70**
Standard limits*	1st class	6.5 – 8.5	1	500	25	60	-	50	12	25
	2nd class		3	750	50	120	-	100	50	50
	3rd class		5.6	1000	250	250	-	200	100	100
	4th class		11.2	1300	300	300	-	300	200	200
	5th class		>11.2	>1300	>300	>300	-	>300	>200	>200

*** *Standard Limits of water quality parameters recommended by the Order No. 161/2006 regarding the classification of surface water quality***

3.2. Electrical conductivity

Water capability to transmit electric current is known as electrical conductivity and it is used to measure the concentration of dissolved solids which have been ionized in a polar solution such as water (Murugesan et al., 2006). This ability depends on the presence of ions, their total concentration, mobility, valence, relative concentrations and temperature of measurement (Shinde et al., 2011). In the Olt River, mean EC levels are between 308.78 $\mu S\cdot cm^{-1}$ at station A3 and 791.0 $\mu S\cdot cm^{-1}$ at station A9. Usually, EC in surface waters is influenced by dissolved ions from natural and anthropogenic origin (Miyittah et al., 2020).

3.3. Total dissolved solids

Total dissolved solids (TDS) comprise inorganic salts and small amounts of organic matter that are dissolved in water. The principal constituents are usually the cations calcium, magnesium, sodium and potassium and the anions carbonate, bicarbonate, chloride, sulphate and nitrate. Station A3 recorded low TDS (207 mg/L), and station A10 recorded highest TDS (881 mg/L). The observed high concentration of dissolved solids in the surface water is a pointer to the fact that there are intense anthropogenic activities along the course of the river and run-off with high suspended matter content. (Chapman, 1996).

3.4. pH

pH is defined as the intensity of the acidic or basic character of a solution at a given temperature. pH is the negative logarithm of hydrogen ion concentration (pH = -log [H+]). pH value of water is important because many biological activities can occur only within a narrow range. Thus, any variation beyond acceptable range could be fatal to a particular organism (Slingsby and Cook, 1986). The favorable range of pH is 6.5 - 8.5 at daybreak, are most suitable for fish production (Lloyd, 1992). The increase in pH in the rivers could be related to photosynthesis and growth of aquatic plants, where photosynthesis consumes CO_2 leading to arise in the pH values (Yousry et al., 2009; Ezzat et al., 2012). In the study period (from March 2018 to October 2018), the pH value ranged from 7.20 to 9.10. Its value is higher in May for station A7, due to the water levels and concentration of nutrients in water (Narayana et al., 2008) and the lowest in May for station A13, due to of rain water (Reddy et al., 2009).

3.5. Calcium, magnesium and sodium

Calcium is the most abundant ion in fresh water and is important in shell construction, bone building and plant precipitation of lime. It is the indicator of hydrology and solution of fertilizer into water. Magnesium is often associated with calcium in all kinds of waters, but its concentration remains generally low than the calcium. Magnesium is essential for chlorophyll growth and acts as a limiting factor for the growth of phytoplankton (Moss, 1973). All natural waters contain sodium; almost all sodium compounds dissolve easily in water and drain naturally from rocks and soils.

Calcium in the river ranged from 29.34 to 156.20 mg/L, magnesium from 3.42 to 21.14 mg/L and sodium from 11.74 to 93.80 mg/L. Calcium, magnesium and sodium were within the limits of the quality standards established by Order no. 161/2006 for quality Class 1-3.

3.6. Chloride

The chloride in drinking water originates from natural sources, sewage and industrial effluents, urban runoff containing de-icing salt and saline intrusion (Solanki, 2012). The observed chloride content in the Olt River samples were ranges from 9.92 mg/L and 312.70 mg/L, domestic and industrial wastewater constitutes a constant polluting source.

3.7. Nitrate

Nitrate in water is derived from three primary sources: rainfall, decomposition of soil organic matter, and nitrogen amendments (fertilizers, manures, etc.) (Goher, 2002). Nitrates are essential plant nutrients, but in excess amounts they can cause significant water quality problems. Together with phosphorus, nitrates in excess amounts can accelerate eutrophication, causing dramatic increases in aquatic plant growth and changes in the types of plants and animals that live in the stream (Uduma, 2014). Nitrate indicates the pollution in surface water due to agricultural activities, sewage percolation beneath the surface. Presence of nitrate in water indicates the final stage of mineralization. The nitrate (N-NO_3^-) concentration, found to be in the range of 0.01-0.32 mg/L, it is within the desirable limit (Order 161, 2006).

3.8. Sulphate

Sulfate is an inorganic anionic substance that forms salts with sodium, potassium, magnesium and other cations. It is the indicator of hydrology and solution of fertilizer into water. During the study sulphate ranged from 11.00 mg/L (minimum in station A8) to 48.00 mg/L (maximum in station A17). The sulphate content in surface water samples are within the limit prescribed by Order no. 161/2006. Many sulphate components are readily soluble in water. Most of sulphate components originate from the oxidation of sulphite ores, presence of shales and the solution of gypsum and anhydrite. Under anaerobic conditions, sulphate ion is reducing to sulphate ion, which establishes equilibrium with hydrogen ion to form hydrogen sulphide.

Table 4. Summary of the CWQI factors and ratings for the sampling locations in Olt River

Location No.	F1	F2	NSE	F3	CCME CWQI	CWQI Category
A1	33.33	16.67	0.095	8.71	77.90	fair
A2	33.33	13.89	0.070	6.56	78.81	fair
A3	22.22	11.11	0.023	2.22	85.60	good
A4	33.33	13.89	0.037	3.55	79.05	fair
A5	33.33	16.67	0.096	8.72	77.90	fair
A6	33.33	19.44	0.126	11.15	76.81	fair
A7	33.33	19.44	0.339	25.35	73.34	fair
A8	33.33	27.78	0.924	48.01	62.64	marginal
A9	33.33	27.78	0.945	48.59	62.39	marginal
A10	33.33	27.78	0.958	48.93	62.24	marginal
A11	44.44	36.11	0.595	37.32	60.54	marginal
A12	44.44	33.33	0.188	15.85	66.65	fair
A13	33.33	36.11	0.611	37.92	64.16	marginal
A14	33.33	33.33	0.284	22.10	69.94	fair
A15	33.33	33.33	0.533	34.78	66.18	fair
A16	33.33	33.33	0.643	39.13	64.63	marginal
A17	33.33	33.33	0.625	35.05	66.08	fair
A18	44.44	36.11	0.555	35.71	61.04	marginal
A19	33.33	33.33	0.655	39.57	64.47	marginal
A20	44.44	41.67	0.647	39.30	58.14	marginal
A21	44.44	36.11	0.846	45.83	57.65	marginal
A22	44.44	41.67	0.823	45.14	56.22	marginal

Table 5. Comparison of the CCME CWQI quality classification of sampling stations in the Olt River with those of other rivers throughout the world

Study location	CCME CWQI	CWQI Category	Reference
Olt River Basin, Romania	67.8	Marginal	This work
Coruh River Basin, Turkey	35.5 (2011, year)	Poor	(Bilgin, 2018)
	54.2 (2012, year)	Marginal	
	61.0 (2013, year)	Marginal	
	43.5 (2014, year)	Marginal	
Three Gorges Reservoir, China	64.7	Fair	(Qiang Gao, 2016)

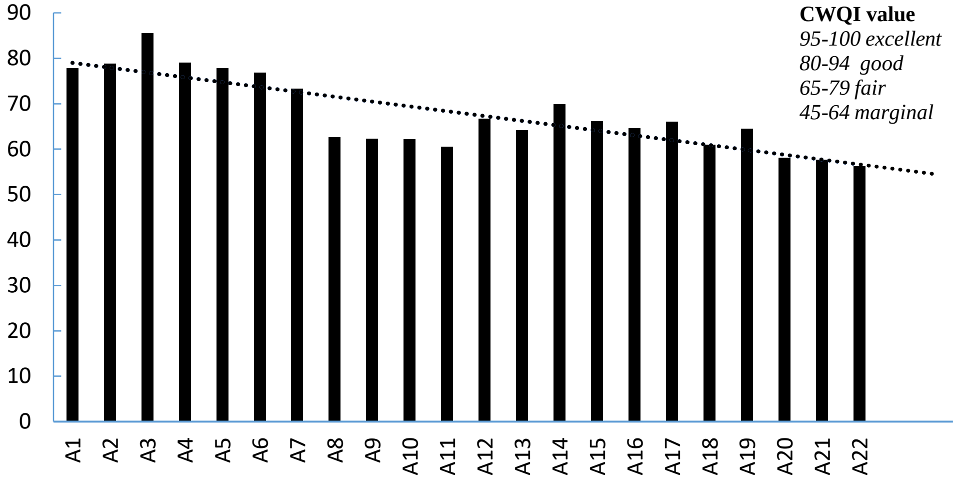

Figure 1. Comparison of the canadian water quality index in different locations of the Olt River

The results showed that, 10 points had fair quality water, 11 points had marginal quality water and 1 point he had good quality water (Table 4). The quality of river water has changed due to the release of pollutants in the environment and the excess consumption of these resources (Eslami et. al, 2017).

The influence factors for different parameters used to highlight the relative importance of variables compared to other variables in a Pearson correlation (PC) were classified as having *"strong", "moderate" and "low" correlation*, corresponding to factors influencing the values > 0.75; 0.50÷0.75 and 0.30÷0.50 respectively (Zhou et al., 2007; Lu et al., 2012). Pearson's correlation coefficients (r) for investigated metals are found in Table 6.

Table 6. Pearson's correlation of physico-chemical parameters of water samples

	pH	**$N\text{-}NO_3^-$**	**TDS**	**Cl^-**	**SO_4^{2-}**	**EC**	**Ca**	**Mg**	**Na**
pH	1.000								
$N\text{-}NO_3^-$	-0.111	1.000							
TDS	0.397	-0.608	1.000						
Cl^-	0.421	-0.518	**0.986**	1.000					
SO_4^{2-}	**0.633**	-0.586	**0.626**	**0.582**	1.000				
EC	0.387	-0.587	**0.997**	**0.984**	**0.613**	1.000			
Ca	0.346	-0.697	**0.947**	**0.911**	**0.590**	**0.948**	1.000		
Mg	-0.163	-0.522	0.013	-0.128	0.350	0.015	0.159	1.000	
Na	0.489	-0.605	**0.823**	**0.801**	**0.770**	**0.805**	0.702	0.073	1.000

In the water samples, strong correlations were observed for Cl^--TDS (r = 0.986), EC-TDS (r = 0.997), Ca-TDS (r = 0.947), Na-TDS (r = 0.823), EC-Cl^- (r = 0.984), Ca-Cl^- (r = 0.911), Na-Cl^- (r = 0.801), Na-SO_4^{2-} (r = 0.770), Ca-EC (r = 0.948), and Na-EC (r = 0.805); moderate correlations for pH-SO_4^{2-} (r = 0.633), TDS-SO_4^{2-} (r = 0.626), Cl^--SO_4^{2-} (r = 0.582), EC-SO_4^{2-} (r = 0.613) and Ca-SO_4^{2-} (r = 0.590); and low correlations for Mg-SO_4^{2-} (r = 0.350), TDS-pH (r = 0.397), Cl^--pH (r = 0.421), EC-pH (r = 0.387), Ca-pH (r = 0.346) and Na-pH (r = 0.489). The nitrate concentration is significantly influenced by the TDS concentration (-0.608); Cl^- (0.518); SO_4^{2-} (-0.586); EC (-0.587); Ca (-0.697); Mg (-0.522) and Na (-0.605) having a negative correlation index; if the concentration of Cl^-, SO_4^{2-}, Ca, Mg and Na increases, the value of nitrates decreases and inverse.

4. CONCLUSION

Canadian water quality index is a preliminary informative tool for the quality of a river water. Rivers water is the base of agriculture, and industry. It may be inferred that the aim of CWQI is to give a single value to water quality of a source along with reducing higher number of parameters into a simple expression resulting into easy interpretation of water quality monitoring data. On the basis of CWQI, the quality of water is categorized from good to marginal. Application of CWQI in this study has been found useful when assessing the overall quality of water. This method appears to be more systematic and gives comparative evaluation of the water quality in the different sampling stations. It is also helpful for public to understand the quality of water as well as being a useful tool in many ways in the field of water quality management.

This method provides an assessment of water quality along the river.

Acknowledgments: *This work is part of the project PN 19110303 "Advanced techniques for identifying sources of contamination and biochemical reactions in aquatic ecosystems" financed by the Romanian Ministry of Research and Innovation.*

Funding

Project PN 19110303 "Advanced techniques for identifying sources of contamination and biochemical reactions in aquatic ecosystems" Contract no. 9N/2019, financed by the Ministry of Education and Research

Author Contributions

Claudia Sandru set the concept of the paper, draw the draft manuscript; Mihaela Iordache performed analysis; Andreea Maria Iordache contributed to data interpretation; Roxana Elena Ionete revised the data and completed the final manuscript; Ramona Zgavarogea participated to data interpretation.

Conflict of Interest Statement: There is no conflict of interest on this article

REFERENCES

Adimalla, N., Li, P., Venkatayogi, S., 2018. *Hydrogeochemical evaluation of groundwater quality for drinking and irrigation purposes and integrated interpretation with water quality index studies.* Environ. Process. 5, 363-383.

Bereskie, T., Haider, H., Rodriguez, M.J., Sadiq, R., 2017. *Framework for continuous performance improvement in small drinking water systems*. Sci. Total Environ. 574, 1405-1414.

Bilgin A., 2018, *Evaluation of surface water quality by using Canadian Council of Ministers of the Environment Water Quality Index (CCME WQI) method and discriminant analysis method: a case study Coruh River Basin*, Environ.Monit. Assess, pp. 190: 554.

Boyacioglu, H., 2007, *Surface water quality assessment using factor analysis*, Water Sa 3, pp. 389-393.

Brown R. M., Mccleiland N. J., Deiniger R. A, O'Connor M.F.A., 1972, *Water quality index–crossing the physical barrier*. In: Jenkis SH (ed.) International Conference on Water Pollution Research, Jerusalem. 6: 787-797.

Caiero, S., Costa, M. H., Ramos, T. B., Fernandes, F., Silveira, N., Coimbra, A., Medeiros, Painho M., 2005, *Assessing heavy metal contamination in Sado Estuary sediment: An index analysis approach.* Ecological Indicators, 5, pp. 151-169.

Chapman, D.V., 1996. *Water Quality Assessments: a Guide to the Use of Biota, Sediments and Water in Environmental Monitoring*/. In: Chapman, Deborah (Ed.), second ed. World Health Organization, UNESCO & United Nations Environment Programme, London. E & FN Spon

Chaterjee, C. and Razuddin, M., 2002, *Determination of Water Quality Index (WQI) of a degraded river in Asanil Industrial area*, Ranigunj, Burdwan, West Bengal Nature, Environment and Pollution Technology, 1(2): 181-189.

de Almeida, G.S., de Oliveira, I.B., 2018. *Application of the indexWQI-CCME with data aggregation per monitoring campaign and per section of the river: case study—Joanes River, Brazil*. Environ. Monit. Assess. pp. 190:195.

Eslami F, Shokoohi R, Mazloomi S, et al., 2017, *Evaluation of Water Quality Index (WQI) of groundwater supplies in Kerman province in 2015*, Journal of Occupational and Environmental Health.;3 (1):48-58).

Ezzat, S. M., M. Hesham, M. A. Mahdy, E. Abo-State, H. Abd El-Shakour and M.A. El-Bahnasawy, 2012, *Water quality assessment of river Nile at Rosetta branch: Impact of drains discharge.* Middle-East J. Sci. Res., 12(4): 413-423.

Gao, Q., Li, Y., Cheng, Q., Yu, M., Hu, B., Wang, Z., Yu, Z., 2016. *Analysis and assessment of the nutrients, biochemical indexes and heavy metals in the Three Gorges Reservoir, China, from 2008 to 2013*. Water Res. 92, 262-274.

Gawas A. D., Lokhande P. B. and Mujawar H. A., 2006, *Study of physico- chemical parameters in Mahad Industrial Area.* Poll Res., 25 (1), 109-114.

Gikas, G.D., 2017.*Water quantity and hydrochemical quality monitoring of Laspias River, North Greece*. J. Environ. Sci. Health Part A 52 (14), 1312-1321.

Goher M. E. M, 2002, *Chemical studies on the precipitation and dissolution of some chemical element in lake Qarun*, Ph.D. Thesis faculty of sciences, Al- Azhar University, Egypt.

ISO 5667-10, 1992 *Water quality – Sampling – Part 10: Guidance on sampling of waste waters.*

Kalavathy S., T. Rakesh Sharma and P. Sureshkumar, 2011, *Water uality Index River Cauvery in Tiruchirappalli district, Tamilnadu*, Arch. Environ. Sci., 5, 55-61.

Law no. 310 of 28 June 2004 amending and supplementing *Water Law no. 107/1996.*

Lloyd R., 1992, *Pollution and Freshwater Fish*. Fishing News Books, Oxford.

Liu, L., Liu, D.F., Johnson, D.M., Yi, Z.Q., Huang, Y.L., 2012. Effects of vertical mixing on phytoplankton blooms in Xiangxi Bay of Three Gorges Reservoir: implications for management. Water Res. 46 (7), pp. 2121:2130.

Marta Terrado, Elena Borrell, Sergio de Campos, Damia` Barcelo´, Roma` Tauler, 2010, *Surface-water-quality indices for the analysis of data generated by automated sampling networks*, Trends in Analytical Chemistry, Vol. 29, No. 1, pp. 40-52.

Michael K. Miyittah, Samuel Kofi Tulashie, Francis W. Tsyawo, Justice K. Sarfo, Archibald A. Darko, 2020, *Assessment of surface water quality status of the Aby Lagoon System in the Western Region of Ghana*, Heliyon 6, pp. 1-9.

Moss B., 1973, *The influence of environmental factors on the distribution of freshwater algae: An experimental study. The role of pH and the carbon dioxide-bicarbonate system*. J. Ecol. 61: 157-177.

Murugesan A., Ramu A. and Kannan N., 2006, *Water quality assessment from Uthamapalayam municipality In Theni District*, Tamil Nadu, India.Pollution Research 25: 163-166.

Narayana J., E. T. Puttaiah and D. Basavaraja, 2008, *Water Quality Characteristics of Anjanapura Reservoir near Shikaripur, District Shimohga*, Karnataka Aquatic Biology 23(1): 59-63.

Onojake, M.C., Ukerun, S.O., Iwuoha, G., 2011, *A statistical approach for evaluation of the effects of industrial and municipal wastes on Warri Rivers, Niger Delta, Nigeria*. Water Qual. Expo. Health 3 (2), pp. 91.

Onwughara N. I., V. I. E. Ajiwe and H. O. Nnabuenyi, 2013, *Physico-chemical Studies of Water from Selected Boreholes in Umuahia North Local Government Area, in Abia State, Nigeria*. International Journal of Pure & Applied Bioscience 1 (3): 34-44.

Order no. 161/February 16th, 2006 approving the *"Norms on surface water quality classification to determine the ecological status of water bodies".*

Reddy V. K., Prasad K. L., Swamy M., Reddy R., 2009, *Physico-chemical parameters of Pakhal lake of Warangal District Andhra Pradesh, India.* Journal of Aquatic Biology 24: 77-80.

Qiang Gao, Yi Li, Qingyuan Cheng, Mingxia Yu, Bo Hu, Zhigang Wang, Zhiqiang Yu, 2016, *Analysis and assessment of the nutrients, biochemical indexes and heavy metals in the Three Gorges Reservoir, China, from 2008 to 2013,* Water Research 92, pp. 262-274.

Shinde, S. E., T. S. Pathan, K. S. Raut and D. L. Sonawane, 2011, *Studies on the physicochemical parameters and correlation coefficient of Harsoot Savanari dam, District Aurangabad, India.* Middle East Journal of Scientific Research, 8 (3): 544-554.

Slingsby, D. and C. Cook, 1986, *Practical Ecology.* Macmillan Education Ltd., London.

Smitha, P. G. and Byrappa, K. and Ramaswamy, S. N. (2007) *Physico-chemical characteristics of water samples of Bantwal Taluk, south-western Karnataka, India*. Journal of Environmental Biology, 28 (3), pp. 591-595.

Solanki, H. A., 2012, *Status of Soils and Water Reservoirs near Industrial Areas of Baroda*: Pollution and Soil – Water Chemistry. Lap Lambert Academic Publishing, Germany, ISBN: 978-3-659-18299-0.

Trikoilidou, E., Samiotis, G., Tsikritzis, L., Kevrekidis, T., Amanatidou, E., 2017. *Evaluation of water quality indices adequacy in characterizing the physico-chemical water quality of lakes*. Environ. Process. 4, 35-46.

Tsaboula, A., Papadakis, E.-N., Vryzas, Z., Kotopoulou, A., Kintzikoglou, K., Papadopoulou-Mourkidou, E., 2019. *Assessment and management of pesticide pollution at a river basin level part I: aquatic ecotoxicological quality indices.* Sci. Total Environ. 653, 1597-1611.

Uduma A. U., 2014, *Physico-chemical analysis of the quality of sachet water consumed in Kano metropolis.* American Journal of Environment, Energy and Power Research 2: 1-10.

Varol, M., Sen, B., 2009, *Assessment of surface water quality using multivariate statistical techniques. A case study of Behrimaz stream, Turkey*, Environ. Monit. Assess. 159, pp. 543-553.

Venkatramanan, S., Chung, S.Y., Ramkumar, T., Rajesh, R., Gnanachandrasamy, G., 2016. *Assessment of groundwater quality using GIS and CCME WQI techniques: a case study of Thiruthuraipoondi city in Cauvery deltaic region, Tamil Nadu, India*. Desalination Water Treat 57 (26), 12058-12073.

Wagh, V.M., Panaskar, D.B., Muley, A.A., Mukate, S.V., 2017. *Groundwater suitability evaluation by CCME WQI model for Kadava River Basin, Nashik, Maharashtra, India*. Model. Earth Syst. Environ. 3, 557-565.

WHO Guidelines for drinking – *Water Quality.*

Yadav P., Yadav V. K., Yadav A. K., Khare P. K., 2013, *Physico-chemical characteristics of fresh water pond of Orai, U.P., central India*. Octa Journal of Biosciences, 1(2):177-184.

Yan Feng, Qiao Danying, Qian Bao, Ma Lin, Xing Xigang, Zhang You, Wang Xiaogang, 2016, *Improvement of CCME WQI using grey relational method*, Journal of Hydrology 543, pp. 316-323.

Yousry M., A. El-Sherbini, M. Heikal and T. Salem, 2009, *Suitability of water quality status of Rosetta branch for west Delta water conservation and 22 irrigation rehabilitation project.* Water Sci., pp. 46: 47-60.

Zhai, X.Y., Xia, J., Zhang, Y.Y., 2014. *Water quality variation in the highly disturbed Huai River Basin, China from 1994 to 2005 by multi-statistical analyses*, Sci. Total Environ. 496, pp. 594:606.

Zotou, I., Tsihrintzis, V.A., Gikas, G.D., 2019. *Performance of seven water quality indices (WQIs) in a Mediterranean river*. Environ. Monit. Assess. 191 (505), 1-14.