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J. Geogr. Inst. Cvijic. 62(3) (1-18)

Original scientific paper

UDC: 911.2:551.482(497.113)
DOI: 10.2298/IJGI1203001J

SERBIAN AND CANADIAN WATER QUALITY INDEX OF DANUBE RIVER IN SERBIA IN 2010

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Received 26 September 2012; reviewed 10 November 2012; accepted 12 December 2012

Abstract: This paper aims to assess water quality of Danube River in Serbia for 2010. Two methodologies were applied for this purpose: Serbian Water Quality Index (SWQI) and Canadian Water Quality Index (CWQI). WQI value is dimensionless, single number ranging from 0 to 100 (best quality) derived from numerous physical, chemical, biological and microbiological parameters. SWQI was mainly good and very good. This methodology includes parameters for assessment of organic loading, but does not involve parameters of heavy metals concentration. For that purpose CWQI was used. Besides overall, CWQI was calculated for following uses: aquatic habitat, drinking, recreation, irrigation and livestock. Overall CWQI was marginal and fair, which was equivalent with poor and good SWQI. CWQI methodology showed increased concentration of copper in all cases which affected overall water quality and aquatic habitat while increased turbidity in many cases had negative influence on drinking water. Differences between SWQI and CWQI resulted from different methodology: different methods of calculation and parameters. In order to get more comparable results it is necessary to develop unique WQI methodology.

Key words: SWQI, CWQI, Danube River water quality

Introduction

Water quality plays a vital role in all aspects of human and ecosystem survival. All living and industrial activities are controlled by physical, chemical, biological and microbiological conditions in watercourses and subsurface aquifers. Water quality generally refers to the composition of a water sample. Evaluations of water quality parameters are necessary to develop better water resources management and plan. Water quality modeling involves the prediction of water pollution using mathematical simulation techniques. Most water quality models use Water Quality Index (WQI) developed by the National Sanitation Foundation (NSF) of United States for assessment of water quality. WQI value is a dimensionless, single number ranging from 0 to 100 (best quality), derived from large quantities of water characterization data. It is a function of different

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parameters such as pH, Biological Oxygen Demand (BOD), Dissolved Oxygen (DO), Fecal Coliform, Electric Conductivity (EC), Ammonium, Temperature, Turbidity, Total Residue, Total Phosphorus, etc. (Ma et al. 2013; Mahapatra et al. 2011; Nasirian 2007; Sánchez et al. 2007; Simões et al. 2008; Taner et al. 2011).

Many WQI systems are developed by different environmental departments or agencies: National Sanitation Foundation (NSF), British Columbia Water Act Quality Index, Oregon Water quality Index, Stream Watch (Southern Indiana), Malaysian Water Quality Index, Florida Stream water Quality index, British Colombia Water Quality Index, Canadian Water Quality index, Taiwan Water Quality index, Washington State Water Quality index, France Water Quality Index, French Creek quality index (Nasirian 2007), Serbian Water Quality Index.

Serbian Water Quality Index (SWQI) is developed by Serbian Environmental Protection Agency. Serbian Water Quality Index was applied for assessment of water quality of main watershed in Serbia (Sava, Velika Morava, Province of Vojvodina, Contributories of Djerdap lake, and Danube) in the period 2001–2006 (Veljković et al. 2008), for water quality evaluation of the reservoir Gruža in the period 2003–2010 (Stefanović et al. 2012), for water quality of lake accumulation Barje in the period 2005–2009 (Takić et al. 2011).

This paper aims to assess water quality of the Danube River in Serbia for 2010 using Serbian Water Quality Index (SWQI) and Canadian Water Quality Index (CWQI). These both methodologies were applied because of different set of parameters which were used for WQI computation.

Data and methods

Parameters of physical, chemical, biological and microbiological water quality were measured at the following stations: Bezdan (11 times), Bogojevo (9 times), Bačka Palanka (8 times), Novi Sad (12 times), Slankamen (11 times), Čenta (11 times), Smederevo (12 times), Banatska Palanka (10 times), Veliko Gradište (12 times), Dobra (12 times) and Radujevac (12 times). Their values are presented in Hydrological annual book for 2010 of Republic Hydrometeorological Service of Serbia. These data were processed by two methods: SWQI and CWQI. SWQI was calculated for each station and each measuring. CWQI was calculated and presented as a single value for each station.

Serbian Water Quality Index (SWQI)

Serbian Water Quality Index is environmental indicator, developed by Serbian Environmental Protection Agency, based on method Water Quality Index (Development of a Water Quality Index, Scottish Development Department, Engineering Division, 1976). SWQI methodology uses ten quality parameters: Oxygen Saturation, Biochemical Oxygen Demand (BOD_5), Ammonium, pH, Total Nitrogen oxides, Orthophosphate, Suspended Solids, Temperature, Conductivity and Most probable number of coliform bacteria (E. Coli/MPN). Each of these parameters has value q_i and weight unit w_i (Živković et al. 2011). SWQI is calculated as a sum of $q_i \times w_i$ (Table 1).

Table 1. SWQI parameters and $q_i \times w_i$ maximum value

Parameter (unit)	Max value $q_i \times w_i$
Oxygen Saturation (%)	18
BOD_5 (mg/l)	15
Ammonium (mg/l)	12
pH	9
Total Nitrogen oxides (mg/l)	8
Orthophosphates (mg/l)	8
Suspended solids (mg/l)	7
Temperature (°C)	5
Conductivity (μS/cm)	6
E. Coli (MNP/100 ml)	12
$\sum q_i \times w_i =$ SWQI	100

Source of data: Veljković et al. (2008)

For each SWQI range a descriptive quality indicator have been defined ranging from very poor (0–38), poor (39–71), good (72–83), very good (84–89), and excellent (90–100). Main limitation for SWQI is relative small number of parameters. Used parameters give information about organic loading, but not about heavy metal pollution. Also, SWQI can be computed even in a case of missing some values. Practically, it means that SWQI can be calculated on the basis of just one parameter.

Canadian Water Quality Index

Canadian Water Quality Index (CWQI) has been developed by Canadian Council of Ministers of the Environment based on water quality index developed by British Columbia in 1995. CWQI methodology uses following parameters: Temperature, Conductivity, Color, Turbidity, Dissolved Oxygen (DO), pH, Alkalinity (Total Alkalinity), Calcium (Ca), Sodium (Na), Magnesium (Mg), Potassium (K), Sulphate (SO_4^{2-}), Chloride (Cl^-), Fluoride (F^-), Dissolved Organic

Carbon (DOC), Phosphorus (P), Nitrate, Nitrite (NO_3^-, NO_2^-), Nitrogen (N), Silicon Dioxide (SiO_2), Aluminium (Al), Arsenic (As), Barium (Ba), Beryllium (Be), Cadmium (Cd), Cobalt (Co), Chromium (Cr), Copper (Cu), Iron (Fe), Mercury (Hg), Lithium (Li), Manganese (Mn), Molybdenum (Mo), Nickel (Ni), Lead (Pb), Selenium (Se), Strontium (Sr), Vanadium (V), Zinc (Z).

CWQI is based on three attributes of water quality that relate to water quality objectives:
Scope (F_1): How many? – The number of water quality variables that do not meet objectives in at least one sample during the time period under consideration, relative to the total number of variables measured ("failed variables"):

$$F_1 = \left(\frac{\text{Number of failed variables}}{\text{Total Number of variables}} \right) \times 100$$

Frequency (F_2): How often? – The number of individual measurements that do not meet objectives, relative to the total number of measurements made in all samples for the time period of interest ("failed tests"):

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

Amplitude (F_3): How much? – The amount by which failed test values do not meet their objectives. F_3 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 as "excursion". When the test value must not exceed the objective:

$$excursion_i = \left(\frac{FailedTestValue_i}{Objective_1} \right) - 1$$

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

$$excursion_i = \left(\frac{Objective_j}{FailedTestValue_i} \right) - 1$$

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 as the normalized sum of excursions, or *nse*, is calculated as:

$$nse = \frac{\sum_{i=1}^{n} excursion_i}{\neq of\ tests}$$

F_3 is than calculated by an asymptotic function that scales the normalized sum of the excursion from objectives (*nse*) to yield a range between 0 and 100.

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

Once the factors have been obtained, the index itself can be calculated by summing the three factors. The sum of the squares of each factor is therefore equal to the square of the index. With this model the index changes are in direct proportion to changes in all three factors:

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

For each CWQI range a descriptive quality indicator have been defined ranging from poor (0– 44), marginal (45–64), fair (65–79), good (80–94), excellent (95–100). Besides overall water quality, CWQI gives information about water quality for different uses: habitat for aquatic life, drinking, recreation, irrigation and livestock (Mercier et al. 2005). Both, SWQI and CWQI have same disadvantages: the loss of information on single variables, the sensitivity of the results to the formulation of the index, and the loss of information on interactions between variables.

Results

SWQI was calculated 11 times for Bezdan station (Table 2) and ranged from 76 (good) to 89 (very good). In the case where the SWQI was very good (85) result should be considered as questionable, because of lack of three parameters: BOD, suspended solids and E. coli.

Table 2. SWQI and CWQI for Bezdan station in 2010

Date and Time	Temperature	pH	Conductivity	O_2 saturation	BOD	Suspended solids	Total Nitrogen Oxides	Ortho-phosphates	Ammonium	E coli	SWQI
13.1. 14:00	5	8	2	17	14	5	5	6	11		83 good
3.2. 12:00	5	8	1	16	14	4	5	6	10		78 good
10.3. 11:30	5	8	2	18	14	4	4	7	12	7	81 good
7.4. 15:00	5	7	2		13	4	6	8	12	10	82 good
5.5. 14:00	4	7	2	15	13	6	6	8	12	10	83 good
2.6. 11:00	5	8	2	17	14	2	6	7	12		83 good
7.7. 10:00	2	7	2	17	9	3	7	8	12	11	78 good
11.8. 14:30	3	8	2	17	13	2	6	6	12	7	76 good
8.9. 11:30	5	8	2	17	12	1	7	7	12	10	81 good
6.10. 14:30	5	8	2	17			6	6	12		85 Very good
10.11.11:30	5	8	2	18	14	7	6	7	12	10	89 Very good

	Overall	Drinking	Aquatic	Recreation	Irrigation	Livestock
CWQI	66	87	58	100	100	95
Categorization	Fair	Good	Marginal	Excellent	Excellent	Excellent
F_1 (Scope)	47	21	55	0	0	8
F_2 (Frequency)	14	5	20	0	0	1
F_3 (Amplitude)	32	2	44	0	0	1
variables tested	19	14	11	1	11	12
variables failed	9	3	6	0	0	1
most failed tests	Cu	Turbidity	Cu	None	None	Hg
highest nse	Cu	Turbidity	Cu	None	None	Hg

CWQI (Table 2) for Bezdan station was overall fair (66), marginal (58) for aquatic habitat, good (87) for drinking, excellent for livestock (95) as well as for recreation and irrigation (100). CWQI upper limit for overall and aquatic habitat for copper (0.002 mg/l) was exceeded in all 11 cases of measuring, i.e. copper values ranged from 0.0036 to 0.028 mg/l. Turbidity upper limit for drinking (1 JTU) was exceeded in three cases and turbidity values were 1.14 JTU, 1.45 JTU and 1.82 JTU. Mercury value exceeded upper limit for livestock (0.003 μg/l) in one case and amounted 0.006 μg/l.

SWQI was calculated 9 times for Bogojevo station (Table 3) and ranged from 78 (good) to 88 (very good). CWQI for Bogojevo station (Table 3) was overall fair (73), marginal for aquatic habitat (60) and excellent for drinking (96), as well as for recreation, irrigation and livestock (100). Copper limit value was exceeded in all 9 cases. It ranged from 0.0045 to 0.0205 mg/l. Turbidity exceeded upper limits in two cases (1.43 and 1.61 JTU).

Table 3. SWQI and CWQI for Bogojevo station in 2010

Date and Time	Temperature	pH	Conductivity	O_2 saturation	BOD	Suspended solids	Total Nitrogen Oxides	Ortho-phosphates	Ammonium	E coli	SWQI
8.3. 11:00	5	8	2	18	13	4	5	7	12		84 Very good
22.4. 13:00	5	8	2	18	13	6	6	8	12	10	88 Very good
27.5. 12:00	5	8	2	18	13	1	6	7	12		82 good
9.6. 14:30	4	9	3	14	13	3	7	6	12	11	82 good
29.7. 12:00	2	8	2	17	14	2	7	7	12		81 good
31.8. 12:00	3	8	2	17	14	4	6	6	11	7	78 good
13.9. 14:00	5	8	2	17	13	5	7	7	12		86 Very good
18.10.12:30	5	8	2	17	14	3	6	7	12		84 Very good
3.11. 10:30	5	8	2	18	14	5	6	7	12		88 Very good

	Overall	Drinking	Aquatic	Recreation	Irrigation	Livestock
CWQI	73	96	60	100	100	100
Categorization	Fair	Excellent	Marginal	Excellent	Excellent	Excellent
F_1 (Scope)	37	7	55	0	0	0
F_2 (Frequency)	14	2	25	0	0	0
F_3 (Amplitude)	25	1	37	0	0	0
variables tested	19	14	11	1	11	12
variables failed	7	1	6	0	0	0
most failed tests	Cu	Turbidity	Cu	None	None	None
highest nse	Cu	Turbidity	Cu	None	None	None

SWQI was calculated 8 times for Bačka Palanka station (Table 4) and ranged from poor (58) to very good (84). Poor SWQI was the consequence of big deficit of O_2 saturation, which amounted 34%, three times lower than ideal value.

CWQI for Bačka Palanka station (Table 4) was overall marginal (54), poor for aquatic habitat (37) good for drinking (91) and excellent for recreation, irrigation and livestock (100). Copper limit value was exceeded in all 8 cases. It ranged from 0.0055 to 0.1098 mg/l. Turbidity exceeded upper limits in four cases and ranged from 1.01 to 1.41 JTU.

Table 4. SWQI and CWQI for Bačka Palanka station in 2010

Date and Time	Temperature	pH	Conductivity	O_2 saturation	BOD	Suspended solids	Total Nitrogen Oxides	Ortho-phosphates	Ammonium	E coli	SWQI
22.3. 10:00	5	7	1	17	9	5	5	8	12		78 good
22.4. 9:30	5	8	2	18	12	3	6	8	12	10	84 Very good
27.5. 9:00	5	8	2	17	13	2	6	7	12		82 good
28.6. 14:30	4	9	2	2		2	7	4	9	10	58 poor
29.7. 9:00	2	7	2	17	14	3	7	7	12		81 good
31.8. 9:00	3	8	2	17	14	3	6	6	12		81 good
21.9. 14:00	5	8	2	16	14	3	6	7	12		83 good
18.10. 9:30	5	8	2	17	14	3	6	6	12		83 good

	Overall	Drinking	Aquatic	Recreation	Irrigation	Livestock
CWQI	54	91	37	100	100	100
Categorization	Marginal	Good	Poor	Excellent	Excellent	Excellent
F_1 (Scope)	47	14	73	0	0	0
F_2 (Frequency)	25	5	39	0	0	0
F_3 (Amplitude)	60	1	72	0	0	0
variables tested	19	14	11	1	11	12
variables failed	9	2	8	0	0	0
most failed tests	Cu	Turbidity	Cu	None	None	None
highest nse	Cu	Turbidity	Cu	None	None	None

SWQI was calculated for Novi Sad station (Table 5) 12 times and ranged from good (76) to excellent (90).

CWQI for Novi Sad station (Table 5) was overall marginal (54), poor for aquatic habitat (39), good for drinking (88) and excellent for recreation, irrigation and livestock (100). Copper limit value was exceeded in all 12 cases. It ranged from 0.004 to 0.1976 mg/l. Turbidity exceeded upper limit in one case (1.34 JTU) as well as pH (8.7) value which should be ranged from 6.5 to 8.5 according the CWQI. Iron had the highest nse, because it amounted in one case 0.61 mg/l, more than twice higher than upper limit (0.3 mg/l).

Table 5. SWQI and CWQI for Novi Sad station in 2010

Date and Time	Temperature	pH	Conductivity	O_2 saturation	BOD	Suspended solids	Total Nitrogen Oxides	Ortho-phosphates	Ammonium	E coli	SWQI
27.1. 8:30	5	8	2	17	12	6	5	6	11		82 good
10.2. 8:00	5	8	1	17	13	6	5	7	10		82 good
16.3. 8:00	5	8	2	18	10	7	5	7	12		84 Very good
27.4. 8:30	5	7	2	17	8	4	6	8	12	11	80 good
26.5. 8:30	5	8	2	15	12	3	6	6	12		78 good
17.6. 8:30	2	9	2	15	11	4	6	6	12	10	77 good
29.7. 8:30	1	8	2	17	10	3	7	7	12		76 good
31.8. 8:30	3	8	2	16	12	3	6	6	12	8	76 good
22.9. 8:30	5	8	2	15	14	5	7	6	12		84 Very good
28.10. 8:30	5	8	2	18	14	5	6	7	12		88 Very good
25.11. 8:30	5	8	2	17	14	7	7	7	12		90 excellent
28.12. 8:30	5	9	1	16	12	7	4	6	11		81 good

	Overall	Drinking	Aquatic	Recreation	Irrigation	Livestock
CWQI	54	88	39	100	100	100
Categorization	Marginal	Good	Poor	Excellent	Excellent	Excellent
F_1 (Scope)	53	21	73	0	0	0
F_2 (Frequency)	18	2	30	0	0	0
F_3 (Amplitude)	57	1	70	0	0	0
variables tested	19	14	11	1	11	12
variables failed	10	3	8	0	0	0
most failed tests	Cu	Turbidity pH	Cu	None	None	None
highest nse	Cu	Fe	Cu	None	None	None

SWQI was calculated for Slankamen station (Table 6) 11 times and ranged from poor (68) to very good (89). Poor SWQI was the consequence of O_2 saturation deficit (64%).

CWQI for Slankamen station (Table 6) was overall fair (77) as well as for aquatic habitat (68) and drinking (76) and excellent for recreation, irrigation and livestock (100). These results should be considered as questionable, because there were no heavy metals measuring, i.e. small number of variables was tested. Dissolved Oxygen values were under the lower limit (9.5 mg/l) in five cases and ranged from 5.7 to 8.8 mg/l. Turbidity exceeded upper limit in four cases and ranged from 1.13 to 1.34 JTU.

Table 6. SWQI and CWQI for Slankamen station in 2010

Date and Time	Temperature	pH	Conductivity	O_2 saturation	BOD	Suspended solids	Total Nitrogen Oxides	Ortho-phosphates	Ammonium	E coli	SWQI
26.1. 15:30	5	8	2	17	14	6	6	6	10		84 Very good
9.2. 9:00	5	8	1	17	14	5	6	7	10		83 good
15.3. 9:30	5	8	2	18	12	7	4	8	12		86 Very good
19.4. 10:00	5	7	2	18	12	5	6	8	12	7	82 good
25.5. 9:30	5	8	2	17	14	3	6	7	12		84 Very good
23.6. 10:30	3	9	2	9	12	3	7	5	10		68 poor
28.7. 9:30	1	7	2	17	14	2	7	7	12		78 good
9.8. 9:00	2	8	2	18	12	1	7	7	12		78 good
20.9. 9:30	5	8	2	16	14	4	7	6	12		84 Very good
21.10. 9:30	5	8	2	17	14	6	6	7	12		88 Very good
4.11. 9:30	5	8	2	18	15	5	6	7	12		89 Very good

	Overall	Drinking	Aquatic	Recreation	Irrigation	Livestock
CWQI	77	76	68	100	100	100
Categorization	Fair	Fair	Fair	Excellent	Excellent	Excellent
F_1 (Scope)	38	40	50	0	0	0
F_2 (Frequency)	15	14	23	0	0	0
F_3 (Amplitude)	3	2	5	0	0	0
variables tested	8	5	2	1	1	3
variables failed	3	2	1	0	0	0
most failed tests	DO	Turbidity	DO	None	None	None
highest nse	DO	Turbidity	DO	None	None	None

SWQI was calculated for Čenta station (Table 7) 11 times and ranged from poor (65) to excellent (90). Poor SWQI was the consequence of O_2 saturation deficit (59%) and increased BOD (3.7 mg/l), which was more than quadruple than ideal value (0.9 mg/l).

CWQI for Čenta station (Table 7) was overall fair (77), as well as for aquatic (68) and drinking (76), and excellent for recreation, irrigation and livestock (100). Dissolved Oxygen values were under the lower limit in five cases and ranged from 5.3 to 9 mg/l. pH values were higher than upper limit in two cases (8.6 and 8.7) and turbidity with 1.12 JTU had the highest nse. These results were almost identical with Slankamen station, because there also were no measures of heavy metals concentration.

Table 7. SWQI and CWQI for Čenta station in 2010

Date and Time	Temperature	pH	Conductivity	O_2 saturation	BOD	Suspended solids	Total Nitrogen Oxides	Ortho-phosphates	Ammonium	E coli	SWQI
26.1. 14:30	5	8	1	17	13	7		6	11		85 Very good
9.2. 10:30	5	8	1	17	14	7	5	7	10		84 Very good
15.3. 10:30	5	8	2	18	12	6	5	7	12		85 Very good
19.4. 11:00	5	7	2	18	12	4	6	8	12	12	86 Very good
23.5. 10:30	5	8	2	17	13	3	6	6	12		82 good
23.6. 11:30	3	8	2	8	10	4	7	4	11		65 poor
28.7. 10:30	1	7	2	17	13	3	7	8	12		82 good
9.8. 10:30	1	8	2	18	13	1	7	7	12		78 good
20.9. 10:30	5	8	2	17	14	3	7	6	12		84 Very good
21.10. 10:30	5	8	2	17	14	6	6	7	12		88 Very good
4.11. 10:30	5	8	2	18	15	5	6	8	12		90 excellent

	Overall	Drinking	Aquatic	Recreation	Irrigation	Livestock
CWQI	77	76	68	100	100	100
Categorization	Fair	Fair	Fair	Excellent	Excellent	Excellent
F_1 (Scope)	38	40	50	0	0	0
F_2 (Frequency)	13	8	23	0	0	0
F_3 (Amplitude)	2	0	5	0	0	0
variables tested	8	5	2	1	1	3
variables failed	3	2	1	0	0	0
most failed tests	DO	pH	DO	None	None	None
highest nse	DO	Turbidity	DO	None	None	None

SWQI was calculated 12 times for Smederevo station (Table 8) and ranged from 72 (good) to 91 (excellent). CWQI for Smederevo station (Table 8) was overall fair (73), as well as for aquatic habitat (66), good for drinking (86) and irrigation (89) and excellent for recreation and livestock (100). Copper limit value was exceeded in all 10 cases where copper was measured and ranged from 0.0055 to 0.015 mg/l. Turbidity exceeded upper limit in four cases and ranged from 1.12 to 1.9 JTU. Chromium exceeded upper limit for irrigation (0.0049) in one case and amounted 0.007 mg/l. Manganese exceeded upper limit in two cases for drinking (0.05 mg/l) in two cases and for irrigation in one case (0.2 mg/l), and amounted 0.09 and 0.79 mg/l.

Table 8. SWQI and CWQI for Smederevo station in 2010

Date and Time	Temperature	pH	Conductivity	O_2 saturation	BOD	Suspended solids	Total Nitrogen Oxides	Ortho-phosphates	Ammonium	E coli	SWQI
20.1. 14:00	5	9	3	17	14	3	7	8	12		89 very good
17.2. 13:00	5	9	2	18	13	5	8	7	12		90 excellent
17.3. 13:00	5	9	2	18	13	3	7	7	10		84 very good
21.4. 16:00	5	8	3	18	13	6	8	6	10	10	87 very good
19.5. 14:30	5	8	3	17	14	6	8	7	12		91 excellent
16.6. 15:00	0	8	1	18	9	7	8	2	12	11	76 good
21.7. 9:00	0	9	2	6	14	5	8	7	12		72 good
18.8. 18:30	1	8	2	14	14	5	7	6	12	10	79 good
15.9. 10:30	3	8	2	17	11	5	7	6	9		77 good
20.10.15:30	5	8	2	17	14	6	8	7	8	10	85 very good
17.11.10:30	5	9	2	17	13	5	7	7	12		88 very good
29.12.13:30	5	8	2	18	14	5	8	7	12		90 excellent

	Overall	Drinking	Aquatic	Recreation	Irrigation	Livestock
CWQI	73	86	66	100	89	100
Categorization	Fair	Good	Fair	Excellent	Good	Excellent
F_1 (Scope)	37	21	45	0	18	0
F_2 (Frequency)	16	5	24	0	2	0
F_3 (Amplitude)	23	11	28	0	3	0
variables tested	19	14	11	1	11	12
variables failed	7	3	5	0	2	0
most failed tests	Cu	Turbidity	Cu	None	Cr Mn	None
highest nse	Cu	Mn	Cu	None	Mn	None

SWQI was calculated 10 times for Banatska Palanka station (Table 9) and ranged from poor (66) to very good (86). Poor SWQI was the consequence of deficit O_2 saturation (52%), which was twice lower than ideal value and increased E. coli (24000 MPN/100 ml), 109 times higher than ideal value.

CWQI for Banatska Palanka station (Table 9) was overall marginal (51), poor for aquatic habitat (37), fair for drinking (76), good for irrigation (84) and excellent for recreation and livestock (100). Copper limit value was exceeded in all 10 cases and ranged from 0.006 to 0.12 mg/l. Iron also exceed upper limit in all 10 cases and ranged from 0.68 to 5.6 mg/l. This maximum value was almost 19 times higher than upper limit value. Chromium exceeded upper limit for overall and aquatic habitat (0.001 mg/l) in all 10 cases and for irrigation (0.0049 mg/l) in two cases and ranged from 0.002 to 0.013 mg/l. Manganese exceeded upper limit (0.2 mg/l) for irrigation in two cases and amounted 0.26 and 0.78 mg/l.

Table 9. SWQI and CWQI for Banatska Palanka station in 2010

Date and Time	Temperature	pH	Conductivity	O_2 saturation	BOD	Suspended solids	Total Nitrogen Oxides	Ortho-phosphates	Ammonium	E coli	SWQI
21.1. 11:30	5	8	3	17	12	0	6	7	9		76 good
18.2. 11:00	5	8	2	18	12	3	6	7	9		80 good
18.3. 11:30	5	8	2	18	13	3	6	7	11	11	84 Very good
15.4. 11:00	5	8	2	17	14	4	7	8	11	10	86 Very good
20.5. 11:00	5	9	2	15	14	3	7	7	11	10	83 good
17.6. 11:00	2	9	2	6	14	3	7	7	9	7	66 poor
26.8.	1	9	2	13	13	3	7	6	10	10	74 good
16.9. 11:00	4	9	2	15	14	3	7	7	10	10	81 good
14.10. 11:30	5	9	2	15	14	4	7	6	11	10	83 good
18.11. 11:30	5	8	2	16	14	4	7	7	10	10	83 good

	Overall	Drinking	Aquatic	Recreation	Irrigation	Livestock
CWQI	51	76	37	100	84	100
Categorization	Marginal	Fair	Poor	Excellent	Good	Excellent
F_1 (Scope)	47	21	64	0	27	0
F_2 (Frequency)	32	12	50	0	5	0
F_3 (Amplitude)	62	33	72	0	5	0
variables tested	19	14	11	1	11	12
variables failed	9	3	7	0	3	0
most failed tests	Cr Cu	Fe	Cr Cu	None	Cr Mn	None
highest nse	Cu	Fe	Cu	None	Mn	None

SWQI was calculated 12 times for Veliko Gradište station (Table 10) and ranged from 72 (good) to 91 (excellent). CWQI for Veliko Gradište station (Table 10) was overall fair (76), marginal for aquatic habitat (64), good for drinking (90) and excellent for recreation, irrigation and livestock (100). Copper limit value was exceeded in all four cases where copper was measured and ranged from 0.0042 to 0.035 mg/l and it has highest nse for overal and aquatic habitat. Turbidity exceeded upper limit in five cases and ranged from 1.22 to 5.47 JTU, more than five times higher than upper limit. Dissolved oxygen values were under lower limit in four cases and ranged from 7.2 to 9.4 mg/l.

Table 10. SWQI and CWQI for Veliko Gradište station in 2010

Date and Time	Temperature	pH	Conductivity	O_2 saturation	BOD	Suspended solids	Total Nitrogen Oxides	Ortho-phosphates	Ammonium	E. coli	SWQI
25.1. 12:00	5	8	3	16	13	3	7	7	7		78 good
23.2. 10:00	5	8	2	16	7	1	7	6	11		72 good
16.3. 8:30	5	8	2	18	13	3	7	7	12		85 very good
19.4. 11:00	5	8	2	17	13	5	7	7	11	8	83 good
24.5. 9:00	4	8	3	18	14	6	8	7	12		91 excellent
22.6. 9:00	2	9	3	15	11	7	7	7	11	12	84 very good
19.7. 12:30	0	8	2	12	13	7	8	6	12		77 good
23.8. 17:30	1	8	2	16	11	5	7	6	9	7	72 good
21.9. 9:00	4	8	2	15	14	6	7	6	10		82 good
2.11. 13:30	5	8	2	17	14	7	8	7	12	8	88 very good
27.11.10:00	5	8	2	17	12	7	8	7	10		86 very good
17.12 15:00	5	8	2	17	14	5	7	7	12		88 very good

	Overall	Drinking	Aquatic	Recreation	Irrigation	Livestock
CWQI	76	90	64	100	100	100
Categorization	Fair	Good	Marginal	Excellent	Excellent	Excellent
F_1 (Scope)	32	14	45	0	0	0
F_2 (Frequency)	13	7	21	0	0	0
F_3 (Amplitude)	23	8	36	0	0	0
variables tested	19	14	11	1	11	12
variables failed	16	12	5	0	0	0
most failed tests	turbidity DO	Turbidity	DO	None	None	None
highest nse	Cu	Turbidity	Cu	None	None	None

SWQI was calculated 12 times for Dobra station (Table 11) and ranged from 75 (good) to 89 (very good). CWQI for Dobra station (Table 11) was overall fair (68), marginal for aquatic habitat (56), good for drinking (85) and excellent for recreation, irrigation and livestock (100). Copper limit value was exceeded in all five cases, where it was measured and ranged from 0.004 to 0.061 mg/l. Turbidity exceeded upper limit in five cases and ranged from 1.06 to 8.53 JTU, more than 8 times higher than upper limit.

Table 11. SWQI and CWQI for Dobra station in 2010

Date and Time	Temperature	pH	Conductivity	O_2 saturation	BOD	Suspended solids	Total Nitrogen Oxides	Ortho-phosphates	Ammonium	E coli	SWQI
26.1. 13:20	5	8	3	17		3	7	7	9		81 good
16.3. 12:00	5	8	2	17	8	1	7	6	12		75 good
23.3. 12:00	5	7	2	18	14	4	7	7	12		86 very good
20.4. 10:00	5	8	2	17	14	6	7	7	10	12	88 very good
25.5. 11:30	5	8	3	15	14	3	8	7	12		85 very good
22.6. 12:30	2	9	3	11	12	5	8	6	11	12	79 good
20.7. 10:00	0	8	2	14	14	7	7	6	12		80 good
24.8. 9:00	1	8	2	17	11	6	7	6	11	7	76 good
21.9. 11:30	4	8	2	15	14	7	7	6	8		81 good
3.11. 10:00	5	8	2	18	14	6	8	7	12	8	88 very good
26.11.10:00	5	8	2	18	14	6	8	7	10		89 very good
14.12.17:00	5	8	2	18	14	3	7	7	12		86 very good

	Overall	Drinking	Aquatic	Recreation	Irrigation	Livestock
CWQI	68	85	56	100	100	100
Categorization	Fair	Good	Marginal	Excellent	Excellent	Excellent
F_1 (Scope)	42	21	55	0	0	0
F_2 (Frequency)	15	8	23	0	0	0
F_3 (Amplitude)	34	12	48	0	0	0
variables tested	19	14	11	1	11	12
variables failed	8	3	6	0	0	0
most failed tests	turbidity Cu	Turbidity	Cu	None	None	None
highest nse	Cu	Turbidity	Cu	None	None	None

SWQI was calculated 12 times for Radujevac (Table 12) and ranged from 75 (good) to 92 (excellent). CWQI for Radujevac station (Table 12) was overall marginal (57), poor for aquatic habitat (40), good for drinking (80) and irrigation (94) and excellent for recreation (100) as well as livestock (95). Copper limit value was exceeded in all cases and ranged from 0.004 to 0.03 mg/l as well as iron which ranged from 0.33 to 2.47 mg/l. Chromium limit value was exceeded in three cases for irrigation and amounted 0.006, 0.0064 and 0.009 mg/l. Arsenic limit value for livestock (0.025 mg/l) was slightly exceeded in one case and amounted 0.0251 mg/l.

Table 12. SWQI and CWQI for Radujevac station in 2010

Date and Time	Temperature	pH	Conductivity	O_2 saturation	BOD	Suspended solids	Total Nitrogen Oxides	Ortho-phosphates	Ammonium	E coli	SWQI
28.1. 12:00	5	9	3	17	13	4	7	7	7		82 good
24.2. 11:00	5	8	2	18	12	3	7	6	12	12	85 very good
17.3. 12:30	5	8	2	18	13	4	7	0	11	11	79 good
21.4. 10:30	5	9	3	16	14	6	7	7	8	12	87 very good
26.5. 12:30	5	9	3	17	14	5	8	4	12	11	88 very good
23.6. 11:30	2	9	2	15	14	4	7	6	12	11	82 good
21.7. 11:30	0	9	2	9	11	7	8	5	12	12	75 good
25.8. 13:00	1	9	2	10	13	7	7	7	12	12	80 good
22.9. 13:30	4	9	2	14	13	7	7	7	12	11	86 very good
4.11. 11:00	5	8	2	16	14	7	7	5	10	11	85 very good
24.11.13:30	5	9	2	17	14	7	7	7	12	12	92 excellent
15.12.13:00	5	9	2	18	11	3	7	6	10	11	82 good

	Overall	Drinking	Aquatic	Recreation	Irrigation	Livestock
CWQI	57	80	40	100	94	95
Categorization	Marginal	Good	Poor	Excellent	Good	Excellent
F_1 (Scope)	53	29	73	0	9	8
F_2 (Frequency)	27	11	45	0	3	1
F_3 (Amplitude)	46	17	60	0	1	0
variables tested	19	14	11	1	11	12
variables failed	10	4	8	0	1	1
most failed tests	Cu Fe	Fe	Cu Fe	None	Cr	As
highest nse	Cu	Fe	Cu	None	Cr	As

Discussion

According to the SWQI, water quality of Danube River in Serbia in 2010, was mainly assessed as good and very good. In few cases SWQI was poor and excellent. Poor SWQI was mainly result of O_2 saturation deficit. However, these results should be accepted as questionable, because SWQI gives information about organic loading, but not about heavy metals pollution. This limitation was the reason of using methodology CWQI for assessment of water quality in depth.

CWQI methodology gives information about heavy metal pollution and evaluates water quality for different purposes such as aquatic habitat, drinking, irrigation, recreation and livestock. CWQI was overall fair and marginal and ranged from 51 to 77 which complied with poor and good SWQI. Disagreement between SWQI and CWQI was the result of different methods of calculation and

used parameters (especially heavy metals). This statement should be confirmed with two cases (Slankamen and Čenta), where there was no data about heavy metals concentration and SWQI and CWQI were similar. In these two stations dissolved oxygen was below of lower limit in five cases. This was in line with deficit of O_2 saturation, which was used for SWQI. Expressive example for this statement was 23.6. 2010, when O_2 saturation was 59% for Čenta station and 64% for Slankamen station, and dissolved oxygen 5.3 mg/l for Čenta station, and 5.7 mg/l for Slankamen station. Copper values exceeded upper limits in all cases where it was measured and it had negative impact on overall CWQI as well as for aquatic habitat. CWQI for aquatic habitat was poor, marginal and fair and ranged from 37 to 68, which was confirmation of bad conditions for aquatic life. CWQI for drinking was good and fair, and excellent in one case. Turbidity often had increased value, in some cases three to more than eight times higher than upper limit, which had negative impact on drinking water. Excellent conditions were for recreation, livestock and irrigation except for irrigation in cases of Banatska Palanka station and Radujevac station, where it was good. According to CWQI these two stations had most signs of heavy metals pollution. Besides copper, chromium exceeded upper limits for overall, aquatic habitat and irrigation, iron for drinking as well as manganese for irrigation in Banatska Palanka station. Similar results were derived for Radujevac station: besides copper, upper limits were exceeded for iron (overall, drinking and aquatic habitats) and chromium for irrigation. Heavy metal pollution in these two stations could be, eventually, explained by impact of Iron Gate (for Radujevac) and tributaries water quality for Banatska Palanka, which could be a subject of some future research. Excellent CWQI for recreation in all cases should be considered as questionable, because just one parameter (pH) was tested.

This paper points to the complexity of the problem of water quality determining and its dependence on research methods. In order to achieve relevant results it is necessary to standardize research methods, or at least to develop unique WQI methodology.

Acknowledgment:
This paper is the result of the project 47007, funded by the Ministry of Education, Science and Technological Development of Republic of Serbia.

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