Research Article

Water Pollution and Water Quality Assessment of Major Transboundary Rivers from Banat (Romania)

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This study focuses on water resources management and shows the need to enforce the existing international bilateral agreements and to implement the Water Framework Directive of the European Union in order to improve the water quantity and quality received by a downstream country of a common watershed, like Timiș-Bega hydrographical basin, shared by two countries (Romania and Serbia). The spatial trend of water quality index (*WQI*) and its subindexes are important for determining the locations of major pollutant sources that contribute to water quality depletion in this basin. We compared the values of *WQI* obtained for 10 sections of the two most important rivers from Banat, which have a great importance for socioeconomic life in southwestern part of Romania and in northeastern part of Serbia. In order to assess the water quality, we calculated the *WQI* for a long period of time (2004–2014), taking into account the maximum, minimum, and the mean annual values of physical, chemical, and biological parameters (*DO*, *pH*, *BOD₅*, *temperature*, *total P*, *N-NO₂⁻*, and *turbidity*). This article highlights the importance of using the water quality index which has not been sufficiently explored in Romania and for transboundary rivers and which is very useful in improving rivers water quality.

1. Introduction

The water quality from the rivers has a considerable importance for the reason that these water resources are generally used for multiple matters such as: drinking domestic and residential water supplies, agriculture (irrigation), hydroelectric power plants, transportation and infrastructure, tourism, recreation, and other human or economic ways to use water [1].

For a given river the water quality is the result of several interrelated parameters with a local and temporal variation which are influenced by the water flow rate during the year [2].

In the context of sustainable water management, many hydrological studies have been published around the world, which highlights the ecological role of water from the rivers. Moreover, there have been more researches based upon water quality evaluation [3–5]. This category of studies is related to the quality of watercourses which generally use many statistical and mathematical models.

Most of the studies related to the assessment of the water resources quality use several water quality indices among

the most important are water quality index (*WQI*), water pollution index (*WPI*), and river habitat survey (*RHS*) [6, 7].

Studies focusing on water quality of water bodies from Romanian territory and especially of major transboundary rivers from Banat hydrographical area are scarce, so this study has a great importance for the reason that it describes the suitability of surface water sources from this hydrographical area for human consumption being useful for communication of overall water quality information to the concerned citizens and policy makers.

To determine the locations of major polluting sources that contribute to water quality depletion in the Timiș-Bega hydrographical basin and its tributaries, an analysis has been made in order to evaluate the two largest waterways from Banat (Timiș and Bega transboundary rivers), using the water quality index (*WQI*) method, which is one of the most reliable indicators of the watercourses pollution and the most convenient way to express the water quality at the same time [8].

Timiș-Bega hydrographical system is located in the western part of Romania, overlapping the hydrographical basins

FIGURE 1: The geographical position of the Timiș-Bega hydrographical basin within Romania.

of Timiș and Bega rivers, named after the hydrotechnical works constructed in the two basins. These works are meant to ease the better management of the water resources within them, interconnecting the two rivers, through the Coștei-Chizătău Supply Channel and Topolovăț-Hitiaș Discharge Channel (Figure 1).

Timiș River is the most important river of Banat historical region, springing from the crystalline massif of Semenice, under the Piatra Goznei Peak, from the approximate altitude of 1135 m, and it discharges on a total length of 249 km up to the confluence point with the Danube, located in the South of Pancevo locality, on the current territory of Serbia [9, as amended]. The river gathers its tributaries that spring from the Banat Mountains, Țarcuții Mountains, Poiana Ruscă Mountains, and, finally, the piedmont hills of Lugoj and Pogăniș, summing up a total length of the watercourses of approximately 462 km and a watershed surface of 5505 km² on the territory of Romania, representing approximately 2.31% from the total surface of Romania (238391 km²) [10].

Bega River springs from Poiana Ruscă Mountains, under Padeș Peak (1359 m), from an altitude of 1150 m, discharging into Tisa River, near Titel locality, found on the current territory of Serbia where it collects its tributaries from Poiana Ruscă Mountains, Lipova Piedmont, the pied mountainous, and divagation field of Banat that are summing up a length of 176 km and a surface of 2675 km² on the territory of Romania (almost 1.12% from the total surface) [10].

Human activities in the basin of the two most important rivers from Banat have a great importance for socioeconomic life in southwestern part of Romania and in northeastern part of Serbia. Moreover, these human activities have an important influence in the geographical environment generally speaking with a particularity in what concerns the water resources, their quantity, and quality.

The problems involving the water resources management activity from Timiș-Bega hydrographical system consist of the assurance of the required water demand by the various social-economic objectives, the prevention of damaging effects of the waters, and the maintenance of a good environmental quality.

The water intakes from Timiș-Bega hydrographical system are providing the drinkable water supply or the use of water for industrial purposes, which can influence the river hydromorphological level, changing the features of the natural water discharge regime on their courses.

In Timiș-Bega hydrographical system the river monitoring activity started in the 19th century, when the achievement of drainage works of great amplitude was started, in the subsidence area of the Western Plain, where several swamps and frequent floods took place, and when several hydrotechnical works were performed, based on studies and projects, for which several observations and hydrological measurements were necessary.

According to the Water Framework Directive of European Union (WFD 2000), Timiș-Bega watershed has been selected several watercourses, well-delimited in the territory, for the operational monitoring of the surface and ground waters and for the determination of water quality status, as follows: 14 surface water bodies found in natural status, 12 surface water bodies which are heavily modified and artificial, 3 surface reservoirs, and 8 monitored ground water bodies [10].

2. Materials and Methods

The water quality index (WQI) is a numeric expression used to evaluate the quality of a given water body meant to be easily understood by managers from many countries [11].

TABLE 1: Index value intervals and the corresponding quality category [17].

Value intervals (%)	Water quality status
90–100	Excellent
70–90	Good
50–70	Medium
25–50	Bad
0–25	Very bad

In order to calculate the water quality index, Horton proposed in 1965 the first formula which takes into account all parameters necessary for determining the quality of the surface waters and which reflects the composite influence of different parameters important for the assessment and management of water quality [12, 13].

This index was for the first time used to highlight the physical-chemical changes that may occur during the year on the flowing water quality [14, 15].

Most often, the water quality index is used in the evaluation of surface water quality. This index incorporates data from multiple parameters into a mathematical equation that rates the quality of water bodies with numbers from 1 to 100 which can be separated in five classes, each class with a different quality state and with a different usage domain [13, 16].

One of the most computation formulas used to determine the water quality index can be noticed in the following arithmetic expression:

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

where i is the quality parameter, q_i is the registered value, and w_i is the rank of implication of the parameter in the computation formula [12].

Seven factors have been chosen, in order to rate this index; each of them is more important than others, so weighted mean is used to combine the values of these factors.

The classes of the water quality status obtained according to the quality intervals of the WQI are presented in Table 1.

WQI scores above 80 represent stations of “lowest concern” that generally meet state water quality standards, WQI scores between 40 and 80 indicate stations of “marginal concern,” and WQI scores below 40 did not meet expectations and are of “highest concern” [18].

In order to obtain the WQI values a selection of the parameters has been made according to the Global Quality Classes established through the norms regarding the classification of surface water quality towards the determination the ecological status of the water bodies.

Thereby, some of the most important parameters of water quality index have been taken into account with the impossibility of considering two of these parameters (total coliforms and turbidity), for the reason that, first of all, the total coliforms parameter is monitored only in the sections where the water is targeted for the potable use and secondly

because turbidity was not considered from sampling stations analyzed.

The results have been further analyzed using current Romanian legislation (the Water Law number 107/1996, as amended and supplemented, the Law number 310/2004, and Order number 161/2006 approving the norms concerning the classification of surface water quality to determine the ecological status of water bodies) which complies with WFD 2000 [19–22].

This directive has been adopted by European Parliament and Council (Directive 2000/60/EC) on establishing a framework for European Community action in the field of water, and it contains for each parameter the limit values for corresponding chemical status of all five classes set, namely, very good (1st grade of quality), good condition (2nd grade of quality), moderate condition (3rd grade of quality), poor condition (4th grade of quality), and bad condition (5th grade of quality) [23].

Another step in calculating the values of water quality index from each sampling sections analyzed has been the one that brings all the measurement units at the same reference scale.

Determining the degree of involvement of the parameters has been accomplished in correspondence with the specific methodology, which takes into account the role of each analyzed parameter in defining the status of the water bodies and of the aquatic ecosystems [12]. Afterward the last step has been completed using an online calculator of the water quality index advanced by Mr. Brian Oram in 2010, according to the Field Manual for Water Quality Monitoring book [12, 17].

The computation of the WQI for two of the most important rivers from Banat (Timiș and Bega) has been performed taking into account the mean annual values of each quality parameter, which were registered at the six monitoring stations on the Timiș River (Sadova Veche, Potoc, Lugoj, Hitiaș, Șag, and Grăniceri) and at the four monitoring stations on the Bega River (Luncanii de Jos, Balinț, Timișoara, and Otelec).

3. Results and Discussions

In order to assess the water quality of Timiș and Bega rivers the water quality index for a long period of time (2004–2014) has been calculated which has been applied also for 10 sampling sections, along the Timiș (6) and Bega (4) rivers, taking into account the maximum annual, the minimum annual, and the mean annual values of 7 following physical, chemical, and biological parameters: *DO* (oxygen saturation in percent), *pH* (in pH units), *BOD5* (biochemical oxygen demand in mg O₂/L), temperature (°C), *total P* (total phosphorus in mg P/L), *N-NO₂⁻* (total nitrates in mg N/L), and *turbidity* (mg/L), with units of measurement adapted according to International Union of Pure and Applied Chemistry (IUPAC).

The average values of physical (*temperature* and *turbidity*), chemical (*pH*, *total phosphorus* and *nitrates*), and biologic/organic (*oxygen saturation* and *biochemical oxygen demand*) parameters of water from Timiș and Bega rivers

TABLE 2: Water quality status and WQI values at sampling stations from the Timiș River.

Water quality parameters (unit)	Water sampling station								
	Sadova Veche			Potoc			Lugoj		
	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean
DO (%)	125.9	56.1	84.5	128	57.7	85.7	163.8	54.1	98.1
pH (U pH)	7.9	7.1	7.5	7.9	7.2	7.6	9	6.8	7.6
BOD5 (mg O ₂ /L)	3	1.2	1.9	3	1.1	1.9	5.8	1.2	2.8
Temperature (°C)	17.3	1	7.9	17	1.9	8.6	24.5	1.5	12.9
Total P (mg P/L)	0.075	0.032	0.050	0.106	0.026	0.052	0.298	0.028	0.106
N-NO ₂ ⁻ (mg N/L)	0.021	0.004	0.010	0.037	0.008	0.017	0.041	0.004	0.016
Turbidity (mg/L)	37.2	18.7	26.1	41.4	17.9	27.1	198.3	4.6	37.5
Overall WQI	79	83	86	78	84	86	58	81	83
Class	II	II	II	II	II	II	III	II	II
Water quality status	Good	Good	Good	Good	Good	Good	Medium	Good	Good
Water quality concern	Marginal concern	Lowest concern		Marginal concern	Lowest concern		Marginal concern	Lowest concern	

Source. Data processed by the Banat Water Basin Administration (ABAB) Archives, Timișoara.

TABLE 3: Water quality status and WQI values at sampling stations from the Timiș River.

Water quality parameters (unit)	Water sampling station								
	Hitiaș			Șag			Grăniceri		
	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean
DO (%)	130.9	40	79.1	147.7	51.2	89.3	144.7	47.4	86.7
pH (U pH)	7.7	6.8	7.3	7.7	7	7.4	8	7.2	7.6
BOD5 (mg O ₂ /L)	10.8	1.3	4.2	4.8	1.1	2.4	6	1.6	3.7
Temperature (°C)	23.6	2.7	12.6	23.6	2.1	12.1	23.3	3.1	12.7
Total P (mg P/L)	0.437	0.042	0.145	0.263	0.041	0.123	0.434	0.058	0.171
N-NO ₂ ⁻ (mg N/L)	0.078	0.009	0.030	0.042	0.007	0.021	0.046	0.006	0.021
Turbidity (mg/L)	291.4	8.9	68	185.2	6.2	44.9	124.9	11.5	46.8
Overall WQI	66	76	79	66	81	83	62	79	81
Class	III	II	II	III	II	II	III	II	II
Water quality status	Medium	Good	Good	Medium	Good	Good	Medium	Good	Good
Water quality concern	Marginal concern			Marginal concern	Lowest concern		Marginal concern		Lowest concern

Source. Data processed by the Banat Water Basin Administration (ABAB) Archives, Timișoara.

and the results of water quality data analysis are presented in Tables 2, 3, 4, and 5.

At Sadova Veche and Potoc monitoring stations, located on the upper course of Timiș River, the water quality status is good (70–90%), according to the average, maximum, and minimum annual values of the analyzed parameters during the period under review (2004–2014), which make these sampling stations fall into the “lowest concern” category (Table 2).

Downstream on the Timiș River beginning with Lugoj monitoring section until the border between Romania and Serbia the water quality is preserved in good condition according to the mean and minimum annual values. Only the maximum annual values decreased, which cause the medium status of water quality (50–70%) at all other sections (Lugoj,

Hitiaș, Șag, and Grăniceri), fitting them into the “marginal concern” category (Table 3).

The values of the water quality index from these stations correspond to the moderate class, which are influenced by the nutrients, respectively, by the high values of the nitrates from Timiș river water, as a result of the agricultural practices, municipal and industrial wastewaters, manure from farms, and so on.

The water quality of the Timiș River is influenced by many factors including the quantitative variation of biogenic and organic substances. All biogenic elements within the water bodies are the result of the decomposition process of the organic substances therefore the regime of the biogenic elements depends directly on the vital activity of the organisms from the rivers. Moreover this river is characterized

TABLE 4: Water quality status and WQI values at sampling stations from the Bega River.

Water quality parameters (unit)	Water sampling station					
	Luncanii de Jos			Balint		
	Max.	Min.	Mean	Max.	Min.	Mean
DO (%)	146.3	60.6	97.6	154.1	48.3	89.1
pH (U pH)	8.3	7.6	8	8.1	7.2	7.7
BOD5 (mg O ₂ /L)	3.7	0.8	2	6.1	1.5	3.4
Temperature (°C)	19.8	2.2	10	23	1.7	11.4
Total P (mg P/L)	0.242	0.032	0.099	0.381	0.037	0.128
N-NO ₂ ⁻ (mg N/L)	0.015	0.002	0.007	0.041	0.006	0.017
Turbidity (mg/L)	54.9	4.4	18.8	232.4	5.2	55.5
Overall WQI	66	84	85	61	80	82
Class	III	II	II	III	II	II
Water quality status	Medium	Good		Medium	Good	
Water quality concern	Marginal concern	Lowest concern		Marginal concern	Lowest concern	

Source. Data processed by the Banat Water Basin Administration (ABAB) Archives, Timișoara.

TABLE 5: Water quality status and WQI values at sampling stations from the Bega River.

Water quality parameters (unit)	Water sampling station					
	Timișoara			Otelec		
	Max.	Min.	Mean	Max.	Min.	Mean
DO (%)	148.9	44.9	85.6	136.9	23.8	61.9
pH (U pH)	7.8	7	7.4	7.7	6.9	7.3
BOD5 (mg O ₂ /L)	3.8	0.8	1.8	10.3	3.2	5.7
Temperature (°C)	23.9	1.4	12.2	24.7	1.5	13.1
Total P (mg P/L)	0.395	0.026	0.117	0.881	0.161	0.418
N-NO ₂ ⁻ (mg N/L)	0.041	0.004	0.013	0.268	0.011	0.056
Turbidity (mg/L)	132.1	5.7	30.1	134.8	5.2	28.9
Overall WQI	65	80	84	64	69	68
Class	III	II	II	III	III	III
Water quality status	Med.	Good		Medium		
Water quality concern	Marginal concern	Lowest concern		Marginal concern		

Source. Data processed by the Banat Water Basin Administration (ABAB) Archives, Timișoara.

by the presence of several impurities in natural state with a composition which depends on the types of soils from the reception basin, waste water spills from different kind of users, and the dissolving capacity of the gases in the atmosphere [24, 25].

Within the water of unpolluted rivers, the concentration of nitrates often oscillates between the limits of a few tenths of mg/l. The main cause for the loading of the flowing waters with nitrates consists in the eviction of the urban waste waters [26]. This is the reason why the content in N-NO₂⁻ of the river water is almost double at Lugoj station and the reason why the water quality is changing from good to a moderate status according to the maximum annual values.

Generally, the best water quality status from Bega River concerning average and minimum annual is centralized in the sections from the upper course, which falls into the “lowest concern” category (Tables 4 and 5).

Downstream from Timișoara until the Romanian Serbian border the water quality status is deteriorated according to the average annual, maximum annual, and minimum annual

values of the water quality index (50–70% – medium state), so the water quality of Bega River has a moderate status at the exit of our country, weaker compared with Timiș River, which causes Grăniceri station to have a “marginal concern” regarding water quality.

Water quality of the most important rivers from Timiș-Bega hydrographical basin is a result of human activity and demographic characteristics on one side and urbanization and industrialization on the other side. Discharging of untreated waste waters from industry, households, and pollution from agriculture (sewage water from rural localities, from animal farms and from industry) are the main causes of pollution on surface water resources and groundwater in this region [27, 28].

The human stress on the surface water within Timiș and Bega catchments is induced by the total number of inhabitants (almost 700000 people) and the urban inhabitants (428168 people, by National Institute of Statistics (INS) from Romania, 2011) from cities like Timișoara, Lugoj, Buziaș, Făget, Recaș, Ciacova, Caransebeș, and Oțelu Roșu, by the

organic loading that they generate through the industrial activities, land use, and animal husbandry in animal farming complexes, and finally through the degree of improvement of the hydrographical network, as a result of human activity.

At the monitoring sections situated downstream of the wastewater discharge high values of nitrogen compounds have been identified, more exactly of the nitrate, nitrite, and ammonium ions, which influence the quality of the watercourses, especially Timiș and Bega that flow into the Tisa River and Danube River on the territory of Serbia.

The waters of Timiș River and Bega River at the exit from Romania country are much polluted because the rivers quality state suffers a slight depreciations downstream thanks to effects of the urban sewage, of the urban wastewaters, of the agricultural wastes, and of the natural causes such as erosion in the hydrographical basins of these main rivers from Banat [29].

Water pollution by nitrates reaches high levels due to the introduction of intensive farming methods, with increased use of chemical fertilizers and higher concentrations of animals in smaller areas, especially in animal farming complexes from the Timiș-Bega hydrographical basin. In this basin the values of these parameters vary from one monitoring station to another due to the hydrological regime of the surface water but also to the origin and the behavior of the physical, chemical, and biological parameters.

The anthropogenic factor has an important role in the formation and the influence of leakage water processes on the rivers of this hydrographical system. Starting from 1716 and up to the present, it has mostly influenced the water discharge, by achieving several types of hydraulic structures, among which the most important are the regulation of maximum discharges on the main rivers and the most important tributaries, the performance of flood mitigation works, and river bed regulation, damming works on the most important rivers and tributaries, within the proximity of the most important localities [30, 31].

More than that, in Timiș-Bega hydrographical basin several significant water intakes and two secondary intakes (Slatina and Borlova) have been identified. The most important units that require large amounts of water within the basin are S.C. Aquacaraș S.A. from Caransebeș and Oțelu Roșu, S.C. Meridian 22 S.A. from Lugoj, S.C. Aquatim S.A. from Timișoara, and the National Administration for Land Improvement from Romania (ANIF).

The company which represents the main economic actor in the water supply field from the Timiș-Bega hydrographical basin is S.C. Aquatim S.A. This company operates with public water and wastewater services for Timișoara Municipality and many other localities [32].

During the analyzed period (2004–2014) the evaluation of the ecological status of surface water courses (rivers), existing within Timiș-Bega hydrographical system has revealed the fact that the most rivers have been found in good ecological status.

Concerning the evaluation of the chemical status, one could notice that most rivers have been found in good chemical status and only some of them have been characterized by a

bad chemical status (ANPM-Timiș Environment Protection Agency, Timișoara).

Regarding the surface water courses that are heavily modified (rivers), which exist within this basin, it has been found that most of the water courses have had a moderate ecological potential, the difference being represented by the water courses that have had a good ecological potential; and from a chemical status point of view, more than half had a good chemical status and less than half have had a bad ecological status.

Also in the same period, the evaluation of the ecological potential of the three surface reservoirs existing within the basin analyzed has revealed the fact that all these have had a moderate ecological potential and that all have been found in a good chemical status.

However, the evolution trend within the last few years of the pollutant concentrations recorded at the monitoring stations on the basin rivers has had a significant decrease, due to the measures introduced by the national and European legislation, referring especially to the treatment of the urban waste waters and to the reduction of the pollution with nitrogen and phosphorous from the agricultural practices.

In the analyzed period, the limited excess on the water quality according to the Law 311/2004 was due to the zootechnical complexes (Recaș, Peciu Nou, Pădureni, Parța, Ciacova, Voiteni, etc., some of them owned by COMTIM, currently S.C. Smithfield Ferme S.R.L.) within the Timiș-Bega hydrographical basin, as well as to the spray irrigation of the fields with phenolic waters from S.C. Solventul S.A. from Margina, which at the moment, although it has suspended its activity, continues to influence the quality of ground waters from this region.

Another source which influences quite a lot the surface and underground waters quality from this hydrographical area is Waste Deposit Parța, which does not have environment factor protection equipment [29].

4. Conclusions

The results of this paper present the water polluting and quality assessment of two transboundary rivers (Timiș and Bega) from two different hydrographical basins and show that *WQI* values of the Timiș River ranging from 86 to 58 and *WQI* values of the Bega River ranging from 85 to 61 denote degradation of water quality downstream of the rivers.

Water quality in the upstream sections of the Timiș and Bega has been in a better condition than the downstream river sections. There have been significant deterioration in values of the most important water quality parameters (*DO*, *pH*, *BOD5*, *temperature*, *total P*, *N-NO₂⁻*, and *slurry*) downstream of the rivers, which indicates that the local pollutants may be contributing incrementally to the degradation of river quality.

The given *WQI* values control sections of the studied area are distributed on quality classes as follows: 90% in the 2nd class of quality (good) and 10% in the 3rd class of quality (medium) taking into account the mean annual values; 20% in the 2nd class of quality (good) and 80% in the 3rd class of quality (medium) taking into account the maximum annual; 90% in the 2nd class of quality (good) and 10% in the 3rd

class of quality (medium) taking into account the minimum annual values.

The trend in the water quality index is determined by the economic activities in the agriculture, industrial, and residential areas in the sampling stations vicinity in the Timiș-Bega hydrographical basin. For these reasons a constant monitoring is necessary in order to ensure water quality of Timiș and Bega rivers at the optimum level according to the Water Framework Directive (2000/60/EC), especially because these rivers flow further through the territory of Serbia where they are discharging into Tisa and Danube rivers.

This article focuses on water resources management and shows the need to enforce the existing international bilateral agreements and to implement this European directive in order to improve the water quantity and quality received by the downstream country of a shared watershed, like Timiș-Bega hydrographical basin, shared by two countries, Romania (EU country) and Serbia (non-EU country).

According to the Water Framework Directive requirements, knowledge of anthropogenic pressure formed on water resources is highly imperative, in order to identify the quality of water bodies and ultimately for adopting appropriate measures to protect and conserve the water in this region of Romania which have so many transboundary rivers.

In order to protect the environment in general and preserve a good water quality in particularly, especially of the transboundary rivers from Banat, shared by two countries and by so many communities, it is necessary to implement an adequate wastewater management through the construction of modern and efficient waste water treatment plants.

Conflicts of Interest

The author declares that he has no conflicts of interest.

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