

## ASSESSMENT OF ECOLOGICAL STATUS OF THE RIVER IBAR IN TERMS OF PHYSICOCHEMICAL PARAMETERS

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**Abstract.** *The importance of preservation and improvement of the quality of surface waters implies the consideration of the current ecological state of water quality. The aim of this paper is to present the two methodologies used for determination of the ecological status of the Ibar River. The analysis of measured concentrations of selected physical and chemical parameters, which are the indicators of water quality, is based on the data obtained from the stations along the river. Ecological classification of watercourse is defined in accordance with the methodology prescribed by Regulation on the parameters of the ecological and chemical status of surface water and the parameters of the chemical and quantitative status of groundwater. The research data were obtained from the Serbian Environmental Protection Agency from 2013. It was found that some parameters exceeded the limit values of required good status, and therefore, the Ibar is given moderate ecological status. Moderate ecological status of the river Ibar corresponds to Class III watercourses. The conditions that correspond to biological parameters are typical for a given status. The ecosystem approach clearly indicates the need to take continuous monitoring in order to prevent disruption and to improve water quality as an integral part of the environment protection.*

**Key words:** *ecological status, the Ibar River*

### 1. INTRODUCTION

Water Framework Directive (WFD) has established a new approach for protection, improvement and sustainable utilization of water systems, which includes integrated management of the water resources. The general goal of WFD is to achieve and maintain „good ecological status” and „good chemical status” of water bodies, and „good ecological

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potential” for heavily modified or artificial water bodies by 2015 [1]. Legislation in the field of sustainability of water systems in Serbia and harmonization with the European Directives has been implemented since 2012, through various laws, regulations and provisions on water and The Surface Water Quality Monitoring Programme. These legislation and procedures arising from them were the basis for setting up our research methodology within the definition of the status and sustainability of the Ibar water system.

The river Ibar basin belongs to the West Morava, that is, the Black Sea basin. The river Ibar, the longest and the most important tributary of the Western Morava river is 276 [km] long. The surface of its basin is 8060 [km<sup>2</sup>]. It springs from the strong fountainhead under Hajla Mountain (1360 [m]) in Montenegro, 10 [km] upstream from Rožaje. It enters the territory of the Republic of Serbia 20 [km] downstream from Rožaje, flows east to Kosovska Mitrovica taking tributary the river Sitnica, and turns north to Kraljevo, where it flows into the West Morava River [2]. The original scientific paper by Ockoljic et al., classifying the river waters in Serbia by the degree of their pollution, ranks the river Ibar as one of the most polluted rivers in Serbia [3].

The selection of methodology for analysis of collected data on water quality was a problem that needed to be solved. Nowadays, a large number of data processing methodologies based on statistic procedures and mathematical models are used worldwide. In this case, the first step was to solve the problem of what type of analysis should be conducted: whether to analyse the collected data in their spatial milieu according to time and location of sampling or to analyse them as incomplete time series. These are two different approaches to data processing. The understanding of processes in watercourse suggests to use both of them in the analysis and multivariable analysis of obtained results. A good ecological status is defined by „unalterable” condition, permitted small deviations from natural conditions, and determined reference values that indirectly define the goal that given water body must reach. Ecological status is determined in terms of chemical and physicochemical quality elements, which are important for biological elements of certain types of surface waters.

## 2. MATERIALS AND METHODS

Ecological status of surface waters is determined according to three groups of quality elements: biological, hydromorphological and physicochemical. Ecological status of unalterable water bodies, surface waters is classified as High (I), Good (II) and Moderate (III). All surface waters that have a status lower than moderate are classified as Poor (IV) or Bad (V). Waters showing signs of major changes in the values of biological quality elements, for a given type of surface waters, and in which relevant biological communities deviate substantially from the ones common for that type under undisturbed conditions are classified as poor. Waters showing very large changes in the value for that type of water are classified as bad. Generally, Regulation on the parameters of the ecological and chemical status of surface water and the parameters of the chemical and quantitative status of groundwater („Official Gazette of RS”, No. 74/2011) prescribes ecological status parameters and defines types and related aquatic bodies. According to this Regulation, all sections of the river Ibar are classified as the water body TYPE 2-big rivers in which middle layer dominates [4].

The assessment of ecological status class is determined according to defined chemical and physicochemical parameters: pH, dissolved oxygen, biochemical oxygen demand (BOD-5), ammonium ion, nitrates, orthophosphates, total dissolved phosphorus and chlorides. Table 1 presents the limits of chemical and physicochemical parameters for the assessment of ecological status class [4].

**Table 1** Chemical and physicochemical limits of ecological status for water bodies TYPE 2.

Parameter	Units	Limits between the classes of ecological status			
		I-II	II-III	III-IV	IV-V
pH value	-	6,5-8,5	6,5-8,5	6,5-8,5	<6,5 or >8,5
Dissolved oxygen	mg/l	8,5	7,0	5,0	4,0
BOD-5	mg/l	1,8	4,5	6,0	20,0
Total organic carbon (TOC)	mg/l	2,0	5,0	7,0	23,0
Ammonium ion (NH <sub>4</sub> -N)	mg/l	0,05	0,1	0,8	1,0
Nitrates (NO <sub>3</sub> N)	mg/l	1,50	3,00	6,00	15,00
Orthophosphates (PO <sub>4</sub> -P)	mg/l	0,02	0,1	0,2	0,5
Total dissolved phosphorus (P)	mg/l	0,05	0,2	0,4	1,0
Chlorides	mg/l	50	100		

In this paper, we analysed mean values of the parameters for the year 2013 at three measurement points of the river Ibar (Batrage, Raska and Kraljevo). Based on the monthly concentrations, their mean value at the annual level at each measurement point has been estimated.

In the introductory part of the paper, it is noted that the assessment of the ecological status of the water body depends on the selection of indicators of the water body quality and related processing methodologies. Determination of the ecological status of the rivers, which are mainly flow systems, is a very specific case. Sampling is conducted at a location, that is part of the water body movable in space due to mixing, and movable in time due to the water flow. Having this in mind, we must clearly set down the analyses of data that also have time delay in the analysis of values of parameters. Therefore, it is always better to be precise about the status assessment. In order to illustrate this hypothesis, Figure 1 presents two simple tests for data collected at the station Batrage for the year 2013. The first test comprises spectral analyses conducted by observing data as time series. The second figure presents a classical motivational analysis where data were observed from the aspect of measurement points immovable in time that are obtained via the software program *Statistica 7*.

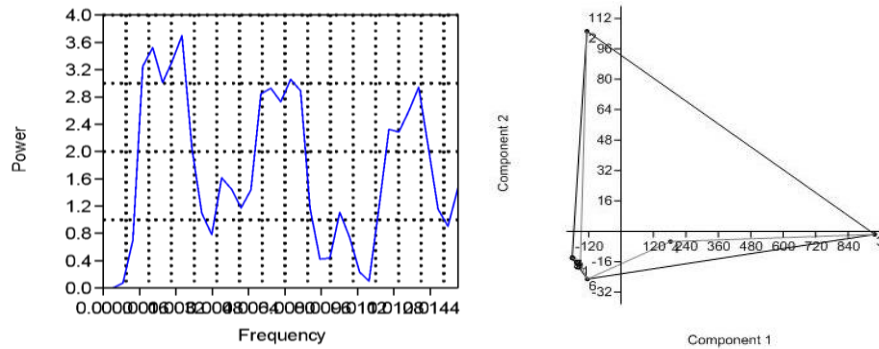
### 3. RESULTS AND DISCUSSION

In order to assess the ecological status, nine chemical and physicochemical parameters of water quality indicators were analysed: pH, dissolved oxygen, biochemical oxygen demand, ammonium ion, nitrates, orthophosphates, total dissolved phosphorus and chlorides.

The ecological status of the river Ibar was determined based on the data from the Serbian Environmental Protection Agency. The data resources were measured at the stations Batrage, Raska and Kraljevo. This is done in accordance with the methodology prescribed by the Regulation on the parameters of the ecological and chemical status of

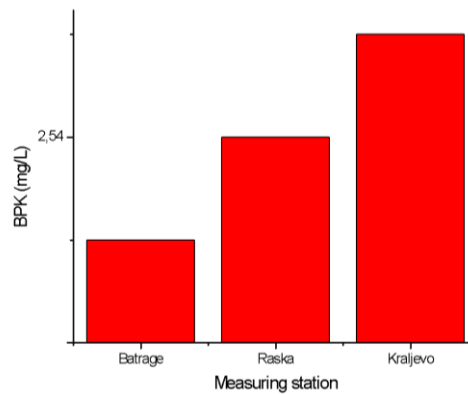
surface water and the parameters of the chemical and quantitative status of groundwater („Official Gazette of RS”, No. 74/2011).

Because of the need to assess the current ecological status, the latest available data from the year 2013 were used [5]. We explained earlier that these data sets were analysed as the time series or as multifactorial data. The figure below presents the analyses of the time series for all data and the spatial analyses of the same data.



**Fig. 1** An example of time and spatial data analysis in the station Batrage for the year 2013

Changes in water quality along the river Ibar to the place of confluence near Kraljevo are presented on Figure 2 by statistical analysis of BOD-5 values.



**Fig. 2** The basic statistical data analysis for BOD-5 at

Designed values of physicochemical parameters observed in the assessment of ecological status are given in Table 2.

**Table 2** Parameters values at measurement points of the river Ibar in 2013.

		Physicochemical quality elements								
		pH	Dissolved oxygen	BOD-5	Total organic carbon( TOC)	Ammonium ion (NH <sub>4</sub> -N)	Nitrates (NO <sub>3</sub> -N)	Orthophosphates (PO <sub>4</sub> -P)	Total dissolved phosphorus (P)	Chlorides
Measuring stations (data from 2013)	Batrage	8,52	11,9	1,33	2,74	0,12	0,47	0,04	0,08	8,5
	Raska	8,41	9,75	2,54	4,23	0,35	1,12	0,14	0,22	12,0
	Kraljevo	8,44	11,0	1,83	4,43	0,19	1,16	0,10	0,14	11,8

The water in the Ibar has base character and the greatest number of measured pH values, at all three stations, and are on the very limit of permitted. Oxygen regime is relatively balanced, and the lowest values are recorded at the measuring station Raška. The pointed data of load indicator of river water by organic matter (BOD-5) show that it is the strongest at the measuring station Raška, while total organic carbon (TOC) has the highest value at the measuring station Kraljevo. Measured concentrations of total organic carbon at the measuring station Kraljevo in 2013 were approximately 50 [%] higher than the measured concentrations at the measuring station Batrage. The highest value of ammonium ion was measured at the measuring station Raška, while the value of nitrates was highest at the measuring station Kraljevo. In the observed period, significant fluctuations in concentration of orthophosphates and chloride at the measuring station Raška were recorded.

It is recommended to look at the correlations between measured time data and their values as it is presented in Table 3.

**Table 3** Assessment of water quality of the river Ibar in 2013.

		Physicochemical quality elements									Summary of ecological status
		pH	Dissolved oxygen	BOD-5	Total organic carbon( TOC)	Ammonium ion (NH <sub>4</sub> -N)	Nitrates (NO <sub>3</sub> -N)	Orthophosphates (PO <sub>4</sub> -P)	Total dissolved phosphorus (P)	Chlorides	
Measuring stations (data from 2013)	Batrage	I	I	I	II	III	I	II	II	I	III
	Raska	I	II	II	II	III	II	III	III	I	III
	Kraljevo	I	I	II	III	III	II	III	II	I	III

In the Article 5, Paragraph 5 of the Regulation on the parameters of the ecological and chemical status of surface water and the parameters of the chemical and quantitative status of groundwater it is stated: „If one or more parameters of the ecological status exceed the limits of good status, the ecological status of ecological status of surface waters can only be moderate” [3]. The ecological classification of analysed chemical and physicochemical parameters at the measuring station Batrage, in accordance with the Regulation, corresponds to I, II and II Class in terms to pH value, dissolved oxygen, BOD-5, nitrates, chloride, observed organic oxygen, orthophosphates and total dissolved phosphorus, that is, ammonium ion, respectively.

At the measuring station Raska, the contents of pH and chlorides corresponds to Class I of water quality, the contents of dissolved oxygen, biochemical oxygen demand, total organic carbon and nitrates corresponds to Class II, while the contents of ammonium ion, orthophosphates and total dissolved phosphorus is within the limits of Class III. The values of pH, dissolved oxygen and chlorides at the measuring station Kraljevo belong to Class I; the contents of biochemical oxygen demand, nitrates and total dissolved phosphorus corresponds to Class II, while the presence of increased concentration of total organic carbon, ammonium ion and orthophosphates impairs the water quality to Class III.

It has been concluded that, from the group of observed physico-chemical parameters, the concentrations of ammonium ion, orthophosphates and total dissolved phosphorus exceed the values of good status so the water quality of the river Ibar corresponds to *moderate* ecological status. According to this Regulation, moderate ecological status provides conditions that correspond to values of biological parameters typical for a given status, that is, ecological changes of watercourse are not irreversible for the environment.

#### 4. CONCLUSION

Ecological status of the river Ibar, the sign of quality of the structure and functioning of an aquatic system, was determined according to the data obtained from the Serbian Environmental Protection Agency. The measuring stations are Batrage, Raska and Kraljevo. Methodology is based on recommendations of the Regulation on the parameters of the ecological and chemical status of surface water and chemical parameters and quantitative status of groundwater. The Ibar River has *moderate* ecological status according to the data obtained in 2013. Ecological classification, Class III watercourse, shows moderate deviation from the values of parameters in natural state. The conditions for functioning of aquatic ecosystem of the river Ibar were not significantly disturbed. The applied research methodology confirms the implementation of WFD recommendations in the accomplishment of sustainable water management principles and preservation of environmental quality in Serbia. Based on the results of the analysis, it can be concluded that the presence of increased concentrations of ammonium ion, orthophosphates and total dissolved phosphorus indicates the presence of municipal waste waters and industrial effluents along the river. Ecological classification of the current situation clearly indicates the need to protect recipient to achieve required water quality of the river Ibar which is as an integral part of the environment.

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## PROCENA EKOLOŠKOG STATUSA REKE IBAR U FUNKCIJI FIZIČKO-HEMIJSKIH PARAMETARA

*Značaj očuvanja i unapređenja kvaliteta površinske vode podrazumeva sagledavanje trenutnog stanja kvaliteta vode kao integralnog dela životne sredine. Cilj rada je da na osnovu analize izmerenih vrednosti koncentracije određenih fizičko-hemijskih parametara, pokazatelja kvaliteta vode na mernim stanicama duž toka reke, prikaže metodologija geostatističkih (vremenskih) analiza i multivarijacionih analiza pri proceni ekološkog statusa reke Ibar. Ekološka klasifikacija vodotoka određena je u skladu sa metodologijom koju propisuje Pravilnik o pramaterima ekološkog i hemijskog statusa površinskih voda i parametrima hemijskog i kvantitativnog statusa podzemnih voda i, korišćenjem podataka Agencije za zaštitu životne sredine iz 2013. godine. Ustanovljeno je da određene vrednosti pojedini parametri prekoračuju granice vrednosti zahtevanog dobrog statusa, tako da je sumarno rezultovan umeren ekološki status kvaliteta vode reke Ibar. Umeren ekološki status Ibra, odgovara III klasi vodotoka i obezbeđuje uslove koji odgovaraju vrednostima bioloških parametara koji su tipični za dati status. Ekosistemske pristup jasno ukazuje na potrebu preuzimanja mera prečavanja narušavanja i unapređenja kvaliteta vode kao integralnog dela životne sredine.*

Ključne reči: *ekološki status, Ibar*