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ANALYSIS OF SWQI INDEX OF THE RIVER IBAR (SERBIA)

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ABSTRACT

The characterization of water quality is based on data from five hydrological measuring stations along the Ibar River flow through Serbia for the period from 2007 to 2013.The paper presents a new approach to surface water quality research using SWQI index assessment (Serbian Water Quality Index). The SWQI indicator is based on the original WQI (Water Quality Index) method. The environmental indicator for the area of waters SWQI shows that the calculated values of the index number are in the range of 77 to 82, the water quality of the Ibar River, which corresponds to the descriptive indicator of "good water" i.e. II class of watercourse rating. A significant correlation exists between the values of the BPK5 and SWQI parameters.

KEYWORDS:
Water quality, quality of index, the river Ibar

INTRODUCTION

When it comes to the Ibar water system, there are relatively few papers and official reports dealing with the Ibar ecosystem as a whole. Most reports deal with various incidental situations, mainly with increasing the concentration of phenols and heavy metals [1, 2]. Only Ocokoljic and his associates pointed out that the Ibar is one of the most polluted rivers of Serbia [3]. If the Ibar flow is considered, the first fact that comes to mind is that it passes through a part of the country where there are a large number of small, but also large industrial plants that, without a controlled system, discharge wastewater into the Ibar. A large number of small workshops in Raska area for the production of clothes from jeans discharge waste water into the Raska and Josanica rivers, which are being pumped into the Ibar River. Due to the technological properties of the jeans processing in the bleaching process, the content of chromium in the water increases. According to literature [4], the Ibar is burdened with continuous pollution by heavy metals originating from the mine waters of the Kopaonik mine "Belo Brdo". In addition to the already mentioned extreme contamination of the Ibar with phenols, it is undoubtedly found that RMHK "Trepca" is the largest pollutant of the Ibar River with heavy metals [4]. A very significant fact is pollution originating from factories that are not in operation (chemical industry, zinc metallurgy, battery factory), but their tailings are in the alluvial of the river [5]. The particular problem of Ibar pollution is its tributaries. The best example is the Raska River, which has been converted into a sewage and waste collector of various industrial plants, and the most serious polluters are the city sewerage and the Golo Brdo landfill, which was established by previous analyses [6]. The middle flow of the Ibar River, between the mouth of Sitnica in Ibar near Kosovska Mitrovica and the mouth of the Raska river near Raska, is characterized by the largest number of pollutants with heavy metals - there are nine lead and zinc mines, three flotations, two metallurgies, a chemical industry and a battery factory. There are also nine huge industrial dumps that are located next to the Ibar River itself, and with their chemical composition make primary pollutants of the Ibar with heavy metals [7]. The Ibar from the area of the northern part of Kosovo and Metohija is polluted with a number of different pollutants. Permanent contaminants are tailings in Zvecan, Zitkovac and Leposavic, which directly burden the Ibar River with complex chemical pollution [8].

EXPERIMENTAL

The subject of the research is the analysis of the water quality of the Ibar River on the watercourse from the leaving of the Gazivode Lake to the flowing into the West Morava.The observation was made from the aspect of flowing water bodies and pollutants as permanent actors of changes in the observed aquatic ecosystem. As a qualitative indicator of the weather and spatial variation of the ecosystem of the river, the water quality of the Ibar on a 230 km long waterway was analysed. The assessment of the state of the environment was made on the basis of the change in the value of the indicators that directly point to the improvement or deterioration of the state of the environment. By long-term monitoring of the selected parameters, water quality indicators of the Ibar, in five observed locations, changes in the value of the indices of the state of the environment of the river basin were followed. The research was carried out using the data of the RHMZ of Serbia (Republic Hydrometeorological Institute of Serbia), for the period from 2007 to 2012, at five hydrological measuring stations of the Ibar waterway through Serbia. The state of the environment was assessed on the completed complex analysis of existing pollutants, qualitatively defined in the form of a "pollution tree". A new approach to the research of surface water quality has been applied with the criteria: using indexes of the Serbian Water Quality Index (SWQI). Water quality evaluation was performed using the water quality index WQI (Water Quality Index) and SWQI (Serbian Water Quality Index).

METHODOLOGY

The SWQI indicator is based on the original WQI (Water Quality Index) (Development of a Water Quality Index, 1976). According to this method, the ten selected parameters (saturation with oxygen, coliform bacteria, BPK5, pH value, nitrogen oxides, phosphates, suspended matter, ammonium ion, temperature and conductivity) represent the surface water properties by narrowing them to a single index number by their quality (qi).The share of each of the ten selected parameters on the total water quality does not have the same relative importance, therefore each of them has received its weight (wi) and the number of points according to the share in the endangering of quality. By summarizing the product (qi x wi), the index 100 is obtained as the ideal sum of the weight of all parameters. How many index points in the range from 0 to 100 will belong to some water depends on the points won by individual parameters. In the case where the quality data for some parameter is missing, the value of the arithmetically measured WQI is corrected by multiplying the index with a value of 1/x, where x is the sum of arithmetically measured weights of available parameters. SWQI as a composite indicator of water quality follows nine selected physical and chemical parameters and one parameter of the microbiological quality of water summarizing them in the index number that shows the measure of the state of surface water. The adopted classification criteria of the descriptive quality indicator and the determination of the surface water class based on the calculated value of the SWQI index number are shown in Table 1.

Correlation with the Decree on the Classification of Waters ("Official Gazette SRS", no.5/68), where water is divided into I, II, IIa, IIb, III and IV classes based on indicators and their limit values, the Serbian Water Quality Index (SWQI) has been defined with five descriptive quality categories (excellent, very good, good, bad and very bad).The surface water quality indicators are classified with the compatibility of the existing classification according to their purpose and degree of purity:

- Excellent - waters that are in a natural state with filtration and disinfection, can be used for supplying settlements with water and in the food industry, and surface waters also for cultivating precious fish species;
- Very good and good - waters that can be used in the natural state for bathing and recreation of citizens, for water sports, for cultivation of other fish species, or which, with modern methods of purification, can be used for the supply of drinking water and food industry;
- Bad - waters that can be used for irrigation, and after using modern methods of purification in industry as well, other than food industry;
- Very bad - waters that adversely affect the environment with their properties, and can only be used after the application of special purification methods.

The adopted classification criteria of the descriptive water quality indicator based on the calculated values of the SWQI index number are shown in Table 2.

TABLE 1
Classification of surface waters using the Water Quality Index method

WQI-MDK-I class	WQI-MDK- II class	WQI-MDK-III class	WQI-MDK-IV class
85-84	74-69	56-44	51-35
100-90 89-84	83-72	71-39	38-0
excellent very good	good	bad	very bad
Serbian Water Quality Index (SWQI)			

TABLE 2
Classification criteria of the described indicator SWQI

	Index (range)	Descriptive indicator	Color
Serbian Water Quality Index	100-90	excellent	blue
	84-89	very good	light blue
	72-83	good	green
	39-71	bad	yellow
	0-38	very bad	red
	No data		white

The numerical value of the water quality index is calculated using the software package "Calculate Your SWQI" of the Environmental Protection Agency of the Ministry of Environment and Spatial Planning of the Republic of Serbia (http://www.sepa.gov.rs). The Rulebook on the National List of Environmental Indicators highlights the significance of the SWQI indicator as easily understandable, since changes in indicators can easily be associated with deterioration or improvement of the observed phenomenon in the environment. Regarding the legal framework for the control of surface water quality according comparative to our Regulation from the point of view of the suitability of use for water supply is the Council Directive 75/440/EEC which refers to the required quality of surface water intended for catching drinking water in the Member States. With this Directive, surface waters are classified in relation to the limit values of the quality indicators in three categories:

A1 - simple physical treatment and disinfection, e.g. rapid filtration and disinfection;

A2 - normal physical treatment and disinfection, eg. previous oxidation/disinfection, coagulation, flocculation, filtration, disinfection;

A3 - intensive physical and chemical treatment, extended treatment and disinfection, e.g. contact chlorination, coagulation, flocculation, adsorption, disinfection.

These groups correspond to three different surface water qualities according to their physical, chemical and microbiological characteristics established in Table of Annex II of the Council Directive 75/440/EEC. Surface waters whose physical, chemical and microbiological characteristics deviate from the mandatory limit values that correspond to type A3 treatment cannot be used to catch drinking water (European Union Water Directive, 2005). Table 3 shows the correlation of the original WQI method with Council Directive 75/440/EEC.

RESULTS AND DISCUSSION

The environmental indicator for the area of waters SWQI shows that the calculated values of the index number are in the range of 77 to 82, the water quality of the Ibar River, which corresponds to the descriptive indicator of "good water" i.e. II class of watercourse rating (Table 4).

The long-term trend of change in the index number is insignificant, i.e. the water quality of the Ibar River is practically unchanged over the observed period (Figure 1). The mean values of the time series of the observed parameters of the water quality indicators were within the limit values for the required watercourse quality. Descriptive water quality indicator of the Ibar watercourse "Good Water" classifies surface water according to the degree of purity and its purpose in waters which, in their natural state, with modern methods of purification, can be used to supply the settlement with drinking water and in the food industry.

TABLE 3
Correlation of the WQI method and Directive 75/440/EEC

Parameters (Unit of measure)	WQI_{max}	A1	WQI_{A1}	A2	WQI_{A2}	A3	WQI_{A3}
Oxygen saturation (%)	18	>70	11	>50	6	>30	2
BPK_5,(ml/l)	15	<3	11	<5	7	<7	4
Ammonium (mg/l)	12	0,05	12	1	3	2	2
pH value	9	6,5-8,5	9-7	5,5-9	5	5,5-9	5
Total nitrogen oxides (mg/l)	8	1	7	2	6	3	5
Orthophosphates (mg/l)	8	0,4	4	0,7	1	0,7	1
Suspended substances (mg/l)	7	25	4	25	4	25	4
Temperature (°C)	5	22	2	22	2	22	2
Electroconductivity (μS/cm)	6	1000	0	1000	0	1000	0
E.coli(MPN u 1000 ml)	12	20	12	2000	10	20000	7
$\Sigma(q_i x w_i)$=WQI	100		70		44		32

TABLE 4
SWQI water quality of the Ibar River for the period 2007-2013

Parameters (Unit of measure)	2007	2008	2009	2010	2011	2012	2013
Temperature (°C)	12,78	12,47	11,00	11,31	11,46	11,79	10,44
pH value	8,43	8,42	8,36	8,24	8,47	8,48	8,46
Electroconductivity (μS/cm)	416,20	448,62	428,73	433,33	447,08	432,50	392,90
Oxygen saturation (%)	99,14	93,49	94,22	99,63	95,50	95,43	95,94
BPK_5 (mg/l)	3,03	2,76	2,30	2,37	2,12	2,02	1,90
Suspended substances (mg/l)	21,05	25,78	24,24	21,45	26,95	27,41	22,50
Total nitrogen oxides (mg/l)	1,73	2,10	1,42	0,93	1,21	0,86	0,94
Orthophosphates (mg/l)	0,11	0,14	0,11	0,10	0,11	0,09	0,11
Ammonium (mg/l)	0,02	0,01	0,03	0,25	0,14	0,24	0,22
Coliform bacteria (in 100ml)	13483,33	15274,33	15150,00	14703,33	7714,60	174,65	/
SWQI	78	77	81	78	81	82	81

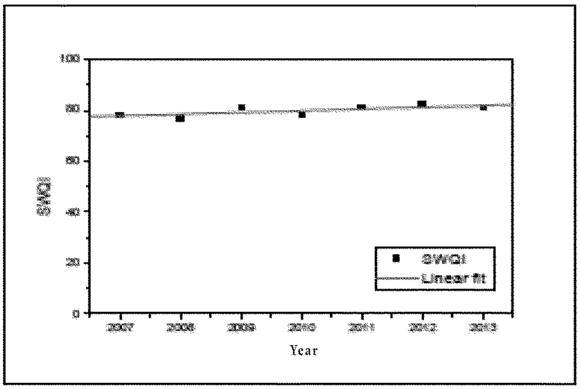

FIGURE 1
Trend of changes of the water quality index of the Ibar River

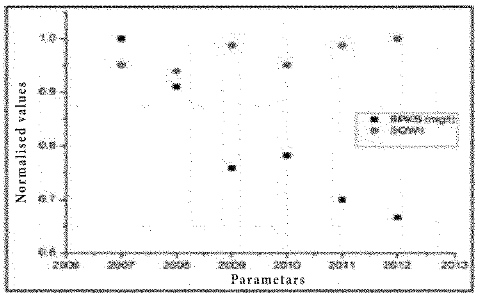

FIGURE 2
Normalization of the average annual value of BPK5 and SWQI along the Ibar flow

TABLE 5
Correlation analysis of SWQI and water quality parameters

	T(°C)	pH	Electro.	Sat. Acid	BPK5	Susp. Subst.	Total N	Ortho.	Ammoni	Coliform bacteria	SWQI
T(°C)	1.00	0,42	-0,18	0,14	0,78	-0,18	0,65	0,43	-0,44	0,07	-0,58
pH		1.00	0,16	-0,48	-0,09	0,68	0,20	0,08	-0,23	-0,63	0,42
Electro.			1.00	-0,59	-0,37	0,67	0,10	0,47	0,10	-0,09	-0,01
Sat.Acid				1.00	0,29	-0,79	-0,33	-0,47	0,37	0,14	-0,33
BPK5					1.00	-0,64	0,79	0,58	-0,68	0,65	-0,82
Susp. Subst.						1.00	-0,13	0,05	0,15	-0,66	0,60
Total N							1.00	0,91	-0,91	0,60	-0,63
Ortof.								1.00	-0,75	0,61	-0,63
Ammo									1.00	-0,59	0,37
Coliform bacteria										1.00	-0,73
3SWQI											1.00

The results shown in Table 5, obtained by the correlation analysis, show that there is no correlation between the parameter values and the calculated SWQI index number for the period from 2007 to 2012.The only significant correlation exists between the values of the BPK5 and SWQI parameters although the index number of the water quality of the Ibar is algorithmically calculated on the basis of all parameter values. The explanation is in the fact that there are changes between the measuring points in the observed time that are uncontrolled, or caused by different influences, or, with higher probability, different pollutants located along the Ibar flow. Also, it should be emphasized that each parameter is calculated with the appropriate weight which disturbs the correlation. The normalized mean annual values of BPK5 and SWQI along the Ibar River watercourse were analyzed (Figure 2).

From Figure 2 it can be seen that there is no correlation of the observed parameters, which implies that the change in the SWQI value does not follow the change in the value of the BPK5 parameter [9]. The degree of water contamination with organic compounds is defined by the amount of oxygen required for the oxidation of the present biologically degradable water components by aerobic microorganisms. From the aspect of self-purification of watercourses aeration and reaeration are key processes. Reaeration and BPK5 as two basic reactions during the process of self-purification of the aquatic environment are the basis for determining the spatial and temporal distribution of dissolved oxygen, that is, the balance of oxygen. The resultant of these two processes is the real content of the dissolved oxygen along the watercourse. The summarized SWQI index number clearly illustrates the water quality of the Ibar River as a reliable indicator of the state of the environment, but, like all integral criteria, it does not indicate the processes of the observed aquatic ecosystem [10].

CONCLUSION

The characterization of water quality in the function of environmental assessment is based on data from five hydrological measuring stations along the course of the Ibar River through Serbia for the period from 2007 to 2013. Based on the results of the analyses carried out, the following conclusions can be made: the environmental indicator for the area of waters, SWQI (Serbian Water Quality Index) shows that the calculated values of the index number are in the range of 77 to 82, the water quality of the Ibar

River, which corresponds to the descriptive indicator of "good water" i.e. II class of watercourse rating. The ecological status of the water quality of the river Ibar at the Raška monitoring station is classified as moderate (class III) and deviates from the required water quality in 2013.

Using the comparative analysis the overrun of the concentration of the parameters BPK5, TOC, NH4-N and PO4-P was determined in relation to the reference values. When assessing the chemical status, the environmental quality standards (EQS) of the first and second group are considered, so the EQS implies the concentration of a single priority substance or group of priority substances in surface waters, which cannot be exceeded for the purpose of protecting the environment and human health. The conclusion is that the concentration of values of a large number of observed parameters deviates from the reference values of the target I class of water quality of the Ibar River. The ecosystem approach clearly indicates the need to take measures to prevent the disturbance and urgent improvement of water quality as an integral part of the environment. The improvement of the quality of the water of the Ibar River must be given special attention, as it has been found to be at significant ecological risk. The operational monitoring of this water body is proposed, which implies periodic one-year assessment of the change in the ecological status of water quality as a result of the program of protection measures. In this way, the control and prevention of pollution of the recipient would be realized and the principle of sustainable management of the water quality of the Ibar River as the most important part of the environment would be respected.

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