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IDENTIFICATION OF POLLUTION SOURCES IN THE SOUTH MORAVA RIVER USING THE INDEX METHOD

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Ljiljana Takić[1], Nenad Živković[2], Amelija Đorđević[2], Ljiljana Ranđelović[3]

[1]Faculty of Technology, Leskovac, University of Niš
E-mail: ljilja_t@yahoo.com
[2]Faculty of Occupational Safety, Niš, University of Niš
[3]Leskovac Waterworks

Abstract. *The aim of this paper is to evaluate the state of water quality at the hydrological measuring stations based on the calculated SWQI index values, and to draw attention to the current pollution of the South Morava river. The water quality is determined by the Serbia Water Quality Index (SWQI) method using the data set provided by the Hydro-meteorological service of the Republic of Serbia for the year 2009, according to parameters obtained, on average, once a month. Data grouped on a sampling site basis, averaged on a yearly level, resulting in a median SWQI for each sampling station, are employed to obtain a synthesized quality indicator. The final result of such an analysis shows the water quality, expressed by the SWQI index value as the indicator of pollution sources in the South Morava River.*

Key words: *water quality, SWQI index, pollution, the South Morava River*

INTRODUCTION

Special attention must be given to the evaluation of the quality of water in the South Morava River, and the problem of the pollution and protection of the sea, since it is one of the most valuable natural water resources in Serbia. The extent, type and frequency of quality testing of the water ways in the Republic of Serbia have been regulated by the program of water quality testing. According to the established methodology, the basic physical-chemical parameters are tested once a month. Additional physical-chemical parameters are determined at least four times a year, and trace metals and other damaging and dangerous matters three to twelve times a year, depending on the economic significance of the given segment of the water ways. Total radioactivity is measured two to seven times a year on all the more important points. The subject matter of this study is the

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analysis of the quality of the South Morava River water through Serbia, using the data fund of the RHMZ of Serbia for the year 2009 [1].

The mouth of the South Morava River is t the base of the Skopska Crna Gora mountain, FYRM. It is formed from the Ključevka and Slatinska rivers, which make the river Golema, which, after passing the Serbian-Macedonian border, is known as Binačka Morava. After 49 km of flow, Binačka Morava confluences with the Preševska Moravica in Bujanovac and becomes the South Morava River. The river belongs to the Black Sea drainage basin, and has a drainage area is 15,469 km², with an average discharge of 100 m^3/s at its mouth. The South Morava has a composite valley, which means it consists of a series of gorges and depressions with 157 tributaries, the most important among them being the Jablanica, Veternica, Pusta Reka and Toplica, and the Vrla, Vlasina, Nišava and Sokobanjska Moravica.

The South Morava River is 295 km long. It flows mostly in the direction south-north from the Macedonian border to central Serbia, where it joins West Morava near the town of Stalać, making the Great Morava River. The South Morava has a great potential for the production of electrical energy, but it has not been exploited. Its water is used for irrigation to some extent. The river valley plays a very important role in transportation. It is the natural route for the railway and highway Belgrade-Skopje-Thessaloniki [2].

The investigation of the water quality of the South Morava River included five hydrology measuring stations situated at specific distances from the confluence up the river flow: 1. Ristovac – 237 km – entry point, 2. Vladičin Han – 195 km, 3. Grdelica – 163 km, 4. Aleksinac – 61,8 km, and 5. Mojsinje –18,1 km – exit point. Figure 1 shows the map of the profiles where the water quality of the South Morava River were analyzed and the five measuring stations with the calculated SWQI values for the studied period.

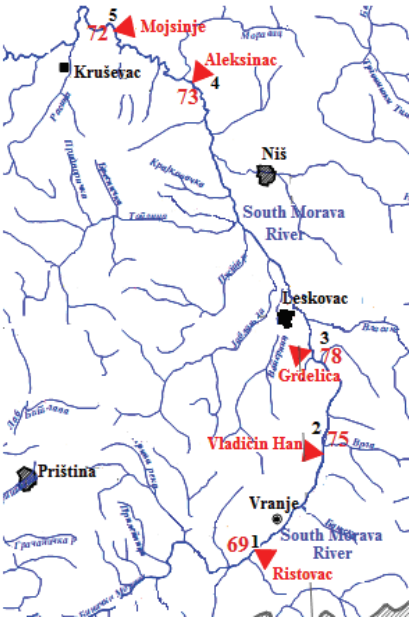

Fig. 1. The map of profiles where the South Morava River water quality was investigated [1]

METHODOLOGY

The surface waters are a complex multi-component system, the study of which depends on the application and recognition of facts, principles and methods of chemistry, physics, geology, hydrology, meteorology, mathematics, and other sciences, in order to solve the problems that are basically ecological in nature. The specificity and complexity of the chemical composition of the surface waters and the quality indicators as the consequence of the mineral and organic matter dissolved within, and gases, colloids, suspended particles and microorganisms that came into it by natural or manmade processes, emphasize the importance of the application of index methods for their evaluation by finding the common factors applicable to the quality as a whole.

According to our regulations, the surface waters quality control implies the application of the Regulation on Watercourse Categorization and the Regulation on Water Classification in Serbia (Sl. Glasnik SRS, No. 5/68). All the watercourses are classified into four categories, and required classes of water quality are defined at given watercourse segments. The surface waters are then classified according to the limited values of quality indicators, into class I, II, IIa, III, IV, and NC (not classified). Categorization is done based on the following indicators: suspended solids, total dry residue, pH, dissolved oxygen, BOD_5, degree of saprobity according to Liebman, degree of biological productivity, maximum number of coliform bacteria, visible waste matter, noticeable colour, and noticeable odour [2].

This regulation, however, does not provide a procedure for the determination of a single regular class based the eleven individual parameters, which could be compared with the prescribed one. Further improvement of legislation led to the Regulation on Classification of Water from Inter-republic Watercourses, Interstate Waters, and Yugoslav Coastal Waters which also categorized the watercourses into four categories. The qualitative categorization hereby introduced new indicators (oxygen saturation, % O_2, COD, toxic matter, and the radioactivity index). However, as was the case in the previous regulation, there was no procedure for the determination of the summary quality class based on the class of individual quality indicators [4]. The law does not precisely define the procedure for the final assessment of the total watercourse quality class, which leaves room for arbitrary assessments.

The Environmental Protection Agency of the Ministry for Environment and Spatial Planning of the Republic of Serbia has developed an environment index for watercourses designated for reports to the public and experts on the state of the water quality. This indicator is based on the Water quality Index *(Development of a Water Quality Index, Scottish Development Department, Engineering Division, Edinburgh, 1976)* [5], according to which ten selected parameters (oxygen saturation, coliform bacteria, COD, pH value, nitrogen oxides, phosphates, suspended matter, ammonium ion, temperature and conductivity) define, by their characteristics, the quality of the surface waters expressed by a single index number. The share of influence of each of the ten selected parameters does not have the same relative importance; so, each of them was assigned a significance and number of points according to their part in the quality impairment. By summing up the products ($qi \times wi$) the index 100 as the ideal sum of all parameters was obtained. The number of index points, ranging from 0 to 100, to be assigned to the given water samples depends on the number of points of individual parameters. The classification system of surface water quality description according to the Serbian Water Quality Index (SWQI) method represents a method for the evaluation of the quality of a group of selected parameters, which

means that by the implementation of this method an overall evaluation of the surface water quality can be obtained. SWQI indicators of the surface water quality were obtained by comparing the quality parameters according to our classification with those of the original *WQ*I method [5] [6]. The adopted descriptive classification criteria of the descriptive quality indicators and the determination of the surface water class according to the calculated SWQI value are given in Table 1 [7].

Table 1. Classification of surface waters according to the Water Quality Index method [7]

WQI-MDK (Class I)		WQI-MDK- Class II	WQI-MDK- Class III	WQI-MDK- Class IV
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)				

Average quantitative values of the selected measured parameters for the water of the South Morava River are calculated based on the data fund of the RHMZ of Serbia published in the Hydrology Almanac – water quality for 2009 [1]. The numeric value of the water quality index was calculated by using the "Calculate your SWQI" software package of the Environmental Protection Agency of the Ministry for Environment and Spatial Planning of the Republic of Serbia [7].

RESULTS AND DISCUSSION

The analysis of the South Morava water quality is based on the data of the RHMZ of Serbia published in the Hydrology Almanac – Water quality for 2009, and it consists of calculating the average values of water parameters and the calculated SWQI indices of the water quality at the measuring stations Ristovac, Vladičin Han, Grdelica, Aleksinac and Mojsinje, presented in Table 2.

Table 2. The quality of water at the South Morava River measuring stations for the year 2009

Parameters (Measuring Unit)	1 Ristovac	2 Vladičin Han	3 Grdelica	4 Aleksinac	5 Mojsinje
Temperature (^oC)	13.5	14.9	12.6	12.3	12.8
pH value	8.1	8.1	8.1	7.9	7.9
Electrical conductivity (μS/cm)	412	420	316	392	559
Oxygen saturation (%)	103	101	101	94	93
COD (mg/l)	5.2	5.1	3.4	4.3	4.1
Suspended matter (mg/l)	41.4	29.1	31.4	39.6	90.6
Total nitrogen oxides (mg/l)	1.6	1.80	2.26	2.22	2.46
Orthophosphates (mg/l)	0.15	0.15	0.1	0.1	0.2
Ammonium (mg/l)	0.02	0.02	0.01	0.1	0.15
Coliform bacteria (in 100ml)	24000	24000	24000	24000	24000
SWQI	72 - II	73 - II	78 - II	75 - II	69 - III
SWQI index average value	73	Good water			Class II

It is important to emphasize that the overall quality of water is expressed as the average value of SWQI = 73 for the studied one year period and it corresponds to class II of the surface water, i.e. to the descriptive indicator "*good water*". According to the indication and purity level, this water quality corresponds to the waters that in their natural state can be used for swimming and recreation, water sports, certain fisheries, or, with modern purification methods, as drinking water for human consumption and use in the food industry.

The calculated values for the four measuring stations show that the South Morava River water quality along the river have an SWQI index in the range from 72-78, which corresponds to the descriptive indicator "*good water*". The water quality at the entry profile of the South Morava River at Ristovac measuring station corresponds to the descriptive indicator "*bad water*" with the calculated SWQI value of 69 points, which indicates the presence of a strong pollutant to be identified.

The analysis of the available data indicates that there is a great disproportion between the required quality of the water and the actual state of the water quality of the South Morava River classified, according to the valid stipulations of the Regulation on Classification of Water from Inter-republic Watercourses, Interstate Waters, and Yugoslav Coastal Waters, as Class IIa and IIb [4].

It can be seen from Table 2 that the concentration of suspended matter and ammonium ions was significantly higher at the Ristovac measuring station in comparison to the other measuring stations, as the characteristic indicators of the presence of organic pollutants and an urgent need for high grade waste water treatment before discharge into the recipient. Figure 2 illustrates the change of concentration and characteristic parameters at the measuring stations along the river which identify the discharge of untreated or partially treated industrial waste waters.

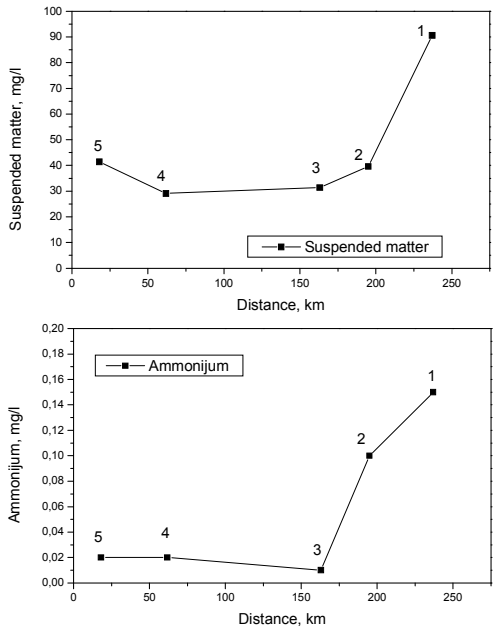

Fig. 2. Variations of the characteristic water quality parameters along the South Morava River

The study results given in Table 2 indicate that the water quality has relatively small fluctuations amounting to 72-78 points from the river and 78-69 points at the entry profile of the river. The water quality profile of the South Morava River is shown in Figure 3.

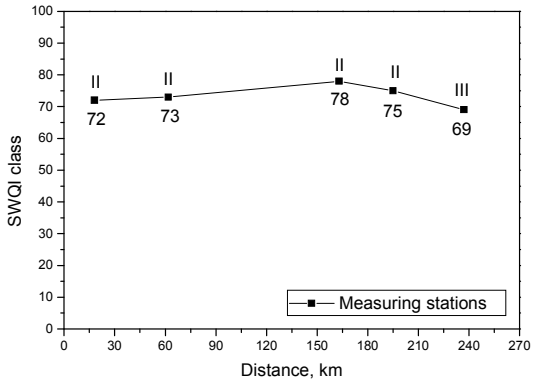

Fig. 3. The South Morava River water classifications at the measuring stations

According to the SWQI classification, the South Morava water in 2009 corresponded to Class II for the length of 195 km of the river course, while at the entry profile of the river at the Ristovac measuring station there was a decrease in the water quality, and it belonged to Class III of the water quality. The analysis of the pollution agents of the South Morava River at this profile indicates the presence of a possible pollution source, the factory of cellulose and paper FOPA of Vladičin Han. An important piece of information is that the factory takes the water required for the realization of the technological process directly from the South Morava River (approx. 180 m^3/h). The FOPA factory produces corrugated cardboard. The production line capacity is about 100t of cellulose per day, with the waste water flow of 234 m^3/h is discharged directly into the South Morava River.

CONCLUSIONS

The complexity of the study of the influence of certain pollutants on the quality of watercourses in the drainage basin, as well as the specificity and the complexity of the chemical composition of the surface water and the quality indices as the consequences of the polluting agents discharged into the watercourses emphasize the importance of implementation of methods for their evaluation by finding a common indicator treating the quality as a whole.

The investigations show that in the surface waters monitoring system, the o SWQI index method can be used as the indicator of the influence of pollution on the surface water quality, as illustrated by the assessment of the quality of water in the South Morava River.

SWQI values show that the South Morava River water quality is in the range from 72-78 SWQI, which corresponds to the descriptive indicator *"good water"*. The water quality at the entry profile of the South Morava River at the Ristovac measuring station corresponds to the descriptive indicator *"bad water"* with a SWQI index value 69, which clearly indicates the presence of significant polluter at this profile, the FOPA factory of cellulose and wrapping paper of Vladičin Han.

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IDENTIFIKACIJA IZVORA ZAGAĐENJA REKE JUŽNE MORAVE INDEKSNOM METODOM

Ljiljana Takić, Nenad Živković, Amelija Đorđević, Ljiljana Ranđelović

Istraživanje u radu obuhvata monitoring kvaliteta površinskih voda, primenom Serbian Water Quality Index (SWQI), kao indikatora uticaja zagađenja. Cilj rada je da se metodom SWQI, oceni stanje kvaliteta vode reke Južne Morave na hidrološkim mernim stanicama, korišćenjem fonda podataka RHMZ Srbije za 2009. godinu, prema odgovajajućim parametrima koji su uzorkovani u proseku jednom mesečno. Sračunata je srednja vrednost SWQI za svako merno mesto na godišnjem nivou i iz medijane uređenog niza indeksa kvaliteta SWQI svih stanica, dobijen sintetizovani indeks kvaliteta. Istraživanje je pokazalo kvalitet vode, izražen preko SWQI indeksne vrednosti, kao indikatora izvora zagađenja reke Južne Morave.

Ključne reči: *kvalitet vode, SWQI indeks, zagađenje, reka Južna Morava*