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POLLUTION RISK MANAGEMENT MODEL OF THE RIVER NIŠAVA

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Abstract. *This paper presents a pollution risk management model of the river Nišava. The institutional and legal framework in the water sector in the Republic of Serbia, as well as the general risk management model, was used to create this model. The model has four basic stages (planning, evaluation, treatment, and risk monitoring), which are correlated and necessary for water quality improvement. Risk evaluation stage was discussed in greater detail, and the Nišava water quality was estimated using the Serbian Water Quality Index (SWQI) method. SWQI method summarizes ten selected parameters of physical, chemical and microbiological characteristics (oxygen saturation, coliform bacteria, BOD5, pH value, total nitrogen oxides, orthophosphates, suspended matter, ammonium ion, temperature and electrical conductivity) in an index number of water quality. The results from the year 2011 show that the Nišava water quality index is 88, which corresponds to class I of surface water and the descriptive indicator "very good". This model can generally be used as a common pollution risk management model for other rivers, with some modifications.*

Key words: *pollution risk management, water quality, Serbian Water Quality Index (SWQI), quality indicators*

1. INTRODUCTION

Water is distributed on Earth in the form of hydrosphere and includes all liquid and frozen surface waters, groundwater in the soil and rocks, and atmospheric moisture. Although its distribution changes over time, it is considered that its total amount in the world has been unchanged in the last billion years. Human activity significantly affects parts of the hydrosphere and the hydrological cycle, and it is manifested through the release of toxic chemicals, radioactive substances, industrial waste, fertilizers, herbicides, pesticides, petroleum products, urban waste, thermal pollution. In environmental protection, especially in the field of water resources, the quality of surface freshwaters is a big problem.

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The subject of the research paper is the pollution risk management model of the river Nišava based on a generic risk management model, as well as on the institutional and legal framework in the water sector in the Republic of Serbia.

The river Nišava flows through Bulgaria and Serbia, and with a length of 218km is the longest tributary of the South Morava river. The Nišava originates in Bulgaria under the peak Kom in Stara Planina. The source of the Nišava is near the border with Serbia, so that the flow of Nišava through Bulgaria is only 67km, with no major tributaries. Flowing generally to the west for the remaining 151 km, Nišava passes through Dimitrovgrad, Pirot, Bela Palanka, Niška Banja and Niš. Approximately 10km to the west of Niš, Nišava empties into the South Morava. [2]

The water quality of the river Nišava in the year 2011 was determined by using data set provided by the Environmental Protection Agency of the Republic of Serbia and by applying the Water Quality Serbian Index (SWQI) method. The research includes three measuring stations along the river: Dimitrovgrad, Bela Palanka and Niš. The proposed pollution risk management model can be used as a general management model and applied in other cases, because it includes all the necessary stages of risk management of surface water pollution.

2. METHODOLOGY

Based on the institutional and legal framework in the water sector in the Republic of Serbia, as well as on the general risk management model [8], the pollution risk management model of the river Nišava is formed, as shown in Figure 1. This model has four main stages: planning, evaluation, treatment and monitoring.

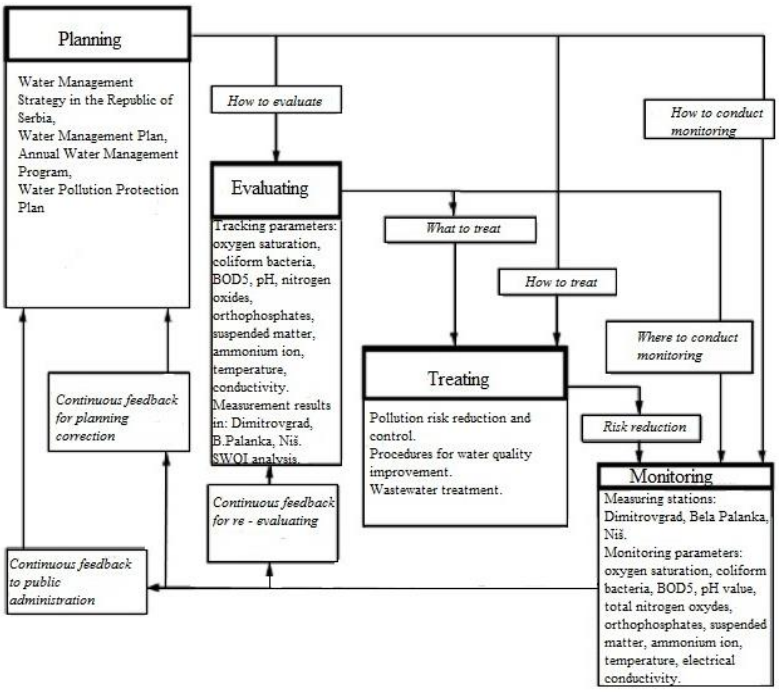

Fig. 1 Pollution risk management model of the river Nišava

2.1. First phase: Planning

The first step in water pollution risk management is planning, which is based on the planning documents for water management. The most important of these are: Water Management Strategy for the Republic of Serbia, Water Management Plan, Annual Water Management Program, and Water Pollution Protection Plan.

Water Management Strategy for the Republic of Serbia is a document which defines the long - term trends of water management. It contains an evaluation of the existing state of water management, objectives and policies for water management, measures for the achievement of the established objectives of water management and the projection of water management development. [12]

Water Management Plan contains general description of the space characteristics, the importance of the influence of human activity, measures for achieving the objectives, the list of relevant institutions in the field of water management, water balance, measures of informing the public and public involvement, and many other elements related to sustainable water management. [12]

Annual Water Management Program is a planning document which defines water facilities, the type and scope of works or activities that are financed in the period for which the annual program is adopted, the amount of funds for activities realization, the amount of participation and other issues related to the construction, reconstruction, rehabilitation and maintenance of water facilities and to performing activities of public interest. [12]

Water Pollution Protection Plan contains control, prevention, interruption and reduction measures for hazardous substances intake into the water, measures for preventing the intake and disposal of waste and other materials in areas where it can cause a decrease in water quality, measures for wastewater treatment, and many other measures necessary for the protection and improvement of water quality. [12]

2.2. Second phase: Evaluation

The surface water quality control in Serbia initially implied the application of the Regulation on Water Classification and the Regulation on Watercourse Categorization in Serbia. [6] All watercourses are classified into four categories and the required classes of water quality are defined at certain segments of watercourses. The surface waters are then classified according to the limiting values of quality indicators into class I, II, III, IV and NC (not classified). Categorization is based on the following indicators: suspended solids, total dry residue, pH, dissolved oxygen, BOD5, degree of saprobity by Liebman, degree of biological productivity, maximum number of coliform bacteria, visible waste matter, noticeable colour, and noticeable smell. This regulation does not give a procedure how to determine the class which can be compared with the prescribed one by using eleven individually categorized parameters. [3]

By improving the regulation, the Regulation on Classification of Water from Inter-republic Watercourses, Interstate Waters, and Yugoslav Coastal Waters was adopted. [4] It also divided the watercourses into four categories. The qualitative categorization was expanded with new indicators (oxygen saturation %, COD, toxic matter, and the radioactivity index). However, as with the previous regulation, the procedure of determining the summary quality class based on the class of individual quality indicators was not provided. [3]

Surface water class I in natural state, or with primary disinfection, can be used for drinking, in food industry and for the cultivation of some species of fish (salmonids). Surface water class II in natural state can be used for bathing and recreation, water sports, for the cultivation of some species of fish (cyprinids) and after the application of conventional treatment processes (coagulation, filtration, disinfection, etc.), it can be used for drinking and in food industry. Surface water class III can be used for irrigation, and after the conventional treatment processes in industry, except food industry. Surface water class IV can be used only after appropriate treatment, while NC means not classified. [3]

The Environmental Protection Agency of the Ministry for Environment and Spatial Planning of the Republic of Serbia develop and coordinate the information system for environmental protection. Part of that information system for the water sector - Serbian Water Quality Index (SWQI), is based on data about surface waters according to the program of the Environmental Protection Agency.

For the calculation of the indicators trend, SWQI method uses a procedure that involves multiple samples at one sampling site during a period of one year. SWQI is obtained by aggregating nine parameters of physical and chemical and one parameter of microbiological water quality (oxygen saturation, coliform bacteria, BOD5, pH value, total nitrogen oxides, orthophosphates, suspended matter, ammonium ion, temperature and electrical conductivity). Each of the ten parameters has a constant weight number (w_i) according to the importance of that parameter in threatening water quality. Also, each parameter, depending on the measured concentration, has an appropriate qualitative number (q_i). By summing the products ($q_i \times w_i$), index 100 as the ideal summation of the parameters quality contribution is obtained. This procedure is repeated for ten parameters. The summary value is the unnamed number from 0 to 100 as a quantitative quality indicator of a certain sample of water, where 100 is the maximum quality. By correlating with the Regulation on Water, where water is divided into classes I, II, III, and IV and NC, based on indicators and their limiting values, SWQI is determined with five descriptive categories (excellent, very good, good, bad and very bad). The indicator is shown as a frequency distribution of sample water quality according to the descriptive categories of quality at the national level and in the basins, while the descriptive categories of quality at the measuring stations are derived from the arithmetic mean on an annual basis. Measure units are five descriptive indicators (on a scale of 0 to 100), presented in Table 1, and the color indicators: very bad (0 - 38) - red, bad (39 - 71) - yellow, good (72 - 83) - green, very good (84 - 89) – light blue and excellent (90 - 100) – dark blue. [5]

Table 1 The surface water classification using SWQI method [9]

I class		II class	III class	IV class
100 – 90	89 – 84	83 - 72	71 – 39	38 - 0
Excellent	Very good	Good	Bad	Very bad

It can be concluded that in the evaluation stage it is necessary to take into account the sources of water pollution and the results of measurements on specific measuring stations. The measurements were conducted on the river Nišava in Dimitrovgrad, Bela Palanka and Niš, while the results were analyzed using the SWQI method, on the basis of which the evaluation is performed.

2.3. Third phase: Treatment

Treatment is the third phase which contains plans for pollution risk reduction and control and includes procedures for water quality improvement (previously, stimulated primary, secondary and tertiary treatment).

2.4. Fourth phase: Monitoring

Monitoring as the last and crucial stage represents the continuous tracking of water quality based on certain parameters on measuring stations in Dimitrovgrad, Bela Palanka and Niš. The evaluation of water quality condition is performed again after a certain period of time. Parameters which are monitored on the measuring stations and which are used for calculating the SWQI are: oxygen saturation, coliform bacteria, BOD5, pH value, total nitrogen oxides, orthophosphates, suspended matter, ammonium ion, temperature and electrical conductivity.

3. Results and Discussion

This paper analyzes the water quality of the river Nišava through Serbia using the data fund of the Environmental Protection Agency for the year 2011. Calculations are based on data about water quality obtained by sampling approximately once a month, according to relevant parameters, using the SWQI method, on the measuring stations in Dimitrovgrad, Bela Palanka and Niš. The arithmetic mean for every station on an annual basis is calculated and from the median of arranged series of quality indices which includes all stations, the unique indicator of quality is obtained. The study shows that the application of the SWQI method can give a comprehensive overview of water quality of the river Nišava, with trend analysis and interpretation of the results with the descriptive index of water quality.

Table 2 shows the results of monitoring [7] and calculation of SWQI on the measuring stations obtained by using Environmental Protection Agency program, based on the method SWQI [10].

Table 2 Monitoring and calculation results of SWQI on the measuring stations on the river Nišava for the year 2011

Parameters		Dimitrovgrad	Bela Palanka	Niš
1.	Temperature (^{0}C)	12.525	11.918	13.23333
2.	pH value	8.29	8.327	8.43333
3.	Electrical conductivity (μS/cm)	476.667	407.545	436.25
4.	Oxygen saturation (%)	98.917	97.45	99.66667
5.	BOD5 (mg/l)	2.225	1.8545	2.33333
6.	Suspended matter (mg/l)	3.25	6.3	11.6875
7.	Total nitrogen oxides (mg/l)	0.665	0.878	0.752
8.	Orthophosphates (mg/l)	0.00933	0.0701	0.0981
9.	Ammonium ion (mg/l)	0.06	0.0645	0.14667
10.	Coliform bacteria (in 100ml)	220	716.66667	17266.66667
	SWQI	92 - Excellent	90 - Excellent	82 - Good

According to the adopted classification criteria of quality indicators and classes of surface waters and based on the calculated value SWQI for each measuring station, the appropriate class of water for the river Nišava at the individual measuring stations as well as for the entire flow is shown in Table 3.

Table 3 SWQI and class of water of the river Nišava on the measuring stations Dimitrovgrad, Bela Palanka and Niš

Measuring station	Dimitrovgrad	Bela Palanka	Niš	Nišava
SWQI	92 - Excellent	90 - Excellent	82 - Good	88 – Very good
Class of water	I	I	II	I

The highest SWQI value is recorded on the measuring station in Dimitrovgrad with the value of 92, which corresponds to the descriptive indicator "excellent" (classification interval 100 – 90), i.e. to class I of surface water. The lowest SWQI value is recorded on the measuring station in Niš with the value 82, which corresponds to the descriptive indicator "good" (classification interval 83 – 72), i.e. to class II of surface water.

The analysis of SWQI values for the year 2011 shows that the unique indicator of water quality of the river Nišava is 88, which corresponds to the descriptive indicator "very good" (classification interval 89 – 84), i.e. to class I of surface water. As already mentioned in the legal framework of surface waters, surface water class I in natural state, or with primary disinfection, can be used for drinking, in food industry and for the cultivation of some species of fish (salmonids).

Two similar applications for calculating Water Quality Index can be found on the Internet, which do not provide identical results. [10] Limiting values for the water quality determination have slightly different values during their application, which is presented in Table 4.

Table 4 Example of another way for surface water classification using Water Quality Index method [1]

100 – 91	90 – 71	70 - 51	50 – 26	25 - 0
Excellent	Very good	Good	Bad	Very bad

The Institute of Public Health in Niš published its results of Water Quality Index for the river Nišava in 2011. Measurements were conducted on five measuring stations, eight times during 2011. The calculation results of WQI based on the measurement results are presented in Table 5.

Table 5 Published results of WQI for the river Nišava in 2011 [1]

Nišava - village Prosek	Nišava – in the level of water intake system NAISSUS	Nišava - 100m upstream from where the sewage collector flows into the river	Nišava - 300m downstream from where the sewage collector flows into the river	Nišava – 100m river empties into the South Morava	City of Niš
73 – Very good	73 – Very good	71 – Very good	63 - Good	61 - Good	68 - Good

According to the results of the Institute of Public Health, it can be concluded that there is no significant difference between the results presented for the measuring station in Niš in Table 3, where the SWQI value is 82, which corresponds to the descriptive indicator "good" (classification interval 83 – 72), and the results of the Institute of Public Health, where the value of the indicator is 68, which also corresponds to the descriptive indicator "good" (classification interval 70 – 51).

4. CONCLUSION

The most important measure for water resources protection is water pollution risk management, which consists of planning, evaluation, treatment and monitoring of water. The comparison between Serbian legal regulations with the classification system which describes the quality of surface water using Serbian Water Quality Index method is important as a basis for the preparation of the country for the integration processes of the European Union from the point of view of international cooperation in water management. Water quality analysis using the method SWQI shows that this method can be used in the accumulation monitoring system intended for water supply. Improving the quality of water supply involves the comparison and harmonization of our current legal framework with the accepted European standards for determining the quality of surface water.

The results show that the SWQI method represents an essential IT tool that provides reliable data about the long - term trends, which is important in developing water pollution risk management models.

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MODEL UPRAVLJANJA RIZIKOM OD ZAGAĐENJA NIŠAVE

U radu je prikazan model upravljanja rizikom od zagađenja reke Nišave. Za izradu modela korišćen je institucionalni i zakonski okvir u oblasti voda u Republici Srbiji, kao i opšti model upravljanja rizikom. Model se sastoji iz četiri osnovne faze (planiranje, ocenjivanje, tretiranje i monitoring rizika), koje su međusobno povezane i neophodne za poboljšanje kvaliteta vode. Detaljnije je razmatrana faza ocenjivanja rizika u okviru koje je procenjen kvalitet vode reke Nišave metodom Serbian Water Quality Index (SWQI). Prema SWQI metodi deset odabranih parametara fizičko - hemijskih i mikrobioloških karakteristika (temperatura, pH vrednost, elektroprovodljivost, zasićenost kiseonikom, BPK 5, suspendovane materije, ukupni azot, ortofosfati, amonijum, koliformne klice) se sumira u jedan indeksni broj kvaliteta vode. Rezultati analize za 2011. godinu pokazuju da indeks kvaliteta vode reke Nišave iznosi 88, što odgovara I klasi površinske vode i opisnom indikatoru „veoma dobar". Ovaj model suštinski se može koristiti kao opšti za upravljanje rizikom od zagađenja drugih reka, sa malim izmenama i dopunama.

Ključne reči: *upravljanje rizikom od zagađenja, kvalitet vode, Serbian Water Quality Index (SWQI), indikatori kvaliteta*