CASE STUDY OF WATER MANAGEMENT PROCESSES: SERBIAN WATER QUALITY INDEX

Nebojša Veljković, Dejan Lekić, Milorad Jovičić
Republic of Serbia, Ministry of Environmental Protection
Serbian Environmental Protection Agency
11060 Beograd, Str. Ruže Jovanovića 27a
nebojsa.veljkovic@sepa.sr.gov.yu; dejan.lekic@sepa.sr.gov.yu

Abstract

This paper gives a general analysis of the river water quality in Republic of Serbia for the period 2001 -2006. The indicator is created by using combined water quality index according to both "Regulation on water classification" and Water Quality Index methodology. For example, the surface water that can be categorized in the class I according to the "Regulation on water classification" can also be evaluated using WQI if the appropriate index is in range 84-85. Consecutively, all the other categories have corresponding WQI ranges (II class - WQI 72-78, III class - WQI 48-63, IV class - WQI 37-38). Moreover, for each WQI range a descriptive quality indicator has been defined, ranging from very poor (0-38), poor (39-71), good (72-83), very good (84-89) and excellent (90-100). Using correlations between Serbian and European legislative a new descriptive surface water quality indicator has been developed - Serbian Water Quality Index. Surface water quality, requested for drinking water abstraction, has been represented on the river network map, marking each control profile with an appropriate color (very poor - red, poor - yellow, good - green, very good - blue, excellent - light blue). This paper presents the water quality indicators calculated for each measuring location, grouped by the high/low water quantity season. Applied methodology and results of the analysis in creating SWQI should be seen as a contribution to the European integration of Republic of Serbia in the field of environmental protection through the implementation of the Water Framework Directive on the national level.

Keywords: *water management, water quality index, descriptive indicator.*

1 INTRODUCTION

European water policy is based on the sustainable development of water management sector through the implementation of the Water Framework Directive (WFD) and other Directives. Better understanding of the key principles presented in these Directives is essential not only as a starting point for country preparation for EU integration processes but also as a framework for international cooperation in the water management field. In recommendation to the European Environment Agency (EEA) on how they should proceed with the development of a strategy for Integrated Environmental Assessment, Serbian Environmental Protection Agency SEPA proposed the use of a framework, which distinguished driving forces, pressures, states, impacts and responses. This became known as the DPSIR framework and has since been more widely adopted by the EEA, acting as an integrated approach for reporting, e.g. in the EEA's State of the Environment Reports. The framework is

seen as giving a structure within which to present the indicators needed to enable feedback to policy makers on environmental quality and the resulting impact of the political choices made, or to be made in the future.
The increase in quantity and quality of water related data and their systematization should be seen as a key prerequisite in environmental protection policy making that will result in a better decision support system in the water management field. The usual way to organize and present a wide set of data is to apply indexes and indicators as a tool that summarize many parameters and creates an information. Using this method, numerous data are reduced to an acceptable amount of information while keeping their essential meaning. This paper presents an environmental indicator related to the water quality field, mainly targeting public sector, experts and policy makers. The indicator is based on the Water Quality Index (WQI) methodology, thus grouping ten physico-chemical and microbiological water quality parameters into one composite surface water quality indicator.

2 LEGAL FRAMEWORK FOR WATER QUALITY CONTROL

Appropriate legislative in Republic of Serbia defines four classes of water quality (I, II, III and IV) by defining the threshold values of water quality parameters for each class. The categorization is applied using following parameters: (1) Suspended solids, (2) Total Dissolved solids, (3) pH, (4) Dissolved oxygen, (5) BOD_5, (6) Degree of saprobity, (7) Degree of biological production, (8) (E.Coli /MPN), (9) Visible waste material, (10) Visible color, (11) Detectable smell, (12) Oxygen saturation ($\%O_2$), (13) COD, (14) Toxic materials and (15) Radioactivity level (Regulation on water classification, Official Gazette 1978). This Regulation also defines methodology for calculating a representative value from numerous measurements, using a 95% occurrence probability value as a representative one in case when at least 24 measurements are made during the year or an arithmetic mean of two most unfavorable measurements if there are less than 24 samples taken per year. The Regulation doesn't give any instructions on how to aggregate these 15 parameters in order to make the overall classification of the water stream (Regulation, Official Gazette 6/78).
When focusing on the issue of surface water quality in sense of possibility of using this water for water supply, the above mentioned Regulation is comparable to the Council Directive 75/440/EEC which defines a required quality of surface water used for drinking water abstraction in EU member states. The Directive defines three categories of surface water quality, with appropriate threshold values for each class: A1 (simple physical treatment and disinfection, i.e. quick filtration and disinfection), A2 (normal physical treatment and disinfection, i.e. oxidation/disinfection, coagulation, flocculation, filtration, disinfection), A3 (intensive physical and chemical treatment, extended treatment and disinfection, i.e. contact chlorine treatment, coagulation, flocculation, adsorption, disinfection).
Three different groups of stakeholders in the field of water management and protection, policy makers, experts and public, do not share the same point of view when defining the procedures of Regulation enforcement. That is the main reason why the state of environment indicators should be inline with user requirements and to present a simple and easily understandable message. High level of "correspondence" between user and indicator has to be reached so that the right information can be passed providing valuable input in decision making process.

Experts in scientific, educational institutions as well as public authorities (inspection, policy makers) should be informed about the water quality using an indicator that will include information on physico-chemical, microbiological and biological state of the water resources. On the other hand, wide public should be approached with more descriptive indicators such as "high/low water quality level". This paper presents an environmental indicator related to the water quality field, mainly targeting public sector, experts and policy makers.

3 THE CREATION AND DEVELOPMENT OF A DESCRIPTIVE QUALITY INDICATOR

3.1 Methodology

The creation and development of a descriptive indicator is based on the Water Quality Index methodology which uses ten chosen quality parameters (Oxygen Saturation, BOD_5, Ammonium, pH, Total Oxidised Nitrogen, Orthophosphate, Suspended solids, Temperature, Conductivity and E.Coli /MPN) as an input in form of ten values (q_i) representing surface water quality that are summarized as one index on a 0-100 scale.

Table 1. Correlation between WQI methodology and Regulation - Official Gazette 1978 (required water quality class - MCL)

Parametar (unit)	Max. value $q_i \times w_i$	MCL I class	MCL II class	MCL III class	MCL IV class
Oxygen Saturation (%)	18	90-105 -	75-90 105-115	50-75 115-125	30-50 125-130
BOD_5 (mg/l)	15	2	4	7	20
Ammonium (mg/l - N)	12	0,1	0,1	0,5	0,5
pH	9	6,8-8,5	6,8-8,5	6-9	6-9
Total Oxidised Nitrogen (mg/l - N)	8	10,0	10,0	15,0	15,0
Orthophosphate (mg/l - P)	8	(0,005)	(0,005)	(0,01)	(0,01)
Suspended solids (mg/l)	7	10	30	80	100
Temperature (^oC)	5	-	-	-	-
Conductivity (µS/cm)	6	-	-	-	-
E.Coli /MPN/ 1000 ml	12	2.000	100.000	200.000	200.000
$\Sigma q_i \times w_i$ = WQI	100	84,3 - 85,4	71,9 - 76,4 77,5	48,3 - 57,3 61,8 -62,9	37,1 - 38,2

Each parameter doesn't have a same influence on the final, indexed overall water quality, thus each parameter has an appropriate weight (w_i) where the sum of all weights equals to 1. By summarizing the products of all quality parameters and all weights an index is created representing a weighted sum of all parameters.
Through an analysis and comparison of Regulation on Classification and *WQI* methodology, a composite surface water quality indicator has been created - Serbian Water Quality Index (*SWQI*). The surface water quality is classified and relations between classes defined in Regulation on water classification (Regulation, Official Gazette 6/78) and indexes calculated using *SWQI* have been defined as described in Table 1. (Veljković, 2004)
The same methodology has been applied when creating a correlation between classes defined in the Annex 1 of the Council Directive (A1, A2. A3) and indexes created using *WQI* methodology. Table 2 gives a detailed overview of these classes and appropriate *WQI* values. (Veljković *at al*., 2006)

Table 2. Correlation of Method WQI and Directive 75/440/EEC

Parametar (unit)	WQI_{max} $q_i \times w_i$	A1	WQI_{A1} $q_i \times w_i$	A2	WQI_{A2} $q_i \times w_i$	A3	WQI_{A3} $q_i \times w_i$
Oxygen Saturation (%)	18	> 70	11	> 50	6	> 30	2
BOD_5 (mg/l)	15	< 3	11	< 5	7	< 7	4
Ammonium (mg/l N)	12	0,05	12	1	3	2	2
pH	9	6,5-8,5	9-7	5,5-9	5	5,5-9	5
Total Oxidised Nitrogen (mg/l N)	8	1	7	2	6	3	5
Orthophosphate (mg/l P)	8	0,4	4	0,7	1	0,7	1
Suspended solids (mg/l)	7	25	4	25	4	25	4
Temperature (^oC)	5	22	2	22	2	22	2
Conductivity (µS/cm)	6	1000	0	1000	0	1000	0
E.Coli /MPN/ 1000 ml	12	20	12	2000	10	20000	7
$\Sigma q_i \times w_i$ = WQI	100		70		44		32

The descriptive indicator, corresponding to an appropriate range of WQI values has been defined as: WQI = 0-38 *very poor*, WQI = 39-71 *poor,* WQI = 72-83 *good*, WQI= 84-89 *very good* and finally WQI = 90-100 *excellent*. This indicator also corresponds to the different classes/categories of water quality in sense of physical, chemical and microbiological characteristics on the continuous WQI scale as described in Table 3.
The described methodology for creating Serbian Water Quality Index as an indicator that is in compliance with both national Regulation on on water classification and EU

Council Directive gives a detailed way for classification of surface water used for drinking water abstraction.

Table 3. Methodology for creating a descriptive indicator *SWQI*

WQI-MCL I class		WQI- MCL II class	WQI- MCL III class	WQI- MCL IV class
85 - 84		78 - 72	63 - 48	38 - 37
100 - 90	89 - 84	83 -72	71 - 39	38-0
Excellent	Very good	*Good*	*Poor*	*Very poor*
Light blue	Blue	Green	Yellow	Red

Indicator SWQI can be used and presented using appropriate colors on the map of surface water streams and lakes but also using descriptive way to link each water quality category with the needed treatment of water and possible fields of use:

a) *Excellent/Very Good* - After applying simple physical treatment and disinfection, water can be used as for drinking water supply while in the natural state it can be used for breeding of fish species like Salmonidae.
b) *Good* - Water that can be used as bathing water and for public recreation in its natural state. Fish breeding of species such as Cyprinidae can be performed. Symple physico-chemical treatment and disinfection should be applied before using this type of water for drinking water supply.
c) *Poor* - Water can be used in the melioration, normal physico-chemical treatment and disinfection should be applied before using in drinking water supply systems.
d) *Very poor* - These water resources have an overall negative influence on the environment and cannot be used as a source for drinking water supply systems. In some exceptional cases, if in accordance with drinking water quality standards after applying an intensive physico-chemical treatment, extended treatment and disinfection, it can be also used for water supply.

3.2 Results

Descriptive SWQI indicator has been applied to the main watersheds of Republic of Serbia: Province of Vojvodina (Danube-Tisa-Danube channel system and rivers on the left side of the Danube River), Danube, Sava (including Drina and Kolubara watersheds), Contributories of Djerdap lake (right contributories of Danube, downstream of Velika Morava confluence) and Velika Morava watershed. Water quality data collected on 143 measuring locations at the average rate of once per month for the period 2001-2006 are used as input values.
Surface water regime on the major part of territory of Republic of Serbia mainly shows that the river streams belong to rain/snow regime, having high level of discharges during the winter/spring (January - June) period and low discharges in summer/autumn season (July - December). Applied methodology and analysis resulted in the *SWQI* indicator for both high water level and low water level seasons.

Calculated *SWQI* is presented for all the measuring locations in Serbia as described in Table 4.

Table 4. Percentage of occurrence of particular descriptive *SWQI* indicator for 143 measuring locations in Serbia for the period 2001 - 2006

Water quality	Number of samples (%)	
	high water level season	low water level season
Excellent	14	12
Very good	25	20
Good	41	42
Poor	19	24
Very poor	1	2

Summary analysis of river water quality for selected watersheds (Vojvodina, Danube, Sava, Djerdap contributories and Velika Morava) has been also applied in Table 5.

Table 5. Percentage of occurrence of particular descriptive *SWQI* indicator for main watershed in Serbia for the period 2001 - 2006

Catchment name and season		Water quality				
		Very poor	*Poor*	*Good*	*Very good*	*Excellent*
		Number of samples (%)				
Sava	high water level season	0,2	9,9	24,9	26,3	38,8
	low water level season	0,4	11,4	30,5	25,7	31,9
Velika Morava	high water level season	0,1	9,8	41,7	36	12,4
	low water level season	0,1	16	44,6	26,1	13,2
Province of Vojvodina	high water level season	4,2	42,6	41,9	9,2	2,1
	low water level season	6,7	47,7	35,4	7,5	2,6
Contributories of Djerdap lake	high water level season	0	5,2	35,6	44,4	14,8
	low water level season	0	10,9	30,6	38,3	20,2
Danube	high water level season	0	5,2	64,6	26,4	3,8
	high water level season	0	5,6	66,2	25,5	2,7

The results of research show that *SWQI* methodology can be used for general assessment of state of water resources in Serbia. Interpretation of acquired descriptive water quality indicator clearly point out the region of Vojvodina province as the most polluted one. More then 50% of surface water samples (rivers and channels) during the observation period are in the *poor*/*very poor* category, while for all other watersheds/regions the number of samples in these two categories is from 5% to 16%. Water bodies in Vojvodina region (both rivers and Danube-Tisa-Danube channel system) are used for the direct waste water dump not only from agglomerations but also from the food and beverages industry and livestock production. The water body that is under the highest pressure in this region is the Vrbas - Bezdan channel, known as "Veliki bački kanal" which is used as a recipient of untreated waste water from food industry, sugar production plants, pig farms, etc. Actually, the only place in Serbia where descriptive *SWQI* indicator is in the *very poor* category, is downstream from the town of Vrbas.

4 CONCLUSION

The national regulations in water management and protection field differ among European countries, meaning that the comparison of results cannot be easily performed. That is the main reason why *SWQI* indicator calculation uses Water Quality Index methodology as its base. The research results presented in this paper together with the analysis and results made for the territory of Serbia, clearly illustrate that applied methodology can give an overall assesment of the surface water quality. It is important to emphasize that the creation of *SWQI* indicator somehow "sacrifices" a part of validity of original water quality data. As general public should be seen as one of the main user groups of water quality indicator presented in this work, the indicator is created to be descriptive, clear and easily understandable. It should provide assistance to all target groups providing additional inspiration and motivation in tackling water related environmental issues.Applied methodology and results of the analysis in creating *SWQI* should be seen as a contribution to the European integration of Republic of Serbia in the field of environmental protection through the implementation of the Water Framework Directive on the national level.

References

Council Directive 75/440/EEC of 16 June 1979 concerning the quality required of surface water intended vfor the abstraction of drinking water in the Member States: Official Journal L 194 (1975), p. 26.

Data Fund of the Republic Hydrometeorological Service of Serbia - RHMS (2001-2006).

Development of a Water Quality Index (1976), Scottish Development Department, Engineering Division, Edinburgh.

Guidelines for Data Collection and Processing - EU State of the Environment Report. (1998), Annex 3. EEA.

Uredba o klasifikaciji voda međurepubličkih vodotoka, međudržavnih voda i voda obalnog mora Jugoslavije (Regulation, Official Gazette 6/78), Sl.list SFRJ 6/78.

Veljković N. (2004): Eco-agglomeration development index as an Indicator of sustainable development, PhD thesis, Faculty of Safety at Work, University in Niš, Serbia.

Veljković N., Jovičić M. (2006): Analiza kvaliteta voda akumulacija u Srbiji u odnosu na granične vrednosti Direktive 75/440/EEC (Analysis of water quality in accumulations in Serbia in terms of treshold values under 75/440/EEC Directive), Zaštita voda 2006, Jugoslovensko društvo za zaštitu voda, Beograd. p.121-126.