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# Assessing the surface water status in Pannonian ecoregion by the water quality index model

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ABSTRACT

The results of a 3-year monitoring study of surface water status in the Pannonian ecoregion for three different water types (4, 5B, 5C) are presented and evaluated statistically with descriptive and multivariable analyses. A modified water quality index ($WQI_M$) for the Pannonian ecoregion is performed based on 7 indicators of water quality (pH, dissolved oxygen, biological oxygen demand (BOD), total organic carbon (TOC), nitrate, total nitrogen and total phosphorus). The applied analysis indicates correlation between individual variables with particularly strong correlation between BOD and TOC. Two linear prediction models (multivariable linear regression model (MLR) and piecevise linear regression model (PLR)) of WQI for assesment of water status in the Pannonian ecoregion were developed. In these linear models, indicator BOD was replaced with indicator TOC. In predicting WQI for the three different water types in the Pannonian ecoregion, better results were obtained with a correlation coefficients $R^2_{(4)} = 0.88$, $R^2_{(5B)} = 0.76$ and $R^2_{(5C)} = 0.79$ by piecevise linear regression model.

## 1. Introduction

Different regions of the world are faced with different problems associated with the occurence, use, and control of water resources, which may endanger sustainable development of this resource. Anthropogenic influences as well as natural processes degrade surface water quality (Carpenter et al., 1998; Jarvie et al., 1998; Simeonov et al., 2003).

Rivers, as sources of drinking water, irrigation, fishery and energy production, are important multi-usage components (Hacioglu and Dulger, 2009). In recent years both the anthropogenic influences (urban, industrial, and agricultural activities) as well as natural processes (precipitation inputs, erosion, weathering of crustal materials, degradation of surface waters and rendering the water bodies unsuitable for both primary and secondary use) have increased exploitation of water resources (Agbaire and Obi, 2009; Najafpour et al., 2008).

The water quality is described by its physical, chemical and microbiological characteristics (Rajeshwari and Saraswathi, 2009). Traditional approach in assessing water quality is based on comparison of experimentally determined parameters with existing guidelines. In many cases, the use of this methodology allows proper identification of contamination sources and may be essential for checking legal compliance. However, it does not readily give an overall view of the spatial and temporal trends in the overall water quality in a watershed (Debels et al., 2005). Traditional monitoring approach in Croatia includes determining two water states: ecological and chemical status. Ecological status is assessed according to the worst status assessment of three quality elements which are biological, supporting physico-chemical and hydromorphological quality elements. Chemical status is assessed by determining 45 priority and priority hazardous substances. According to the concentration of certain priority substances, surface waters are classified into two chemical classes: good status and good status not reached. A surface body of water has a good chemical status if the average and maximum annual concentration of each priority substance does not exceed the prescribed quality standard of the aquatic environment (Regulation on water quality standards, OG 73/13). Complex data matrices, which are the result of monitoring, need to be systematized and edited by using various statistical methods. The application of different multivariate approaches (cluster analysis, principal components analysis) for the interpretation of complex data matrices offers better understanding of water quality and ecological status of the studied systems. In addition, it allows the identification of possible factors/sources that influence the water systems and offer a valuable tool for reliable management of water resources as well as rapid solutions to pollution problems (Wunderlin et al., 2001). The use

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of water quality indices is a simple practice that overcomes many of the previously mentioned problems. Furthermore, it allows all stakeholders to receive information on water quality. WQI permits to assess changes in the water quality and to identify water trends. A quality index is a unitless number that ascribes a quality value to an aggregate set of measured parameters. Water quality indices generally consist of sub-index scores assigned to each parameter by comparing its measurement with a parameter-specific rating curve, optionally weighted, and combined into the final index. Such WQI gives a number that can be associated with a quality percentage, it is easy to understand, and is based on scientific criteria for water quality.

The following four steps are most often associated with the development of any WQI:

1) parameter selection, 2) transformation of the parameters of different units and dimensions to a common scale, 3) assignment of weightages to all the parameters, 4) aggregation of subindices to produce a final index score.

A single number cannot provide a complete assessment of the state of the entire water body because there are several other water parameters that are not included in the index. However, the WQI is based on main water quality parameters and can be used as a simple indicator (Štambuk-Giljanović, 1999). The use of a WQI was initially proposed by Horton (1965) and Brown et al. (1970). Since then, many different methods for the calculation of WQI have been developed. In general, they all consider similar physical and chemical parameters but differ in the way the parameter values are statistically integrated and interpreted (Zagatto et al., 1998; Štambuk-Giljanović, 1999). Most of water quality indices were developed according to the U.S. National Sanitation Foundation ($WQI_{NSF}$) (NSF, 2007). The modified water quality index ($WQI_M$), adjusted for the Pannonian ecoregion, has been developed according to the $WQI_{NSF}$ and includes 6 indicators of water quality. These are: pH, dissolved oxygen, BOD, nitrate, total nitrogen and total phosphorus (Tomas et al., 2013). Biological oxygen demand (BOD) is one of the indicators in overall $WQI_M$ that indicates biological degradation of organic matter. The disadvantage of BOD is the long duration of the test which is 5 days.

The aim of this work is to establish models for prediction of $WQI_M$ where BOD indicator is replaced with TOC. Unlike BOD, TOC oxidizes total organic matter, and is a faster and more accurate method of determining the quality of surface water.

## 2. Materials and methods

### 2.1. Monitoring area

The study area is located in the southern part of the Pannonian basin and covers the area of Croatia (Fig. 1). It is located in the boundary zone between the African and Eurasian plates, and includes the Pannonian basin along with several different geotectonic units. The Pannonian basin is characterised by extending structures (Posgay et al., 1995) and its origins are most frequently considered in relation to the Carpathian range in terms of a "back-arc" basin (Stegena et al., 1975; Royden et al., 1983). Marginal areas of the southern Pannonian basin are influenced by events in the Dinarides (Pamić et al., 1998; Tari and Pamić, 1998) and transport mechanism of the Alpine fragments that are included in the north Pannonian basin and the Internal Carpathians (Kazmer and Kovacs, 1985; Csontos et al., 1992).

The southern marginal fault is Fella-Sava-Karlovac, which is a boundary between the Dinarides and the Pannonian basin (Prelogović et al., 1998), with neogene and quaternary sediments in the south-west part of the Pannonian basin. The Sava and Drava depressions are filled with neogene deposits and characterized by hydrocarbon reservoirs in the south-west part of the Pannonian basin. They are of asymmetrical shape with steeper southern limbs that are elongated in the northwest-southeast (NW-SE) direction. The Sava depression is located along the very southwestern edge of the Pannonian basin and the Drava depression is located further to the north. Boundary fault of the Drava depression is a dextral transcurrent fault of NW-SE direction (Prelogović et al., 1998). There are several mountains of the Pannonian basin, Slavonian Mountains and the Moslavačka gora are located between the Sava and Drava depressions and consist of Paleozoic – Mesozoic rocks. Also, Medvednica and Samoborsko gorje mountains consist of ophiolites and are located at the northern margin of the Sava depression (Tomljenović, 2002). According to relief and hydrogeological characteristics, Croatia is divided into two ecoregions: Pannonian and Dinaridic ecoregions. In this study, the Pannonian ecoregion with the Sava, Drava, Krapina, Ilova, Glogovnica and Česma rivers is examined. According to water typology and Croatian legislative, these rivers belong to three water types labelled as 4, 5B, 5C (Fig. 1). Water type 4 represents medium and large lowland streams, water type 5B represents very large lowland streams (the lower course of the Mura River and the middle courses of the Sava and Drava Rivers), while water type 5C represents very large lowland streams (the lower course of the Sava and Drava Rivers) (Regulation on water quality standards, OG 73/13).

### 2.2. Sampling strategy and analytical procedure

The sampling was conducted monthly during a three-year period (2009–2011) at different monitoring stations (Table 1). Table 1 shows the GPS coordinates as well as water types according to water typology.

Surface water status is determined by the worse of ecological and chemical status. For the characterization and assesing of surface water status by $WQI_M$ and WQI models, 7 indicators of water quality (pH, dissolved oxygen (DO), biochemical oxygen demand (BOD), nitrates, total nitrogen (TN), total phosphorus (TP) and total organic carbon (TOC)) were observed. All parameters were determined according to ISO standards. Water temperature and pH were measured in situ by using Mettler Toledo portable equipment. DO was determined according to the Winkler method. BOD was determined as the difference between the initial and 5th day oxygen concentration in bottles assayed by the Winkler method after incubation at 20 °C. $NO_3$-N was determined by ion chromatograph Dionex ICS 3000. TN and TOC were determined by Shimadzu analyzer TOC with TNM-1 unit and TP was determined by spectrophotometric method with acid molybdate.

### 2.3. Water quality index

The modified WQI ($WQI_M$), which was adjusted to the Pannonian ecoregion, was calculated considering 6 important physico-chemical parameters and based on their indication to eutrophication of water-courses and to organic pollution. These parameters were: pH, DO, BOD, nitrate ($NO_3$-N), TN and TP. The $WQI_M$ was calculated according to the following formula:

$$WQI = \sum_{i=1}^{n} q_i w_i \quad (1)$$

where:

WQI – water quality index

$q_i$ – sub-index for $i^{th}$ parameter

$w_i$ – weight for $i^{th}$ parameter

On the basis of the WQI, water quality is categorized from excellent to poor status (Boyacioglu, 2007) (Table 2).

Sub-indexes are developed according to linear regression starting from the threshold values which are prescribed by the Croatian National Standards (Tomas et al., 2013).

Numbers from 1 to 4 were assigned to the selected indicators on the basis of importance, proposed by $WQI_{NSF}$ (Table 3). On this scale, 1, 2, 3 and 4 indicate respectively little, average, high and very high importance in overall WQI. Each weight was divided by the sum of all weights in order to get relative weight factor (Boyacioglu, 2007).