

APPLICATION OF AN INTEGRAL METHODOLOGY IN DETERMINING TMDL FOR DISSOLVED OXYGEN IN THE BEČEJ-BOGOJEVO CANAL

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SUMMARY: Water quality (WQ) in the canal network in Vojvodina is not satisfactory. The most important WQ parameter is the concentration of dissolved oxygen, which indicates suitability for life of aquatic organisms. The reach of Bečej-Bogojevo canal has been chosen since it receives seriously polluted water from the Vrbas-Bezdan canal. In the research an integral methodology has been applied consisting of WQ modeling using QUAL2K, Geographic Information Systems (GIS) mapping of spreading of dissolved oxygen concentration and calculating Total Maximum Daily Load (TMDL) values of polluting substances. The calibration of the model has been conducted using the data of WQ parameters obtained from field work, previously imported into GIS database. Besides, using data on concentrations of polluting substances from the cadastre of polluters a few simulations has been conducted for various scenarios and as a result GIS maps have been obtained showing changes in concentrations of dissolved oxygen along the reach. Finally, the TMDL values of major polluting substances affecting the concentration of dissolved oxygen have been determined.

Key words: *integral methodology, dissolved oxygen, canal network, modeling, QUAL2K.*

INTRODUCTION

The concentration of dissolved oxygen (DO) represents one of the most important WQ parameters for sustaining aquatic life, especially for non photosynthetic organisms. The basic canal network of the Hydrosystem Danube-Tisa-Danube (HS DTD) consists of huge canals which are formed as slow flowing streams with poor aeration, due to small slope and relatively large amount of water that depends on seasonal variations. This explains variable concentration of DO

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ranging from super saturation to low concentrations, and deficient. Because of the mentioned processes macrophytic vegetation grows. Džigurski et al. (2009) have investigated canal vegetation diversity which is also conditioned by controlled water regime and different depth of some sections. Besides, canal network has significant potential for receiving and diluting waste water, but in some cases, because of excessive pollution, it represents a problem and often causes algal blooms or vegetation overgrowth. This is predominantly influenced by effluents from food processing industries, farms, pollutants coming from municipal waste waters, as well as urban and agricultural runoff and other sources (Piperski and Salvai, 2008; Piperski et al., 2010; Savić et al., 2010). The problem of WQ in the canal network is complex, and in order to overcome the problem, modern integral approach needs to be considered. The integral approach is based mostly on the requirements of Water Framework Directive (WFD) of the European Union, as well as on the concept of Total Maximum Daily Load (TMDL) developed by the United States Environmental Protection Agency (US EPA). The research was focused upon the application of an integral methodology for determining acceptable oxygen concentration in correlation to pollution loads along a reach of the canal Bečej-Bogojevo.

MATERIAL AND METHOD

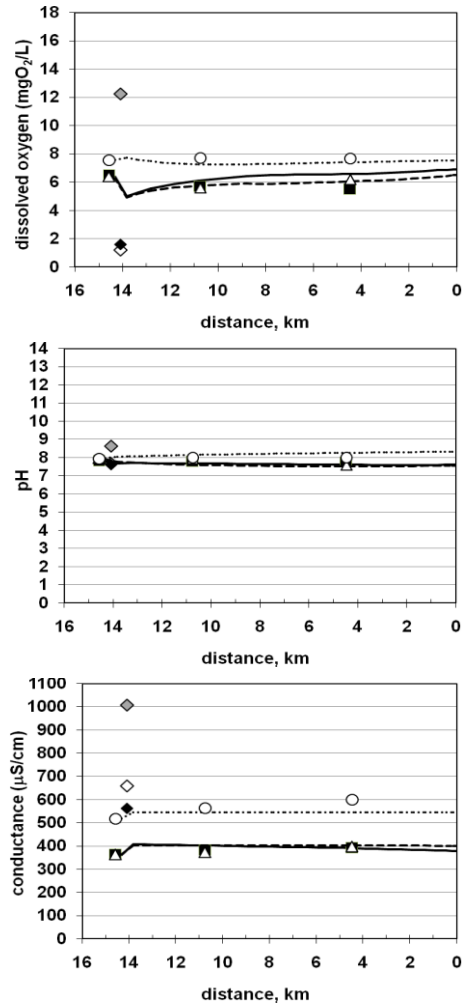
The canal Bečej-Bogojevo receives highly polluted water from the canal Vrbas-Bezdan after the point of their confluence – Triangle. In the downstream Triangle the processes of dilution and self-purification occur. The research was conducted on a 14.58 km long reach where the most intense processes of self purification take place.

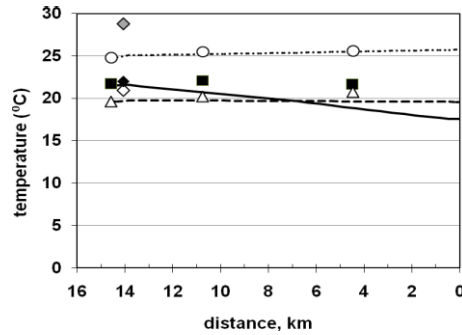
The data for major pollutants (total P, inorganic P and ammonium) have been obtained from the cadastre of polluters of the PWMC “Vojvodina Vode”. Data on canal flow rates measured on the locks Vrbas for the canal Vrbas-Bezdan and Kucura for the canal Bečej-Bogojevo were obtained from the same institution. Since flow rates within the whole HS DTD have been controlled and conditioned by the users’ needs, hydrometeorological conditions have only partial significance. In the past decade 2000-2010 canal flow rates were analyzed during four years as representative: 2000, 2003, 2007, and 2009 partly because these give good reflection on variable meteorological conditions and because the systematized data on flow rates exist only for these years. Generally, according to the average daily precipitation measured by hydrometeorological station Bečej, the years 2000 and 2003 could be characterized as dry ones, 2007 as extremely wet, while 2009 was with average precipitation according to the database of the Republic Hydrometeorological Service of Serbia. The average daily flow rate for both locks for mentioned years is 5.21 m³/s, while the maximal one is 17.24 m³/s.

Three data sets of hydrometric and WQ measurements were used for calibration and validation: for calibration from May 28th, 2009, and for validation measurements conducted on September 23rd, 2009, and August 13th, 2010 (Figure 1). The Hydrometeorological data on temperature and cloudiness were obtained by direct field measurements simultaneously with WQ measurements, while the data on wind speed and humidity were taken from the database of the Republic Hydrometeorological Service of Serbia for the meteorological station Bečej for the same hours. Figure 1 presents results of calibration and validation for DO,

temperature, conductivity and pH. The complete modeling procedure using QUAL2K was explained in details in the previous research (Grabić, et al., 2011).

The simulations applying QUAL2K have been performed using different combinations of input data for canal flow rates and for pollution loads (Table 1). The QUAL2E has been well known and widely used for modeling DO concentrations (Cox, 2003), but for this research its improved version QUAL2K has been chosen since it is easier for application and enables more modeling options.





Legend:

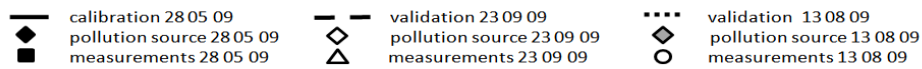


Figure 1. Calibration and validation of the WQ model for DO, pH, conductivity and temperature

Table 1. Input data for simulations

Simulations:	Canal flow rates		Pollution loads			
	descriptive	(m ³ /s)	descriptive	Total P (kgP/dan)	Inorg. P (kgPO ₄ /dan)	NH ₄ -N (kgN/dan)
1	average	5.21	minimum	73.59	0.12	55.04
2	average	5.21	average	110.47	7.07	602.38
3	average	5.21	maximum	1346.04	55.58	6558.42
4	maximum	17.24	minimum	73.59	0.12	55.04
5	maximum	17.24	average	110.47	7.07	602.38
6	maximum	17.24	maximum	1346.04	55.58	6558.42

RESULTS AND DISCUSSION

The Fish Directive (Directive 2006/44/EC) defines the concentration of dissolved oxygen in Cyprinid waters as guide and mandatory. A guide concentration in 50 % has to be ≥ 8 and 100 % ≥ 5 , while mandatory, 50 % ≥ 7 mgO₂/l. When the oxygen concentration falls below 4 mgO₂/l, the competent authority must prove that this situation will have no harmful consequences for the balanced development of the fish population.

According to the simulations outputs it can be concluded that the most favourable conditions for DO concentrations are in cases of minimal pollution loads and maximal and average canal flow rates, when DO concentration drops only along 2km below 7 mgO₂/l, as well as for average pollution loads and maximal canal flow rate (Figure 2a, 2b). In the simulation where average pollution loads and average canal flow rate is employed for the majority of the reach, DO concentration is between 6-7, while only at the end of the reach it raises below 7 mgO₂/l (Figure 2b). The worst scenario is for the maximal pollution loads where, in case of the average canal flow rate, DO concentration is below 2 for majority of the reach, while a bit

better situation is for the maximal canal flow rate and maximal pollution loads, when DO concentration is above 4 mgO₂/l (Figure 2c).

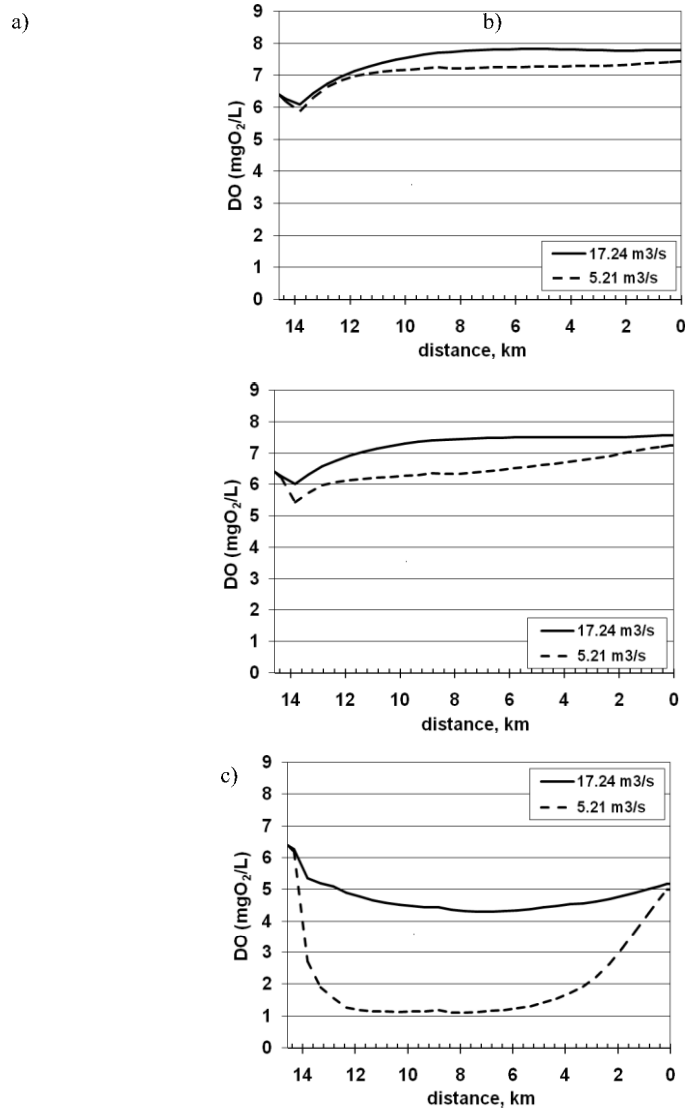


Figure 2. Changes in concentration of dissolved oxygen along the reach after receiving a) minimal, b) average and c) maximal pollution loads for maximal and average canal flow rates

TMDL values have to be calculated in a way following changes in instream canal conditions. In this paper six possible scenarios are presented and the TMDL has been calculated for the most common case – Simulation 2, for which the allowable loads of pollutants are: 58.52kg/day of total P, 21.57kg/day of inorganic P and 351.11kg/day of ammonium.

Linking GIS with WQ models brings a new opportunity in a form of maps where DO concentration changes could be easily observed along the canal reach. Differently colored ranges of DO concentrations belonging to corresponding WQ classes could help concluding whether the applied scenarios are favorable or not. Figure 3 presents changes of DO concentration along the reach after the results of Simulation 3. Results are colored in accordance with WFD coloring scheme and classification for artificial water bodies according to contemporary Serbian regulation adjusted to WFD requirements (Sl. Glasnik RS, br.74/2011).

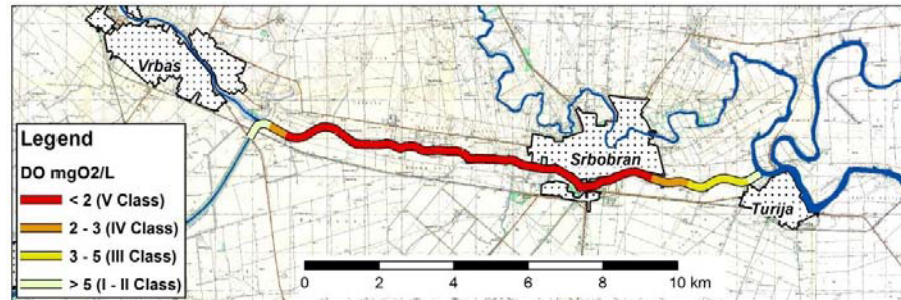


Figure 3. GIS presentation of Simulation 3 results for DO concentration changes along the canal reach

CONCLUSION

DO concentration changes along the reach of the Bečej-Bogojevo canal obtained in the research by application of the integral methodology showed that it is highly dependent on pollution loads of nitrogen and phosphorus compounds. Therefore, determination of TMDL values for polluting substances is of great importance for canal WQ management in order to maintain good WQ. Besides, linking GIS with WQ model brings a new quality in the form of presenting modeling outputs on GIS maps, which eases further data analysis. The methodology could be successfully applied on the whole canal network in Vojvodina and on the modeling various WQ parameters.

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PRIMENA INTEGRALNE METODOLOGIJE PRI ODREĐIVANJU TMDL VREDNOSTI ZA RASTVORENI KISEONIK U KANALU BEČEJ-BOGOJEVO

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Izvod

Kvalitet vode u kanalskoj mreži u Vojvodini nije zadovoljavajući. Najznačajniji parametar kvaliteta vode je koncentracija rastvorenog kiseonika, koja ukazuje na pogodnost za život vodenih organizama. Deonica kanala Bečej-Bogojevo je odabrana pošto prima vodu veoma opterećenu zagađenjem iz kanala Vrbas-Bezdan. Primljena je integralna metodologija koja se sastoji iz modeliranja modelom kvaliteta vode QUAL2K, kartiranja rasprostriranja koncentracije rastvorenog kiseonika u GIS-u i određivanja TMDL vrednosti za zagađujuće materije. Kalibracija modela je sprovedena korišćenjem podataka preaćenja kvaliteta vode koji su prethodno uneti u GIS bazu podataka. Pored toga, korišćenjem podataka o zagađujućim materijama iz katastra zahgađivaća urađeno je nekoliko simulacija za različite scnearije, a kao rezultat su dobijene GIS karte koje pokazuju promenu koncentracije rastvorenog kiseonika duž deonice kanala. Na kraju su određene vrednosti za TMDL za najznačajnije zagađujuće materije koje utiču na koncentraciju rastvorenog kiseonika.

Ključne reči: integralna metodologija, rastvoreni kiseonik, kanalska mreža, modeliranje, QUAL2K.

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