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Water Quality and Population Standpoints as Factors Influencing the Utilization for Agricultural Purposes of the Great Bačka Canal, Serbia

ABSTRACT

Great Bačka Canal (GBC) is part of the canal system that connects two rivers, the Danube and the Tisza. It extends through Vojvodina (northern Serbia) and remains to be insufficiently exploited as an agricultural resource. With the aim of fostering agricultural development and sustainable management, the standpoints of the local population as regards the utilisation of the GBC for irrigation and drainage was analyzed. The presented results were obtained through theone-way analysis of variance (ANOVA) and the post hoc Scheffe's test covering a sample of 500 interviewees from ten settlements. The results of the survey were compared tothe results of the GBC water quality as per control points (CP). The quality of the watercourses was determined using the Serbian Water Quality Index (SWQI) method. The results show that the GBC includes sections which are pure and entirely suitable to be used for irrigation and drainage (CP 1, 2, 3 and 5; SWQI >70 in most cases) and a section which is completely degraded and unusable (control point 4, SWQI <37 in most cases). The local population has a positive standpoint when it comes to the functions of irrigation and drainage, which differ depending on their place of residence. The residents of Vrbas stand out for their highly negative standpoints that correspond to the water quality results, which were noted to be extremely bad.

Key words: *irrigation and drainage, population standpoints, water quality, Great Bačka Canal*

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INTRODUCTION

The preservation and rational utilisation of water resources which are considered to be the most important segment of the environment as well as the very foundation of sustainable development represent one of the key problems of the 21st century. In different ways, people change the characteristics of the river systems, through their activities, most frequently by the construction of canals (*Bravard and Petts 1996*). All the changes on canals were made in order to improve and advance their functions in space. Intense works and the rapid development of industry very often lead to serious problems, i.e. pollution of the canal bottom.

The Great Bačka Canal (GBC) in the Vojvodina Province (northern part of Serbia) is the most polluted watercourse in Europe (*Milanović et al., 2011*) and possibly one of the most polluted in the world. In previous studies, its water quality has been marked as being out of any quality class in one part of GBC and in others, water quality was not much better than that (*Pantelić et al. 2012a*). The same area and canal banks were heavily populated by the industrial plants that use water from GBC and they are also a place for industrial wastewater discharge (*Pantelić et al. 2012b*). For local habitants, the local industry is a source of livelihood but they were also aware of industry's bad impact on landscape, ecosystems and water quality. The population standpoints on the present status of GBC, the possibility to exploit the function of the canal, and the future of GBC are the most interesting topics for analysis. Recent surveys of population standpoints mostly target issues related to ecosystem quality (*McCright and Dunlap 2011*); the dilemma "job versus environment" (*Räthzel and Uzzell 2011*) is not specific only of Serbia. The quality of a watercourse at any of the points depends on several key factors particularly in terms of basin lithology, atmospheric influences, climatic conditions and anthropogenic influences (*Shrestha and Kazama 2007*). River systems play an important role in the sustainable development of the entire environment, especially if they flow through inhabited areas (*Kowalkowski et al. 2006*). The quality of surface waters is controlled by complex anthropogenic activities and natural factors (*Xian et al. 2007*). Even though natural factors have an influence on the quality of the watercourses, anthropogenic influences often cause by far more negative consequences in a very short period of time (*Massoud et al. 2006*). The pollution of watercourses occurs as a result of both human activities and intense development of urbanisation and industrialisation (*Dragićević et al. 2010*). The organic matter load, as well as its influence on watercourses are good indicators of anthropogenic pollution (*Gurzau et al. 2010*).

The GBC is the hub of a number of smaller drainage and irrigation canals in the central part of the Province of Vojvodina, Serbia. The GBC was built at the end of the 18th century and its main purpose was transport, drainage of soaked soil and irrigation during the dry season. The GBC was the main watercourse in the region and along its banks were settlements and industrial centres. The decades-long release of industrial, communal and effluent water from farms without treatment, as well as the low flow rate and the small ecological capacity of the watercourse have led to an overall degradation of certain sections downstream from the major polluters (*Andrejev 2002*). The intense pollution of the GBC started during the 1960s. Due to agricultural and industrial development, the melioration canals and watercourses became direct recipients ofuntreated wastewater. Because of the minimal flow and the washout of the surrounding soil, a layer of sediment was formed in the bottom of the GBC and at certain places the layer is more than 2.5m thick. The GBC connects the Danube and the Tisza, from the settlement of Bezdan, to the settlement of Bečej and it constitutes a part of a complex hydrosystem, which consists of several canals connected by water gates and locks reaching 123 km in total length (*Pantelić et al. 2012b*).

The aim of this study is to define the quality of the GBC watercourse by means of the classificational method – Water Quality Index (WQI), i.e. Serbian Water Quality Index (SWQI). At the same time, it presents the results of the survey on the standpoints of the local population regarding the utilisation of GBC for irrigation and drainage. The starting point of the present study is the hypothesis that the standpoints of the local population are in correlation with the quality of canal water at the sections of the GBC where the population resides.

MATERIALS AND METHODS

Research area

The GBC is a part of the Danube-Tisza-Danube hydrosystem (HSDTD) and it flows through the central part of the Province of Vojvodina, Serbia, connecting the

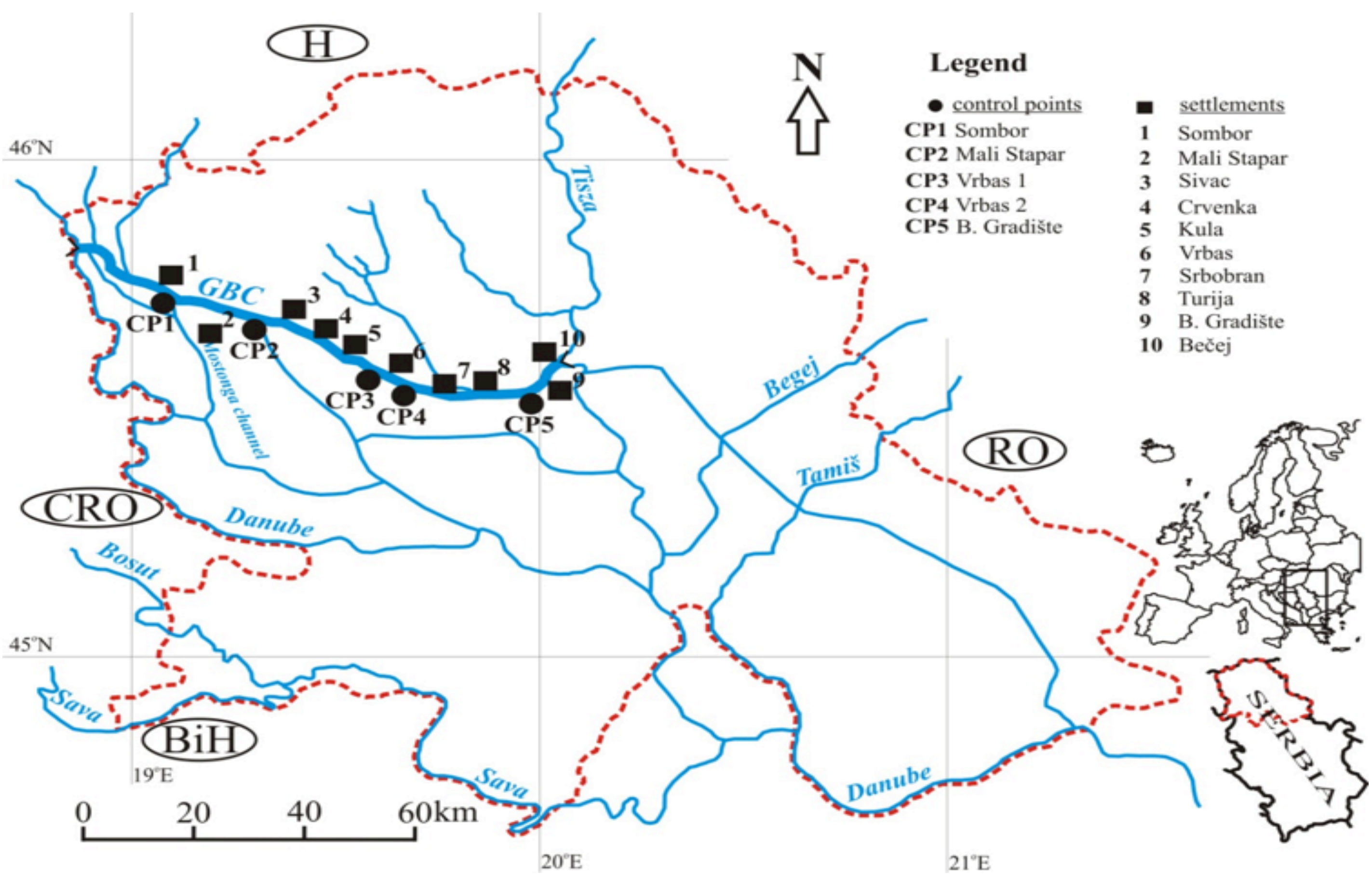

Figure 1. Research area with the position of the GBC and the location of the settlements.

rivers of Danube and Tisza (**Figure 1**). One of the major European problems regarding water pollution is related to the GBC which has been officially declared as the "black point"of pollution in the Danube water system (*NIVA 2006*). The Republic Hydrometeorological Service of Serbia measures certain physical and chemical parameters on five control points along the entire watercourse and these parametres are the subject of analysis in this research. The control points (CP) were as follows: control point 1 (CP1) at the city of Sombor, control point 2 (CP2) at the village of Mali Stapar, control point 3 (CP3) at the city of Vrbas upstream from the water gate on the GBC, control point 4 (CP4) at the city of Vrbas downstream from the water gate on the GBC and control point 5 (CP5) at the city of Bačko Gradište (**Figure 1**). Many settlements were located along the GBC: Sombor, Mali Stapar, Sivac, Crvenka, Kula, Vrbas, Srbobran, Turija, Bačko Gradište and Bečej (**Figure 1**) and the water quality in these sections of the GBC were also the subject of this study. In the research survey, 500 interviewees participated,while the sample was defined by means of the random choice method. In 2012, the sample was formed so as to include the interviewed parties of different sexes, ages, educational background and places of residence. Interviewees from ten settlements (Sombor, Mali Stapar, Sivac, Crvenka, Kula, Vrbas, Srbobran, Turija, Bačko Gradište and Bečej) formed the sample and 50 individuals were interviewed in each settlement.

Data

For defining the water quality, the Water Pollution Index (WPI) is the most frequently used (*Liu et al. 2011*); it is followed by the River Habitat Survey method (RHS) for the classification and evaluation of the physical characteristics of flowing waters and determination of the ecological status of the river flow (*Kamp et al. 2007, Urošev et al. 2009*) as well as the Water Quality Index (WQI) as one of the most reliable indicators of waterflow pollution (*Córdoba et al., 2010, Milanović et al. 2011, Srebotnjak et al. 2012, Brankov et al. 2012*). The WQI is a set ofcriteriafor the classification of surface waters on the basis of standard parametres for the categorisation of waters (*Nagel 2001, Liou et al. 2003*). The WQI method is the most frequently used in expert analyses and scientific research. It provides a mechanism for cumulative representation, numeric expression and defining a certain level of water quality (*Hambright et al. 2000, Jonnalagadda and Mhere, 2001*). In Serbia, the SWQI is a surface water quality description system, i.e. a method for quality evaluation of a group of chosen parameters. Previous research and published papers indicate that byapplying this method, an overall picture of the surface water quality in Serbia can be created (*Veljković and Jovičić 2007, Đurašković and Tomić 2009, Bjelajac et al. 2013*).

Table 1. Classification of water quality on the basis of Water Quality Index (*Veljković 2000*).

WQI value	Descriptive indicator
0 – 38	very bad
39 – 71	bad
72 – 83	good
84 – 89	very good
90 – 100	excellent

The essence of the SWQI lies in the fact that the quality (qi) of the ten chosen parametres (oxygen saturation, BPK5, ammonium ion, pH value, total nitrogen, orthophosphates, suspended matter, temperature, electroconductivity and coliform bacteria) represents the characteristics of surface waters reducing them to a single index number (**Table 1**). The impact of each of the ten chosen parametres on the overall water quality does not have the same relative importance, which is the reason why each of them is assigned a different weight (wi) and a number of points per share in endangering quality. By adding up the products (qi x wi) the index 100 is obtained as the ideal sum of the weight of all the parameters (Oregon Water Quality Index Summary Report (1996-2005). The number of index points in the range from 0 to 100 to be assigned to a water sample depends on the points scored by individual parameters.

For the presentation of the current statusof the Great Bačka Canal water quality, the database of the RHMS of Serbia for 2009 (*RHMS 2009*) has been used. The formula used for the calculation of the SWQI is the following (*Veljković 2000*):

$$SWQI = 0{,}18\%O2 + 0{,}15BPK5 + 0{,}12NO4 + 0{,}09pH + 0{,}08N + 0{,}08PO4 + 0{,}07SM + 0{,}05t + 0{,}06\mu S + 0{,}12MPN$$

Statistical Analysis

The instrument used in the study wasa closed-ended questionnaire survey divided into two parts. The first part consisted of questions related to the socio demographic characteristics of the interviewees, while the second part consisted of questions related to the evaluation. The instrument used in the second part was a scale by means of which the interviewees assessed the possibilities for the sustainable use of the canal's functions. Similarly to previous research, this study used the Likert scale (*Vargas-Sánchez et al. 2009*). The answers were given by circling a number on a scale of numbers ranging from 1 as the lowest mark to 5 as the highest mark. The obtained data were processed in the SPSS statistical program which has been applied in previous similar studies (*Vuković et al. 2002*). Furthermore, the most frequently used statistical analyses were applied in this research, including the following: a descriptive statistical analysis (*Maguire and Klobucar 2011*) and the one-way analysis of variance ANOVA (*Jursík et al. 2013, Amaizah et al. 2013, Wang et al. 2013, Škarpa et al. 2013*). The descriptive statistical analysis was applied for the calculation of the average scores as per questions and groups of interviewees. For determining the importance of differences between certain groups, the post hoc Scheffe's test (*Banha and Anastácio 2011*) was used as one of the most rigorous and themost frequently applied tests (*Petz 1981*). The sample fulfilled the basic conditions for the application of parametric tests, i.e. the data used in the analyses were from the interval scale and they were normally distributed.

RESULTS AND DISCUSSION

SerbianWater Quality Index (SWQI)

On CP1, the values are in the range from 61 (bad) during the summer of 2010 up to as much as 95 (excellent) in the winter of 2010. On CP2 highest value of the SWQI, 90 (excellent), recorded in the cold period of the year, during autumn and winter (2007 and 2009). The lowest value of the SWQI, 65 (bad), was recorded during the summer of 2010. CP3 is a control point that is characterized by high values of the SWQI, especially in autumn 92 (excellent). The lowest values were recorded during the summer of 2010, the SWQI 74 (good). The study shows that the SWQI at CP4 in all observed periods is generally lower than 38, i.e. it belongs tothe very bad category. Slightly higher SWQI values – 40 and 50 (bad), were recorded in 2011 in the cold period of the year. In the most downstream section of the VBK, CP5, the SWQI values range from 51 (poor) during the winter of 2007 to 89 (very good) in the autumn of 2008 year (**Table 2**). If SWQI>80, conditions are acceptable for the aquatic life. At the same time, the water of this quality can be used for navigation, irrigation, recreation and even for water supply after a certain degreeof purification (*Yunus and Nakagoshi 2004*). Pollution is mostly organic, but heavy metals, nonorganic solids, pesticides and other harmful substances are also present. Downstream from Vrbas (CP 4), the GBC is turned into an open collector of wastewater from food industry, farms and the settlements of Crvenka, Kula and Vrbas (*Pantelic et al. 2012b*).

Analysis of variance (ANOVA) results

The local population believes that the functions of irrigation and drainage are possible (the mean values are generally larger than 3), provided that intensive sanitation is carried out and the prevention of further pollution is ensured.

Irrigation is the basis of quality agricultural production and it ensures the regional economic security (*Hillel 2000, Tanji 1990*). The analysis shows that the total of 3.5 M ha of farming land in Vojvodina can be irrigated. Nevertheless, less than 1% of land, i.e. 30.000 ha, is irrigated at the moment (*NIVA 2006*). The analysis of the mean values of the interviewees'answers per settlement show that the inhabitants of Sombor, Sivac and Turija believe that there are possibilities to use the GBC for irrigation and they therefore assign high marks to this function (mean values higher than 4), while the inhabitants of Vrbas believe that this function is virtually impossible to restore (mean value 1.92) (**Table 3**). The one-way analysis of variance and the application of the post hoc Scheffe's test confirmed the existence of difference among interviewees from different settlements regarding the level of significance $r<0.01$ (F=10.953, p=0.000); the difference is the greatest between the inhabitants of Sivac and the inhabitants of Vrbas (**Table 3**). The results of survey research are in correlation with water quality, i.e. the water quality of the GBC on CP1, CP2, CP3, CP4 and CP5 is close to adequate (SWQI>75 in most cases), which means that water can be used for the irrigation of the surrounding agricultural areas, as agreed by the local population from the settlements of Sombor, Sivac, Turija and Bačko Gradište. During the entire year, the SWQI valuesin most cases are lower than 37 on CP 4 near Vrbas, which means that water quality is extremely bad. In the surrounding area of Crvenka, Kula and Vrbas, food industry facilities release enormous quantities of industrial wastewater, due towhich the concentration of nutrients in the canal water is increased. Such water must not be used

Table 2. 2007-2011 Serbian Water Quality Index for five control points on the GBC.

Year		CP 1	CP 2	CP 3	CP 4	CP 5
	Spring	79	82	82	36	65
	Summer	75	67	82	26	73
	Autumn	87	86	88	36	57
2007	Winter	90	90	82	38	51
	Spring	72	84	79	39	79
	Summer	86	85	84	36	80
	Autumn	90	87	91	35	89
2008	Winter	83	83	86	32	85
	Spring	81	85	86	28	65
	Summer	70	83	81	25	67
	Autumn	93	90	92	37	73
2009	Winter	85	88	90	32	65
	Spring	86	82	81	37	65
	Summer	61	65	74	32	55
	Autumn	70	72	84	37	62
2010	Winter	95	88	90	41	59
	Spring	82	76	79	37	87
	Summer	79	84	86	30	82
	Autumn	85	88	91	40	86
2011	Winter	79	80	75	50	84

Table 3. One-way analysis of variance ANOVA – standpoints of the population from different settlements on the possibilities of using the functions of the GBC.

Question	Settlement	M	σ	F	p
You believe that the GBC can be used for irrigation?	Bezdan	3.60	1.414	10.953	0.000*
	Sombor	4.06	1.236		
	Sivac	4.08	1.368		
	Crvenka	3.30	1.581		
	Kula	3.18	1.304		
	Vrbas	1.92	1.291		
	Srbobran	3.28	1.642		
	Turija	4.06	1.449		
	Bačko Gradište	3.90	1.329		
	Bečej	3.54	1.249		
You believe that the GBC can be used for drainage?	Bezdan	3.20	1.457	6.201	0.000*
	Sombor	3.78	1.329		
	Sivac	3.72	1.512		
	Crvenka	3.12	1.547		
	Kula	2.86	1.370		
	Vrbas	2.10	1.403		
	Srbobran	3.32	1.477		
	Turija	3.34	1.586		
	Bačko Gradište	3.74	1.275		
	Bečej	3.44	1.312		

Note: $*p < 0,01$; $F \geq 3,32$; M – mean values, σ – standard deviation, F – Fisher's Exact Test, p - statistical significance

for irrigation as agreed by the local population.

Drainage was one of the main reasons for the construction of the GBC– the collection and drainage of water from the swamp terrains of the larger part of Vojvodina's territory. Although the level of groundwater is still high, 1.2-4 m from the topographic surface, the GBC has a drainage function. Drainage surfaces in Bačka (the western part of Vojvodina) occupy 550,000 ha. The network of the main canal receives 156 $m^3 s^{-1}$ of waterfrom this territory (*NIVA 2006*). Although there are substantial benefits for crop production, a large amount of nitrates is introduced by draining the land profile; therefore, there are concernsregarding their hazardous impact on the quality of of surface waters (*Baker et al. 1975, Gilliam 1987, Skaggs et al. 1994*). The data related to the possibility of using the VBC for drainage show that the inhabitants of Sombor, Sivac and Bačko Gradište believe that such possibilities exist and assign a high mark to this function (mean values higher than 3.7) while the inhabitants of Vrbas believe that this function is virtually impossible to restore (mean value 2.10) (**Table 3**). By applying the one-way analysis of variance, it has been determined that there are differences among interviewees from different settlements regarding the level of significance r<0.01 (F=6.201, p=0.000) and that the difference is the greatest between the inhabitants of Sombor and the inhabitants of Vrbas (**Table 3**). On CP4, where water quality is very bad and the GBC is extremely shallow and narrow due to high pollution (*NIVA 2006*), it is impossible to use the GBC for drainage, i.e. draining water surplus from surrounding surfaces. Other sections of the GBC are suitable for this purposeand can be used for draining as confirmed by the local population.

CONCLUSIONS

Based on the chemical parametres of water quality, it can be concluded that there are sections (CP1, CP2 and CP3) along the entire course of the GBC,which is only 123 km long, which are pure and completely suitable for exploitation and utilisation of all its functions. As a contrast to them, there is a section (CP4) which is entirely degraded and unusable. Organic pollution from industrial facilities, communal wastewaterand agricultural complexes is characteristic of all the CPs. The presence of pollutants in water questions the functionality of the GBC. When it comes to the possibilities for restoringthe functions of the GBC, the local population believes that there are possibilities to successfully restore the functions of irrigation and drainage. The interviewees' answers to all of the survey questions differ depending on their place of residence; the inhabitants of Vrbas particularly stand out with highly negative standpoints, which was expected having in mind the results of water quality in this part of the GBC. The expressed standpoints of the interviewees show their attitude that the majority of GBC's earlier functions can be restored. In order to achieve the previously stated, it is necessary to control the places of wastewater inflow into the GBC, while wastewater should be treated and brought into a condition in which it will not endanger water quality in the GBC. In further activities, it is necessary to clean the GBC from sediments on the bottom and plants in the canal bed. Low flow rates over a long period of timehave resulted in numerous shallow streams and massive reed belts along the canal bed on many locations. By restoring all of the functions of the GBC and by utilising its potentials, i.e. using water resources for economic purposes, the means for adequate maintenance and care of the GBC as a civilization's heritage would be provided.

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