AgroLife Scientific Journal - Volume 6, Number 1, 2017
ISSN 2285-5718; ISSN CD-ROM 2285-5726; ISSN ONLINE 2286-0126; ISSN-L 2285-5718

THE QUALITY OF WATER USED FOR IRRIGATION OF AGRICULTURAL SOIL IN THE BASIN OF RIVER GREAT MORAVA

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Abstract

This paper presents the results of testing the quality of water for irrigation during the growing seasons 2012/2013, in the basin of the Velika ("Great") Morava River, from Batovac to Varvarin (Gornji Katun), in three monitoring cycles on 20 selected sites belonging to agricultural area under irrigation. It was established that the quality of the surface water corresponded to the standards for irrigation according to pH, conductivity (ECw), dissolved solids (TDS), ion balance: Ca^{2+}, Mg^{2+}, K^{+}, Na^{+}, chlorides (Cl^{-}), sulfates (SO_4^{2-}), Sodium Adsorption Ratio (SAR). The content of the following trace elements and heavy metals was determined: Cr, Ni, Pb, Cu, Zn, Cd, B, As, Fe, Hg. The obtained results imposed that the contents of trace elements and heavy metals in the studied water samples were in the recommended limits. The obtained results also implies on very strong linear correlation for ECw-B in the studied water samples, and moderate linear dependence TDS-Ni; Cr-Fe; Cr-Ni; Cd-Ni; Cr-Pb; Fe-Ni; Fe-Pb; Ni-Pb.
Data analysis revealed that the anthropogenic impact on River Velika Morava water in the investigated area does not affect water quality with a view to its applicability for irrigation purposes. Based on results of analysis of water quality of River Velika Morava it can be concluded that it is usable for irrigation of crops and soil with restrictions and frequent quality checking during the summer months.

***Key words**: trace elements, heavy metals, irrigation water, soil.*

INTRODUCTION

The scope of the research conducted in this paper is the study of quality of irrigation water from the River Velika Morava, complies with the requirements of FAO and U.S. Salinity Laboratory classification (Doneen and Westcot, 1988; U.S. Salinity Laboratory Staff, 1954), designed for usability evaluation of irrigation water. Irrigation means the artificial watering the soil in order to wet the rhizosphere layer at a time when the amount of available soil moisture is insufficient to meet the optimum energy crops. Irrigation is a hydro-reclamation measure that aims to improve the physical properties of the soil by adding water to achieve optimum moisture during the growing season and thus achieve optimum yield. It may be applied during part of the growing season or during the whole growing season. Irrigation of cultivated plants on agricultural soil involves the use of water of appropriate physical, chemical and biological properties, so it is very important to examine the quality of water used for its intended purpose in order to assess the impact on soil and plants. Intensification of irrigation depends primarily on the provision to the required amount of water of adequate quality.

Anthropogenic impacts and natural processes can affect the quality of surface waters and threaten their use as drinking water, and for use in industry, agriculture, and for other purposes (Carpenter et al., 1998; Jarvie et al., 1998; Simeonova et al., 2003).

The aim of this study is to assess the current water quality of the River Velika Morava in order to be used for irrigation of agricultural soil near the streams and highlight the pollution risk. Pollution risks are mainly the direct consequence of the discharge of waste water from industrial plants, agricultural intensification or anthropogenic factors.

The major pollutants of surface water in the country are industrial enterprises, farms and settlements with sewage systems, without built facilities for waste water treatment, and such with acting, but technically outdated (Konstandinova et al., 2013).

Agricultural lands used for intensive agriculture and fertilized with nitrogen and phosphate, treated with pesticides, and manure from livestock farms are one of the major sources of diffuse pollution (mainly nitrogen, phosphorus and biodegradable organics).

MATERIALS AND METHODS

Description of the study area

In geographical terms, the basin of Velika ("Great") Morava River lies between 43°44' and 44°45' of North latitude and 21°05' and 21°23' of East longitude (Figure 1).

The Great Morava begins at the confluence of the Južna ("South") Morava and the Zapadna ("West") Morava, located near the small town of Stalać, a major railway junction in central Serbia. From there to its confluence with the Danube northeast of the city of Smederevo, the Velika Morava is 185 km long.

The drainage basin of the Velika Morava is 6,126 km². Velika Morava flows through the most fertile and densely populated area of Central Serbia, called the Morava river valley or Pomoravlje. Pomoravlje was formed in a fossil bay of a vast, ancient Pannonian Sea.

The average discharge of the Velika Morava on its confluence with Danube is 297 $m^3 s^{-1}$ (120 $m^3 s^{-1}$ brought by West Morava, 100 $m^3 s^{-1}$ by South Morava, and 35 $m^3 s^{-1}$ amounted by the Velika Morava itself).

Pomoravlje with its surroundings has a very low annual amount of precipitation of about 665 mm, which are values close to those of sub arid areas. Distribution of precipitation trough seasons is not favorable for the development of crops which in summer have a greater demand for water like maize, sugar beet, vegetables, forage crops. Precipitation per months is not equally distributed, but it is noticeable that the maximum amount occurring in June. Very low rainfall occurs from January to March and in September. Droughts during the summer and automn may cause that the soil can dry up to 2-4 m depth. The exceptions are the areas with the groundwater in shallow depths but on very restricted areas.

Fluctuations in the flow of the Velika Morava during the hydrological year are noticeable and directly dependent on amount of precipitation. The main peak is the spring and is primarily due to snow melting, a major summer minimum caused by a slight precipitation amount, elevated temperature, and maximum transpiration and using the water for irrigation.

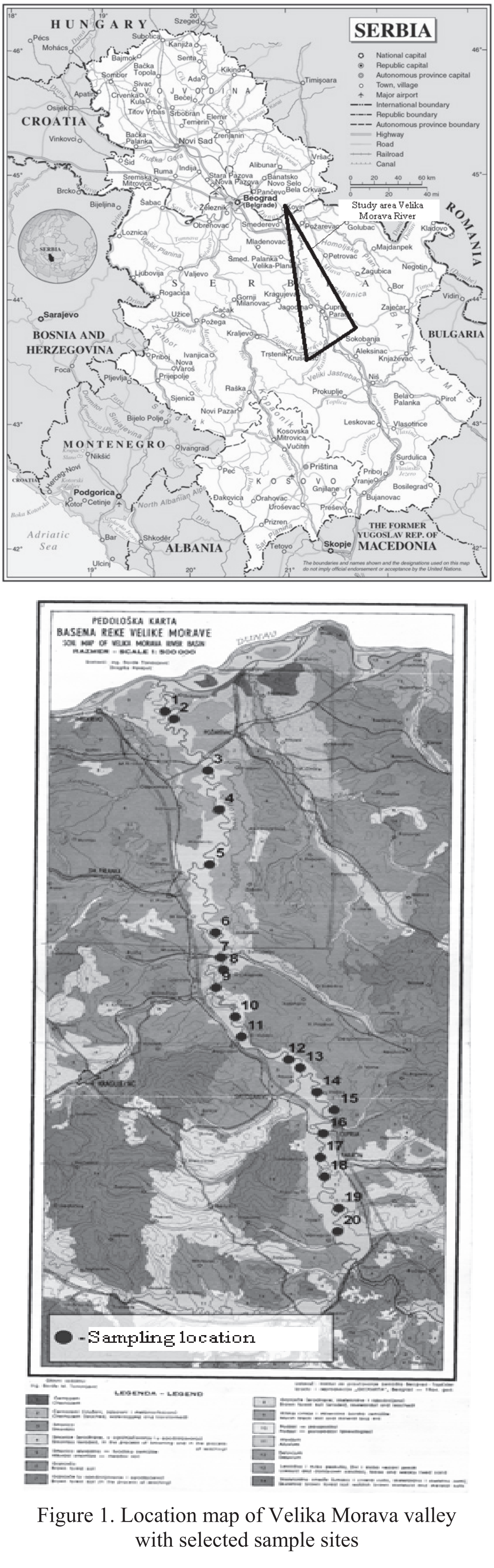

Figure 1. Location map of Velika Morava valley with selected sample sites

Another autumn peak is due to rainfalls and winter minimum is due to snow cover.

Soils suitable for irrigation are primarily alluvial soils along the River Velika Morava and meadow soils that are heavier texture from alluvium (Tanasijević et al., 1966). Water physical properties of the soil along the Velika Morava are very heterogeneous composition. Represented are applied gravel, sandy gravel, sandy, loamy and clay composition. All of these can be irrigated land varying amounts of water. The basic soil types in the river basin are Fluvisols, Luvisols, Eutric Luvisols, Eutric cambisols and Eutric Vertisols (WRB, 2014). These soils have a high potential for fertility, and irrigation is one of the factors that contributes. Irrigation provides increased yields of the grown crops in the river basin.

River Velika Morava, is of great importance for the national economy - agriculture, industry, energetic and other human activities. The river is subjected to strong anthropogenic impact as it passes through plenty of settlements, along industrial enterprises, farms and areas with intensive agriculture that discharge their wastewaters into the river creating preconditions for deterioration of the water quality.

Sampling and collection of water samples

A total of 60 water samples were collected from 20 sampling points (Table 1). Water samples were collected in three cycles of sampling, in July and October 2012 and April 2013, using 2000 ml plastic bottles. The sampling bottles for heavy metal determination were pre-soaked overnight with 10% HCl, then, rinsed with distilled water and also rinsed using river water before sample collection. Sampling bottles for the determination of physico-chemical parameters were cleaned and rinsed using distilled water only. Preservation of water samples was done by adding 2 drops of concentrated HNO_3 to each water sample before storage below 4°C until it was analysed.

Analytical methods

The measured parameters were determined by the following methods: pH- potentiometrically (SRPS H.Z1.111:1987), electrical conductivity (ECw)-conductiometric (SRPS EN 27888:1993), total dissolved solids (TDS)-gravimetric, CO_3^{2-}; HCO_3^-; Cl^- - volumetric, K^+; Na^+ - plamenfotometric (APHA, 1992). The acid-available fraction of heavy metals and other toxic elements (As, B, Cd, Cr, Cu, Hg, Fe, Ni, Pb, Zn) and SO_4^{2-}; Ca^{2+}; Mg^{2+} was determined using EPA 200.7 methods, as well as an ICAP 6300 ICP optical emission spectrometer (ICP-OES) (EPA, 2007). Sodium Adsorption Ratio (SAR)-calculation (Rhoads et al., 1992).

The concentration of Hg was determined by a flame atomic adsorption analyser SensAA Dual (GBC Scientific Equipment Pty Ltd, Victoria, Australia) (Nelson et al., 1996).

Table 1. Sampling points along the Velika Morava River

Sampling point	Easting	Northing
1	7504330	4946930
2	7505630	4945400
3	7510750	4935100
4	7512430	4927240
5	7511000	4916330
6	7511880	4902730
7	7512700	4897730
8	7513110	4895280
9	7511920	4891700
10	7514870	4885920
11	7515820	4881950
12	7522900	4877390
13	7524570	4875730
14	7527100	4870850
15	7529730	4831910
16	7528090	4829100
17	7527600	4857870
18	7528260	4853990
19	7530420	4847690
20	7530220	4843070

Data processing methods

The experiment data were presented with mean of three tests with the presented summarized basic statistics of the dataset. Analysis of the interdependence of variables was carried out by calculating linear Pearson correlation coefficients. It has been assumed that the regression modelling of the potential usefulness of the selected variable (explanatory) to model another variable (explained variable) determines the absolute value of the high correlation coefficient between these two variables. The statistical analysis usually assumes that if the correlation coefficient is >0.9, a very strong linear dependence exists; 0.7- Sulfates distribution in surface and ground waters is principally controlled by dissolution processes and precipitation of mineral and amorphous solid phases, dissolved oxygen concentration, atmospheric precipitation, biological

interactions, point and non-point pollution sources (Hudak and Sanmanee, 2003; Souligny and Hollabaugh, 2002). Concentration of chlorides, sulfates, Ca and Mg in observed samples are in recommended values (Table 2).
0.9-significant linear dependence; 0.4-0.7-moderate linear dependence; 0.2-0.4-distinct linear dependence, but low; <0.2-no linear dependence (Dabioch et al., 2013).

Table 2. Average values of the water quality parameters of irrigation water, along with the standard limits by Republic of Serbia and irrigation water by US and FAO

Parameters	Mean± STDEV	Standard limits		
		Duncun et al., 2000	Ayers et al., 1994	Official Gazette, 1994/2012*
(n=60)				
pH	7.85±0.35	6.0-9.0	6.5-8.4	
ECw 25˚C (dSm^{-1})	0.36±0.06		<0.7	<1.0*
TDS ($mg\,l^{-1}$)	359.73±121.62		0-2000	
SAR	0.39±0.10	5.7	0-15 [ə]	
CO_3^{2-}($mg\,l^{-1}$)	21.05±5.05		30	
HCO_3^-($mg\,l^{-1}$)	292.80±39.26		0-10 [ə]	
Ca^{2+} ($mg\,l^{-1}$)	55.91±10.99	20-60	0-20[ə]	
Mg^{2+} ($mg\,l^{-1}$)	16.68±3.33		0-20[ə]	
Cl^-($mg\,l^{-1}$)	22.10±4.41		0-30[ə]	50*
SO_4^{2-}($mg\,l^{-1}$)	29.46±5.77		0-20[ə]	50*
K^+($mg\,l^{-1}$)	11.34±1.58	5-20	0-2[ə]	
Na^+($mg\,l^{-1}$)	12.81±3.05		0-40[ə]	
As ($mg\,l^{-1}$)	0.012±0.024		0.1	0.05
B ($mg\,l^{-1}$)	0.064±0.026	2.0	0-2	1.0
Cd ($mg\,l^{-1}$)	0.0001±0.00004		0.01	0.01
Cr ($mg\,l^{-1}$)	0.0008±0.0006		0.1	0.5
Cu ($mg\,l^{-1}$)	0.0017±0.0016	0.2	0.2	0.1
Fe ($mg\,l^{-1}$)	0.061±0.066	5.0	5.0	
Ni ($mg\,l^{-1}$)	0.0028±0.001		0.2	0.1
Pb ($mg\,l^{-1}$)	0.0016±0.001		5.0	0.1
Zn ($mg\,l^{-1}$)	0.0064±0.0068	2.0	2.0	1.0
Hg ($mg\,l^{-1}$)	bdl			0.001

*References (listed below in reference list); bdl-below detection limit
[ə] - in me/l = mill equivalent per liter (mg/l ÷ equivalent weight = me/l); in SI units, 1 me/l= 1 mill mol /liter adjusted for electron charge.

RESULTS AND DISCUSSIONS

The seasonal and annual averages of physicochemical characteristics are given in Table 2 and Figure 2.
The pH value is a measure of alkalinity and acidity of the water. If the value is less than seven, the water or the aqueous solution is acidic, and if it is higher, then it is alkali.

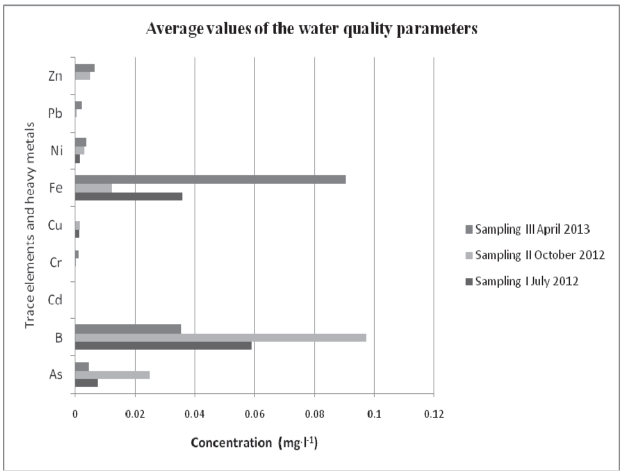

Figure 2. Average values of the water quality parameters of Velika Morava River

Plants for growth and development favors the slightly acidic solution, or the pH should be around 5.5. The pH is an important factor that determines the suitability of water for a variety of purposes, inter alia, for irrigation. The tested samples showed pH values from neutral to slightly alkaline during the second cycle of sampling a growing trend (Figure 3). This may be a drought which influences on an increased flow of wastewater from agriculture and households, and as well on intensive microbial activity.
Conductivity is a measure of the ability of an aqueous solution to carry an electric current.
Increasing levels of conductivity and cat ions are the products of decomposition and mineralization of organic materials (Begum et al., 2008).

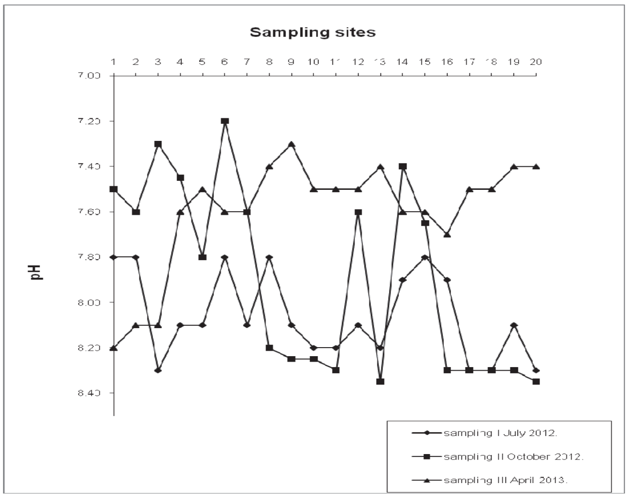

Figure 3. pH value of the tested water samples in batches of monitoring

The aqueous salt solution and dissociated are broken down into positive and negative ions.

Electrical conductivity in natural waters is generally with values less than usual. Measurement of the conductivity is performed at a specific temperature and it corresponds to the presence of dissolved salts. These are most commonly sodium chloride, and may be present, and sodium sulfate, calcium chloride, calcium sulfate, magnesium chloride etc. Absolutely de-mineralized water does not conduct electricity, but even with small additions becomes a good conductor. Salts dissolved in the water influence on increase of the water conductivity values. Conductivity measurements obtained indirectly calculate the amount of salt. If the measured value is 1 μS per liter of water it means that it was dissolved approximately 0.7 g of salt. Some of a large number of different elements dissolved in the water favor the plant and their presence is helpful, but sometimes useful for these elements may become hazardous if their concentration is high.

In all three cycles of analyzing the water from Velika Morava (Figure 4), according to FAO classification, the samples belong to a class of water for drinking and irrigation, and as well to a class for irrigation water.

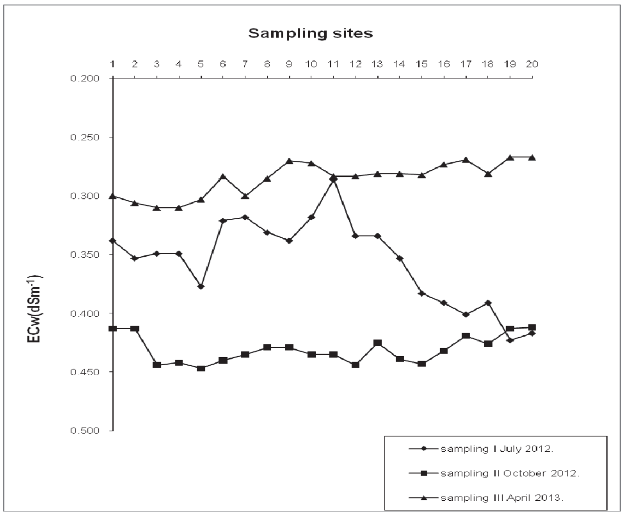

Figure 4. ECw value of the tested water samples in batches of monitoring

By classification of U.S. Salinity Laboratory, all of the samples belong to the C2 S1 class of water, where ECw values range from 0.250 to 0.750 dSm^{-1} and, as such, it can be used for irrigation of the plants with medium tolerance to salt, except for the sample points No. 2 and 3, where in the second cycle of sampling it was determined that sampled water belongs to the class C3, meaning that there is a high risk of soil salinization (ECw values range from 0.750 to 2.250 dSm^{-1}) (http://tnau.ac.in/eagri/ eagri50 /SSAC122/lec27.pdf).

Sodium adsorption ratio of irrigation water, SAR is used to determine whether sodium (Na) levels of water will cause soil structure to deteriorate. Unadjusted SAR considers only Na, Ca, and Mg (Duncan et al., 2000).

Total dissolved solids (TDS) are an important characteristic for determination of the quality of water for irrigation because it expresses the total concentration of soluble salts in water. Dissolved solids in water include all inorganic salts, silica and soluble organic matter. Pure water must be free from most suspended particles, which are responsible for turbidity. TDS was the highest in summer due to evaporation and reduced intake, which contributed to an increase in concentration, and had the minimum value in the rainy season, due to the increased entry of rain and a corresponding reduction in concentration at all locations (Figure 5).

Chlorides and sulfates are among the basic components found in fresh water. Some of the anthropogenic sources of chlorides in surface water are agricultural activities (organic and mineral fertilizers), sewage, landfill leakage, industrial wastewaters etc. Scientific investigations proved that water with chloride concentrations > 150 $mg\cdot l^{-1}$ are inappropriate for irrigation due to their toxicity to crops (Konstandinova et al., 2013; Szynkiewicz et al., 2008).

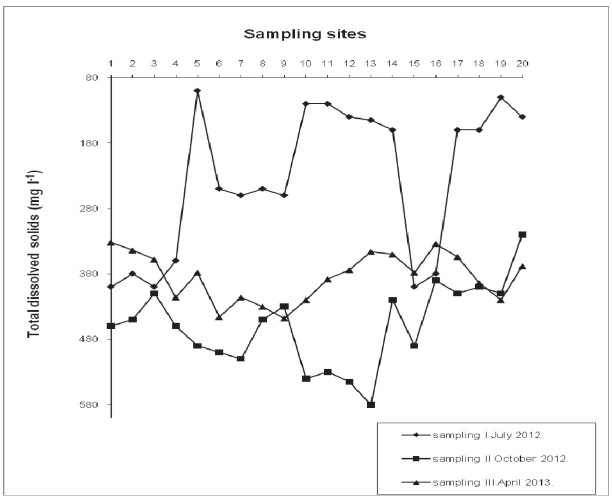

Figure 5. TDS value of the tested water samples in batches of monitoring

Sulfates distribution in surface and ground waters is principally controlled by dissolution processes and precipitation of mineral and amorphous solid phases, dissolved oxygen concentration, atmospheric precipitation, biological interactions, point and non-point pollution sources (Hudak and Sanmanee, 2003; Souligny and Hollabaugh, 2002). Concentration of chlorides, sulfates, Ca and Mg in observed samples are in recommended values (Table 2).

The contents of trace elements and heavy metals in the samples of water are generally below the maximum allowable concentration (MAC) (Official Gazette of Republic Serbia, 1994; 2004).

The main sources of metal pollution of natural water are: industrial and domestic wastewater, agricultural activities, mining, waste and intermediate products from power plants, factories for the production of non-ferrous metals, sludge from sewage treatment plants for municipal and industrial wastewater, as well as the processes of natural erosion and sedimentation (Aktar et al., 2010).

The observed diversity in the results together with the demonstrated dynamic variations suggests impact of a number of various environmental factors on the pattern of metals distribution in the water. In this regard (Ozmen et al., 2004), reported that the concentration of metal ions strongly depend on the biological processes, redox potential, ionic strength, pH, the activity of organic and inorganic chelators and the purification processes in water.

Correlation coefficients between various physicochemical parameters are shown in Table 3. It shows the correlation between the samples and the characteristics of the water where the pH value has a significant negative correlation to all studied parameters except to the concentration of B (Gong et al., 2013; Eliot et al., 2004). ECw values were positively correlated to all studied parameters except to the concentration of Cr, Fe, Ni, Pb and Zn. TDS values show a positive correlation to the concentration of As, B, Cd, Cu, Fe, and Ni, and a negative to the concentration of Cr, Pb and Zn in the samples of water.

The obtained results also implies on very strong linear correlation for ECw-B in the studied water samples, and moderate linear dependence TDS-Ni; Cr-Fe; Cr-Ni; Cd-Ni; Cr-Pb; Fe-Ni; Fe-Pb; Ni-Pb, for Ecw-TDS; Ecw-As; Ecw-Cu; TDS-As; TDS-B; TDS-Fe; As-B; As-Cd; Cd-Pb; Pb-Zn, distinct linear dependence, while for the rest of observed parameters there is no linear dependence.

CONCLUSIONS

Results from water samples showed that the concentration of heavy metals in the water of the Velika Morava River in most of the samples analyzed is within the MAC values. Variations of the content of heavy metal concentrations in the water are the result of a wide range of human activities (primarily agriculture) in the study area and water levels throughout the year.

Tabele 3. Correlation coefficients between water characteristics in Velika Morava River (n=60)

	pH	ECw	TDS	As	B	Cd	Cr	Cu	Fe	Ni	Pb	Zn
pH	1	-0.337	-0.427	-0.084	0.029	-0.272	-0.258	-0.299	-0.363	-0.522	-0.477	-0.159
ECw		1	0.229	0.355	0.929*	0.074	-0.810	0.280	-0.309	-0.245	-0.894	-0.173
TDS			1	0.208	0.332	0.184	-0.426	0.080	0.386	0.614	-0.466	-0.189
As				1	0.347	0.302	-0.363	0.198	-0.453	0.036	-0.221	-0.150
B					1	0.059	-0.833	0.139	-0.395	-0.175	-0.869	-0.027
Cd						1	-0.346	0.100	-0.370	0.468	0.257	-1.000
Cr							1	-0.260	0.599	0.552	0.667	0.198
Cu								1	-0.872	0.032	-0.055	-1.000
Fe									1	0.430	0.455	0.029
Ni										1	0.630	0.168
Pb											1	0.315
Zn												1

Based on the obtained and analyzed results of testing the quality of water for irrigation from the Velika Morava River, it can be concluded that it can be used for irrigation of crops and soil in the vicinity of said water flow to the restrictions and frequent quality checks during the summer months.

ACKNOWLEDGEMENTS

This research was supported by the Ministry of Education, Science and Technological Development, Republic of Serbia, Project TR 37006.

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