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CLASSIFICATION OF WATER QUALITY OF BANAT WATERCOURSES IN SERBIA FOR THE NEEDS OF IRRIGATION

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Abstract

The composition of water used for irrigation has a significant impact on the production characteristics of the land, yield and irrigation equipment, and therefore its analysis, or assessment of the usability of irrigation water is very important. In this paper, the potential impact of the waters of the Banat watercourses of Moravica, Karaš and Nera is assessed on the basis of monthly water samples from the measuring stations of Vatin, Dobričevo and Kusić, for the period of April-September from the year 2007 to 2017. The assessment was carried out using the classification of irrigation water: FAO, USLL and water categorization according to Nejgebauer, and the Serbian Water Quality Index (SWQI). For the needs of these classifications, a total of 20 water parameters were analyzed: quality, physical, chemical and biological parameters. According to all the classifications, the analyzed watercourses can be a good source of water for irrigation in terms of its quality, but with control and appropriate measures, in particular, the presence of bicarbonate, but also the ratio of Na^+ to Ca^{2+} and Mg^{2+}.

Keywords: Water quality, WQI, Irrigation, Vojvodina

INTRODUCTION

The frequent occurrence of extreme drought periods is a major constraint on agricultural production that needs to meet the demands of increasing food demand. Production under the irrigation systems can significantly increase yields, as indicated by the fact that about 40-50% of plant production in the world is realized on about 16% of arable irrigated area (Savić et al., 2013). The result of irrigation is in the function of many factors, both natural and anthropogenic, and in terms of water, it is necessary to pay attention to the amount that is being applied, but also to pay attention to its quality. It is known that the composition of water used for irrigation has a major impact on soil characteristics, on yield and quality of cultivated plants, and on irrigation equipment (Ayers and Westcott, 1985; Bortolini et al., 2018; Bauder et al., 2011; Fipps, 2003). Increasing total salts, individual ions and their adverse relationship increases the risk of unwanted consequences. The assessment of the usability of water should be done according to parameters that have a direct impact on the soil in terms of its productivity and in accordance with its characteristics. The most common problems that occur with the use of inadequate irrigation water according to Ayers and Westcott (1985) can be divided into four groups: salinization, permeability, toxicity and miscellaneous problems. Each of the problems can be expressed individually or in combination with other problems. The problem of salinity was observed at about 20-30 million ha of about 260 million hectares of irrigated land in the world (Tanji and Kielen, 2002). On some of the irrigated areas in Vojvodina, heavily mineralized water has already led to the emergence of secondary salinization of soil. The problem of salinization is considered in terms of degradation of soil and accessibility of water to plants. Stress caused by lack of water is similar to stress caused by excess of salt in the soil (Munns, 2002). Salinization has impact on growth of plants (Ghoulam et al., 2002; Munns, 2002), on their water regime, (Ayers and Westcott, 1976), mineral intake (Grattan and Grieve, 1999; Hassan et al., 1970;), the capacity of the photosynthetic apparatus decreases with increased saturation (Asharaf, 2001), etc. Water of inadequate quality can cause deterioration of soil structure and thus reduce infiltration. Reduced infiltration ability prevents plants from being supplied with the required amount of water. Two factors related to the quality of water for irrigation that most affect the degree of infiltration are the total amount of salt in water, as well as the ratio of individual cations, more precisely the ratio of sodium to calicum and magnesium (Ayers and Westcott, 1985). Some ions show toxic effects on plants by reducing their yield and quality, among which Cl^-, Na^+ and B are distinguished, and maximal allowed concentration depends on the plant species. Irrigation equipment can be damaged by the presence of certain elements, which primarily refers to congestion of the emitters, and this results in poor uniformity of watering, leading to unequal development of plants. Regarding the impact on the equipment of the irrigation system, suspended solids, bicarbonates, sulfides, manganese and iron are separated (Bortolini et al., 2018). In order to prevent adverse effects, water quality assessment should become a necessary measure in the production under irrigation systems (Joshi et al., 2009), whereby agronomic, ecological, technical and economic criteria can be applied. An analysis of water

quality parameters of three water courses in South Banat was carried in this paper out in order to be classified in certain classes and in accordance with them defined the possibility of use for irrigation in the spatial sense.

STUDY AREA

Vojvodina belongs to the southern parts of the Pannonian Plain and is located between 44º 38' and 46º 11' northern geographic width, that is of 18º 49' and 21º 00' of eastern geographic length with an area of 21 506 km^2. It represents one of the most productive areas in the world for agricultural production. However, agricultural production is not at the level at which it can be, and one of the main reasons is the lack of moisture during the vegetation period, which is due to high temperatures and insufficient precipitation (Rajić, 2003). Exceptional natural benefits, i.e. the plain of highly productive agricultural land and a relatively sufficient amount of surface water provide the possibility of intensive development of production under irrigation conditions. The Government of the Republic of Serbia plans to increase the area under the irrigation systems and therefore it is necessary to consider all the factors of convenience for implementation or deficiencies in order to make a decision on potential irrigated areas. On existing systems, most water is obtained from surface flows, which indicates the importance of their quality assessment for these purposes (Savić et al., 2013).

Watercourses Moravica, Karas and Nera are located in the South Banat District (eastern part of Vojvodina, Serbia) in settlements and the measuring stations with the same names: Vatin, Dobricevo, and Kusic. Out of the total area of the South Banat, the agricultural area extends to around 80%, more precisely, 341.268 ha. Figure 1 shows the location of the measuring points from which the analyzed samples were taken.

MATERIALS AND METHODS

The quality of water of Moravica (15+000), Karaš (14+000) and Nera (21+000) was assessed upon monthly samplings obtained in the period of April-September (vegetation period) from 2007 to 2017. Data on physical, chemical and biological parameters of sample quality were taken from the Hydrological Yearbook of water quality of the Republic Hydrometeorological Institute of Serbia (HIDMET, 2007-2010) and from the Agency for the protection of the environment (SEPA, 2011-2017).A detailed analysis of the parameters required for the application of the three water classification classes for irrigation has been carried out: FAO classification (Ayers and Westcott, 1985), US Salinity Laboratory classification (USSL) (Richards, 1954) and categorization of water according to Nejgebauer, which is adapted to the natural conditions of Vojvodina (Belić et al., 2011). The basis of these classifications is the analysis of potential problems of salinization and alkalization, i.e. analysis of the concentration of total salt in water and of sodium, or its relation to divalent cations (Ca^{2+} and Mg^{2+}), and FAO classification provides more detailed analyses. In addition to the above classifications, water quality is assessed by the index method Serbian Water Quality Index (SWQI) (www.sepa.gov.rs) which could be characterized as the general assessment of water quality. In addition to chemical parameters, this method also analyzes the biological and physical parameters of water quality. The analyzed quality parameters and their values are given in Table 1.

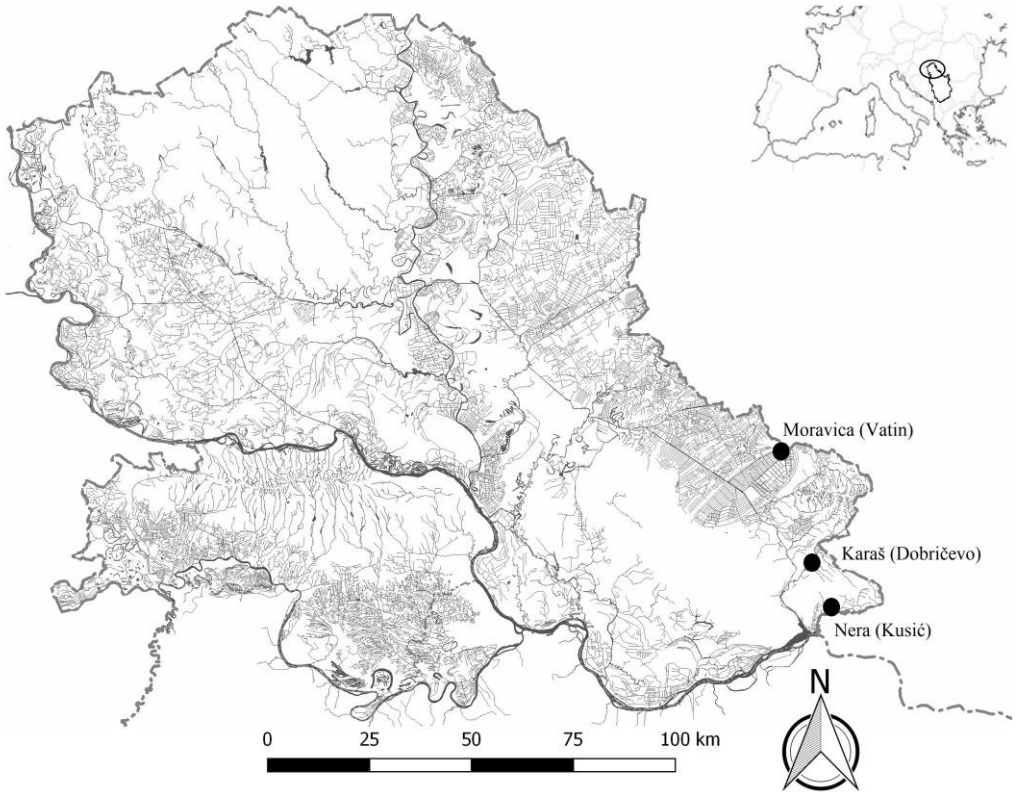

Fig. 1 Location of measuring point on watercourse Moravica, Karaš and Nera

Table 1 Minimum, maximum, means and standard deviations (SD) of analyzed parameters in period April-September, 2007-2017

Parameter	Moravica				Karaš				Nera			
	Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD
Ca^{2+} (mg/l)	33.0	89.0	64.7	15.3	2.6	109.0	70.6	23.4	37.0	67.4	51.3	6.4
Mg^{2+} (mg/l)	12.0	57.0	33.3	10.7	3.0	122.0	85.36	10.2	2.0	10.0	5.2	1.6
Na^{+} (mg/l)	8.4	80.5	42.7	15.2	4.5	29.0	14.9	5.3	0.7	9.0	5.5	1.7
K^{+} (mg/l)	0.9	10.6	4.6	2.1	1.2	7.5	6.4	2.1	0.5	4.6	1.7	0.7
SO_4^{2-} (mg/l)	19.0	73.0	40.5	10.5	20.0	56.0	34.6	8.5	13.0	290.0	36.4	42.3
Cl^{-} (mg/l)	11.4	73.0	27.7	11.5	6.2	24.7	11.6	3.2	3.6	19.0	6.1	2.5
NO_3-N (mg/l)	0.05	9.30	0.51	1.35	0.11	3.78	0.92	0.60	0.02	2.71	0.49	0.38
CO_3^{2-} (mg/l)	0.0	31.1	3.5	7.8	0.0	19.0	2.5	5.3	0.0	27.6	2.5	4.6
HCO_3^{-} (mg/l)	152.0	534.0	385.7	99.9	152.0	354.0	254.2	33.82	105.0	362.0	164.0	34.5
EC (□S/cm)	281	913	655.4	170	317	668	466.9	60.4	224	364	292.3	31.4
TDS (mg/l)	207	560	431.2	92.2	206	458	290.4	39.7	138	226	181.3	17.4
pH value	6.4	8.7	7.9	0.4	7.7	8.4	8.1	0.2	7.7	8.8	8.2	0.2
Temperature (°C)	13.7	28.6	21.1	4.1	10.2	36.0	19.5	4.6	8.5	28.0	18.2	4.9
Oxygen saturation (%)	15	184	75.7	39.1	71	145	95.4	11.2	72	128	99.5	10.0
BOD_5 (O_2 mg/l)	1.0	13.6	3.4	2.4	1.0	5.5	2.2	0.9	0.8	3.5	1.7	0.6
NH_4-N (mg/l)	<0.02	0.65	0.08	0.11	<0.02	0.81	0.09	0.11	<0.02	0.25	0.05	0.04
Total oxides of nitrogen (mg/l)	0.06	9.37	0.53	1.36	0.13	3.84	0.94	0.60	0.03	2.71	0.50	0.38
Orthophospates (mg/l)	0.02	0.85	0.23	0.17	0.01	0.81	0.09	0.11	0.02	0.85	0.23	0.17
Suspended solids (mg/l)	2	213	30.7	38.3	2	208	37.8	46.4	1	205	25.8	40.1
SAR	0.30	2.38	1.06	0.35	0.14	0.78	0.42	0.13	0.03	0.37	0.2	0.06

RESULTS AND DISCUSSION

Moravica

According to the FAO classification criteria, Moravica water qualities in terms of salinization alternately changed from first class, which has no limitations to moderate need for limitation (Class II). According to the influence of water on infiltration, the quality condition is similar. Concentrations of Na^{+} and of Cl^{-} are within are within the limits in which they do not exhibit toxic effects on plants. Special attention should be paid to the possible effects of bicarbonate whose concentration was within the class of moderate use restriction (II classes) with occasional occurrences of the need for serious limitations (III classes). The percentage of Moravica watercourse classes during the observed period according to the FAO classification is given in Table 2.

Table 2 Percentual representation of certain Moravica water classes according to the FAO classification, vegetation period 2007-2017

Potential problems	Class	%
Salinity	I	54.9
	II	45.1
Infiltration	I	52.9
	II	47.1
Toxicity of Na	I	98.0
	II	2.0
Toxicity of Cl^{-}	I	100
Effects of NO_3^{-}	I	98.0
	II	2.0
Effects of HCO_3^{-}	II	94.1
	III	5.9

USSL classification, based on the value of electrical conductivity and the Sodium Adsorption Ratio, water samples Moravica were classified mainly in the C2-S1 class, more precisely about 60% of the samples, and about 40% in the C3-S1 class (Fig. 2). The ratio of sodium to calcium and magnesium is favorable and there is no danger in this respect. In terms of total salt, Moravica water is characterized as "medium salty" and "salty" and therefore measures such as soil erosion, choice of cultures resistant to salt, and the inability to use this water on naturally poorly drained soils are necessary. The fact that benefits in favor of use is that class C3 is observed most often in months when irrigation is only applied intermittently (April, May), but due to occasional occurrence and in the irrigation season, regular controls and measures are in line with quality.

According to Nejgebauer's classification, the quality of water is "good" in most of the observed period, or more precisely, almost 80% of the samples. In addition, the samples were of "excellent quality", and only one sample is classed as unfit for irrigation, which may be the result of a local pollution just before water sampling (Fig. 3).

Water quality of Moravica, according to Serbian Water Quality methodology can be defined as "bad" with approximately 60% of samples which belonged to that class (Fig. 4). However, according to this method, such quality is useable for irrigation. However, the minimum quality index was 41, which is close to the limit of inapplicability (38). The remaining samples were "good", "very good" and in very few cases of "excellent" quality. Table 3 shows the descriptive statistics of the Moravica water quality index for the observed period, and the average monthly values and descriptive water quality indicator are shown in Table 4 where it can be seen that the average values of the index corresponding to the "poor" water quality are closer to the lower border of quality "good" water.

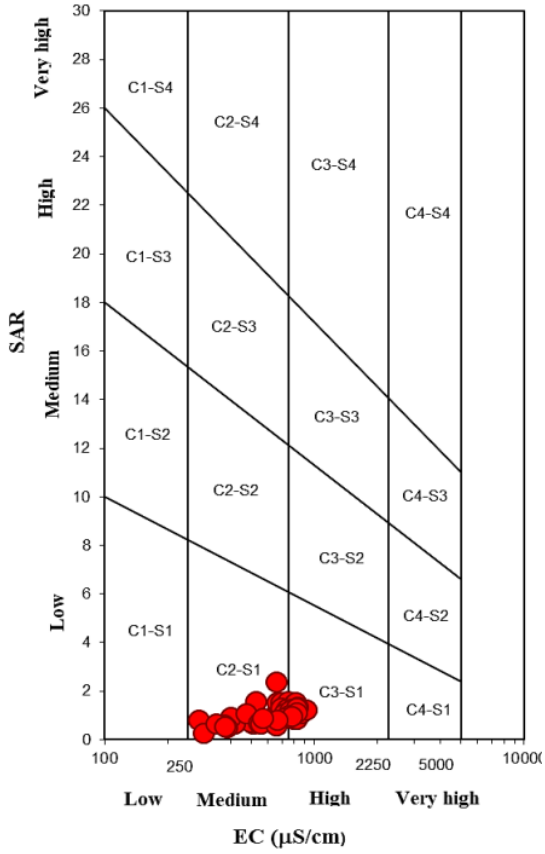

Fig. 2 Moravica water classes according to USSL classification, vegetation period 2007-2017

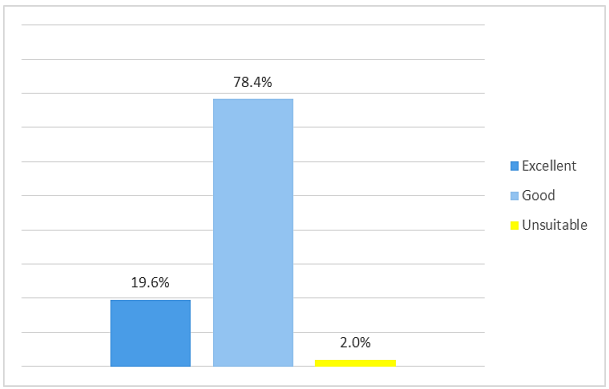

Fig. 3 Percentual representation of certain Moravica water classes according to Nejgebauer classification, vegetation period 2007-2017

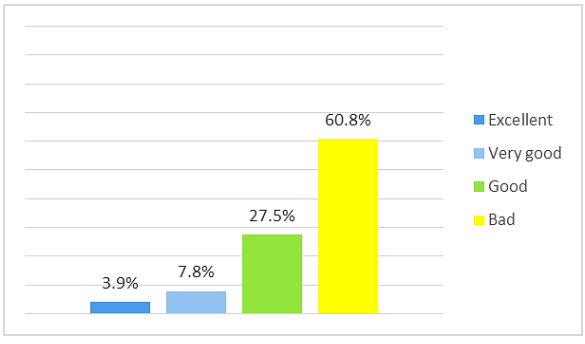

Fig. 4 Percentile representation of certain Moravica water classes according to SWQI methodology, vegetation period 2007-2017

Table 3 Minimum, maximum, mean and standard deviations (SD) of SWQI, vegetation period April-September, 2007-2017

	SWQI
Minimum	41
Maximum	91
Mean	68
SD	11

Table 4 Average monthly values of Index of Moravica water quality, vegetation period 2007-2017

April	May	June	July	August	September
81	71	63	62	61	68
Good	Bad	Bad	Bad	Bad	Bad

Karaš

The water quality of Karaš varied only in one class according to each FAO classification criteria (Table 5). According to the influence of water on permeability all samples are classified in the class of moderate usage limitation (II classes), as well as due to the diverse effects of bicarbonate. According to other criteria, water is of the highest quality for irrigation purposes.

USSL classification classifies water in class C2-S1, i.e. "Salty" water without a significant risk of the effect of adsorbing harmful sodium in terms of alkalization. Figure 5 shows that the EC values varied from lower to upper limit of the class, while all SAR values are closer to the lower limit value of the class.

Table 5 Percentile representation of individual water classes of Karaš according to the FAO classification, vegetation period 2007-2017

Potential problems	Class	%
Salinity	I	100
Infiltration	II	100
Toxicity of Na	I	100
Toxicity of Cl^-	I	100
Effect of NO_3^-	I	100
Effect of HCO_3^-	II	100

Mild criteria have a classification according to Nejgebauer, and it places this water in the first class, i.e. water of "excellent" quality for irrigation, which shows that there are no risks of harmful effects of salt in quantitative or qualitative terms.

Figure 6 shows the results of the SWQI method. This classification shows a higher variability of water quality, but it also takes into account other parameters, in addition to chemical, physical and biological. An equal number of samples, about 40% belong to "very good" and "good" water quality, while others are classified as "excellent" and "bad" quality.

On this watercourse, quality was not unsuitable for use during the analyzed period. The basic statistical indicators of the water quality index Karaš are shown in Table 6. Average monthly values of the index corresponded to "very good" and "good" quality (Table 7).

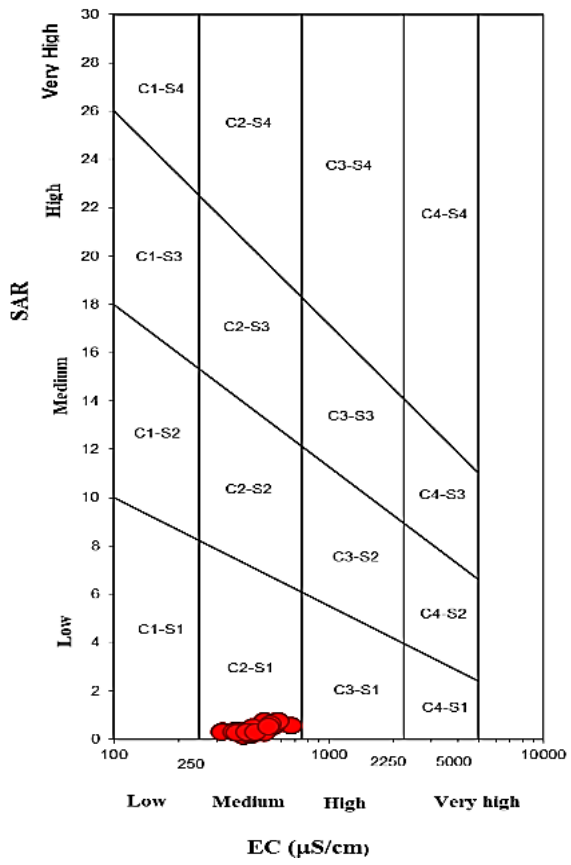

Fig. 5 Classes of water of Karaša according to USSL classification, vegetation period 2007-2017

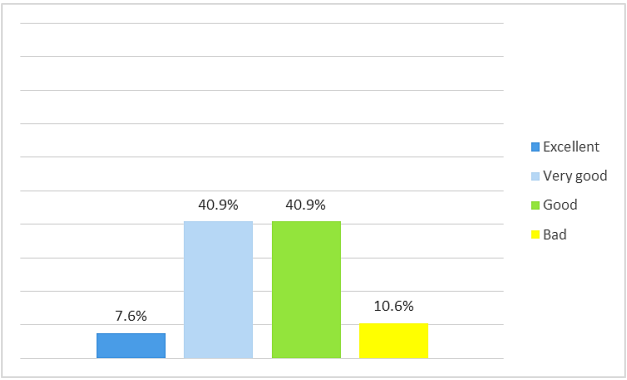

Fig. 6 Percentile representation of individual water classes of Karaša according to SWQI methodology, vegetation period 2007-2017

Table 6 Minimum, maximum, mean and standard deviations (SD) of SWQI, vegetation period April-September, 2007-2017

	SWQI
Minimum	63
Maximum	95
Mean	82
SD	7

Table 7 Average monthly values of the Quality index of water of Karaš, vegetation period 2007-2017

April	May	June	July	August	September
87	84	76	78	80	86
Very good	Very good	Good	Good	Good	Very good

Nera

As well as on the Karas watercourse, Nera's water quality did not exhibit variability outside the class-defined by FAO criteria (Table 8). Problems related to soil infiltration are moderate, as well as problems that can be caused by elevated concentration of bicarbonate. In terms of total salt, i.e. accessibility of water to the plants, there are no problems, nor in terms of toxicity and the content of nitrates.

Figure 7 shows the results of Nera water quality according to the USSL classification where it can be observed that the EC and SAR values are relatively low and low variability. About 95% of the samples are categorized into C2-S1 and 5% in C1-S1. By classification by Nejgebauer, all water samples are classified in "excellent" quality (Fig. 8).

Table 8 Percentile representation of representation of certain Nera water classes according to the FAO classification, vegetation period 2007-2017

Potential problems	Class	%
Salinity	I	100
Infiltration	II	100
Toxicity of Na	I	100
Toxicity of Cl^-	I	100
Effects of NO_3^-	I	100
Effects of HCO_3^-	II	100

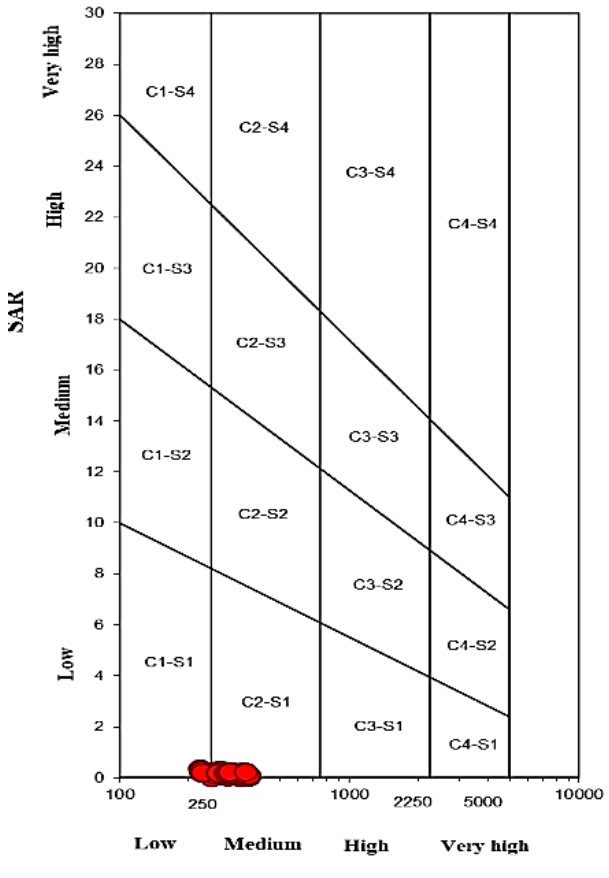

Fig. 7 Nera water classes according to USSL classification, vegetation period 2007-2017

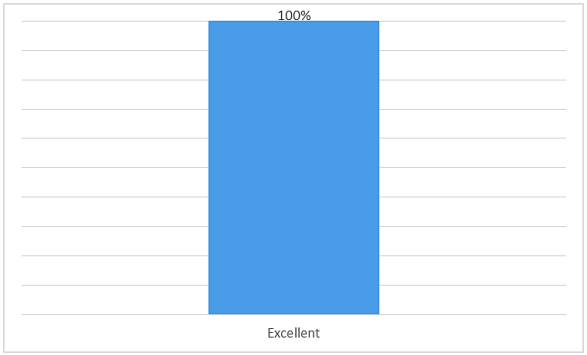

Fig. 8 Percentile representation of certain Nera water classes according to Nejgebauer classification, vegetation period 2007-2017

According to SWQI methodology the quality of water varied from varied from "good" to "excellent". Half of the samples were characterized by excellent quality, about 40% of the samples belonged to the class of "very good" and about 10% of the class of "good" water (Fig. 9).

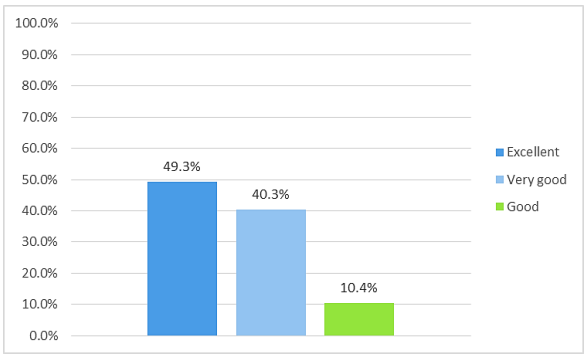

Fig. 9 Percentile representation of certain Nera water classes according to SWQI methodology, vegetation period 2007-2017

Table 9 shows the minimum, maximum and mean value of the Nera water quality index, as well as the standard deviation value. The average value of the index, although indicating "very good" quality, is at the "excellent" quality limit (90). The average values for each analyzed month and their descriptive indicator are shown in Table 10.

Table 9 Minimum, maximum, mean and standard deviations (SD) SWQI of Nera, vegetation period April-September, 2007-2017

	SWQI
Minimum	77
Maximum	97
Mean	89
Standard Deviation	4

Table 10 Average monthly values of the Water Quality Index of Nera, vegetation period 2007-2017

April	May	June	July	August	September
85	82	80	79	79	84
Very good	Good	Good	Good	Good	Very good

CONCLUSION

According to all water classifications, the analyzed watercourses are usable for irrigation, where the best quality is characterized by the Nera water, then Karas and Moravica. All three watercourses require control over the content of total salt, due to the impact on soil and plants, as well as the ratio of sodium concentration to calcium and magnesium (SAR value), due to a moderate danger to the infiltration properties of the soil. Special control is needed on the concentration of bicarbonates from which there is a greater risk of occurrence of various adverse effects on the soil, irrigated plants and irrigation equipment.

The results according to the Nejgebauer classification adapted to the conditions of Vojvodina are most favorable for use. According to this classification, the quality of Moravica is "good" (II class) to about 80% of the samples, the remaining samples were "excellent" quality (class I), except for one unsuitable for use, while Karas and Nera, their samples are classified as 100% in the "excellent" class of quality (class I). Although it may give the most benign results because it is adapted to the natural characteristics of the area being analyzed, it includes a modest amount of data for classification.

The FAO classification is more detailed, but like the USSL classification of a different local character, the direction of future research could be directed to modification towards the natural factors of Vojvodina.

The SWQI methodology includes a wider range of parameters being analyzed, but not all of them are of paramount importance for irrigation purposes, nor are the class boundaries defined accordingly. However, the occasional analysis of these parameters is desirable, with the possible adjustment of the border values for these purposes.

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