IRRIGATION WATER QUALITY AND CRITERIA/STANDARDS IN CROATIA - CONTRIBUTION TO THE ENVIRONMENT AND INDUSTRY

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Abstract: *The water quality used for irrigation should meet the prescribed criteria. The most commonly determined indicators are electrical conductivity (EC), total dissolved salts (TDS), residual sodium carbonate (RSC) and sodium absorption ratio (SAR). Water can also contain harmful substances, regardless of whether irrigation is carried out from surface water or groundwater. The origin of the pollution can be waste, untreated wastewater or saltwater intrusion. The use of poor water quality can cause soil problems such as alkalinity, salinity, increased sodium concentration, toxicity, etc. In Koprivnica-Križevci county (KKŽ) and throughout Croatia, irrigation is currently poorly represented in agriculture. Given the climate change and the trends of very dry and hot seasons, the implementation of irrigation is of increasing importance. According to the results of determining the groundwater quality for irrigation in KKŽ, the values of the indicators are satisfactory (EC = <0.7 dS/m; TDS = <450 mg/l; RSC = <1.25 meq/l; SAR = <3.0 meq/l) for use in agriculture. However, since there are no standards and criteria in Croatian regulations that would define water quality, the results are compared with European/world standards. Water quality testing and the adoption of standards/criteria in Croatia could contribute to the future development of agriculture in increasingly unfavorable climatic conditions and prevent environmental pollution. This would ensure more efficient cultivation of plants, which also contributes to production in our own food industry.*
Key words: *irrigation water quality, agriculture, criteria and standards, environment, industry.*

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1. INTRODUCTION

Considering the evident climate changes, the irrigation of agricultural areas is of increasing importance. The water used for irrigation must meet a certain quality. According to scientific research, the contribution of irrigation water as well as contamination in food production has been determined. It has been shown that the risk is greater in the production of vegetable that is raw used in the diet. Therefore, it is very important to have supervision and control over irrigation water sources (Allende & Monaghan 2015). The type and quality of the soil significantly contribute to water quality. It is known that factors that contribute to water quality are: soil type, slope and drainage, type of irrigation system, method of using fertilizers in agriculture and other practices in soil and water management. In contrast, water quality can affect fertilization efficiency. Therefore, knowledge about water quality is very important and necessary for better productivity in agriculture (Bauder et al. 2014).

To categorize the water quality for irrigation purposes, scientists most often use the following indicators: total dissolved salts (TDS), sodium absorption ratio (SAR), alkalinity, pH, specific ions such as chlorides, sulfates, nitrates. Electrical conductivity (EC) and residual sodium carbonate (RSC) are also tested (Bauder et al. 2014, Kadyampakeni et al. 2018). Water quality varies in different countries, regions and locations depending on the origin of the water, the way it is used, the intensity of precipitation and the aquifer recharge. Considering that the use of groundwater for irrigation purposes during droughts can contribute to the deterioration of water quality (increased salinity), it is very important to determine the water quality in a certain area (Zaman et al. 2018). The toxic effects of irrigation water, eg boron and chlorides, have also been determined. Research has shown that waste, untreated wastewater or intrusion of salt water can significantly contribute to the deterioration of the water quality used for irrigation purposes in food production (Zaman et al. 2018).

In Europe, irrigation is a necessary factor in agricultural production. About 50% of water consumption is used in agriculture. Numerous tests have established that a greater deficit of water in the soil leads to an intolerable decrease in yields in agriculture. The amount of water needed (per unit of agricultural area) in Europe is 2368 mm/year. Therefore, the analysis of the pressure of agriculture on drinking water sources is very important and is different depending on the area (Gunter et al. 2008). Irrigation is very poorly represented in Croatia. Only 2.5% (or less) of agricultural area is irrigated (**Figure 1**).

Considering the climate changes, it is very important in the water management strategy to predict the expansion of the irrigation system and to estimate the quantity and quality of water resources that would ensure the irrigation of larger agricultural areas in the future.

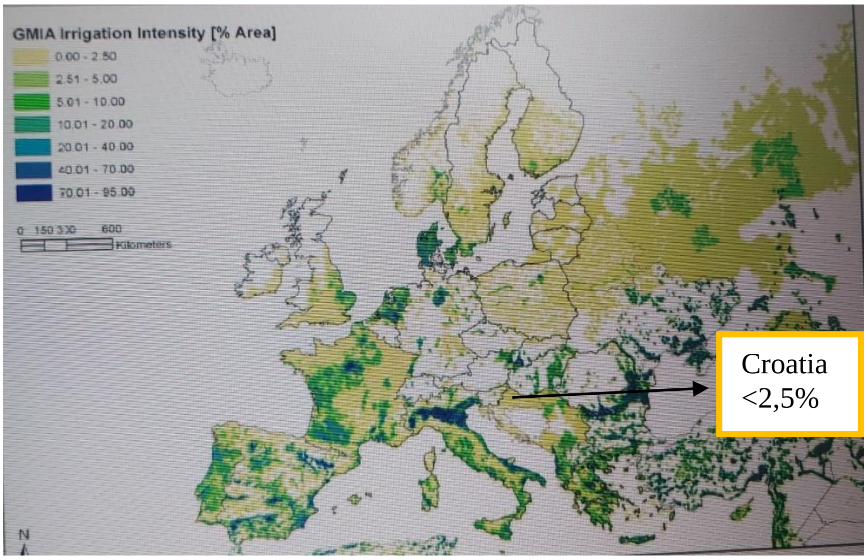

Figure 1 Irrigation intensity of agricultural area in the EU (Croatia)

According to the literature (Nemčić-Jurec et al. 2019), water quality tests were conducted for irrigation purposes. In the Koprivnica-Križevci County, indicators have been established that determine the level of water quality and show whether it can be used for irrigation in agriculture. By measuring a series of indicators (SAR, EV, RSC, pH, TDS and others) and the type of water, water quality was determined, however, the assessment of water quality was carried out according to European or world standards (Ayers et al. 1994), which indicates a lack of regulations in Croatia. In planning the expansion of the irrigation system, it is necessary to plan the regulations/criteria, or standards, according to which water quality would be assessed in order to prevent the use of water contaminated with toxic substances or the use of water that is unacceptable in agriculture.

The aim of this paper is to determine the water quality that could be used for irrigation purposes in Koprivnica-Križevci County according to the standards commonly used in Europe or in the world (Allende et al. 2015; Ayers et al. 1994). The second aim of the paper is to point out the problem in Croatia due to the lack of regulations (standards and criteria) or guidelines that would prescribe the criteria of satisfactory/unsatisfactory water quality that would be used for irrigation. Given that Croatia is a member of the EU, it is important to point out to politicians and managers who decide and draft certain regulations that it is necessary to agree Croatian with EU regulations. This would contribute to the development of agriculture in the future (better quality and higher productivity of products), prevention of environmental pollution and production of our own food industry.

2. MATERIAL AND METHODS

2.1. Study area

Tests were conducted in the area of Koprivnica-Križevci County at 5 locations (L1 to L5, in Prigorje and Podravina) that can be used as sources of water for irrigation purposes (**Figure 2**).

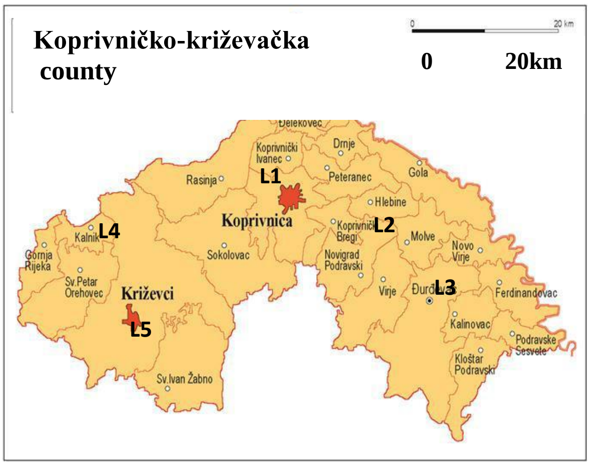

Figure 2. Locations of sampling sites of water for irrigation purposes

The study area covers 1748 km^2. Hydrogeologically, it is located in the Drava River area (L1, L2, L3) where the Quaternary sand-gravel aquifer predominates, in the Kalnik mountain area (L4) where the dolomite aquifer extends, and in the area of the Pleistocene terrace (L5) where the gravel-sand aquifer covered with a layer of clay prevails. The climate is characterized by hot and dry seasons (spring, summer) and cold seasons (autumn, winter). The average annual amount of precipitation is 803 mm. The amount of precipitation is similar throughout the area. The average annual temperature is around 11°C and the climate is moderately warm (Nemčić-Jurec et al. 2019).

2.2. Sampling and testing

Sampling was carried out in 60 samples, during 2016 to 2018 (4 times a year), during the warm and cold seasons. The samples were sampled according to the Norm (HRN ISO 56667-5). After draining the water for 2 to 3 minutes at the sampling location, a 1 l sample was taken in a polyethylene bottle. The samples were transported in a travel refrigerator (1-5 °C) and the ion analysis was performed within 24 hours using the ion chromatography method (anions-HRN EN ISO 10304-1, cations-HRN EN ISO 14911). Indicators as pH and electrical conductivity-EC (pHmetry/conductometry), total dissolved salts-TDS (gravimetry), residual sodium carbonate content-RSC (calculation), sodium absorption ratio-SAR (calculation) and bicarbonates (titrimetry) were also measured (Clesceri and et al. 1998, Standard methods).

3. RESULTS AND DISCUSSION

The test results by season are shown in **Table 1** (min-minimum, max-maximum and average value).

Table 1. Indicators of water quality for irrigation

INDICATOR	MIN	MAX	AVERAGE	MIN	MAX	AVERAGE
	Hot season			Cold season		
pH	6,7	8,3	7,6	7,1	7,65	7,35
EC (uS/cm)	450	543	484	414	589	493
TDS (mg/l)	225	316	268	207	298	258
RSC (meq/l)	-1	-0,25	-0,55	-0,25	-0,15	-0,4
SAR (meq/l)	0,1	0,45	0,2	0,1	0,4	0,25

According to the results, it is evident that there is no significant difference by seasons and that the values of the indicators are similar in the warm and cold seasons. There are noticeable variations, which can be seen through the minimum and maximum values, however, they were also determined during the warm and cold seasons. It is assumed that the composition and water quality do not change significantly throughout the year. According to ion chromatography tests, the dominant ions are calcium and magnesium, as well as bicarbonates and nitrates. The results indicate the natural composition of the water and possible anthropogenic influences (nitrates). Earlier research on the study area showed anthropogenic influences and leaching of nitrates of agricultural origin into the groundwater (Nemčić-Jurec 2019). The quality of irrigation water depends on the available amount of bicarbonate and carbonate in alkaline soil (Singh 2013a). The RSC index was used to determine the ratio of carbonates and bicarbonates according to the following **Equation 1**:

$$RSC = (CO^{3-} + HCO^{3-}) – (Ca^{2+} + Mg^{2+}) \qquad (1)$$

In **Table 1**, RSC values range between -0,15 and -0,55. A comparison of indicators that determine the water quality with the values from **Table 2** (the limit values for categories "acceptable", "marginally acceptable", "unacceptable"), showed that considering the RSC, the quality falls into the category of water that is applicable for irrigation. According to the SAR value, the water quality is also acceptable. TDS is less than 450 mg/l, which is the limit value for "acceptable" water quality. The pH range of high-quality irrigation water ranges from 6,5 to 8,4, which, according to the results, confirms high-quality water with regard to this indicator. Considering that the electrical conductivity depends on the ion concentration, it was expected that the values are within the limits.

Table 2. Limit values of categories the water quality for irrigation purposes (Ayers et al. 1994**)**

INDICATOR	ACCEPTABLE	MARGINALLY ACCEPTABLE	UNACCETABLE
pH	Normal range 6,5 do 8,4		
EC (dS/m)	< 0,7	0,7-3,0	>3,0
TDS (mg/l)	< 450	450-2000	>2000
RSC (meq/l)	< 1,25	1,25-2,5	>2,5
SAR (meq/l)	> 0,7	0,7-0,2	<0,2

The used limit values are prescribed in the guides (Nemčić-Jurec et al. 2019). However, it is important to emphasize that criteria have not been found in Croatia that would define the quality of irrigation water. Given that this will be necessary in the future due to plans to expand the irrigation system at the level of Croatia, this kind of research can certainly contribute to awareness of the need for such regulations at the level of Croatia. The expansion of irrigation systems without water control can have a negative effect on the development of agriculture and the food industry.

It has been shown that in the study area, urbanization and agriculture have a negative effect on water quality (Ruk et al. 2022), therefore it is extremely important to monitor groundwater that is used as drinking water and/or for irrigation purposes. According to the literature (Nemčić-Jurec et al. 2022), the impact of climate change on water quality, the impact of precipitation on pH, nitrates and similar, have been shown, which additionally indicates potential problems related to water quality. Increasingly extreme droughts or floods and global climate change can further deteriorate water sources that are used for various purposes. The approach should be multidisciplinary and should include politicians, the profession, important institutions that make regulations to ensure the future of agricultural food production. Water quality testing without criteria and standards in an area is not acceptable and as such does not contribute to the modern development of agricultural production and the food industry.

4. CONCLUSIONS

Considering the evident climate changes and extreme climatic conditions, it is important to plan and introduce ways of growing plants in agriculture that would contribute to optimal production. One of the important factors in plant production, in these weather conditions, is irrigation. Different irrigation strategies have been defined in Europe, however, there are currently no strategic plans in Croatia, and irrigation is represented on only about 2,5% of agricultural area. The quality of water for irrigation purposes should be an integral part of such strategies. Given that water of poor quality or polluted water can negatively affect agricultural production, requirements and criteria on water quality should be introduced in development strategies. In order to determine and evaluate the water quality, criteria and standards are needed which, have not yet been defined in Croatia. Therefore, future development should be based on understanding the importance of water quality as well as monitoring of water quality used for irrigation purposes. Potential sources of such water pollution should be determined and criteria should be introduced into the regulations in Croatia. As a tool for testing water quality, guidelines and standards with criteria are a necessary factor that contributes to optimal plant cultivation, plant quality, maintenance of soil quality, and maintenance of irrigation systems. Such strategies would also ensure more efficient cultivation of plants, which also contributes to production in our own food industry.

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HRN EN ISO 14911 Water quality-determination of dissolved Li^+, Na^+, NH^{4+}, K+, Mn^{2+}, Ca^{2+}, Mg^{2+}, Sr^{2+}, and Ba^{2+} using ion chromatography-Method for water and waste water (ISO 14911:1998; EN ISO 14911:1999)

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