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Assessment of Irrigation Water Quality of Kosovo Plain

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Abstract

The study aims to assess the quality of irrigation water of the Kosovo Plain. Twelve water samples were collected from sampling points in the peak of dry season in July 2015. Samples were taken from rivers, canals and pumping stations. The contents of the samples have been analyzed. The classification used to assess qualities and the suitability of irrigation water is based on FAO's and USSL's classification criteria of irrigation water. The study revealed that important constituents which influence the quality of irrigation water such as: electrical conductivity, total dissolved solids, sodium adsorption ratio, soluble sodium percentage, residual sodium bicarbonate, permeability index and Kelly's ratio, were found within the permissible limits of water for irrigation purposes. Therefore, the surface water of this area is deemed to be of an excellent quality and its use is highly recommended for the irrigation of crops.

Key words: water, irrigation, quality, classification, assessment

Introduction

The quality of the irrigation water may affect both crop yields and soil physical conditions, even if all other conditions and cultural practices are optimal (FAO, 1985). Irrigation waters whether derived from springs, diverted from streams, or pumped from wells, contain appreciable quantities of chemical substances in solution that may reduce crop yield and deteriorate soil fertility. In addition to the dissolve salts, which have been the major problem for centuries, irrigation water always carries substances derived from its natural environment or from the waste products of human activities (domestic and industrial effluents). The chemical constituents of irrigation water can affect plant growth directly through toxicity or deficiency, or indirectly by altering plant availability of nutrients (Ayers and Westcot, 1985; Rowe et al., 1995).

The suitability of the water for irrigation purposes is not only determined by the total amount of salt present but also by the kind of salt. The problems that result vary both in kind and degree, and are modified by soil, climate and crop, as well as by the skill and knowledge of a water user. As a result, there is no set limit on water quality; rather, its suitability for use is determined by the conditions of use which affect the accumulation of the water constituents and which may restrict crop yield. The soil problems most commonly encountered and used as a basis to evaluate water quality are those related to salinity, water infiltration rate, toxicity and a group of other miscellaneous problems (Ayers and Westcot, 1985; Miller and Donahue, 1995).

In order to evaluate the quality of the water used in the irrigation of crops, it is important to take into consideration the characteristics that are crucial for plant growth as well as the admissible levels of concentrations. The first step in this evaluation process is the testing of the water by a credible and qualified laboratory. The accurate interpretation of the results is of significance in the selection process of fertilizers and irrigation techniques in order to avoid crop damage.

Study area

Kosovo Plain is a large karst field located in the northwest- south direction of Kosovo. The plain stretches from Mitrovica southwards including Obiliq, Kosovo Field (which lies in the centre), Lipjan, and almost to Kacanik. This region stretches roughly from Ferizaj to Vucitern. In the central part, to the west, is the Drenica valley. Kosovo plain lies 500-600 above sea level, and is characterized by a longtime annual precipitation of 640 mm per year, and a longtime annual mean temperature of 10°C.

The Kosovo plain is the most important agricultural region of Kosovo. Agriculture in this area relies heavily on irrigation. The water for irrigation of this area is provided by Hydro-System "Iber-Lepenc" through some primary, secondary and tertiary canals, dams and pumping stations. Extensive research has not been yet conducted regarding the quality or suitability of the water for agricultural uses. Taking into consideration this fact, this research provides an evaluation of the quality of the water used for irrigation in the Kosovo Plain.

Material and Methods

Collection of water samples

A total of 12 surface water samples (Fig. 1) were collected from sampling points in the cropping period of the peak dry season (July, 2015). Samples were taken from rivers, canals and irrigation pumping stations. The samples were collected in 1000 mL, clean plastic bottles. The bottles were kept air tight and labeled properly for identification. Aeration during sampling was avoided by shutting the bottle quickly.

Analytical procedure

Some physical-chemical parameters of the water samples, such as EC, pH and temperature of the samples were measured on the spot using respectively portable EC-meter, pH-meter and thermometer. Ionic TDS (mg/l) was simply determined by multiplying the measured EC values (in dS/m) by 640 as there exists an approximate relation between EC and TDS for most natural water when EC < 5 dS/m (Ayers and Wetscot, 1985; Bauder et al., 2011). Samples collected from study area were carefully transported to the laboratory and were preserved in a refrigerator for analysis. Physiochemical analyses were performed in the laboratory of Agricultural Institute of Peja, Kosovo between July and August 2015.

The analysis for the physico-chemical parameters of the samples were carried out following the established analytical methods. K^{+}, Na^{2+}, were determined by atomic absorption spectrometric (ISO 9964-1, 2, 3:1994); Ca^{2+}, Mg^{2+} by atomic absorption spectrometric (EN ISO 7980:2002); $C1^{-}$ by argentometric method; NO_3-N by ultraviolet spectro-photometric screening method; CO_3, HCO_3 by volumetric method (EPA600/4-79-020USEPA); Boron- by microwave plasma atomic emission spectrometry-MP-AES 4100 (Hettipathirana, 2011).

The important constituents that influence the water quality for irrigation were calculated: the sodium adsorption ratio (SAR) was calculated by the equation using the obtained values of Na^+, Ca^{2+}, Mg^{2+} in me/L (Richards, 1954); the soluble sodium percentage (SSP) was calculated by the equation using the obtained values of Na^+, K^+, Ca^{2+}, Mg^{2+} in me/L (Todd, 1995); the residual sodium bicarbonate (RSBC) was determined by the equation using the obtained values of CO^{2-}_3, HCO^-_3 in me/L (Gupta and Gupta, 1987) and the permeability index (PI) was calculated by the equation using the obtained values of Na^+, Ca^{2+}, Mg^{2+} (Doneen, 1964).

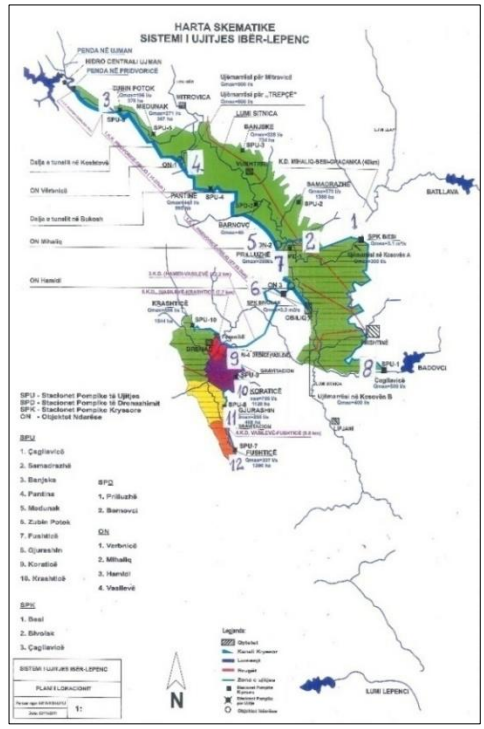

Fig. 1. Map of the study area (Kosovo Plain)
Мапа истраживаног подручја (Косово поље)

Sampling points (*мјеста узорковања*): 1. Besi, 2. Stanovc, 3. Zubq, 4. Verbnic, 5. Mihaliq, 6. Bivolak, 7. Prelluzhe, 8. Cagllavice, 9. Vasiliev, 10. Karotice, 11. Gjurashin, 12. Fushtice.

The magnesium adsorption ratio (MAR) was calculated by the equation using obtained values of Ca^{2+}, Mg^{2+} (Raghunath, 1987) and Kelly's ratio (KR) was determined by the equation using the obtained values of Na^+, Ca^{2+} and Mg^{2+} in me/L (Kelly, 1963).

The analytical results were compared with the FAO's and USSL's classification criteria of irrigation water.

Result and Discussion

The results of physical-chemical parameters and a statistical summary of different indices of irrigation water samples are presented in Tables 1 and 2, respectively.

The pH value of irrigation water samples of the study area ranged from 7.50 to 7.71, showing the alkaline nature of water. These values are within permissible limits for irrigation water (UCCC, 1974; FAO, 1985).

The electrical conductivity (EC) value of water samples varies from 0.250 to 0.560 dS/m with an average value of 0.320dS/m. According to Wilcox (1955) it is classified in 'C1 - Low salinity' water class and can be used safely for irrigation. In terms of the 'degree of restriction on use', EC value of < 0.7dS/m refers the water to 'none'; 0.7 - 3 dS/m 'slight to moderate' and > 3dS/m 'severe' (FAO, 1985). From this point of view, referring to EC values it seems that water of the study area is suitable for irrigation, and it can be classified in "no restriction" category.

In addition to above parameters, it is also important to consider the TDS in water, because many toxic solid materials can remain in water and can be dangerous for plants (Matthess, 1982). Table 1 shows total dissolved solids (TDS) content within the range 122–283 mg/l. This water can be classified as very suitable for irrigation, since TDS values are < 450 mg/l (Ayers and Westcot, 1985). High Sodium content (Na^+) in irrigation water are not desirable, because Na^+ interferes the adsorption ratio of other ions causing displacement of interchangeable cations Ca^{2+} and Mg^{2+} from soil clay minerals. It damages the soil structure and closes soil pores resulting in low permeability of water flow. In this condition the soil fertility and its adequacy for cultivation decreases (Matthess, 1982). That's why the evaluation of SAR is important as an index of sodium hazard.

Sodium Adsorption Ratio (SAR): SAR is the estimation of the degree to which Sodium will be absorbed by soil. A high SAR value in irrigation water suggests a sodium hazard, thus replacement of soil Ca and Mg with Na through cationic exchange. Such a situation is not desirable because damages the soil structure and permeability which ultimately affects soil fertility conditions decreasing the plant production. SAR values of water samples from the study area ranged from 0.101-1.133 me/L (Table 2). All irrigation water samples are included in 'excellent' class according to Richards (1954) based on salinity classification this water is with low sodium hazard (S1).

Tab.1. Physical-chemical parameters of irrigation water of the study area (Iber – Lepence)

Физичко-хемијски параметриц воде за наводњавање истраживаног подручја (Ибер – Лепенце)

W. S. N_0	Location and source of samples *Локација и мјесто узорковања*	pH	EC dS/m	TDS mg/l	K me/l	Na me/l	Ca me/ l	Mg me/l	Cl me/l	HCO_3 me/l	B mg/l
1	BESI (MPS)	7.68	0.290	144	1.15	0.12	2.61	0.22	0.39	3.00	0.02
2	STANOVC (Canal)	7.62	0.294	147	1.20	0.13	2.39	0.22	0.37	2.95	0.02
3	ZUBQ (Main Canal)	7.70	0.285	136	1.30	0.14	2.63	0.21	0.44	2.89	0.02
4	VERBNICE (Main Canal)	7.65	0.291	142	1.25	0.13	2.39	0.22	0.49	2.75	0.01
5	MIHALIQ (DO2)	7.69	0.281	145	1.50	0.13	2.50	0.22	0.62	3.05	0.01
6	BIVOLAK (MPS)	7.71	0.303	151	1.75	0.14	2.72	0.21	0.58	3.10	0.01
7	PRELLUZHE- River, Sitnica	7.50	0.560	283	14.50	1.41	2.73	0.37	1.40	3.25	0.1
8	CAGLLAVICE (IPS-1)	7.63	0.430	217	1.55	0.13	2.16	0.22	1.23	2.80	0.01
9	VASILIEV (DO4)	7.61	0.298	148	1.60	0.14	2.78	0.22	0.85	2.70	0.01
10	KORATICE (PSI – 9)	7.60	0.297	129	1.30	0.12	2.16	0.22	1.45	2.60	0.01
11	GJURASHIN (PSI – 8)	7.60	0.261	125	1.20	0.12	2.39	0.22	0.41	2.50	0.02
12	FUSHTICE (PSI – 7)	7.65	0.250	122	1.30	0.12	2.16	0.22	0.50	2.80	0.01
	MIN	7.50	0.250	122	1.15	1.41	2.16	0.21	0.37	2.50	0.01
	MAX	7.71	0.560	283	14.50	0.12	2.78	0.37	1.45	3.25	0.1
	MEAN	7.64	0.320	157	2.47	0.236	2.47	0.231	0.73	2.87	0.021
	SD	0.058	0.088	46.42	3.794	0.370	0.23	0.044	0.405	0.217	0.025

A quality diagram given by U.S. Salinity Laboratory (Richards, 1954) was used for salinity classification. Referring to SAR as an index of sodium hazard and CE as an index of salinity hazard the diagram classifies 16 classes (Michael, 1992). By comparing the obtained values in the diagram, it results that all of irrigation water samples are categorized in "C2 - S1" class. There is no problem in using this water for irrigation (Richards, 1954).

Soluble Sodium Percentage (*SSP*) is an important factor to study the sodium hazard. It is also used for assessment of irrigation water quality. High sodium (Na^+) percentage can decrease soil permeability and inhibit plant growth. SSP values of surface water in study area vary from 30.976 to 83.693 % with an average value of 39.979 % (Table 2), showing a low alkaline risk and a good (Class II) irrigation water quality (Wilcox, 1955).

Magnesium Adsorption Ratio (*MAR*): Magnesium content is considered as one of the most important criteria for irrigation water assessment. Generally Ca and Mg maintain an equilibrium status in most of waters. Higher magnesium content in water affects plant production, and soil becomes more saline (Joshi et al., 2009). MAR of surface water in this study varied from 7.167 to 11.935 % (Table 2), within accepted limit of 50% (Ayers and Wescot, 1985).

Kelly's Ratio (*KR*). Maximal value of KR was 0.455 me/L in Prelluzhe (Table 2), which means that all values are within the allowed limit of 1.0 me/L, so this water is considered suitable for irrigation purposes (Kelly, 1963).

Permeability Index (*PI*): The study shows that PI values of water samples vary from 56.789 to 71.845 % (Table 2). They are within the classes I and II, so this water is categorized as suitable for irrigation (Doneen, 1964).

Residual Sodium Bicarbonate (*RSBC*): Bicarbonate and carbonate concentration affects the water suitability for irrigation. Water with high RSBC has a high pH. Soil irrigated with such water becomes infertile leading to deposition of sodium carbonate (Eaton, 1950). RSBC values of water samples in study area vary from -0.08 to 0.64 me/L (Table 2). Since these values are lower than 3.0 me/L the water is considered safe for irrigation.

Chlorides in water can cause problems. Many plants are sensitive to high chloride concentration and sometimes to high level of Na in their leaves (Miller and Donahue, 1995). Content of chloride ions in irrigation water increases with increase of CE and sodium ions. Chloride content in water samples varies from 0.37 to 1.45 me/L (Table 1). It is evident that chloride values in water samples from study area were found within recommended limit (Wilcox, 1955; Ayers and Westcot, 1985), so the water is suitable for irrigation (UCCC, 1974; Marschner, 1989).

Bicarbonates (HCO_3) induce calcium precipitation in the form of calcium carbonate (lime) during dry season, resulting in a higher SAR in water (Gupta et al., 1985).

Table 1 showed that bicarbonate values of water samples ranged from 2.50-3.25 me/L with an average value of 2.87 me/L; this water is considered suitable for irrigation (Ayers and Westcot, 1985). Regarding the degree of restriction of use, all surface water in the study area can be classified as 'slight to moderate' (Ayers and Westcot, 1985; UCCC, 1974).

Boron is an essential element for plants, due to its important role in cell division, synthesis of cell membranes, sugar translocation and protein synthesis. The issue of boron level in plants is stated as delicate because the diapason between the level as nutrition element and toxic level of boron is relatively narrow (Gupta et al., 1985).

Boron toxicity can be caused from its high natural concentration in soil (various geological layers), from exceeded fertilization with boron, from irrigation with high boron concentration water and reuse of liquid industrial waste for irrigation.

The boron concentration in water samples during the irrigation peak season in study area varies from 0.01 to 0.1 mg/l (Table1). Results have shown that boron concentration of irrigation water samples in Kosovo Plain are within the allowed limit and are qualified as 'Excellent' according to Boron classification for sensitive plants (Wilcox, 1955; UCCC, 1974; Ayers and Westcot, 1985).

In sample taken in Prelluzhe (Sitnica river) almost all measured parameters were found in relatively high values compared to other samples (Tab. 1, 2), which is not expected because industrial and municipal wastewater from nearby area are discharged in this river.

Tab. 2. Summary statistics of different indices

Сумарна статистика различитих индекса

Parameter *Параметар*	Concentration / *концентрација*			
	Min (me/L)	Max (me/L)	Mean (me/L)	Std. Dev. (me/L)
SAR	0.101	1.133	0.197	0.295
SSP %	30.976	83.693	39.979	14.058
MAR %	7.167	11.935	8.559	1.297
KR	0.042	0.455	0.082	0.117
PI %	56.789	71.845	65.70	4.771
RSBC	- 0.08	0.64	0.40	0.216

Conclusion

Electric conductivity (EC) of all samples is classified in 'C1 - Low salinity' water class based on the salinity classification. Sodium adsorption ratio (SAR) values are categorized as 'Low sodium hazard' and with low sodium risk (S1). Soluble sodium percentage (SSP) values are classified in class II. Residual sodium bicarbonate (RSBC) and Kelly's ratio (KR) values in all samples are in the 'Safe' water category. Magnesium adsorption ratio (MAR), chlorides and boron values in water samples were within the recommended limit for irrigation water. Permeability index (PI) values range between class I and II for all water samples.

Based on all calculated parameters and indexes it can be considered that surface water of Kosovo Plain is of a very good quality for irrigation, so its use is widely recommended for plant irrigation. Considering the relatively high values of measured parameters of water sample from Sitnica river, monitoring of this water source on a regular basis is recommended. Water quality for irrigation in the other regions of Kosovo needs to be assessed.

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Процјена квалитета воде за наводњавање Косовске равнице

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Сажетак

Ово истраживање бави се процјеном квалитета воде за наводњавање Косовске равнице. Укупно 12 узорака воде је прикупљено са мјеста узорковања, у јеку сушне сезоне у јулу 2015. Узорци су прикупљени из ријека, канала и црпних станица. Анализиран је садржај узорака. За процјену квалитета и погодности воде за наводњавање, коришћени су FAO и USSL класификациони критеријуми. Ова студија истиче да су важни састојци који утичу на квалитет воде за наводњавање, као нпр. електро – проводљивост, укупне растворљиве материје, количник адсорпције Na, проценат растворљивог Na, резидуални Na – бикарбонат, индекс пропустљивости и Келијев количник, били у дозвољеним границама када је у питању вода за наводњавање. Стога, може се сматрати да површинска вода овог подручја има одличан квалитет, па се њена употреба за наводњавање усјева веома препоручује.

Кључне ријечи: вода, наводњавање, квалитет, класификација, процјена

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