ASSESSMENT OF IRRIGATION WATER QUALITY OF DUKAGJIN BASIN IN KOSOVO

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Abstract

In this study we evaluated some significant physio-chemical parameters of surface water of Dukagjin basin to assess the quality of irrigation water. Twenty-four water samples were collected in the peak dry season from sampling points in July 2014. Samples were taken from rivers, canals and reservoirs. 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 that influence the quality of irrigation water such as electrical conductivity (EC), total dissolved solids (TDS), sodium adsorption ratio (SAR), soluble sodium percentage (SSP), residual sodium bicarbonate (RSBC), permeability index (PI) and Kelly's ratio (KR), were found within the permissible limits for irrigation water. The results of physic-chemical analyses and calculated water quality parameters suggest that all water samples are suitable for irrigation purposes.

Therefore, the surface water of this area is of an excellent quality and its use is highly recommended for the irrigation of crops.

Key words: *irrigation water, quality, classifications, Dukagjin basin, plain, Kosovo*

1. INTRODUCTION

Assessment of irrigation water quality and its rational management, is becoming an important issue considering the rapid growth of population, together with the extension of irrigation, industrial development and climate change.

Irrigation depends not only on sufficient amounts of water, but also on its good quality which is essential for the quantity of crops, maintenance of soil productivity, and protection of the environment.

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 dissolved salts, which has been the major problem for centuries, irrigation water always carries substances derived from its natural environment or from the waste products of man's 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).

There is no universal criteria for the determination of irrigation water quality, because it is highly dependent on local conditions (Martinez, 1999).

The most common criteria considered in evaluating the quality of irrigation water are: Salinity hazard, Sodium hazard, Salt index, Alkalinity hazard, Permeability hazard, Specific ion toxicity hazards.

Researchers suggest monitoring irrigation water quality throughout the growing season and over time (years), and adjusting management actions (e.g., fertilization, soil amendment, drainage development, and irrigation volume) to maximize plant health while protecting natural resources (Lockett et al, 2008). This research offers an assessment of water quality used for irrigation in Dukagjin Plain.

1.1 Study area

The Dukagjin Plain is a semi-karst field that lies in the south-western part of Kosovo, covering 35% (3,891 km2) of country's total area. It is about 67 km long and 20-40 km wide and its average altitude is 450 m above sea level. It is surrounded by high mountain ranges of Bjeshket e Nemuna in the western part, Pashtrik in the southwest, the Sharr Mountains in the south and southeast. In the eastern part it borders the hilly region of Drenica which divides it from the Kosovo plain. White Drin is the main river that flows in this region, Dukagjin region is highly influenced by the hot air masses that come from the Adriatic Sea through the valley of White Drin river. The annual average temperatures vary from 11.3ºC (Peje) to 12ºC (Prizren). Average annual precipitation of this climatic area is 700 mm per year.

The Dukagjin Plain is the most important agricultural region of Kosovo. Agriculture in this area relies heavily on irrigation. The main water sources for the aforementioned are the White Drin river, Peja's Lumbardh river, Decan's Lumbardh, Istog's Spring and Radoniq's lake. Extensive research has not been 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 Dukagjin Plain.

2. MATERIAL AND METHOD

2.1 Collection of water samples

In the cropping period of the peak dry season (July, 2014) were collected a total of 24 surface water samples from sampling points (rivers, reservoirs and canals). 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 stoppering the bottle quickly.

2.2 Analytical procedure

Samples collected from study area were carefully transported to the laboratory and were preserved in a refrigerator for analysis. Some physic-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 waters when EC<5 dS/m (Ayers and Wetscot, 1985; Bauder et al, 2011).

Physiochemical analyses were performed in the laboratory of Agricultural Institute of Kosovo in Peje, between July and August 2014.

The physico-chemical parameters of the samples were analysed by 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 spectrophotometric screening method; CO_3, HCO_3 by volumetric method (EPA600/4-79-020USEPA); Boron-by microwave plasma atomic emission spectrometry-MP-AES 4100 (Terrance 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); the permeability index (PI) was calculated by the equation using the obtained values of Na^+, Ca^{2+}, Mg^{2+} (Doneen, 1964); the magnesium adsorption ratio (MAR) was calculated by the equation using obtained values of Ca^{2+}, Mg^{2+} (Raghunath 1987); 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 FAO's and USSL's classification criteria of irrigation water.

3. RESULTS AND DISCUSSION

Tables 1, 2, 3 represent respectively: the results of physical-chemical parameters, a statistical summary of different indices of irrigation water samples and limits of some parameter indices for rating surface water quality for irrigation purposes.

The pH value of irrigation water samples of the study area ranges from 6.89 to 7.76 with an average value of 7.23, which is within the permissible limit for irrigated agriculture (UCCC, 1974; FAO 1985).

The electrical conductivity (EC) value of water samples varies from 0.19 to 0.416 dS/m with an average value of 0.278 dS/m which according to Wilcox (1955) falls within the irrigation water quality classification stand 'excellent'. 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 "none" category.

In addition to above parameters, it is also important to consider the TDS in water, because many of the toxic solid materials may be imbedded in the water which may cause harm to the plants (Matthess, 1982). As it is shown in Table 1, total dissolved solids (TDS) content ranges from 123-210 mg/l. The irrigation water of the study area is suitable for irrigation purpose in terms of TDS (Ayers and Westcot, 1985).

Chlorides in water can cause problems. The content of chloride ions in irrigation water increases with the increase of CE and sodium ions. Many plants are sensitive to high chloride concentrations and sometimes to high levels of Na in their leafs (Raymond et al., 1995). In our study the chloride content in water samples varies from 0.36 to 0.60 me/l (Table 1). It is evident that the found chloride values are within recommended limit (Ayers and Westcot, 1985; Wilcox, 1955), so the water is suitable for irrigation (Marschner, 1989; UCCC, 1974).

Bicarbonates (*HCO3*) induce calcium precipitation in the form of calcium carbonate (lime) during dry season, resulting in a higher SAR in water (Gupta et al., 1985). Regarding the degree of restriction on use, all surface waters in the study area can be classified as 'slight to moderate' (Ayers and Westcot, 1985; UCCC, 1974). As it is shown in Table 1 the bicarbonate values of water samples range from 0.80 - 4.80 me/l with average value 2.628 me/l; this water is considered suitable for irrigation (Ayers and Westcot, 1985).

Boron is a micronutrient necessary for plant growth. It regulates transportation of sugars through membranes, cell division, cell development, and auxin metabolism. A continuous supply of boron is important for adequate plant growth and optimum yields (Mahler, R.L. 2009).

Although it is a relatively rare element, boron can be highly concentrated by the action of water, in which many borates are soluble. Its high levels can come 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.

In water samples taken from the study area during the irrigation peak season the boron concentration varies from 0.01 to 0.03 mg/l (Table1). Results have shown that boron concentration of irrigation water samples in Dukagjin basin are within allowed limit and are qualified as 'Excellent' according to Boron classification for sensitive plants (Ayers and Westcot, 1985; UCCC, 1974; Wilcox, 1955).

Table 1. Chemical parameters of irrigation water of the study area (Dukagjin Plain)

W. S. N₀	Sampling area and Sources of samples	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	Xerxe (Canal)	7.08	0.243	123	0.016	0.05	1.67	0.48	0.4	0.8	0.03
2	Bazeni Gradisha (Reservoir)	7.24	0.231	115	0.014	0.05	1.58	0.88	0.36	2.18	0.03
3	Bazeni Rezine (Reservoir)	7.27	0.234	119	0.009	0.05	1.5	1.07	0.44	2.5	0.02
4	Babaj Boges,Erenik (River)	7.63	0.361	175	0.012	0.08	1.58	1.57	0.56	3.9	0.02
5	Bazen No.10 Bec (Reservoir)	7.36	0.241	210	0.011	0.05	1.75	1.64	0.48	1.82	0.02
6	Radoniq (Reservoir)	7.1	0.247	130	0.012	0.04	1.83	0.98	0.4	1.96	0.01
7	Rahushiq (Canal)	7.37	0.236	115	0.006	0.04	2	1.31	0.42	2.02	0.01
8	Peje, Lumbardh (River)	7.76	0.243	125	0.007	0.02	1.88	0.98	0.52	1.5	0.02
9	Loxhe (Canal)	7.52	0.268	138	0.007	0.03	2.02	0.35	0.44	2.8	0.01
10	Peje, Lagja H. Rama (Canal)	7.27	0.277	155	0.010	0.05	1.93	1.04	0.46	2.2	0.02
11	Peje, Fabrika Birres (River)	6.93	0.210	105	0.016	0.09	1.94	0.58	0.52	2.06	0.01
12	Lumbardh, M. Decan (River)	7.39	0.321	164	0.020	0.04	1.33	0.53	0.58	1.8	0.01
13	Isniq (Canal)	7.23	0.192	109	0.014	0.06	2.33	1.05	0.46	2.4	0.01
14	Strellc (Canal)	7.21	0.254	124	0.009	0.05	1.5	0.39	0.51	1.6	0.02

Table 1. Continued

W. S. N₀	Sampling area and Sources of samples	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
15	Burimi Drinit Bardhe (River)	7.09	0.232	136	0.004	0.01	2.33	0.24	0.49	2.6	0.01
16	Vitomerice (Canal)	7.32	0.261	137	0.004	0.01	2.29	0.19	0.45	2.8	0.01
17	Novoselle (Canal)	7.28	0.275	132	0.004	0.01	2.25	0.29	0.55	2.7	0.02
18	Novoselle, L. Thaci (Canal)	7.06	0.383	195	0.006	0.05	2.29	0.74	0.42	2.9	0.01
19	Dubove (Canal)	6.89	0.338	165	0.032	0.12	2.58	0.38	0.6	3.9	0.01
20	Gurakoc (Canal)	6.96	0.389	194	0.017	0.08	2.33	0.53	0.53	3.5	0.01
21	Kanali i Goges (Canal)	6.92	0.368	186	0.018	0.1	2.75	0.67	0.52	3.92	0.01
22	Tomoc (Canal)	6.89	0.317	157	0.007	0.1	2.79	0.57	0.6	3.5	0.01
23	Rudice, Kline (Canal)	7.41	0.365	180	0.006	0.06	3.17	0.42	0.55	4.8	0.02
24	Burimi i Istogut (River)	7.27	0.260	145	0.005	0.01	2.25	0.41	0.54	2.9	0.01
	Range	6.89; 7.76	0.19; 0.416	123; 210	0.63; 1.25	0.01; 0.12	1.67; 3.17	0.19; 1.64	0.36; 0.6	0.8; 4.8	0.01; 0.03
	Mean	7.23	0.278	147	0.445	0.05	2.09	0.73	0.49	2.628	0.01
	SD	0.23	0.062	30.3	0.254	0.03	0.46	0.40	0.06	0.931	0.01
	CV (%)	3.17	22.389	20.5	56.998	58.4	22.0	55.8	13.4	35.452	45.9

In irrigation water high sodium contents (Na^+) are not desirable, because Na^+ interferes with the adsorption ratio of other ions causing the 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 as an index of sodium hazard is important.

Sodium Adsorption Ratio (SAR): Is the estimation of the degree at which Sodium will be absorbed by the soil. It also influences infiltration rate of water.

Irrigation water with a high SAR value suggests a sodium hazard, thus replacement of soil Ca and Mg with Na through cationic exchange. Such a situation is not desirable because it damages the soil structure and permeability which ultimately affects soil fertility conditions decreasing plant production.

The range of SAR values of water samples from the study area is from 0.01-0.09 (Table 2). Based on the quality diagram salinity classification (Fig 1.) given by U.S. Salinity Laboratory (Richards, 1954) this water is with low sodium hazard (S1). All irrigation water samples are included in 'excellent' class according to Richards (1954).

Referring to SAR as an index of sodium hazard and CE as an index of salinity hazard the diagram classifies 16 classes (Michael, 1992).

As it is seen from comparing obtained values in the diagram (Fig.1), it results that about 45 % of irrigation water samples are categorized in "C2-S1" class, whereas the remaining fall in the "C2-S2" class. This water can be used for irrigation without any problem (Richards, 1954).

Soluble Sodium Percentage (*SSP*) Is also used for assessment of irrigation water quality, as an important factor to study the sodium hazard. High sodium (Na^+) percentage can decrease soil permeability and inhibit plant growth. For the surface water in the study area the SSP values vary from 0.552 to 4.886 % with an average value of 2.217 % (Table 2), showing a low alkaline risk and an excellent (Class I) irrigation water quality (Wilcox, 1955).

Magnesium Adsorption Ratio (*MAR*): Generally, Ca and Mg maintain an equilibrium status in most of waters. Magnesium content is considered as one of the most important criteria for irrigation water assessment. Higher magnesium content in water affects plant production, and soil becomes more saline (Joshi et al., 2009). Table 2 shows the MAR values of surface water in this study which vary from 7.661 to 49.841%, within accepted limit of 50% (Ayers and Westcot, 1985).

Kelly's Ratio (*KR*). All values of KR are within the allowed limit of 1.0. The maximal found value of KR was 0.041 (Table 2), so this water is considered suitable for irrigation purposes (Kelly, 1963).

Permeability Index (*PI*): The PI values of water samples as it is shown by the study vary from 40.671 to 72.718 % (Table 2). They are within the class I and II, so this water is categorized as suitable for irrigation (Doneen, 1964).

Residual Sodium Bicarbonate (*RSBC*): Concentration levels of bicarbonate and carbonate affect 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 -0.87 to 2.32 meq/L (Table 2). This water is considered safe for irrigation since the RSBC values are lower than 3.0 meq/L.

Table 2. Summary statistics of different indices of irrigation water

Parameter	Concentration Min (me/L)	Max (me/L)	Mean (me/L)	Std. Dev. (me/L)
SAR	0.01	0.09	0.08	0.176
SSP %	0.552	4.886	2.217	1.157
MAR %	7.661	49.841	25.314	12.366
KR	0.004	0.041	0.018	0.010
PI %	40.671	72.718	58.483	9.571
RSBC	-0.870	2.320	0.550	0.670

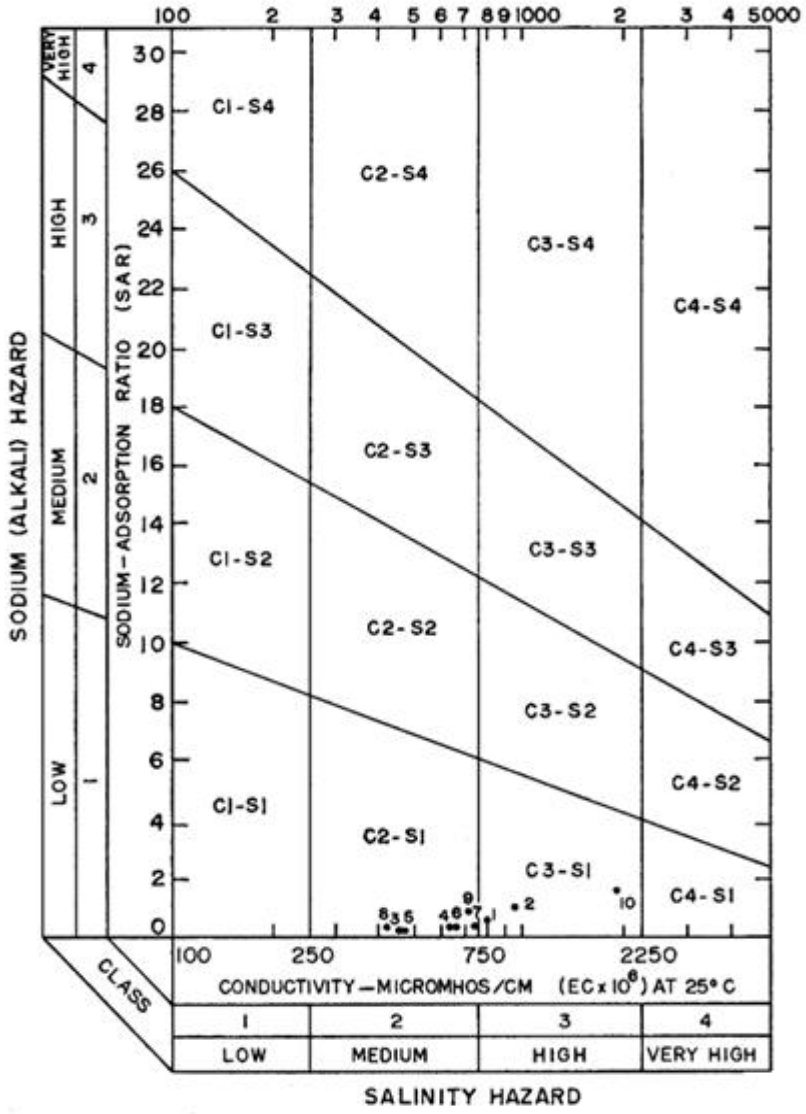


Figure 1. Salinity classification of irrigation water samples (Richards. 1954)

Table 3. Limits of some parameter indices for rating surface water quality for irrigation purposes

EC (dS/m)	Class	RSC (meq/L)	Class	SAR	Class	SSP (%)	Class	KR(meq/L)	Class
0-0.25	Low	< 1.25	Safe	< 10	Excellent	<20	Excellent	< 1	Safe
0.25-0.75	Medium	1.25 – 2.5	Marginal	10-18	Good	20-40	Good	> 1	Unsuitable
0.75-2.25	High	> 2.5	Unsuitable	16-26	Fair	40-80	Fair		
0.75-2.25	Very High	-		>26	Poor	>80	Poor		

*According to Ayers and Westcot (1985), Eaton (1950), Todd (1980), Wilcox (1950) and Kelly (1963) respectively

4. CONCLUSION

The study revealed that important concentration levels and composition of dissolved constituents in water which determine its quality for irrigation use were found within the permissible limits for irrigation water.

Electric conductivity of all samples (EC) as well as Chlorides and Boron are classified in the 'Excellent' class. Sodium Adsorption Ratio (SAR) values are categorized as 'Excellent' and with low sodium risk (S1) based on the salinity classification. Soluble Sodium Percentage (SSP), Magnesium Adsorption Ratio (MAR), Kelly's Ratio (KR) and Residual Sodium Bicarbonate (RSBC) in all water samples are in the 'Excellent' category. Permeability Index (PI) values range in class I and II for all water samples.

Based on all calculated parameters and indexes the surface water of Dukagjin basin can be considered of a very good quality for irrigation, so its use is widely recommended for plant irrigation. Irrigation water quality in the other regions of Kosovo needs to be assessed.

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