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MINERAL SALT CONTENT IN THE WATER OF THE VOGHJI RIVER CATCHMENT BASIN (ARMENIA): ASSESSMENT OF POTENTIAL EFFECTS ON IRRIGATED SOILS AND CROPS

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Agricultural risks of mineral salt (Ca^{2+}, Mg^{2+}, K^{+}, Na^{+}, SO_4^{2-}, Cl^{-}, CO_3^{2-}, HCO_3^{-}) content in the water of the Voghji River catchment basin were assessed. Water sampling and hydrochemical analyses were implemented in July and September 2017. The results of the study showed that anthropogenic salt level in the Voghji River water site located downstream from Kapan Town and in the area of the Norashenik River mouth may have posed serious health risks to irrigated soils and crops.

***Keywords*:** mineral salts, irrigation properties, agricultural risks.

Introduction. Water, the vital element in all aspects of life on Earth, plays an extremely important role for human beings, socio-economic development and the existence of ecosystems. The quality and quantity of any water supply planning are highly important, especially considering for irrigation purposes. For safeguard of healthy growth and sustainable yield of crops, the water used for irrigation has to be of intended quality [1]. The quality of irrigation water has a significant effect on the soil salinity, the growth and yield of agricultural crops [2]. Some irrigation waters can damage plants directly, while others damage soil structure. The impact of irrigation water on soil and plants depends on the water, soil, crop, and environmental conditions [3]. Salinity and sodicity have been extensively reported among the major problems of irrigated agriculture all over the world. It is estimated that over 900 million hectares of agricultural lands are impacted by salinity and sodicity, representing over 6% of all agricultural lands and about 20% of the world's irrigated lands. The main cause of salinization and sodification is the use of poor quality irrigation water and continued use of this water leads inexorably to increasing salinization and sodification problems and ultimately results in increased cost of production and crop failures [4]. High level of salts in irrigation water reduces plant growth and affects the structure, aeration, permeability and texture of soil. Salt water increases the osmotic pressure in soil solution and accordingly restricts water uptake by plants [5].

Irrigation water quality problems in RA are insufficiently studied, whereas the necessity of the investigation of these issues is emphasized by the fact, that

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existing water resources are continuously exposed to pollution and obtain new irrigation properties [6]. Surface waters in the Voghji River catchment area located in the south of RA are mainly used for irrigation and energetic purposes [7]. Insufficient management of industrial, household and agricultural discharges is one of the main environmental issues in the area [8]. Irregular anthropogenic discharges in the catchment basin may cause the deterioration of the irrigation properties of water, adversely affecting soil properties and crop production.

The aim of the present study was to investigate and assess the irrigation properties of the waters of the Voghji River catchment basin and their risks to agricultural lands and plants.

Materials and Methods. Agricultural risks of mineral salt level in the water of the Voghji River and its Norashenik, Vachagan and Geghi tributaries were investigated. Water samples were collected from the rivers in July and September 2017 (Tab. 1). Electrical conductivity (EC) measurements were conducted in field conditions. EC values were determined using a conductometer HI98129.

Table 1

Coordinates of the rivers investigated sites in the Voghji River catchment basin under investigation

№	N/Lat	E/Long	River site location
1	39°09'26.9"	46°06'47.4"	Voghji River site located upstream from Kajaran Town
2	39°09'01.8"	46°11'34.3"	Voghji River site located downstream from Kajaran Town
3	39°13'27.7"	46°20'19.4"	Voghji River site located upstream from Kapan Town
4	39°11'52.5"	46°28'05.4"	Voghji River site located downstream from Kapan Town
5	39°11'54.9"	46°28'02.8"	Norashenik River site located near the river mouth
6	39°11'53.5"	46°23'43.8"	Vachagan River site in Kapan Town
7	39°11'58.3"	46°15'31.8"	Geghi River site located near the river mouth

Water samples were analyzed for potassium (K^+), sodium (Na^+), calcium (Ca^{2+}) and magnesium (Mg^{2+}) ions using an atomic absorption spectrophotometer (novAA 350, Analytic Jena, Germany). K^+ and Na^+ were determined by the flame emission technique, Ca^{2+} and Mg^{2+} were determined by the atomic absorption spectrometric method [9, 10]. Carbonate (CO_3^{2-}) and bicarbonate (HCO_3^-) ions were determined according to GOST 31957-2012, chloride (Cl^-) and sulfate (SO_4^{2-}) ions were determined according to AST ISO 9297-2011 and GOST 4389-72 respectively [11–13].

Sodium adsorption ratio (SAR), soluble sodium percentage (SSP), magnesium adsorption ratio (MAR) and Kelly's ratio (KR) were calculated by the following equations [14–18]:

$$\mathrm{SAR} = \mathrm{Na}^+ \Big/ \sqrt{(\mathrm{Ca}^{2+} + \mathrm{Mg}^{2+})/2}, \quad \mathrm{MAR} = 100 \cdot \mathrm{Mg}^{2+} / (\mathrm{Mg}^{2+} + \mathrm{Ca}^{2+}),$$

$$\mathrm{SSP} = 100(\mathrm{Na}^+ + \mathrm{K}^+)/(\mathrm{Ca}^{2+} + \mathrm{Mg}^{2+} + \mathrm{Na}^+ + \mathrm{K}^+), \quad \mathrm{KR} = \mathrm{Na}^+ / (\mathrm{Mg}^{2+} + \mathrm{Ca}^{2+}),$$

where all the ions are expressed in meq/L.

Results and Discussion. EC is a measure of total soluble salt concentration in water [19]. It is the most important parameter in determining the suitability of water for irrigation use and it is a good measurement of salinity hazard to crop [20]. EC in the waters of the Voghji River catchment basin varied from 76 to

834 $\mu S/cm$, having the lowest values in the Voghji River site located upstream from Kajaran Town (sampling site № 1) and the highest values in the Norashenik River mouth (sampling site № 5). Compared with EC values in the sampling site № 1 not being at the risk of anthropogenic impact, increased EC values in other investigated river sites can be explained by the impact of irregular discharges from household and agricultural activities (Fig. 1). According to USDA classification of irrigation water based on EC values, hazards and limitations in the case of river water used for irrigation purposes were assessed and presented bellow [16]:

Sampling site № 1 – no detrimental effects on plants and no soil buildup expected.

Sampling sites №№ 2, 3, 6 and 7 – sensitive plants may show stress. Moderate leaching prevents salt accumulation in soil.

Sampling sites №№ 4 and 5 – salinity may adversely affect most plants. Requires selection of salt-tolerant plants, careful irrigation, good drainage, and leaching.

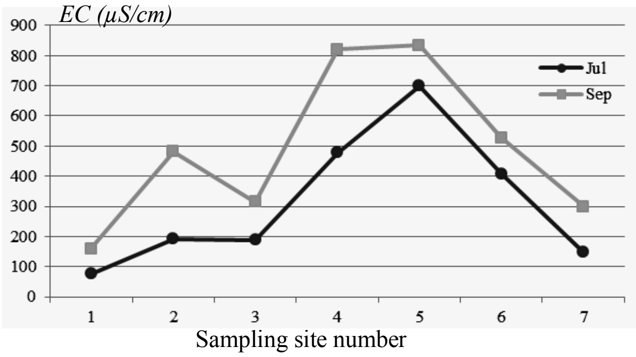

Fig. 1. EC values in the waters of the Voghji River catchment basin.

Ca^{2+} and Mg^{2+} contents in the waters of the investigated rivers were 8.80–72.90 mg/L and 3.90–17.90 mg/L respectively, having the lowest values in the sampling site № 1 and the highest values in №№ 4 and 6 being at the risk of the impact of the household activities of Kapan Town. Ca^{2+} and Mg^{2+} concentrations in the investigated river sites were allowable for irrigation. Drastically increased concentrations of K^+, Na^+ and SO_4^{2-} in the Norashenik River mouth (sampling site № 5) being at the risk of the impact of rural discharges also caused a noticeable increase in K^+, Na^+ and SO_4^{2-} levels in the Voghji River site located about 150 m downstream from the confluence of the Voghji and Norashenik Rivers (sampling site № 4). The concentrations of these ions in the sampling sites №№ 4, 5 were mostly unsuitable for irrigation use (Tab. 2).

When the concentration of sodium is high in irrigation water, the sodium ions tend to be absorbed by clay particles, displacing Ca^{2+} and Mg^{2+}. This exchange process of Na^+ in water for Ca^{2+} and Mg^{2+} in soil reduces the permeability and eventually results in soil with poor internal drainage [21]. Na^+ can also be absorbed directly by plant leaves and will produce harmful effects [22]. High concentration of SO_4^{2-} in irrigation water may limit the uptake of calcium by plants [23]. It can also reduce phosphorus availability to plants [2]. Cl^- content in the sampling sites №№ 1, 7 were formed by natural factors, however Cl^- level in other investigated river sites was also conditioned by anthropogenic sources. The lowest HCO_3^- concentrations were registered in the sampling site № 5, the highest contents in № 6. If in the case of K^+, Na^+ and SO_4^{2-} contents, the Norashenik River negatively affected the Voghji River site located downstream from the confluence of the Voghji and Norashenik Rivers (sampling site № 4), so in the case of HCO_3^- concentration, the Norashenik River favorably influenced the Voghji River, causing decreased HCO_3^- level due to the dilution of the ion concentration in the river water (Tab. 2).

Table 2

Concentrations (mg/L) of major ions in the waters of the Voghji River catchment basin

Parameter	Month	Sampling site number						
		1	2	3	4	5	6	7
Ca^{2+}	July	8.80	20.04	24.80	32.80	33.70	64.10	20.00
	September	19.20	28.80	35.20	44.90	46.50	72.90	40.90
BL		18.30						22.80
MPC		300.00						
Mg^{2+}	July	5.30	9.70	6.80	6.80	3.90	10.20	4.80
	September	4.40	11.20	11.60	17.90	13.60	12.60	13.60
BL		4.80						4.40
MPC		200.00						
K^+	July	NR	1.39	1.12	11.64	20.43	Traces	NR
	September	0.42	7.64	2.22	24.27	27.94	0.64	1.69
BL		1.45						1.12
MPC		11.62						8.96
Na^+	July	0.20	3.99	3.50	38.37	75.35	11.82	2.80
	September	5.22	23.21	5.45	74.36	80.09	15.53	6.59
BL		5.30						4.26
MPC		42.40						34.08
SO_4^{2-}	July	23.00	45.80	25.70	169.00	288.20	29.00	17.90
	September	29.00	38.20	25.30	314.80	350.40	37.60	21.60
BL		26.72						16.00
MPC		250.00						
Cl^-	July	3.50	4.20	5.30	6.30	9.90	10.20	2.80
	September	2.80	23.40	6.70	15.20	15.60	14.50	5.30
BL		6.00						3.53
MPC		200.00						
CO_3^{2-}	July	NR					9.00	1.20
	September	NR						
BL		–						
MPC		–						
HCO_3^-	July	42.70	85.40	85.40	73.80	56.10	222.60	71.90
	September	164.40	231.80	231.80	79.30	67.10	298.00	183.00
BL		–						
MPC		–						

BL is background level; MPC is maximum permissible concentration for irrigation use. NR is not registered.

SAR is an important parameter for determining the suitability of irrigation water [20]. It evaluates the sodium hazard in relation to calcium and magnesium concentrations [24]. SAR in the waters of the investigated rivers ranged from 0.02

to 3.28, having the lowest values in the sampling site № 1 and the highest values in № 5. Noticeable increase in SAR values was registered in the sampling sites №№ 4 and 5, however it may have not had harmful effects on any types of soil (Fig. 2) [25].

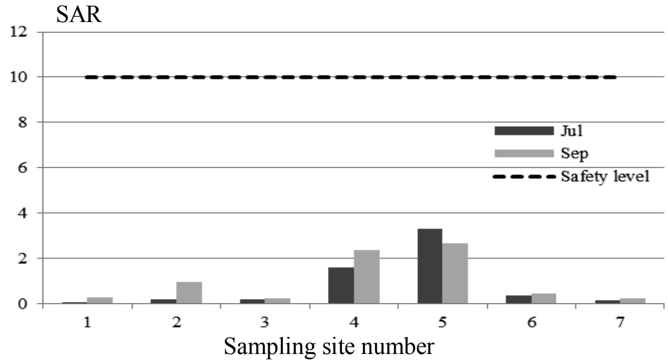

Fig. 2. SAR values in the waters of the Voghji River catchment basin.

SSP is also used to evaluate sodium hazard [1, 22]. SSP values in the waters of the investigated rivers varied from 1.13 to 65.50%, indicating low–high degree of restriction on use of the river waters for irrigation [16]. SSP value in the sampling site № 5 may have caused sodium accumulations and a breakdown of the soil's physical properties in the case of river water use for irrigation purposes (Fig. 3) [1].

MAR is considered to be one of the most important qualitative criterion in determining the quality of water for irrigation [26]. It can be used to specify the magnesium hazard [22]. MAR values in the waters of the investigated rivers varied from 16.0 to 49.8, indicating no magnesium hazard in the case of water use for irrigation purposes (Fig. 4) [15, 17].

KR is also an important parameter for irrigation water quality, which is measured considering sodium ion concentration against calcium and magnesium ion concentrations [1]. KR in the waters of the investigated rivers ranged from 0.01 to 1.64, having the lowest values in the sampling site № 1 and the highest values in № 5. Significantly increased KR values in the sampling site № 5 may have caused alkali hazards in the case of river water use for irrigation purposes (Fig. 5) [27].

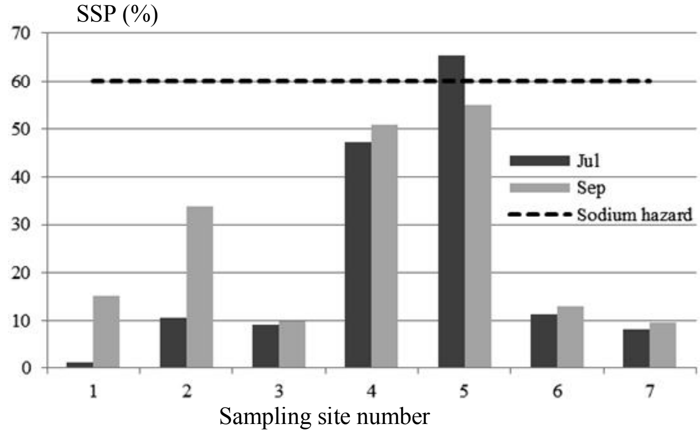

Fig. 3. SSP values in the waters of the Voghji River catchment basin.

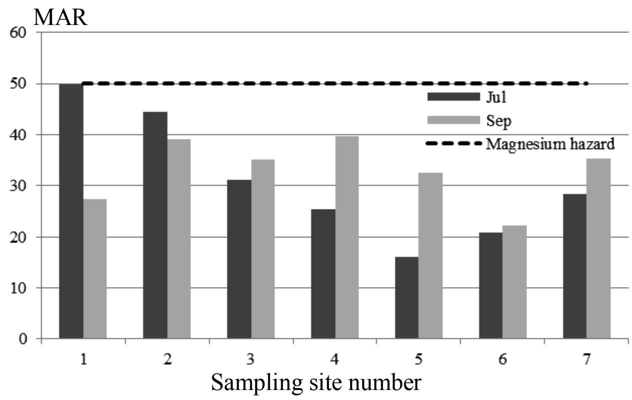

Fig. 4. MAR values in the waters of the Voghji River catchment basin.

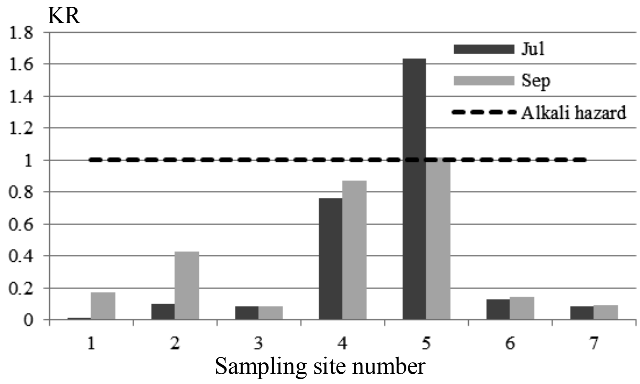

Fig. 5. KR values in the waters of the Voghji River catchment basin.

Conclusion. In general it can be stated that the Voghji, Norashenik, Vachagan and Geghi Rivers were exposed to mineral salt pollution induced by household and agricultural activities in the Voghji River catchment area. Mineral salt level in the Voghji River site located downstream from Kapan Town and in the area of the Norashenik River mouth may have posed alkali and acid hazards to agricultural soils and health hazards to crops in the case of water use for irrigation purposes.

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