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Analysis of leachate from wastewater irrigation experiment with sorghum

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Summary

During the experiment effluent water for irrigation originated from an intensive African catfish farm was applied. This wastewater could be characterized by high ammonium content, high salt content and SAR value. These parameters forecast the hazard of salinization both of surface water and soil. Aim of our research is to evaluate the suitability of the wastewater for irrigation and its impacts on the soil. The experiment was set up in Szarvas, Hungary, in the National Agricultural Research and Innovation Centre, Research Department of Irrigation and Water Management (NAIK ÖVKI) at the Lysimeter Research Station.

The sowing of *Sorghum bicolor (L.) Moench* took place at the end of May 2015 using 9 lysimeters. The lysimeter surface dimensions are 1×1 m (1 m²) and have a soil depth of 0.8-0.9 m over a fine gravel drainage base. The leachates could be collected from each lysimeter for further analysis. During the vegetation period of 2015 the area was irrigated 12 times with 30 mm wastewater and 30 mm fresh water as a control. The fresh water originated from an oxbow lake of Körös River was in compliance with irrigation requirements and there was also a non-irrigated treatment. In the first half of 2016 leachate samples were collected 3 times due to the winter and spring precipitation and to the direct irrigation (for induce leachate). The samples were analysed at the NAIK ÖVKI Laboratory for Environmental Analytics. The aim of our study was to examine the rate of leaching nutrients and salts through the soil profile. According to the chemical analyses of leachate the nitrogen concentration was almost the same as the value of the wastewater although the nitrogen form was different. According to our results neither precipitation nor direct (leaching) irrigation was able to reduce the Na load of soil which was caused by the wastewater irrigation in 2015.

Keywords: sodium, nitrate, leaching

Introduction

The NO_3-N leaching loads from short rotation willow coppice used as vegetation filters for wastewater treatment can be almost negligible once the crop is established (Arronson and Bergström 2001). According to Patterson et al. (2008), pulp mill effluents increased soil extract EC and SAR above values considered safe for agricultural production but addition of supplemental water (natural precipitation or irrigation) could help leach salts through the root zone without further increasing SAR. Our applied wastewater could be characterized by high ammonium content, high salt content and SAR value. These parameters forecast the hazard of salinization and nitrate leaching. Aim of our research is to evaluate the suitability of the wastewater for irrigation and its impacts on the soil.

Materials and methods

Our experiments were conducted at the National Agricultural Research and Innovation Centre (NAIK), Research Department of Irrigation and Water Management in Szarvas, Hungary. The climate is humid continental. In 2015 the average annual precipitation was 498.4 mm and the average temperature was 12,17°C. It was an extreme dry year with low rainfall. In 2016 between January and June the rainfall was 314,2 mm. The sowing of sorghum took place also in May 2015 and 2016 using 9 lysimeters. The lysimeter surface dimensions are 1×1 m (1 m²) and have a soil depth of 0.8-0.9 m over a fine gravel drainage base. Plant density was 15 plant/m² and the row space was 70 cm. In both years 40 kg N/ha was applied. During the vegetation period of 2015, the area was irrigated 12 times with 30 mm wastewater (W30) and 30 mm fresh water as a control (K30) (*Table 1*). The wastewater originated from an intensive African catfish farm. The fresh water originated from an oxbow lake of Körös River what meets the irrigation water quality requirements. There was a non-irrigated treatment (Control) also. In 2016 after sowing 6 irrigation were occurred with fresh water.

Table 1. **Chemical parameters of irrigation water.**

Water parameter	Waste water	River Körös
EC (20 °C) (µS/cm)	1320	430
HCO^{3-} (mg/l)	946	212
NO_2^--N (mg/l)	0.06	<0.020
NO_3^--N (mg/l)	<0.100	0.26
NH_4-N (mg/l)	22.4	0.67
PO_4-P (mg/l)	1.34	0.17
Ca (mg/l)	21	41.4
K (mg/l)	8.8	4.8
Mg (mg/l)	9.5	10.8
Na (mg/l)	275.7	41
Cl^- (mg/l)	32.0	26.9
SO_4^{2-} (mg/l)	40.0	35.5
Sodium Adsorption Ratio (SAR)	12.52	1.47

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From all treatment one water sample were analysed (one leachate sample was collected from each replications and mixed with equally amount). Three samples per treatments originated from rain induced leachate on 16th February, 6th and 27th June in 2016. After the direct irrigation on 19th April 2016 with 60 mm River Körös five further leachate samples were collected within 24 hours from each treatment. The water samples were analysed at the NAIK ÖVKI Laboratory for Environmental Analytics. For the statistical evaluation, univariate analysis of variance with Tukey's HSD test was used with SPSS Statistic Ver.22. software.

Results

Appearance of leachate was always occurred on days after rains and direct irrigation. The least water quantity was in the Control treatment. The total amount value of the leachate were 125, 104, 94 dm³ related to treatment W30, K30, Control between January 1 and 27 June 2016. The specific electrical conductivity (EC) of the leachates was approximately equal all of the treatments. Under K30 treatment the total salt concentration (684.16 mg/l) higher than in the irrigation water (275.2 mg/kg) hence less leachate enough to mobilize the salt from the soil than the applied irrigation water in summer. The leaching requirement ($LR=EC_{irr}/EC_{leachate}$ (Bohn et al. 1985)) in K30 one third (LR=0.45) of the W30 treatment (LR=1.23). The rate of the HCO_3^-, SO_4^{2-} and Cl^- anions in the leachates was favourable because the sodium adsorption rate for the anions was the same: $NaHCO_3$>$NaSO_4$>NaCl (Darab 1962). It is well known that the most mobile nitrogen form is the nitrate. In the Control treatment the nitrate concentration was significantly higher than in the others. According to Szalókiné and Szalóki (2003) the irrigation can cause more dilute concentration and the uptake of the plant in irrigated environment can also rise hence the nitrate leaching is more significant in the non-irrigated cultivation. According to the Hungarian legal regulation, the limit value of the nitrate in the groundwater is 50 mg/l (6/2009. (IV.14.) KvVM-EüM-FVM). None of the treatments reached this limit value. There was no significant difference in the concentration of the orthophosphate in the leachates. The phosphorous leaching was negligible (*Table 2*) because it can be adsorbed well on the soil particles surface (Vermes 1977). The calcium concentration was high compared to sodium concentrations and also to the Ca concentrations of the irrigation waters. This can cause unfavourable Ca:Na rate in the soil adsorption surface. The disadvantageous Ca:Na rate in the wastewater can deteriorate further the negative impact. In the W30 treatment was the highest sodium concentration. Because of the irrigation quality in W30 it is assumed that more sodium accumulated in the soil compared to the other treatments thus the difference of the sodium concentration of leachates was significant. In case of potassium, there were significant differences between the three treatments (*Table 2*). However, potassium and magnesium leaching is relevant only in case of insufficient K and Mg soil supply.

To induce more effluent water from the lysimeters one direct irrigation was applied to decrease the sodium amount of soil. To calculate the effectiveness of the direct irrigation the next equations below were used.

$$Na_{input} = Na_{2015\ irr.} + Na_{2016\ leaching\ irr.} + Na_{2016\ sprout\ irr.} + Na_{rain}$$

$$Na_{output1} = Na_{leachate}$$

$$Na_{output2} = Na_{plant}$$

$$\frac{Na_{output1}}{Na_{input}} * 100 = Na_{leaching\%}$$

$$\frac{Na_{output2}}{Na_{input}} * 100 = Na_{plant\%}$$

$$\frac{Na_{output1} + Na_{output2}}{Na_{input}} = Na_{loss\%}$$

where:

Na_{input}: total Na content (mg/l) between 9 May 2015 and 27 June 2016 of all irrigation and precipitation,

$Na_{2015\ irr.}$: Na content (mg/l) of the irrigation water (K30 = 41 mg/l; W30 = 275.7 mg/l),

$Na_{2016\ leaching\ irr.}$: Na content (mg/l) of the Körös (27.7 mg/l) what was used for direct irrigation 19 April 2016,

$Na_{2016\ sprout\ irr.}$: Na content (mg/l) of the Körös (27.7 mg/l) what was used to help the sprout 6 times (total 110 mm was applied),

Na_{rain}: total Na content (mg/l) of the precipitation between 9 May 2015 and 27 June 2016 (total rainwater 685.2 mm and Na concentration 1.7 mg/l),

$Na_{output1}$: total Na content of the leachates from the lysimeters,

$Na_{leachate}$: leachate amounts multiply the Na concentrations,

$Na_{output2}$: total Na content of the plants. Na_{plant}: dry biomass multiply Na concentration of sorghum (Control = 63.75 mg/kg in dry matter; K30 = 40.85 mg/kg in d.m.; W30 = 45.01 mg/kg in d.m.),

$Na_{leaching\%}$: assumed Na amount of the applied irrigation water which can reach the groundwater in case of natural environment thereby reducing the soil sodium load from irrigation,

$Na_{plant\%}$: assumed Na amount of the applied irrigation water which could accumulate in the sorghums,

Table 2. **Chemical parameters of the leachate.**

	EC (µS/cm)	HCO^{3-} (mg/l)	NO_2^--N (mg/l)	NO_3^--N (mg/l)	PO_4^{3-}-P (mg/l)	Ca^{2+} (mg/l)	K^+ (mg/l)	Mg^{2+} (mg/l)	Na^+ (mg/l)	Cl^- (mg/l)	SO_4^{2-} (mg/l)
K30	950	300.1	0.036^a	19.5^a	0.498	140.8	5.3^a	35.5	47.7^a	20.4	182.6
W30	1069	396.7	0.082^{ab}	25.9^a	0.468	140.0	8.5^c	38.3	74.9^b	20.7	195.3
Contr.	1119	302.6	0.102^b	42.3^b	0.443	172.6	7.2^b	41.7	47.8^a	22.6	221.9

^{a,b,c}: Homogenous subset of the Tukey's HSD Test. Significance level: 0.05

Table 3: **Sodium losses of the soil-plant system from starting of irrigation period in 2015 to starting of irrigation period in 2016.**

	$Na_{leaching\%}$	$Na_{plant\%}$	$Na_{loss\%}$
W30	8.93	0.06	8.99
K30	24.21	0.22	24.43
Control	77.67	0.63	78.30

$Na_{loss\%}$: assumed total Na amount of the applied irrigation water which can not accumulate in the soil because of the leaching or the accumulation in the biomass.

According to our calculations (*Table 3*), sodium accumulation in the plants was negligible for this reason the sodium leaching almost equal to the total sodium loss. In W30 treatment only 9% of all sodium was washed out from the soil, 24% in K30 and 78% in Control treatment due to direct irrigation and the rain. It can be assumed that the sodium accumulated in the soil in each treatment.

Discuss

According to our results, neither precipitation nor direct (leaching) irrigation was able to completely reduce the Na load of the soil which was caused by the wastewater irrigation in 2015. According to one-year experiment we assumed that one direct irrigation was insufficient to decrease the sodium amount in the examined soil profile based on the results of leachate analyses. The sodium accumulation of the plants was negligible therefore the plants were also not able to reduce the sodium load. The sodium uptake of the analysed sorghum completely was insignificant compared to the sodium amount of the irrigation water during one irrigation period in 2015.

Conclusions

Merely one direct irrigation in 2015 and sorghum sodium uptake during one vegetation period were not able to eventuate sodium balance in the water-soil-plant system. According to wastewater irrigation one-year experiment of sorghum sodium accumulation in the soil can be predicted. The sodium content of the wastewater determines its utility for irrigation. To evaluate the impacts of the applied wastewater further soil analyses will be necessary in the future to avoid soil salinization. Likewise repeated direct irrigation to enhance the leaching efficiency of the natural precipitation and expansion of the experiment with new plant species for enhance the sodium uptake also are planned in the next years.

References

Arronson P.G., Bergström L.F. (2001) Nitrate leaching from lysimeter-grown short-rotation willow coppice in relation to N-application, irrigation and soil type. Biomass and Bioenergy, 21 (3): 155-164.

Bohn H.L., McNeal B.L., O'Connor G.A. (1985) Talajkémia. Mezőgazdasági Kiadó - Gondolat Kiadó. Budapest. (In Hungarian).

Darab Katalin (1962) Az öntözővizek minősítésének elvi alapjai. Hidrológiai Közlöny, 42 (4): 303-308. (In Hungarian).

Patterson S.J., Chanasyk D.S., Naeth N.A., Mapfumo E. (2008) Effect of municipal and pulp mill effluents on the chemical properties and nutrient status of a coarse-textured Brunisol in a growth chamber. Can. J. Soil. Sci .p. 429-441.

Szalókiné Zima Ildikó, Szalóki Sándor (2003) Nitrátlemosódás vizsgálata liziméteres és szabadföldi tartamkísérletben. Agrokémia és Talajtan, 52 (1-2): 35-52. (In Hungarian).

Vermes László (1977) Vízminőségi jellemzők és határértékek. In: Gál et al.: Faültetvények szerepe a szennyvizek elhelyezésében és hasznosításában. Vízügyi Gazdasági Tájékoztató. 87. szám. Budapest. (In Hungarian).

6/2009. (IV. 14.) KvVM-EüM-FVM joint decree. Web: http://net.jogtar.hu/jr/gen/hjegy_doc.cgi?docid=A0900006.KVV Available at 5 December 2016.