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Role of the wastewater irrigation in the chemical composition of next-year-leachate

Ágnes Kun[1*], Ildikó Kolozsvári[1], Mária B. Oncsik[1] and Csaba Bozán[1]

Summary

According to the report by the Joint Research Centre (JRC) water reuse can help lower the pressure on freshwater resources. The aim of the report was to determine the minimum quality requirements for water reuse in agricultural irrigation and also in aquifer recharge however in case of many potential environmental risk there are no limit value belonging to wastewater. Nonetheless before wastewater reuse the end-user is responsible to determine further limit values for the prospective irrigation water if its quality is required. In our research the inorganic nitrogen and the sodium content is supposed to harm soil or environment health. Aim of our study was to determine the impact of the irrigation water quality on the chemical composition of the leachate in order to identify the risk of the nitrate leaching and salt accumulation in the soil. The lysimeter experiment was conducted at Szarvas, Hungary started in 2015 with irrigating sorghum. The soil type is Vertisol dominating high clay content where the leaching processes are typically slow. The wastewater is originated from an intensive catfish farm, the current recipient surface water is an oxbow lake where the eutrophication hazard is present but it would be avoidable with irrigation uses.

Keywords: sodium content, nitrate content, field experiment

Introduction

According to Salgot & Folch (2018) is one of the main possibilities to cope with water scarcity is wastewater reclamation and reuse. Wastewater reuse can satisfy different needs: irrigation requests, industrial purposes, potable demands, and civil uses (Roccaro & Verlicchi 2018). Irrigation with raw, partially and treated wastewater is a widespread practice and the importance of wastewater for agriculture has increasingly been recognised not only as a valuable water resource but also for its nutrient value (Elgallal et al. 2016). However, inappropriate management of irrigation with wastewater can pose substantial risks to public health and the surrounding environment (Elgallal et al. 2016). In Hungary alternative water resources utilization should take priority over the conventional irrigation water resources (surface and subsurface waters) in the future, similarly to the global trends because of the global warming and water scarcity.

In our experiment wastewater from an intensive catfish farm with high salt and sodium content was used for sorghum irrigation. The aim of our research was to evaluate the environmental risk of wastewater irrigation. For the assessment, in a lysimeter experiment the leachate chemical composition and the soil available nitrogen level were examined. Our main goal during the analysis was to determine the effects of different quality irrigation water on the leachate nitrate, salt, sodium concentration.

Material and methods

The experiments were conducted at the National Agricultural Research and Innovation Centre (NAIK), Research Department of Irrigation and Water Management (OVKI) in Szarvas, Hungary. The experiment was set up in the NAIK ÖVKI Lysimeter Station in 2015 in 32 pieces of 1 m³ vessels with sorghum (Variety: Gigant). During the irrigation period 360 mm irrigation water was used between 16.6.2015. and 17.9.2015. The lysimeter vessels were filled with disturbed topsoil of Vertisol without layering. The soil is characterised by high clay content (~70-80%), low humus content (~2%), the lime content less than 0.5%, the total dissolved salt content less than 0.08% and the pH_{KCl} values are between 5.88-6.97 before starting the experiment.

There were two different irrigation water applied in the experiment. First one originated from the Oxbow Lake of Körös River (Körös 30 mm– numbers mean one-time irrigation doses/week) with excellent water quality according to Filep‘s classification (Filep 1999, Stefanovits 2010) while the other one was a wastewater (Wastewater 30 mm) from an intensive African catfish farm in Szarvas. The water can be characterized by high specific electrical conductivity; high total salt and sodium content (*Table 1.*)

The leachate and irrigation water and soil samples were analysed at the NAIK ÖVKI Laboratory for Environmental Analytics according to the Hungarian standards. For the statistical evaluation, univariate analysis of variance with Tukey’s HSD test was used with SPSS Statistic Ver.22. software.

Table 1. **The chemical composition of the irrigation waters.**

	River Körös	Wastewater
pH	7.49	7.46
Specific electrical conductivity (µS/cm)	436	1310
HCO_3^- (mg/dm³)	227	949
NH_4^+ (mg/dm³)	0,206	22,4
Ca^{2+} (mg/dm³)	48,3	20
Mg^{2+} (mg/dm³)	12,6	9,42
Na^+ (mg/dm³)	44,6	291
K^+ (mg/dm³)	3,94	6,19

[1] National Agricultural Research and Innovation Centre, Anna-liget utca 35, H-5540 SZARVAS

[*] Ansprechpartner: Dr. Ágnes Kun, kun.agnes@ovki.naik.hu

Table 2. **The chemical composition of the leachate in the different treatments.**

	16.2.2016			16.2.2016-7.7.2016		
	Control	Wastewater 30 mm	Körös 30 mm	Control	Wastewater 30 mm	Körös 30 mm
pH	7,77	7,78	7,7	7,99	7,84	7,98
Specific electrical conductivity (μS/cm)	1720	1280	1050	966	1104	974
HCO_3^- (mg/dm³)	….	….	….	441	604	471
NH_4^+ (mg/dm³)	0,128	0,128	0,165	0,335	0,249	0,284
NO_3^- (mg/dm³)	223	222	88,9	61,4	52,4	52,4
NO_2^- (mg/dm³)	0,143	0,153	0,13	0,160	0,123	0,087
Total N (mg/dm³)	98,4	52,9	25,1	16,8	14,5	14,3
PO_4^{3-} (mg/dm³)	0,285	0,539	0,257	0,466	0,448	0,580
Total P (mg/dm³)	0,299	0,539	0,279	0,468	0,459	0,592
Cl^- (mg/dm³)	….	…	…	21,95	20,75	18,58
SO_4^{2-} (mg/dm³)	..	…	…	136	126	151
Ca^{2+} (mg/dm³)	262	159	141	127	133	130
Mg^{2+} (mg/dm³)	74,0	51,0	44,0	37,7	43,5	40,3
Na^+ (mg/dm³)	49,0	69,4	50,0	54,1[a]	83,3[b]	51,9[a]
K^+ (mg/dm³)	9,83	9,16	7,32	7,65	8,94	6,91

Remark: [a, b] indexes: The Homogenous Subset of the Tukey's Test (ANOVA).

Results

The highest specific electrical conductivity (EC) values were measured after winter time in the first appearing leachate (*Table 2*.).

According to Briggs & Courtney (1993) the concentration of the leachate is depend on the length of the period of the water in the soil matrix, which water is in the soil for a long time is able to balance with soil matrix hence the soluble materials can assemble. Because of the above the leachate from February was excluded from the statistical analyses (values in the first leachate were outlier) and it was used only for descriptions. In February the nitrate concentration were higher than in case of leachate from June and July. According to Bohn (1985) the more mobile nitrogen form is the nitrate while the cation exchange capacity restrain the ammonium. The high nitrate concentration of leachate water threatens groundwater resources. According to the 27/2006. (II.7.) decree on the protection of waters against nitrate pollution from agricultural sources; the water is sensitive to nitrate pollution with nitrate content exceeding 50 mg/dm³. In case of non-irrigated and wastewater treatment the nitrate value exceed the limit value, although during summertime the values decreased. During irrigation period in the non-irrigated treatment more nutrient stayed in the soil what was non accessible for plants due to the less water compare to the irrigated treatments (Szalóki & Szalókiné 2003). To prove this, the available nitrogen content were measured in the soil also (*Figure 1*). In case of wastewater irrigation the ammonium content of the effluent water could cause the higher nitrate concentration in leachate.

According to Kiremit & Arslan (2016) the irrigation water quality determined the EC of the leachate: in the irrigated treatment the value were 4110 μS/cm and in the non-irrigated treatment only 440 μS/cm. In our experiment there were no significant impact on the EC of the leachate.

In the leachate in all treatments the orthophosphate concentration was low. Orthophosphate is the most common form of dissolved inorganic phosphorus and it responsible for eutrophication, although in the soil-water system is important nutrient for plants. According to Marton (2009) the phosphorus concentration in the groundwater is low at all circumstances because of the presence of iron and aluminium oxides.

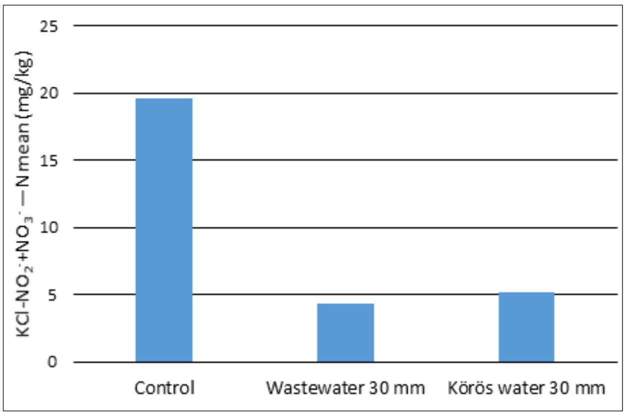

Figure 1. **The available nitrogen content of the soil after the irrigation period.**

The anion and cation composition of the leachates are very similar and the calcium- and hydrogen-carbonate are dominant. According to Marton (2009) calcium- and hydrogen-carbonate prevalence can be explained by the following. Rainwater filtrate into the three-phase soil zone and absorbs ions and organic constituents which determined its initial chemical composition. An aqueous solution of carbon dioxide results in carbonic acid (the solution is slightly acidic, which dissolves limestone, albite, gypsum) thus the immediate effect of the carbon dioxide dissolution is the rapid increase in the carbonate content of water and the decrease in pH. Magnesium and potassium cations were found to be in the same amount as the general groundwater levels in all tested leachate (Mg < 50 mg/l, K < 10 mg/l) (Bowen 1985). High concentration of sodium cation is present in leachate that filtrate through the wastewater-irrigated soil. Sodium and nitrate was the water quality parameter where the irrigation water quality impact is remarkable.

Conclusions

According to the chemical analysis of leachate water, wastewater does not pose a higher risk of groundwater nitrate pollution than irrigation with Körös water. However, taking into account the inorganic nitrogen content of the wastewater during the nutrient management is necessary in the future to avoid the environmental risk. The sodium concentration of the leachate in the wastewater treatment may reduce the impact of the irrigation water on the soil and contribute to the moderation of the soil sodicity. Further investigation is needed in connect with the nutrient and sodium balance in the water-soil-plant system.

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