Effects of the DOC of Treated Municipal Wastewater on Soil Infiltration as Related to SAR and pH

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Introduction

Increasing scarcity of fresh water in arid and semi arid regions means that we must utilize alternative water supplies for irrigation. Treated municipal wastewaters are being increasingly utilized for irrigation. In general only the salinity level, SAR (sodium adsorption ratio) and microbial content of the waters are considered when evaluating their use for crop irrigation. These waters generally contain higher concentrations of sodium, thus higher SAR but in addition higher pH and higher dissolved organic carbon (DOC) as compared to traditional irrigation water supplies. We thus examined the effect of the DOC in treated wastewater on soil physical properties, specifically the infiltration rate, aggregate stability penetration resistance and dispersibility of the soil.

Materials and Methods

Our experiment consisted of treatments of wastewater and prepared waters (free of DOC) at SAR 4, 7 and 10 and at pH 7.0 and 8.0. (Table 1.)

Table 1. Composition of wastewater and treatments

SAR	pH	EC	Ca^{2+}	Mg^{2+}	Na^{+}	NH_4^{+}	K^{+}	Alk	$SO_4^{=}$	Cl^{-}
			$mmol_cL^{-1}$							
Original Wastewater										
4.42	7.2	1.74	4.06	2.3	7.9	1.61	0.5	4.2	4.69	7.31
Wastewater Treatments										
4	6.96	2.65	9.08	4.66	10.6	1.5	0.49	0.14	4.81	19.8
7	7.03	2.60	5.72	3.59	15.2	1.5	0.60	0.14	4.80	19.5
10	6.87	2.68	4.00	2.48	17.9	1.5	0.48	0.14	4.82	18.1
4	7.88	2.60	6.00	6.88	10.4	1.5	0.46	1.50	4.55	19.0
7	7.94	2.67	4.65	4.37	15.5	1.5	0.47	1.52	4.67	20.2
10	8.01	2.65	4.00	2.46	18.0	1.5	0.48	1.52	4.63	18.8
Synthetic Treatments										
4	6.99	2.67	9.16	4.31	10.8	1.5	0.52	0.14	4.62	23.5
7	6.87	2.68	5.89	3.15	15.2	1.5	0.52	0.14	4.64	23.3
10	7.93	2.70	4.11	2.00	15.2	1.5	0.52	0.14	4.65	23.2
4	8.0	2.75	6.83	7.29	12.0	1.5	0.57	1.51	5.18	20.1
7	7.89	2.69	5.38	4.28	15.8	1.5	0.58	1.52	5.27	20.5
10	8.03	2.67	4.44	2.39	20.0	1.5	0.56	1.52	5.13	19.7

We applied the waters to a sandy loam soil in outdoor containers (Fig 1), as discrete alternated irrigation events for 153 days.

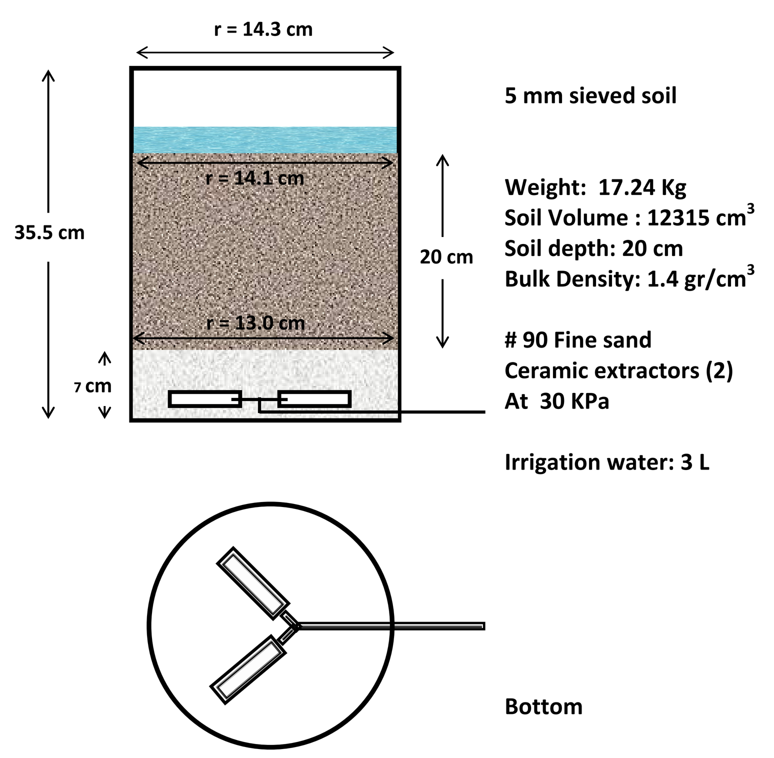

Fig. 1. Schematic representation of the construction of the soil-filled containers.

Infiltration in cm d^{-1} was calculated for each container for each irrigation event. At the end of the experiment, undisturbed soil cores were collected for measurement of penetrometer resistance (electric penetrometer machine by Lausheng Wu), aggregate stability (using a modification of the method of Kemper and Rosenau (1986), adapted by Nimmo and Perkins (2002), dispersion index (DI), using a Emerson dispersion test (Loveday and Pyle, 1973). We collected soil samples from the containers for chemical analyses.

Results

The infiltration rates of the individual water applications decreased with time for all SAR and pH treatments. A comparison of the data in Fig. 3 with those in Fig. 2 reveals that the infiltration rate declined faster in the presence of the DOC (wastewater).

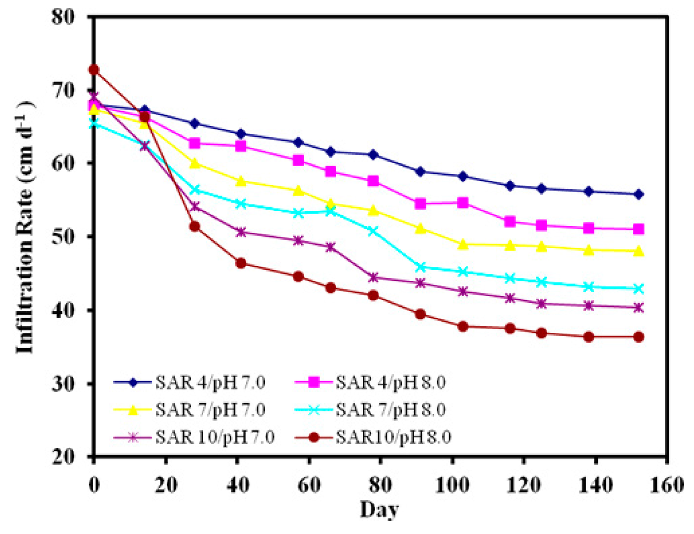

Fig. 2. Infiltration rate versus time for the prepared synthetic water treatments relative to Na adsorption ratio (SAR) and pH.

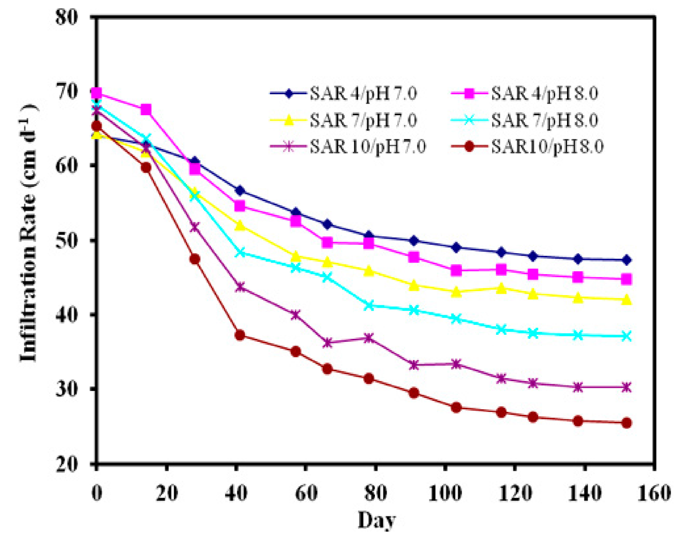

Fig. 3. Infiltration rate versus time for the wastewater treatments as related to Na adsorption ratio (SAR) and pH.

All treatments had reduced relative infiltration under increasing SAR (Fig 4a and 4b.). Comparing the synthetic waters with the wastewaters at the same SAR and pH, we observe an additional loss of 10% in the infiltration rate of the wastewater.

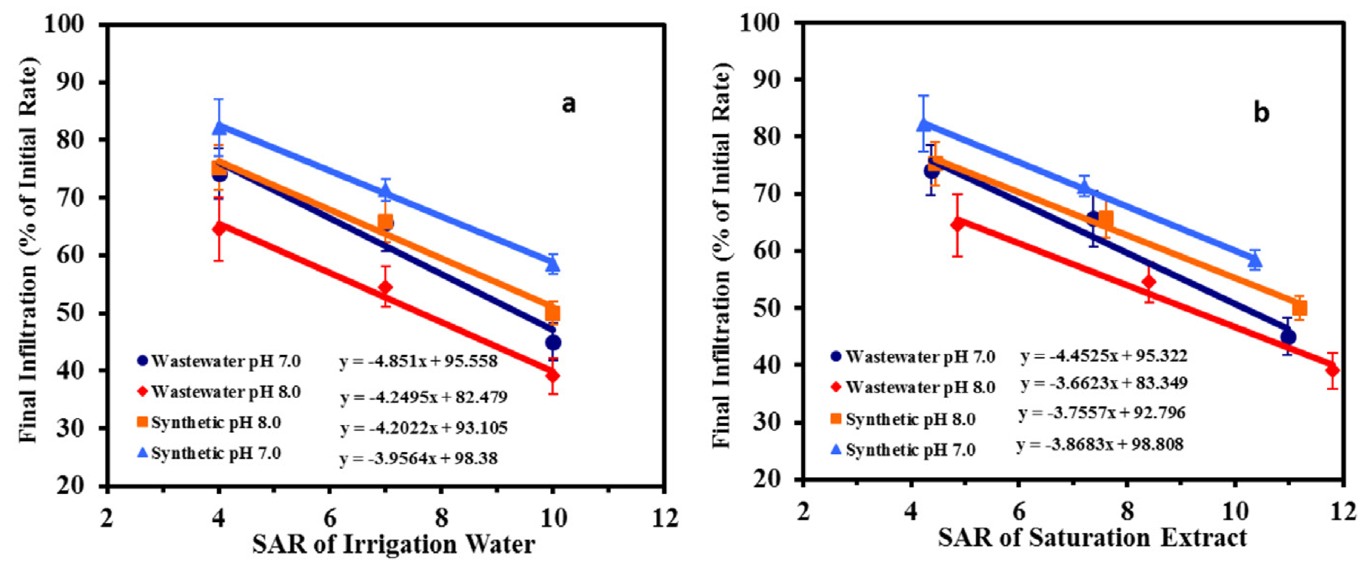

Fig. 4. Relative infiltration rate (final divided by initial) as a percentage for the prepared (synthetic) waters and wastewater treatments relative to pH and (a) Na adsorption ratio (SAR) of the irrigation water and (b) SAR of the soil saturation extract at the end of the experiment.

Penetrometer resistance decreased with depth and increased with SAR for all four treatments (fig. 5a and 5b). Penetrometer resistance was higher for wastewater treatments.

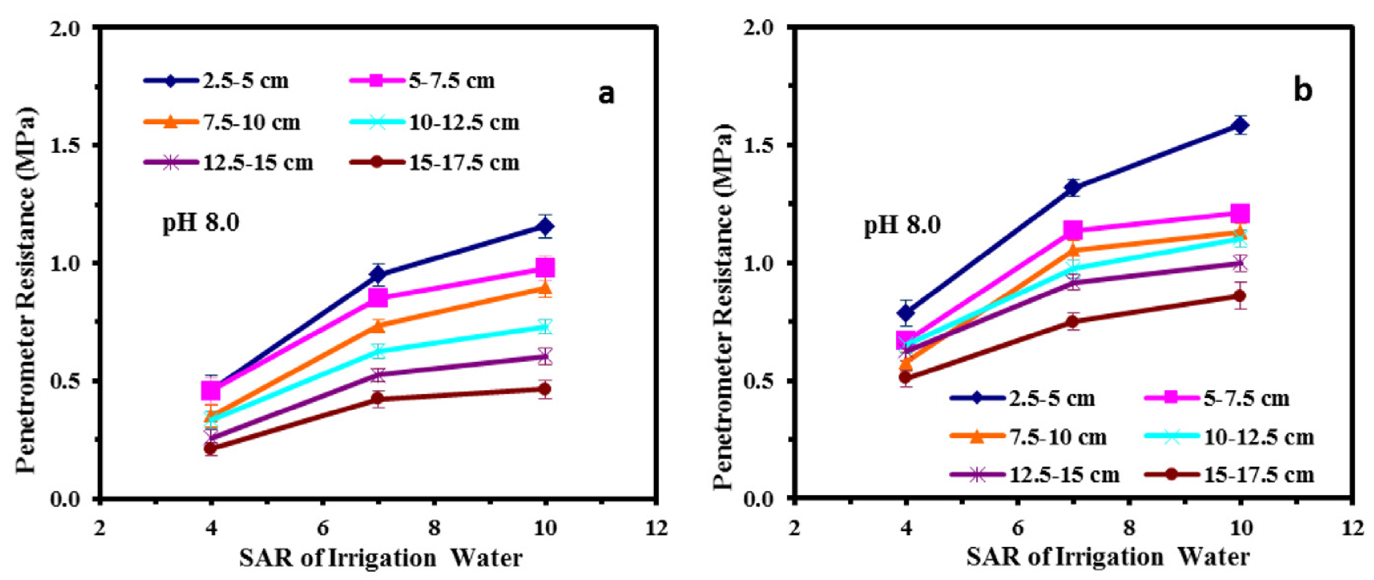

Fig. 5. Penetrometer resistance (MPa) from soil collected at the end of the experiment from the treatments with the (a) prepared synthetic waters and (b) wastewaters, relative to Na adsorption ratio (SAR) and depth. Data are from the pH 8.0 treatments

Comparisons of the pH 7.0 and pH 8.0 treatments in terms of resistance at the soil surface Fig. 6 show that for both waters, the pH 8.0 treatments consistently had a greater resistance at the same SAR., the effect of wastewater was equivalent to the effect of an increase in pH from 7.0 to 8.0.

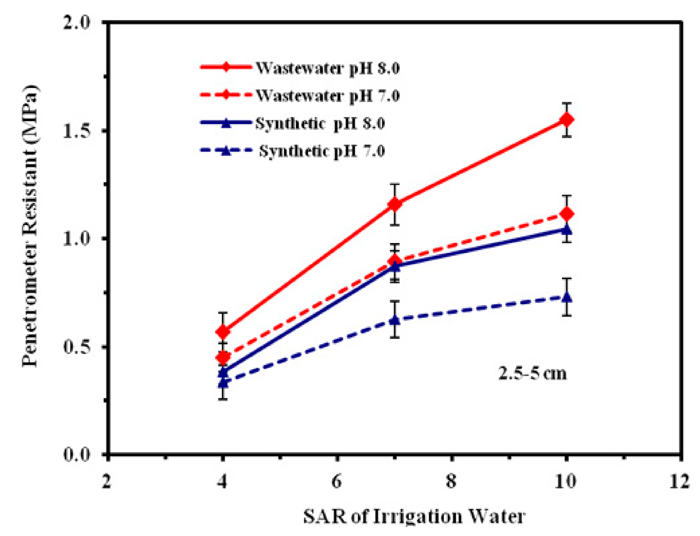

Fig. 6. Penetrometer resistance of soils taken at 2.5 to 5 cm depth from the wastewater and synthetic water treatments.

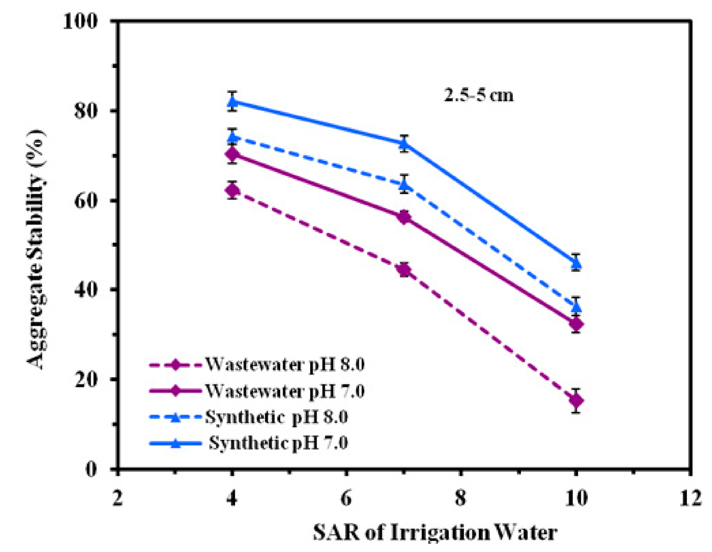

Fig. 7. Aggregate stability (%) of soils taken at 2.5 to 5 cm depth from the wastewater and synthetic water treatments.

The wastewaters had a lower aggregate stability than the DOC-free synthetic waters at all SAR values. In addition, the aggregate stability of the soils treated with pH 8.0 water was lower than those treated with pH 7.0, Fig 7.

The DI increased with increasing SAR (Fig 8.). The changes in DI with changes in SAR are in agreement with the effects of pH and DOC on infiltration and aggregate stability, as discussed above.

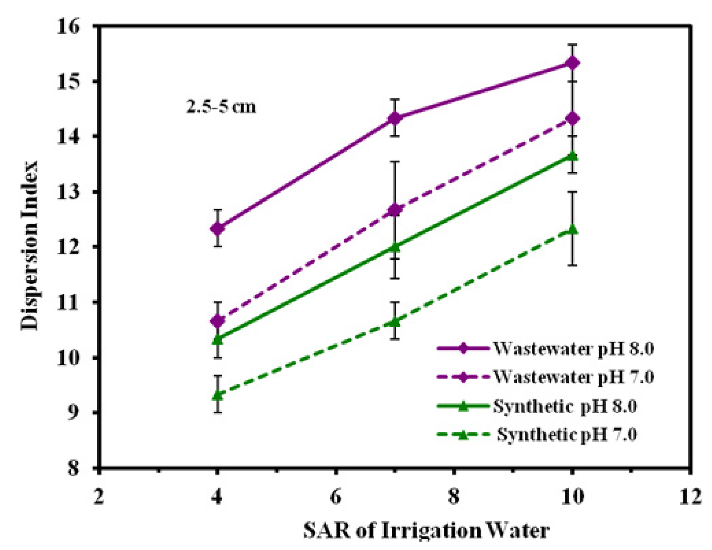

Fig. 8. Dispersion index of soil samples taken at 2.5 to 5 cm depth at the end of the experiment from the wastewater and synthetic water treatments at pH 7.0 and 8.0.

We determined that independent of sodium level and pH the treated wastewater always had a reduced infiltration rate, reduced soil aggregate stability and increased soil dispersibility

Conclusions

- ✓ Short term studies do not represent the longer term consequences of irrigating with degraded water.
- ✓ After 153 days the DOC in treated wastewater caused a decrease in infiltration rate, decrease in aggregate stability and increase in dispersion relative to waters free of DOC.
- ✓ The effect of the DOC was equivalent to an increase in SAR of 2-3 units.
- ✓ The SAR of typical wastewaters is sufficiently high to cause loss of infiltration, and increasing SAR had a detrimental effect on infiltration and soil physical properties.
- ✓ The pH of the water has to be considered when evaluating suitability as Increased pH reduced infiltration, aggregate stability, and increased soil resistance, with and without DOC.

Recommendation

Our recommendations for sustained use of wastewaters for irrigation are that the pH be lowered to below 8.0 and the SAR reduced to below 4, possibly by addition of acid and a Ca source.

Reference

Suarez, D.L., Gonzalez-Rubio, A. 2017. Effects of the DOC of Treated Municipal Wastewater on Soil Infiltration as Related to SAR and pH. Soil Sci. Soc. Am. J. 81:602–611. doi:10.2136/sssaj2016.09.0310