Impact of irrigation wastewater pH on saturated hydraulic conductivity of acidic, neutral, and alkaline Kaolinitic soils.

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Introduction

There is an increasing need to use marginal quality water, including industrial treated wastewater and saline and sodic water for irrigating land in arid and semi-arid regions globally. The use of marginal quality of water potentially increases soil structural degradation, decreasing permeability (Bennett 2012; Shainberg *et al.* 1981), whereby excess sodium (measured as the sodium adsorption ratio, SAR) can result in both intra- and inter-crystalline swelling leading to eventual dispersion (Dang *et al.* 2018a; Ezlit *et al.* 2013). Furthermore, this effect can be enhanced or reduced depending on electrical conductivity (EC) of the irrigation water (Dang *et al.* 2018b). The effect of SAR and EC on saturated hydraulic conductivity (K_s) was classically studied by Quirk and Schofield (1955), with the body of work since identifying that the K_s reduction due marginal quality water depends on soil clay content and mineralogy, soil organic matter, and the electrolyte composition and concentration (Bennett and Raine 2012). However, the effects of marginal water pH and alkalinity on the extent of K_s reduction are less well understood, especially in relation to a soils initial pH and alkalinity. Naturally formed soils usually have a pH ranging from 4 to 10 (Szabolcs 1989), and the soil pH in a specific soil is basically a function of the soil clay minerals, organic portion, associated ion exchange, and hydrolysis reactions (Sumner *et al.* 1991). The aim of this study was to investigate the impact of different pH and EC of treatment solutions at SAR 20 and 40 on K_s reduction for Kaolinitic soils with different original pH values, enhancing the current understanding of Australian soils.

Methodology

Three Kaolinitic soils were selected in this study, and the properties of soils are given in Table1. The soils were sieved through 2.36mm, and packed into PVC cylinders (87.5 mm inner-diameter) with bulk density of 1.4 gm/cm^3. The K_s was measured using similar concept to the Mariotte bottle to supply solutions via plastic bottles placed on the top soil columns. Each soil column was initially leached with the most concentrated solution of the desired pH and SAR treatments. When the K_s of the soil columns and pH of the effluent had stabilised, the next more diluted solution of the same SAR and pH was applied.

Table1: Original chemical and physical properties of the soils used

Soils	pH (1:5)	EC (1:5) (dS/m)	Total alkalinity (mg/L)	SAR (mol$^{0.5}$ m$^{-1.5}$)	CROSS (mol$^{0.5}$ m$^{-1.5}$)	ESP	CEC (meq/100g)	clay content %	Soil texture	Australian taxonomic class
Soil1	4.5	0.08	0	0.9	1.2	26.3	2	15	loam	Kurosol
Soil2	7.1	0.05	55	0.1	0.5	8.0	7.6	12.5	sandy loam	Kandosol
Soil3	8.8	0.3	157	4.3	4.6	10.6	25.4‡	33.8	clay loam	Dermosol

‡ soil3 has a mixture of clay minerals of Kaolinite, Illite and Montmorillonite, and Kaolinite is a dominant clay mineral.

The changes in hydraulic conductivity between treatments were represented as a hydraulic reduction (*RK_s*; Eqn. 1) for comparison purposes, the K_s values were compared to the initial K_s ($K_{s(i)}$) values determined with the 10 dS/m, SAR 20 solution, or 50 dS/m, SAR 40 solution.

$$RK_s = \frac{K_{s(i,n)}}{K_{s(i)}} \tag{1}$$

The chemical compounds $NaHCO_3$, $MgCl_2$. $6H_2O$, and NaCl were used to obtain a desired level of solutions. The use of $CaCl_2$ was avoided to prevent $CaCO_3$ precipitation at high pH and low SAR. The desired pH achieved by adjusting the HCO_3^-/Cl^- ratio and carbon dioxide partial pressure (P_{CO2}) with ±0.05 units of the desired pH using CO_2 gas with 99% purity. This natural approach was used rather than addition of other alkali or acidic compounds for pH adjustment to avoid the change in ionic composition, and electrolyte concentration of solutions.

Results

The K_s of each soil, leached with solutions with various concentrations at SAR 20 and 40, and different pH, are presented as *RK_s* in Fig. 1. The K_s were mainly dependent on pH at higher concentrations, and this effect were more evident for acidic soil. However, soils behaved differently at high electrolyte concentration depending on soil pH. For all three soils, the onset decrease in *RK_s* occurred at EC of the water ≤ 2.5dS/m at SAR 20, whereas at SAR 40 reduction started from EC ≤ 5dS/m due to the higher concentration of Na in water resulting in greater degree of clay dispersion. The pH dependence of K_s in acidic, and neutral soils was greater than that for alkaline soil. The greatest K_s reduction happened in neutral soil, due to the balance of hydroxyl and hydrogen ions in the soil solution. However, pH 9 instigated highest K_s reduction for all soils in particular at low EC values due to an increase in exchangeable cation capacity, and clay dispersion at high pHs as was expected (Chorom *et al.* 1994).

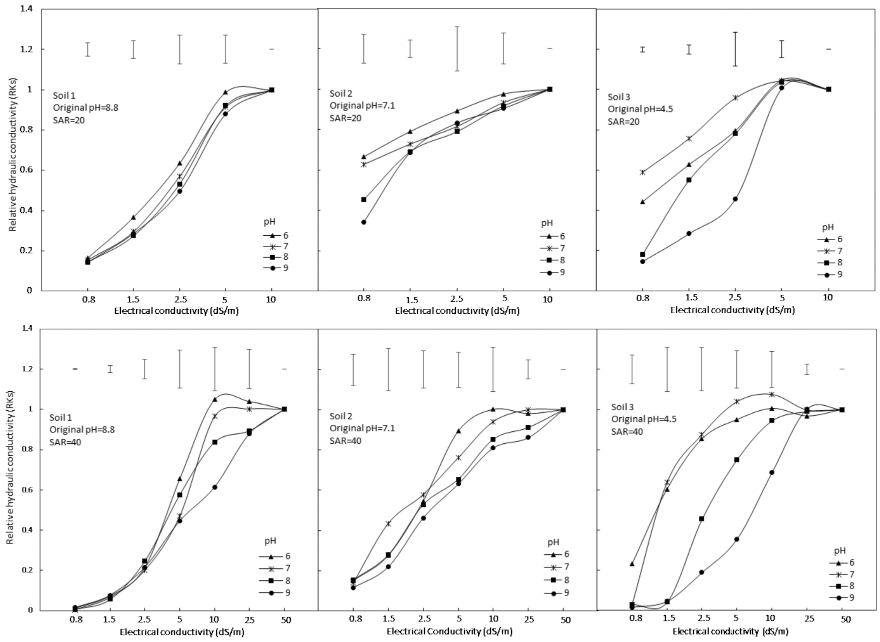

Figure 1 Effects of wastewater pH 6, 7, 8 and 9 on hydraulic conductivity at different electrical conductivity for soils at SAR=20 and 40. Bars represent HSD values for each event.

Keywords: irrigation wastewater*, pH,* hydraulic conductivity*,* soils of different *pH*

Conclusions:

1. The relativce hydraulic conductivity fell with fall in electrolyte concentration for all initial pH and SARs.
2. Effects of pH of irrigation water on saturated hydraulic conductivity are soil specific and also depends on the EC of the irrigation water.
3. The effect of the solution pH was greatest for the originally acidic soil.
4. In this study the soil of neutral pH exhibited the highest K_s at the same pH of the water comparing to the acidic and alkaline soils, particularly when the EC of the irrigation water was below 2.5 and 5.0 dS/m for SAR 20 and 40 respectively.
5. Therefore, to accurately predict the K_s of the soil it is essential to take into account the original pH of the soil and the pH, EC and SAR of the irrigation water.

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