UNIVERSITY OF SOUTHERN QUEENSLAND
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Effect of Dispersed Clay and Soil Pore Size on the Hydraulic Conductivity of Soils Irrigated with Saline-Sodic water

A dissertation submitted by

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I dedicate this work to my mother, father, siblings, wife and children

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Abstract

A shortage of good quality water has led to the use of low quality, high saline-sodic water that was considered unsuitable for irrigation purposes in the past. Using such water can increase the potential of soil degradation, soil pore blockage and consequently reductions in soil saturated hydraulic conductivity (K_s). This can limit crop growth in the long term through the impacts on water and nutrient availability.

Most studies use reductions in soil K_s as an indicator of soil pore blockage when saline-sodic irrigation water is used. However, the use of saline-sodic irrigation water requires improved understanding of the of cation exchange processes, soil structural degradation and the potential for soil pore blockage. In order to address this three laboratory trials were conducted to investigate the effect of soil pore size on soil cation exchange processes, dispersed clay movement and the mechanisms of soil pore blockage in relation to changes in soil K_s.

An initial study was conducted on two soils packed into soil cores at two different bulk densities (ρ_b) and leached with solutions containing varying concentrations of clay sediments. Measurements of soil K_s showed that increasing soil ρ_b and the concentration of clay sediment in the applied solution significantly increased the percentage of clay sediment retained within the soil columns. This in turn significantly decreased soil K_s particularly for compacted soils. Soil pore blockage occurred near the soil surface in compacted soils while soil pore blockage occurred at depth in soil packed at low ρ_b. This confirmed that soil pore size has a significant effect on dispersed clay movement and potential soil pore blockage.

The soil pore size distribution does not provide information about the mechanism of soil pore blockage. It was hypothesised that clay sediment migration and soil pore blockage occurs in saline-sodic soils and that the soil response will vary depending on clay mineralogy and the quality of irrigation water applied. These issues were addressed in later experiments that used saline-sodic irrigation water applied to soil with different properties. A resin impregnation method was also used to gain a better understand the mechanism of soil pore blockage.

Solutions with different sodium adsorption ratios (SAR) were used to understand the relationship between ion exchange and changes in soil K_s for three soils. A Red Ferrosol (RF), Grey Vertosol (GV) and Black Vertosol (BV) were packed into soil cores at two ρ_b (1 and 1.2 g cm^{-3}). The rate of ion exchange and reductions in soil K_s during leaching processes were found to be significantly higher in soils with higher proportions of soil macropores (> 30 µm) compared to those dominated by micropores (< 0.02 µm). Further, the correlation between the rate of ion exchange and changes in soil K_s was stronger for the RF soil compared to the BV soil. This indicated that dispersion was the main mechanism for soil K_s reductions in the RF soil while swelling contributed significantly to reductions in soil K_s for the BV soil. Even though the reductions in soil K_s were greater in lower ρ_b soils, they maintained significantly higher K_s values compared to compacted soil. The measurement of soil exchangeable cations after leaching with high SAR solutions showed a significant increase in soil ESP at the soil surface. The RF soil also reached chemical equilibrium earlier than the GV and the BV soils.

Applications of rain water to the soil cores post-leaching with saline-sodic water led to leaching of soluble cations and significant reductions in the electrical conductivity of the soil solution and soil K_s. These significant reductions were observed just after the first pore volume (PV) of leaching. However, the RF soil maintained higher K_s

values compared to the GV and BV soil. Soils with lower ρ_b maintained higher K_s values and produced higher concentrations of dispersed clay in the leachate compared to compacted soils.

Image analyses of resin impregnated RF soil taken at depth from soil cores irrigated with good quality water (GQW) and saline-sodic irrigation water showed significant soil pore blockage after the application of saline-sodic water. This confirmed that dispersed clay migrated with infiltrated water. In compacted RF soil the soil pore blockage took place near the soil surface. For the BV soil, pore blockage occurred at and near the soil surface for ρ_b = 1 and 1.2 g cm^{-3}, respectively. Soil micropores were completely blocked while incomplete blockage was observed in the soil macropores. After applying rain water to soil cores post-leaching with saline-sodic water significant pore blockage occurred at the soil surface in all treatments except for RF packed at low ρ_b where soil pore blockage was only observed in deeper soil layers.

Soil K_s was positively correlated with increasing the soil porosity and soil macroporesity while a strong negative correlation was found between K_s and soil microporosity. Small changes in soil porosity and soil macropores resulted in significant changes in K_s. This research has shown soil pore size has a significant effect on cation exchange processes, dispersed clay movement and the potential for soil pore blockage. However, this interaction differs between soils and is dependent on the dominant clay mineralogy.

Certification of Dissertation

I certify that the ideas, designs, experimental work, software, results, analyses and conclusions presented in this dissertation are entirely my own effort, except where otherwise indicated and acknowledged.

I further certify that the work is original and has not been previously submitted for assessment in any other course or institution, except where specifically stated.

Endorsement:

Awedat Musbah Awedat, Candidate **Date**

Professor Steven R Raine, Principal supervisor **Date**

Dr John McLean Bennett, Co-Supervisor **Date**

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Table of Contents

List of Tables

List of Figures

List of Symbols and Abbreviations

BV	Black Vertosol
CEC	Cation exchange capacity
DDL	Diffuse double layer
EC	Electrical conductivity
EC_{iw}	Electrical conductivity of irrigation water
ESP	Exchangeable sodium percentage
$EXCa^{2+}$	Exchangeable calcium
EXK^{+}	Exchangeable potassium
$EXMg^{2+}$	Exchangeable magnesium
$EXNa^{+}$	Exchangeable sodium
GQW	Good quality water
GV	Grey Vertosol
K_s	Saturated hydraulic conductivity
LSD	Least significant difference
PV	Pore volume
ρ_b	Bulk density
RF	Red Ferrosol
RSC	Residual sodium carbonate
SAR	Sodium adsorption ratio
SC	Sediment concentration
TDS	Total dissolved salts
TEC	Threshold electrolyte concentration