Grain Size Effect on Both Saturation and Pollutant Migration

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1. **Introduction:** The movement of soluble salts through the soil has important implications for agriculturists and hydrologists and it has importance in a number of environmental problems. In arid and semi arid regions, the groundwater is the only source of water because precipitation rarely occurs. In Egypt many industrial projects are constructed outside the river Nile's valley, disposing many chemical pollutants under the ground surface and due to that the groundwater becomes polluted. Hydrological and environmental studies are necessary to monitor and control the groundwater quality. The objective of this work is to study the effect of grain size on both saturation and the upward solute transport in the unsaturated sandy soil.

2. **Method and measuring apparatus:** Two tracer laboratory experiments were carried out using a packed bed of fine (FS) and coarse sand (CS), where groundwater flowed as a single phase under unsaturated conditions. A constant level of groundwater was kept through the groundwater supply tank for each experiment, d_{FS} = 60 cm and d_{CS} = 25 cm. Evaporation technique was used to create upward potential gradient and a new evaporation measuring technique was used to create an upward groundwater movement (i.e. upward soil water potential gradient) with solute transport during the time of each experiment.
The concentration distribution of sodium chloride (NaCl) over the depth of the unsaturated sand column at the end of each experiment was measured using the electrical potential method. The unsaturated hydraulic properties for the two types of sand were described by van-Gunchten's model and estimated by the back analysis technique (Watanabe et al., 1995) as in Table 1. The moisture profiles which calculated from the numerical solution of Richards' Equation using the estimated parameters fit the measured data well. The average value of the evaporation rate was 2.15 mm/day in the case of fine sand, while 0.5 mm/day in the case of coarse sand.

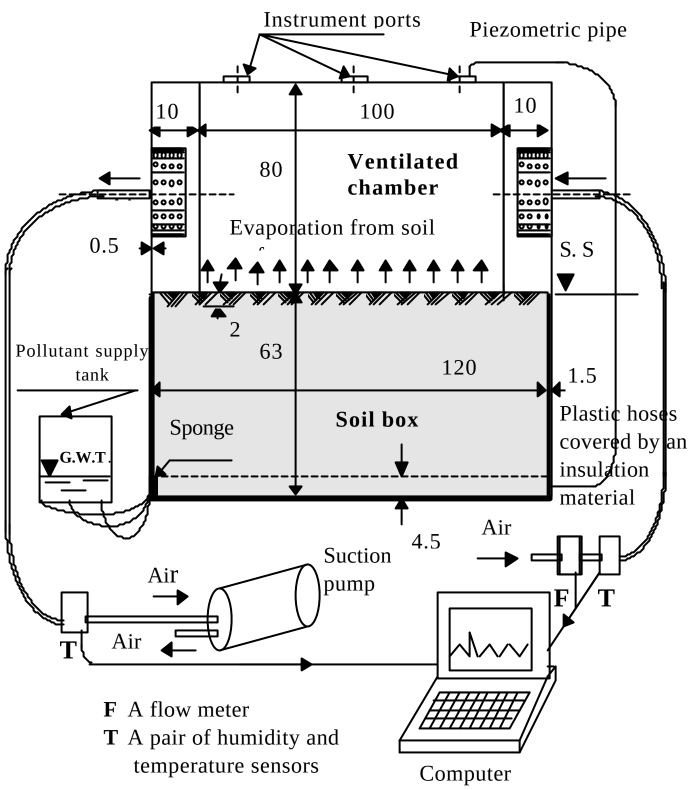

Fig. 1. Cross-section through the measuring apparatus

Table 1. The estimated hydraulic parameters for both fine and coarse sand.

Sand type	θ_s *	θ_r *	α * (m^{-1})	m *
Fine	0.4445	0.0178	0.003587	0.74191
Coarse	0.3861	0.0158	0.0024447	0.69429

* θ_s and θ_r are the maximum and residual volumetric water content and α and m are the van-Genuchten's parameters.

3. **Saturation distribution and pollutant migration analysis:** The solute distribution over the depth of the sand column could be measured experimentally using the electrical potential method. The upward solute

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migration due to evaporation in the unsaturated sandy soil was calculated using the numerical solution of the Convection-Dispersion Equation. Both Richards' Equation for groundwater flow in the unsaturated soil and the Convection-Dispersion Equation (CDE) for solute transport were solved simultaneously using GFEM (Hashem et al., 2000). In this study, the saturation ratio distribution and pollutant (NaCl) migration could be calculated for the two types of sand. We have measured and simulated the saturation ratio after 45.0 and 75.0 days from the beginning time for each type of sand as shown in Figs. 2 and 3. From Figs.2 and 3, it is clear that at the same height above the groundwater table, the degree of saturation is higher in the case of fine sand than in the case of coarse sand. Also, at any time the saturation at the soil surface is higher in the case of fine sand and, accordingly the evaporation rate is higher. We simulated pollutant migration after 45.0 and 75.0 days (Figs. 4 and 5) from the beginning time of each experiment. It is clear from Figs. 4 and 5 that the upward solute travel distance is bigger in the case of the fine sand (*after 45.0 days is* about 21.0 cm and, *after 75.0 days is* about 42.0 cm). In the case of coarse sand, it was 8.0 cm *after 45.0 days*, while is was only 15.0 cm *after 75.0 days.*

4. Conclusions: The saturation profile and pollutant migration could be measured experimentally and simulated numerically using the evaporation technique. The saturation ratio is higher in the case of fine sand than that in the case of coarse sand under the same conditions. The upward solute movement is faster in the case of fine sand than in the case of coarse sand.

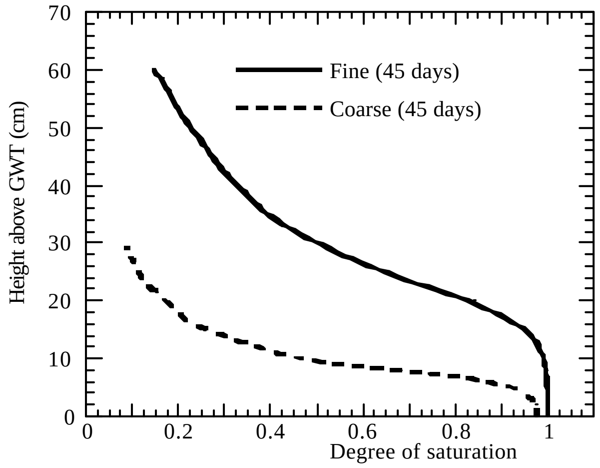

Fig. 2. Relative saturation distribution after 45.0 days from the beginning of the experiments.

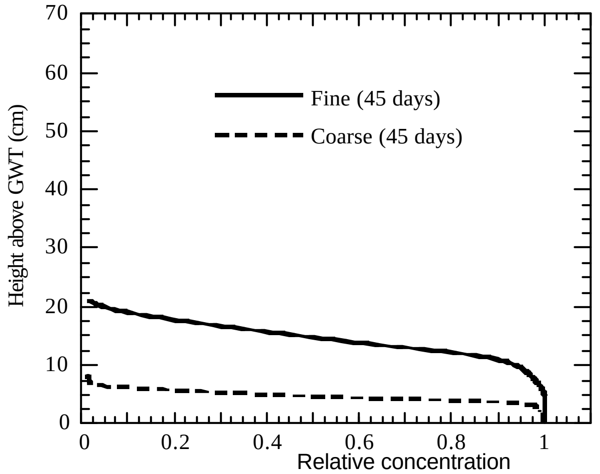

Fig. 4. Relative concentration distribution after 45.0 days from the beginning of the experiments.

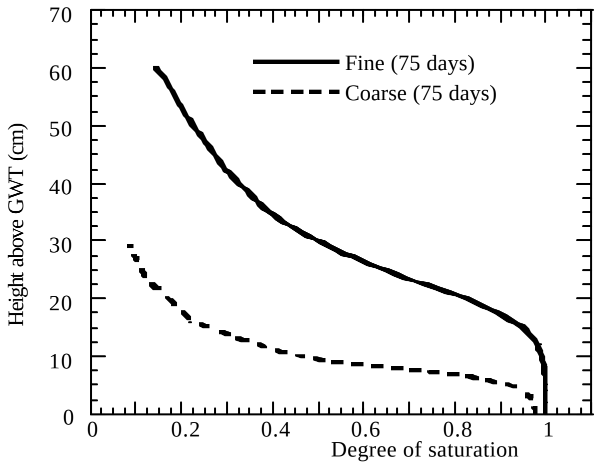

Fig. 3. Relative saturation distribution after 75.0 days from the beginning of the experiments.

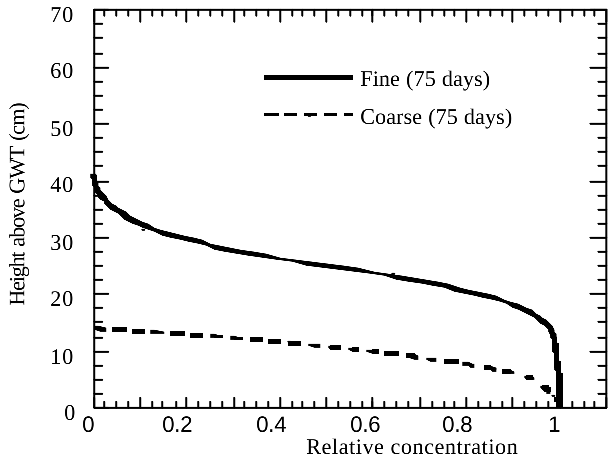

Fig. 5. Relative concentration distribution after 75.0 days from the beginning of the experiments.

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