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Porosity-permeability relationships for subflorescent salt crusts from evaporation of sand columns with varying initial salt concentration

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Salt precipitation due to evaporation from porous media leads to the formation of a salt crust that affects the flow and transport of water and solutes in the top layer of a porous medium, and causes amongst others soil salinization, erosion and land loss, as well as damage to building materials. Despite extensive research on evaporation of saline solutions from porous media, little is known about the effective transport properties of evolving salt crusts besides their importance for accurate modeling of evaporation. Most REV-scale models use porosity-permeability relations to describe how the reduction in porosity through salt precipitation affects the intrinsic permeability and thus the evaporation flux. The aim of this study was to experimentally investigate the relationship between porosity and intrinsic permeability of salt crusts and the associated evaporation using experiments with systematic variation of the initial salt concentration. For this, sand columns were prepared with solutions of MgSO_4 at 0.32 mol/L, 0.64 mol/L, and 0.96 mol/L initial concentration and evaporated until 40%, 30%, or 20% final saturation within the corresponding sample was reached. The mass loss of every sample was measured once a day using a balance in order to determine the evaporation rate. The intrinsic crust permeability was determined using gas flow through the separated dried salt crusts. Additionally, nine selected crusts were partly scanned with a micro-XRCT set-up with 4 μm resolution per voxel in order to determine porosity. The results showed that the evaporation rate was higher for the samples with lower initial concentration, which was attributed to the higher initial saturation pressure and the slower concentration increase of the solution during evaporation. It also was found that the permeability decreased with decreasing final saturation (i.e. increasing time of evaporation) and with increasing initial concentration. This is attributed to the varying amounts of precipitated salt that reduced the pore space. The XRCT measurements showed that subflorescent salt precipitation resulted in deformation of the unconsolidated sand. After segmenting the XRCT grey-scale data sets into air, sand and salt phases using k-means clustering, the segmented sand fraction ranged from 0.35 and 0.49, which was lower than the sand fraction of the initial sample (0.62). This observed deformation is in conflict with the common assumption in modeling evaporation of saline solution with subflorescent salt precipitation, where the porous matrix is assumed to be rigid. Despite the observed deformation, it was found that the initial void fraction (0.38) was reduced to void fractions between 0.12 and 0.31. In addition, a significant correlation between porosity (void fraction) and intrinsic permeability was obtained. However, the use of this porosity-permeability relation in REV-scale modelling of evaporation is not recommended as the change of the pore space not only depends on the precipitated salt volume but also on the (volumetrical) deformation of the porous matrix.

Time Block Preference

Time Block A (09:00-12:00 CET)

References

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