1. Introduction

Saline water evaporation from porous media and salt precipitation affects water management, soil and groundwater salinization, and various other environmental processes (Jardine et al., 2007; Prasad et al., 2001; Russo, 2013; Xiao et al., 2011). Enhancing our understanding of saline water evaporation processes is essential to predict locations and patterns of salt precipitation and the associated drying behavior. Salt precipitation rates and deposition patterns are controlled by complex interactions between the transport properties of the porous medium, atmospheric conditions, and characteristics of the evaporating saline solution (Borgman et al., 2017; Jambhekar et al., 2015; Norouzi Rad et al., 2015; Smits et al., 2012; Vanderborght et al., 2017).

Evaporation from porous media has been the subject of active research in the past due to its central role in the hydrologic cycle and surface energy balance. More recently these efforts have been directed at investigating the effect of the changing climate patterns on the land-climate feedback processes (Decker et al., 2017; Fetzer et al., 2016; Tuttle & Salvucci, 2016). The evolution of evaporation, transpiration, and precipitation rates in the changing climate will undoubtedly affect and will be affected by the distribution and accumulation of salts in soils. Accurate formulation and prediction of evapotranspiration processes therefore relies on improved physical understanding of the mechanisms which govern salt effects on evaporation dynamics.

Basic mechanisms of pure water evaporation from initially saturated porous media are well understood and these are often described in terms of three different drying regimes. In the initial stage, the evaporation rate is relatively constant and liquid is supplied through capillary flow paths to the vaporization plane at the surface (Thiery et al., 2017) (the so-called stage-1 evaporation regime). This stage is followed by a transition
period, where the drying rate continuously decreases due to the disruption of the capillary pathways, into
the final evaporation stage (stage-2 evaporation regime), where all liquid connections to the surface are dis-
rupted and evaporation is dominated by vapor diffusion through the porous medium (Yiotis et al., 2007).
Despite loss of hydraulic connectivity to the surface, stage-2 evaporation rates from the subsurface can
be as high as 50% of potential evaporation rates (Deol et al., 2014). When salt is present in the evaporat-
ing solution, the evaporation process becomes more complex. Evaporation of saline solutions results in
salt precipitation at the vaporization surface when the local solution concentration exceeds its solubility
limit. Recent studies have hypothesized that due to the highly porous nature of the precipitating salt
crust, the ensuing evaporation rate would be controlled by the liquid transport through the evolving salt
layer (Bergstad & Shokri, 2016; Eloukabi et al., 2013; Sghaier & Prat, 2009; Shokri-Kuehni et al., 2017a). Fur-
thermore, during the early stages of evaporation, the rates of capillary flow through the precipitated salt
layer meet the external evaporative demand and may result in a constant evaporation rate similar to the
stage-1 evaporation regime in a pure water system. As evaporation proceeds transport through the precipitated
salt layer is limited, possibly due to the salt precipitation gradually drying out, causing a reduction in the
evaporation rate (Eloukabi et al., 2013; Shokri-Kuehni et al., 2017a). The dynamics of the interacting salt
precipitation layer and its influence on evaporation behavior in porous media is dependent on the prefer-
eential precipitation patterns, which is governed by the presence of porous media heterogeneities. In this
study, we focus on the effects of the presence of capillary-coupled textural contrasts on salt precipitation
and evaporation dynamics.

Natural soils may contain various types of layers, textural contrasts, and material interfaces that reflect
depositional and scouring processes, refilling of cracks formed during freezing and thawing or swelling and
shrinking cycles, and the interception of eolian dust and other local plant alterations. The presence of such
porous media discontinuities induces spatially abrupt changes in the capillarity and flow properties, and
modify transport processes as reported in several studies (Bechtold et al., 2011, Bergstad et al., 2017; Leh-
mann & Or, 2009; Nachshon et al., 2011; Pillai et al., 2009; Veran-Tissoires et al., 2012). In order to understand
and describe salt transport and distribution in soils, it is essential to investigate how the presence of such
heterogeneity influences the evaporative fluxes and salt precipitation dynamics. During evaporation from
porous media containing abrupt textural contrasts (represented here as vertical inclusions of fine and
coarse sand), the main vaporization plane remains anchored primarily at the surface of fine-textured porous
media and is supplied by lateral capillary flow from the coarse domain (Lehmann & Or, 2009). This lateral
flow is driven by a capillary pressure gradient determined by differences in pore size distributions that
drives liquid from the large pores in the coarse domain supplying evaporation from the surface of the fine
domain (capillary pumping) (Lehmann & Or, 2009). Consequently, the fine sand remains saturated long after
the drying front (the interface between saturated and unsaturated porous media) propagates through the
coarse region. A recent study by Bergstad et al. (2017) illustrated the unique role of textural heterogeneity
in promoting preferential salt deposition during evaporation from porous media. Bergstad et al. (2017) have
shown that despite the dominance of evaporation flux from the fine sand region, salt begins to precipitate
preferentially over the coarse regions of the surface for low concentration salt solutions. This counterintui-
tive result is associated with preferential drying (air invasion) of the coarse surface due to lower air entry
pressure (as a result of larger pores in the coarse domain) that reduces the number of remaining evaporat-
izing pores. This in turn, causes locally higher per pore evaporation rates from these spatially distributed
pores (see Bergstad et al. (2017) for detail).

Preferential salt precipitation patterns and salt crust expansion over surfaces of heterogeneous porous
media depends on the pore size distributions and hydraulic properties of the respective domains (Bergstad
et al., 2017). Motivated by the important impacts of the presence of heterogeneity on precipitation dynam-
ics in porous media, we seek to quantify how capillary-coupled porous interfaces and their characteristics
affect salt precipitation patterns and evaporation dynamics of saline solutions by performing a series of
well-controlled drying experiments at the macroscale and microscale.

2. Experimental Considerations

Evaporation experiments were conducted in an environmental chamber at constant temperature of 30°C
and relative humidity (RH) of 30%. Following Bergstad et al. (2017), sand columns containing textural
heterogeneity were packed, in cylindrical columns (70 mm in diameter and 70 mm in height) containing a radially symmetric fine-textured inclusion in the middle of a coarse-textured porous medium. The diameter of the fine inclusion (2.3 cm) was equal to a 1/3 of the column’s diameter (the lateral extent of evaporative water extraction from the coarse to the fine domain extends over the length of the coarse domain (Lehmann & Or, 2009)). Silica sand was separated by sieving into the following size ranges: 1,250–1,600, 1,000–1,250, 700–1,000, 500–700, and 300–500 μm. Six different textural contrasts were created by varying the particle size range of the fine (700–1,000, 500–700, and 300–500 μm) and coarse domains (1,250–1,600 and 1,000–1,250 μm).

All sand columns were saturated with 3 Molal solution of NaCl (note that the solubility limit of NaCl in water at 30°C is 6.14 M). Additional experiments were conducted using pure (deionized) water in sand columns containing similar textural contrasts for reference (sand grains were packed into a cylindrical column with 160 mm in height and 80 mm in diameter in this case). The water mass loss rates from the columns were recorded automatically every 5 min using digital balances, while an automatic imaging system photographed the surface of the columns every hour to record salt precipitation development. Customized codes were developed in MATLAB following the procedure described in Shokri et al. (2008) to segment the recorded images into binary images, where each pixel was assigned a value corresponding to either uncovered sand surface (black) or salt-covered sand surface (white) based on the grey level intensity. This enabled us to analyze the evolution of fractional surface coverage by salt precipitation at the surface of coarse and fine domain, respectively.

In addition to the sand column experiments above, we studied details of the liquid phase distribution in the hydraulically coupled coarse and fine sand domains during evaporation using glass Hele-Shaw cells (100 mm height, 50 mm width, and 4 mm thickness) with half of the cell filled with sand with particle size in the range of 1,000–1,250 μm, and the other half packed with fine sand (either 300–500 or 700–1,000 μm). The experiments with the Hele-Shaw cells were conducted at the same environmental conditions and NaCl concentration as before. Images of the cells were recorded and segmented in MATLAB, which was used to quantify the dynamics of the drying front displacement in sand packs in the presence of vertical textural discontinuity.

Direct and detailed observations of textural contrasts effects on pore-scale dynamics of liquid phase distribution and salt precipitation during evaporation were obtained from time-lapse X-ray micro-computed tomography (CT) imaging. Two columns with 10 mm diameter and 20 mm height were packed with different textural contrasts in the same arrangement as the macroscale columns (and saturated with the same NaCl concentration), where the fine sand was 300–500 μm in both cases and the coarse sand varied from 1,000–1,250 to 1,250–1,600 μm in the two cases. The experiments were carried out within a Nikon X-Tek 225 kV/320 kV customized bay (operating at 80 kV and 250 μA) housed in the Henry Moseley X-ray Imaging Facility of the University of Manchester. Each 3-D scan (24 scans one taken every 60 min) was computationally reconstructed from 2,000 radiographs. The evaporation experiments and image analysis were performed following the procedures detailed in Bergstad et al. (2017). Additionally, Avizo Fire 9.2 was used to visualize the segmented X-ray scans in 3-D.

The capillary pressure-saturation relationship (also denoted as the soil water characteristic curve) of each sand domain with a well-defined particle size range was measured using a HYPROP device (Decagon Devices, USA). The parametric van Genuchten (VG) model (Van Genuchten, 1980) was used to describe the experimental results with the VG parameters presented in Table 1. The obtained water retention curves are presented in Figure 1. The results presented are in good agreement with values reported in

| Particle size range (μm) | hₐ (mm) | α (mm⁻¹) | n (−) | θₛ (−) | θ₀ (−) |
|--------------------------|----------|-----------|------|--------|--------|
| 300–500                  | 165      | 0.00526   | 14.31| 0.073  | 0.404  |
| 500–700                  | 123      | 0.00608   | 9.50 | 0.085  | 0.390  |
| 700–1,000                | 80       | 0.00870   | 8.86 | 0.106  | 0.438  |
| 1,000–1,250              | 60       | 0.01167   | 8.15 | 0.103  | 0.430  |
| 1,250–1,600              | 50       | 0.01340   | 7.55 | 0.085  | 0.370  |

Table 1: Air Entry Pressure hₐ, Saturated and Residual Water Content (θₛ and θ₀, Respectively) and Shape Parameters n and α, Fitted to the Van Genuchten Model (1980) to Describe the Water Retention Curves of Sand Domains Used in This Study.

BERGSTAD ET AL. 3878
the literature for sands of similar particle size distributions and porosity (Lehmann et al., 2008; Yanful et al., 2003).

The air entry value, $h_b$, was calculated using the equation given in Shokri and Salvucci (2011):

$$h_b = \frac{1}{z} \left[ \left( \frac{n}{n-1} \right)^{2-\frac{1}{n}} - \frac{1}{n} \left( 1 + \frac{n}{n-1} \right)^{2-\frac{1}{n}} \right]$$

where $z$ and $n$ are the VG parameters of each sand. In this work, we quantify the magnitude of the textural contrast between fine and coarse sand as $h_{fb} = h_{cb}$, where $h_{fb}$ and $h_{cb}$ are the air entry values of the fine and coarse sand, respectively. Consequently, as $h_{fb} = h_{cb}$ increases, the degree of textural contrast increases.

### 3. Results and Discussions

#### 3.1. Effect of Textural Contrasts on Evaporation From Porous Media

Figure 2a illustrates that for the evaporation of water, the duration of stage-1 evaporation from heterogeneous sand packs increased with increasing levels of textural contrast (expressed in terms of the ratio of the fine to coarse air entry values: $h_{fb} = h_{cb}$). This result is in line with the analysis presented in Lehmann and Or (2009). Surprisingly, this correlation appears not to hold for saline water, as shown in Figure 2b. Our experimental data show no significant change in the duration of the constant evaporation rate period for all textural contrasts studied. This would appear to be due to the presence of salt precipitation at the surface. This is a counterintuitive result, since the presence of such heterogeneities has momentous effects on the transport processes and phase distributions during evaporation (Bechtold et al., 2011; Lehmann & Or, 2009). However, our results clearly show that despite the presence of increasingly pronounced heterogeneity, the evaporation dynamics is controlled by the properties of the precipitated salt at the evaporating surface.

In the initial stages of evaporation, the presence of salt in the evaporating solution causes the suppression of the saturated vapor pressure resulting in a lower evaporation rate compared to evaporation of pure water under similar conditions (Shokri-Kuehni et al., 2017b) (Figure 2). As the salt begins to precipitate and expand over the surface (active evaporation areas are converted to precipitation areas), the active evaporation surface is extended to the exterior of the precipitation layer and the evaporation rate is controlled by the pore-scale dynamics of the salt precipitation, which is considered next.

#### 3.2. Pore-Scale Salt Precipitation Dynamics

Investigation of the formation and growth of the precipitated salt at the surface of evaporating sand columns at high spatial and temporal resolution was made possible by means of time-lapse X-ray microcomputed tomography (CT). The X-ray images reveal that the precipitated salt at the surface goes through a complex dynamical evolution which may influence the evaporation behavior.

Figure 3a shows an example of the evolution of the precipitated salt around a sand grain at the surface of the coarse domain in a heterogeneous sand pack with $h_{fb} = h_{cb} = 3.30$. The time sequence illustrates how the growth of the salt results in contact with neighboring precipitation (6 h) which ultimately results in significant deformation of the
shape and distribution of the precipitated salt (8 h). This suggests that solute redistribution within the precipitated salt has caused dissolution and subsequent regrowth of crystals. Such deformations, or restructuring, of precipitated salt was observed regularly throughout the X-ray experiment (for both columns with different textural contrasts). This direct observation confirms that the salt precipitation comprises liquid phase, which is regularly transported within the porous precipitated salt network at the surface, causing dissolution and recrystallization. Figure 3b shows salt precipitation formed around another grain at the same surface, and illustrates the highly porous structure of the salt, and that the porosity of the precipitated salt continuously changes during drying. Shokri-Kuehni et al. (2017a) recently illustrated that precipitated salt at the surface is a highly evolving porous structure, which facilitates a capillary supply of the evaporating solution from the porous medium to the external surface (acting as a “capillary conductor”). The pore-scale results (Figure 3) verify the evolving porous structure of precipitated salt during evaporation from porous media.

The pore-scale observations presented in Figure 3 could be considered as a first step toward further pore-scale quantifications specifically targeting the link between the complex evolving geometry of precipitated salt and the dynamics of evaporation. In order to describe the drying process in the presence of salt (Figure 2b), it is necessary to take into account such dynamics. Bergstad and Shokri (2016) reported similar evaporation curves to Figure 2 from sand packs with different mixed wettability conditions saturated with NaCl solution. They showed that while the presence of hydrophobic grains does reduce capillarity (and subsequently the duration of stage-1 evaporation of pure water), the capillary pumping effect of wet salt precipitation at active surface sites supports the evaporative demand, which results in negligible effect of mixed wettability on the overall evaporative mass loss and duration of stage-1. These results suggest that the formation of precipitated porous salt on the surface of heterogeneous sand packs supplying the evaporative demand introduces an additional level of control on the resulting evaporation behavior and that in so doing reduces the dependency of drying dynamics on the porous media heterogeneities. This is an important consideration for future modeling approaches and predictions of saline water evaporation dynamics, with significant impacts on hydrological applications and water management.

3.3. Macroscale Salt Precipitation Patterns Influenced by the Textural Contrast

The recorded images of evaporating heterogeneous sand surfaces were segmented to quantify the surface fraction covered by precipitated salt for the coarse and fine domains. This information enabled the assessment of the role of textural discontinuity on salt precipitation patterns, as shown in Figure 4. The results in Figure 4 correspond to salt precipitation patterns observed 1 and 6 days from the onset of the evaporation experiment. Results suggest that with the decrease in the strength of the textural contrast between fine and coarse sand (i.e., lower ratios of $h_F^b/h_C^b$), the salt precipitation on the coarse surface is reduced for the same initial salt concentration (similar in all sand columns). In contrast, a larger fraction of the fine domain surface was covered by the precipitating salt for lower strength of textural contrasts.

Furthermore, the results show that the onset of salt precipitation on the fine surface was strongly influenced by the difference between the air entry pressure of fine and coarse sand $\Delta h_{eb} = h_F^e - h_C^e$. When the textural contrast between fine and coarse domains increases, the fine surface remains saturated for a longer elapsed time, reflected in larger values of $\Delta h_{eb}$ (Lehmann & Or, 2009). These considerations may suggest that the onset of precipitation on the fine surface is strongly correlated to the air entry pressure of this domain, which would explain the observed delay in the onset of salt precipitation for high textural contrasts (Figure 4b).

For a given initial salt solution concentration, and for similar external conditions, salt precipitates first where the local concentration at the phase change plane exceeds the solubility limit. It follows that preferential
salt precipitation is strongly influenced by higher local evaporation flux for a given porous medium surface. In a heterogeneous sand column, the coarse domain is preferentially invaded by air, resulting in formation of disconnected liquid clusters separated by dry sand on the surface. The evaporation flux from the few remaining liquid filled pores is expected to be higher than for a same sized pore on the nearly saturated fine surface (Shahraeeni et al., 2012). Consequently, we expect early onset of salt precipitation over the coarse surface (Bergstad et al., 2017). The fewer of these pores on the surface (i.e., the greater distance between disconnected liquid clusters on a surface), the higher the evaporation flux is per pore (Aminzadeh & Or, 2017; Fabrikant, 1985; Shahraeeni et al., 2012). The observed precipitation patterns (Figure 4) suggest that, since a higher textural contrast results in earlier and faster salt precipitation on the coarse surface, reflecting a higher evaporation flux, the spacing between (or number of) wet pores after air invasion into the coarse surface must have increased with textural contrast (which is discussed next).

3.4. Textural Contrast Effects on Preferential Capillary Flow and Salt Precipitation

Two sets of evaporation experiments were conducted using Hele-Shaw cells to investigate details of the drying front (defined as the interface between saturated and partially wet zones) depth and velocity as it recedes through the fine and coarse sand domains. The magnitudes of the textural contrasts in these two sand packs were $h_f^{b}/h_c^{b}=2.75$ and 1.33 (note that the coarse sand domain was identical in both sand packs and the textural contrasts were varied by changing the particle size of fine sand domain). The results are presented in Figure 5. As illustrated in other studies (Bergstad et al., 2017; Lehmann & Or, 2009), the drying front is formed preferentially in the coarse domain first due to the presence of larger pores (lower air entry pressure). During pure water evaporation, the fine domain remains saturated until the drying front depth in the coarse domain exceeds the characteristic length $D_{hb} = h_f^{c} - h_c^{c}$ (Lehmann & Or, 2009), marking the onset of air invasion and formation of a front in the fine domain.

Our results confirm that for a large textural contrast, the fine domain remains saturated for a longer time due to the greater capillary pressure differences between the fine and coarse domains (and the ability to extract water from larger depths in the coarse domain). Based on the air entry values obtained from the water retention curves (Figure 1), the characteristic length for the two systems was found to be 105 and 20 mm for $h_f^{c}/h_c^{c}$ equal to 2.75 and 1.33, respectively. However, Figure 5a indicates that desaturation of the fine surface starts when the depth of the drying front in the corresponding coarse domain was ~70 and 17 mm (33% and 15% shorter than the characteristic length for pure water). This is due to the effects of the desaturating salt precipitation layer on the continuity of the liquid phase to the surface, and the corresponding evaporation dynamics discussed above, resulting in premature decoupling of the drying front. This finding is relevant to practical applications because it suggests that the presence of salt may cause the disruption of the essential liquid supply from saturated zone to the soil surface affecting vegetation.

The preferential displacement of the drying front in the coarse domain, influenced by the degree of textural contrast, also affects the preferential deposition of salt at the surface. The pressure at the drying front in the coarse domain might be approximated as the air entry value of the coarse sand $h_c^{c}$ (assuming near-hydrostatic conditions as described in Shokri et al. (2008)). Therefore, the pressure head at the surface can be estimated as the summation of the air entry value and gravitational head (i.e., the depth of the drying front). Under the same cumulative mass loss, the drying front is deeper in the coarse domain for higher
textural contrast as a result of the faster moving front (greater capillary gradient), and the pressure at the surface is higher (more negative) (Figure 5). According to the water retention curve, higher surface pressure corresponds to the lower water content at the surface (Figure 5d). Less water at the surface may suggest the presence of fewer liquid patches with greater spacing supporting the evaporative demand. As already shown in Bergstad et al. (2017), greater spacing between liquid patches at the surface increases the evaporation per pore which eventually results in earlier onset of salt precipitation at the surface and consequently faster spread of salt precipitation on the coarse surface as the textural contrast increases. This explains the result observed in Figure 4. Understanding the detailed mechanisms which govern preferential salt deposition in the more representative heterogeneous porous media may aid the development of effective strategies for removing salts from the critical root zones and reclaiming salinized fields (Berezniak et al., 2017).

A closer look at the effect of textural contrast strength on preferential salt precipitation patterns was obtained from time-lapse X-ray microtomography. This enabled us to directly observe and verify some of the mechanisms proposed above.

3.5. Pore-Scale Quantification of Salt Precipitation in Heterogeneous Porous Media

The pore-scale images obtained from the X-ray tomography experiments were analyzed in order to obtain the evolution of the mass of salt precipitation at the surface of coarse and fine domain for two textural contrasts, $h_C/h_f=2.75$ and $1.33$. As observed in the Hele-Shaw experiments, the majority of the evaporative mass loss is supplied from the coarse region due to the lower resistance for air invasion in larger pores.

Figure 5. (a) The evolution of mean drying front depth; (b) the velocity of the drying front in the coarse and fine sand domains for two columns with different textural contrasts with values of $h_C/h_f=2.75$ and $1.33$. The x axis in (b), $M(-)$, represents the cumulative water mass loss by evaporation as a fraction of the final mass loss measured; (c) the segmented images (black = saturated region, white = unsaturated region) of the heterogeneous Hele-Shaw cells 2.5 days from the onset of the evaporation experiments. The coarse sand was identical in both experiments with the particle size range of 1,000–1,250 μm; however, the fine sands with particle size ranges of 300–500 μm was used in $h_C/h_f=2.75$ and 700–1,000 μm in $h_C/h_f=1.33$. The estimated pressures at the column surfaces $P_{High}$ and $P_{Low}$ with $h_b$ the air entry pressure and $L$ the drying front depth; and (d) the water retention curve for the coarse sand which confirms the presence of lower water content at the surface of the coarse domain in the column with the higher textural contrast (due to higher capillary pressure).
Retracted (supporting information Figure S1) (Bergstad et al., 2017). Our X-ray CT results further illustrate the same development of the salt precipitation patterns as observed in the macroscale evaporation experiments (Figure 6a). Salt precipitates first on the coarse surface of the column with the higher textural contrast, and obtains a much larger amount of salt precipitation throughout the evaporation process. Conversely, the onset of precipitation on the fine surface is delayed compared to the column with the lower textural contrast. In both X-ray CT experiments, the majority of the total cumulative salt precipitated above the coarse domain of the heterogeneous surface.

By quantifying the saturation of the liquid phase in each horizontal 2-D slice of the X-ray CT scans, we could determine the evolution of the average water content at the coarse surface as influenced by textural contrast. Figure 6b shows that, for the same mass loss from the coarse domain, the surface water content was consistently lower for the column with the greater textural contrast. This result confirms the analysis presented in Figure 5, and supports the proposed mechanism responsible for the observed salt precipitation patterns; the magnitude of the textural contrasts influences the preferential movement of the drying front in the coarse domain, which affects the pressure at the surface. This results in a lower surface water content, which corresponds to an increase in the evaporative flux from individual active pores supplying the evaporative demand. Ultimately this causes earlier onset and accelerated growth of salt precipitation (Figures 6c and 6).

4. Summary and Conclusions

Evaporation from texturally heterogeneous porous media saturated with NaCl solution with different degrees of textural contrast was investigated under constant external conditions. The evaporation curves and precipitation patterns were recorded for six different textural contrasts between coarse and fine sand distinguished by their air entry pressure ratios $h_F^b/h_C^b$. An additional set of evaporation experiments was conducted using Hele-Shaw cells to investigate details of preferential front displacement and potential.
consequences on salt precipitation patterns. Finally, time-lapse X-ray computed tomography was used to confirm the obtained results at the pore-scale. Results show that, for pure water, an increase in textural contrast in porous media results in prolongation of the stage-1 of evaporation. However, if saturated with NaCl solution, the textural contrast had no noticeable effect on the duration of the constant evaporation period. We attribute this unintuitive result to the formation of precipitated porous salt on the surface, which controls the evaporation process (Bergstad & Shokri, 2016; Eloukabi et al., 2013; Sghaier & Prat, 2009; Shokri-Kuehni et al., 2017a, 2017b). By means of X-ray tomography, we have demonstrated the highly porous and dynamic nature of salt precipitation through direct pore-scale observations.

The contrast between the hydraulic properties of the fine and coarse sand domains influence the velocity of the drying front in the coarse domain, which in turn determines the pressure and water distribution at the coarse surface. The local distribution of wet pores impacts the evaporation flux and subsequently the salt concentration in the solution. We illustrate that increasing the textural contrast between interacting coarse and fine domains results in earlier and faster salt precipitation on the coarse domain, but delayed precipitation on the fine surface. This behavior was attributed to the higher negative pressure at the surface of the coarse domain (the presence of less water at the surface) due to the faster receding drying front in the coarse domain of the heterogeneous sand pack as the textural contrast increases. This process leads to more evaporation per pore on the surface of the coarse domain (Aminzadeh & Or, 2017; Shahraeeni et al., 2012) thus earlier and faster precipitation (Bergstad et al., 2017). Furthermore, we show that the onset of precipitation on fine surface is related to the magnitude of the difference between the air entry pressure of the coarse and fine sand domain $\Delta P_a$.

The results reported here are important for improving physical understanding and accuracy of modeling approaches for management of saline soils, as in most natural and agricultural cases there exists domains with textural contrasts of different magnitudes, and the findings presented here will be instrumental in identifying and describing the areas where precipitation occurs along with the associated evaporative behavior.

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Erratum

In the originally published version of this article, Figure 1, 2, 4, 5, 6, S1 and Table 1 contained errors relating to the range of particle sizes and data corresponding to the water retention curve of sands used in the experiments. They were corrected, including the captions and related article text. All corrections have been made to the online version of this article, but not the PDF, and the online version may be considered the authoritative version of record.

Figure 1

Figure 2
Figure 4

(a) Fraction of surface covered vs. $h_b^F/h_b^C$.

(b) Images of samples with different $h_b^F/h_b^C$ ratios:

- $h_b^F/h_b^C = 1.02$
  - 1 day: Coarse
  - 6 days: Fine

- $h_b^F/h_b^C = 3.64$
  - 1 day: Coarse
  - 6 days: Fine
Figure 5

(a) Drying front depth (mm) vs. moisture content (M)

(b) Drying front velocity (mm/day) vs. moisture content (M)

(c) Heads vs. Water Content

(d) Comparison of experimental and VG model data

Figure 6

(a) Mass of precipitated salt (g) vs. time (hrs)

(b) Surface tension (mN/m) vs. mass loss (g)

(c) Coarse and fine columns at 3 hrs and 15 hrs
**Figure S1**

![Graph showing M/M_T vs Time (hrs) for different particle size ranges.](image)

**Table 1**

| Particle Size range (μm) | (mm) | α (mm⁻¹) | n (-) | (-) | (-) |
|--------------------------|------|-----------|-------|-----|-----|
| 300-500                  | 203  | 0.00423   | 13.92 | 0.076 | 0.404 |
| 500-710                  | 126  | 0.00673   | 12.90 | 0.109 | 0.412 |
| 710-1000                 | 63   | 0.01252   | 8.86  | 0.106 | 0.438 |
| 1000-1250                | 61   | 0.01193   | 7.06  | 0.096 | 0.440 |
| 1250-1600                | 56   | 0.01340   | 7.55  | 0.084 | 0.370 |