

Moisture transport during poultice application

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Abstract

Water movement is the key parameter in poultice application for desalination. Water is the eluent and transport medium for the salts to be extracted from the porous substrate. While from the hypothetical point of view the dynamical processes of water ingress, dissolution of salts, transportation and precipitation seems to be well known, measured data on the water quantities at specific stages of the process are scarce. Especially, time approximations about the change in main movement direction of the water are unidentified. By experimental data we give indications to the total amount of water used with different poultice compositions and the development of the water ratio during the process until equilibrium dryness is reached. In conclusion we suggest increasing the ratio of water and probably the poultice layer thickness from cycle to cycle to increase the effective cross section stepwise.

Keywords: desalination, water movement, salt transport, poultice material

1. Introduction

Desalination by poultice applications is a widely applied technique in restoration.¹ The general idea is to apply temporarily an additional layer on the salt contaminated porous material. That poultice layer brings water to and into the substrate material. Salts dissolve in

the water. With time water evaporates at the surface, which is the poultice surface. The water in the porous material moves to the poultice where it evaporates. The dissolved salt ions are transported in the poultice. When the water evaporates the salts precipitate. The salts are eliminated from the object by removal of the poultice. - Thus there are three moisture pathways during poultice application to be regarded which happen partially in parallel and change their magnitude during the process. There is the ingress of water from the poultice into the substrate and in the substrate, and then there is the reflow from the substrate to the poultice and finally the evaporation from the poultice. Evaporation, also to be regarded as a driving force, acts from the very beginning, although the first situation to be regarded is the water ingress from the wet poultice into the dry substrate due to concentration balancing and capillary suction. Effects of gravitational flow will not be discussed here, but should be taken into consideration much more in future.

Of course in practical execution of that simple and effective idea some more effects do happen, sometimes limiting the efficiency of the application. First to mention is that the procedure acts on the surface of salt contaminated porous material. Thus it is to be assumed, that it does not effect to salts sitting deeper in the material. What could be a drawback could also be regarded as advantage. In the very most cases the salts are concentrated near to the surface, thus poultices act where the problem is and so not af-

fect other parts. Nevertheless the question occurs to which depth that argument is valid. Especially in cases where no or minor evaporation happens and the poultrices are wet all the time of application² the cross section where the effects of diffusion is effective is not clear. However, we focus here on drying poultrices and address their limitations by formulating the requirements: The poultrice material should be free of salts. The same applies to the water to prepare the poultrice. Thus the use of demineralised water is recommended. The ready to use wet poultrice shall be workable on site. The material is either applied by trowel or spittle, or is sputtered, than in terms of viscosity it has to fulfil the requirements of the spraying device. The poultrice has to adhere to the surface to the object. The adherence has to stand all the time of application, as lost of contact does terminate the function. On the other hand the poultrice should be removable from the surface easily and free of residues. The poultrice has to bring the optimal amount of water to the system, enough to get salts in solution but on the same time not flush the salts deeper into the material. Finally the poultrice has to catch the salts. To reach all these demands nearly all poultrices for desalination nowadays are multi component systems. There is material to carry the water, clays to secure adherence and workability, and matrix components for stability, minimising the shrinking and providing a pore structure.^{1,3}

In the study presented here we show the time resolved moisture development in three different substrate materials treated with five different poultrice types.

2. Materials and methods

2.2. Building material to desalinate

Three different important building materials were chosen for the experimental work. Two varieties of natural sandstone material of Elbe Sandstone: Postaer Sandstone and Cottaer Sandstone and one type of brick was used for the tests. In *table 1* some data of those porous building materials is presented, detailed material description is given by.⁴

2.3. Poultrice material

Five commercially available poultrice materials from four trade specific producers were chosen: RE and RA are from building material companies, RI, for fine grained materials, and RII, for coarse grained, from a producer specialises on restoration material and material A is pure cellulose (BC200). The material types were characterised optically, by XRD and sieve measurements, the workability of the pasted material was noted, as well as the development during application. Furthermore on prisms of the hardened poultrice strength measurements were executed.

Material/sample code	Postaer Sandstone/P	Cottaer Sandstone/C	Brick/Z
Total pore volume Vol. (%)	21	22	-
W-Value (kgm ² h ^{-1/2})	9.12	5.61	4.94

Table 1: Three important building materials were chosen for experiments

2.4. Methods, sampling procedure

To win insight in the state of water movement at eight pre-defined time stages dummies were destructively sampled. Consequently for each of the five poultice materials eight dummies from three substrate materials were prepared. The natural sandstone was cut into blocks of 10x15x10 cm, two bricks pieces were glued together to win comparable surfaces for the experiments of 11.3x15 cm. The block sides were sealed, the surfaces contaminated with NaCl-salt spray. All dummies were marked with a 50 μ l drop of ink.⁵ Samples were taken in increasing time intervals after 4 hours, 7 hours, 1 day, 2 days, 3 days, 6 days, 2 weeks, and 3 weeks. At each sampling stage the sta-



Figure 1: Chopping of the block

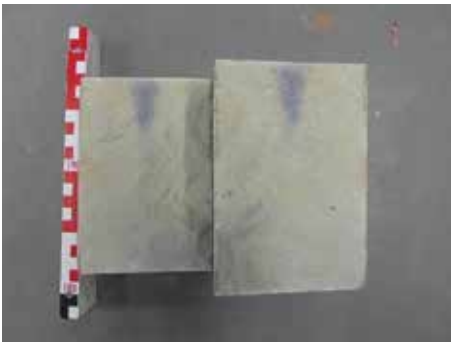


Figure 2: Ingress of ink drop

te of the system was visually inspected, the poultice removed for visual inspection, moisture and salt determination, and the substrate block gravimetrically inspected, drill powder sampled in 12 stages of 1 cm depth and analysed for moisture content⁶ and salt content by electrical conductivity. Finally the block was chopped in stone masons fashion for further visual inspection of the ink drop.

3. Results and Discussion

3.1. Poultice material

Generally looking quite similar with naked eye you could notice in dry raw poultice material RE sand, clay and cellulose, RA contents lesser sand but foam glass spheres, R I looks like pure powder and R II appears as powder with some sand. Table 2 shows significant material data of the poultices, from mass related water content (Wc) as recommended by the producers and the resulting mass of water provided to the wall (Wp). The strength data was determined on samples comparable to the end stage of the desalination action.

Obviously there are major differences in the poultice performances due to divers material compositions. *Figure 3* shows their size fractions with standard sieves. When it comes to the creation of specific pore sizes for effective desalination as recommended by⁷ we suggest to define adapted mesh combinations for the future. Of course the cellulose content in all mixtures hampers the sieving. For displaying the results (diagramms in *Figure 3*) giving the sieve fraction in mass could be misleading due to different densities e.g. sand and foam glass. Reference to volume lead to other difficulties.

Figure 4 gives the XRD patterns of the four smallest mesh fractions, where the clay is to be expected. Here significant

poultice/ code	Wc [-]	Wp [Lm ⁻²]	shrink [mm/m]	Comp. Strength	Flex. Strength	E _{mod,dyn}
RE	0,322	7.0	21.1	1.63	0.79	2.95
RA	0,600	7.7	21.6	0.68	0.41	0.34
R I	0,475	8,7	72.0	nd	1.65	3.13
R II	0,475	6,6	18.7	1.16	0.50	1.03
A	4,500	14.8	52.1	nd	0.06	nd

Table 2: Five commercially available poultice materials

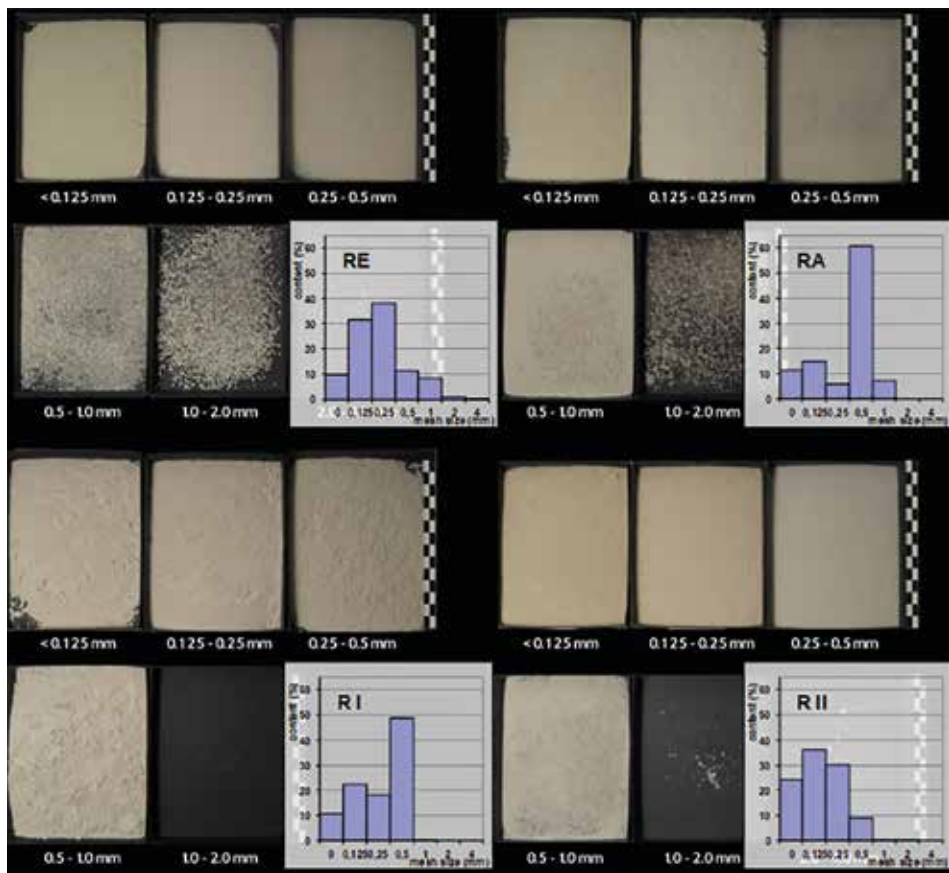


Figure 3: Size fractionated poultice materials (A – cellulose not displayed)

material differences become obvious as sometimes bentonite, sometimes kaolinite is used in the industrial produced material mixtures. Thus as the clays manipulate the workability, effect the work of later cleaning und influence the final strength we could not yet decide if it is the type of clay or the amount or the total sieve line, which leads with RI to those problematic results of high shrinkage, which got also visible through the experiments.

3.2. Water distribution vs. time

The customer has to find out, which poultice material works best in his subject on the given substrate. Wendler⁸ suggested a classifying parameter to evaluate the effectivity of different poultice mixtures by the time the water movement is changed. As to be seen in Figure 5 (first column) it is evaluated when the wetted substrate begins to loose weight. That

happens in most cases after 4 h or 7 h, sometimes 24 h. Despite the lowest W-value laboratory determined for brick the water uptake in the very first (4) hours is always higher than into the sandstones. The data provides the willingness of the poultice to release water to the system: $A >> RA \geq RE >> RI \geq RII$. In that very first 4 hours the sandstones under all poultices take always about 20-30% of the water equal to the minimum of what the brick does take. There the pore system of the substrate is the limiting factor of water uptake. Taking into account the experimental procedure we conclude, that the graviational effects of water flow in those partially supersaturated water systems have to be taken into account much more.

When the poultice gets dryer than the substrate the general water movement is returned at least mathematically. Nevertheless in parallel the water front in the substrate moves on. That is to be seen in Figure 5 2nd column, where the water con-

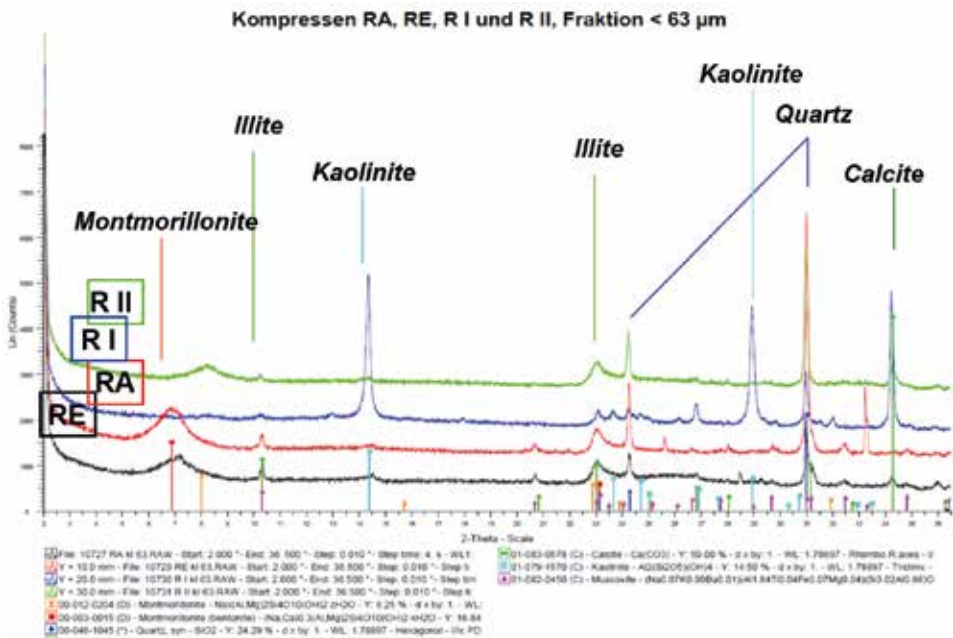


Figure 4: XRD pattern of four poultice materials, smallest mesh fraction

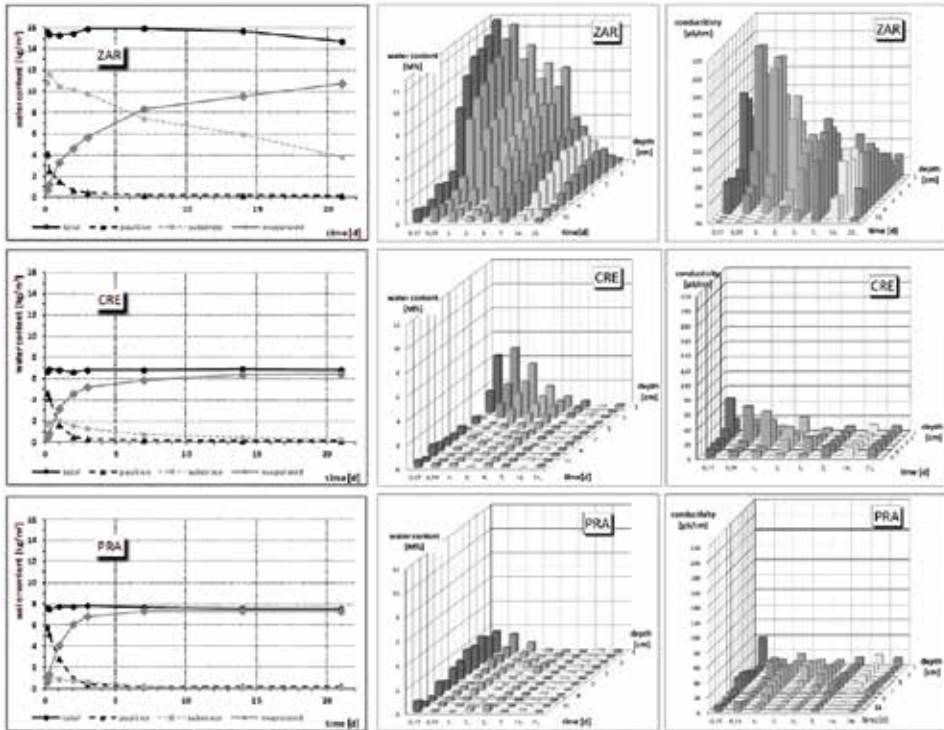


Figure 5: 1st column: water contents in experiment: total, poultice, substrate and mount evaporated vs time; 2nd: depth resolved water content; 3rd: conductivity results

tent in the substrate is shown in all depth at all investigated time stages. In brick material most poultices affect a depth about 4 to 5 cm. In Postaer sandstone RE an RA reach about 7 cm while R I and R II on the other hand affect 4 cm which partially can be explained by a problematic performance during the application.

In spite of the lower W-value the Cottaer sandstone it tends to take up more water than the Postaer Sandstone. It is important to note, that Cottaer sandstone in many cases has not completely dried out after 21 days. Pure cellulose carries about double of the water into the system compared to the poultice mixtures. With such a cellulose treatment Postaer sandstone can be wetted totally down to 12 cm depth.

3.3. Water related effects

The results of the conductivity measurements are heterogenous. Most probably the concentration of contamination was too low, nevertheless trends are to be seen. In the first hours in all cases the salt peak from the very top is flushed into about 3 cm depth. After 1 day it broadens and, of course, decreases. A low, decreased restitic contamination in all the profile where water took access to is visible until the very end of investigation. Under poultice material which loses eager contact during the application, most probably due to high shrinkage and low adherence to the substrate, a top peak and a tail into the materials is visible.

Also the ink drop test has limited interpretation potential. The ink was practi-

cally invisible in the brick, showed a cone in Postaer sandstone. In Cottaer sandstone it was hardly visible but tended to be vanished on the top and was most intensive in about 2 cm depth. Also in the poultice material the ink was solely visible in the pure cellulose material AC. However, we recommend to use much more than 50 µl ink for contamination for possible future experiments.

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4. Conclusion

In the study five different poultice materials were characterised and tested on three substrate materials. The commercial produceres use different material com-

binations to offer workable poultices. Referring to the amount of water provided by the pultice for the desalination the materials have minor differences, while pure cellulose is able to really flood a system. The performance of the poultices already when simple material data like shrinkage measurement is taken into account, is for some of the commercially available products problematic. The advantages and disadvantages of specific clays taken for the mixtures are not well understood. Here much more investigation on one and but also information, what kind is implemented, is needed.

The study shows that the moisturing of the substrate happens within the first hours of poultice application. Depth of several centimeters are reached, a distribution of salts from the top into the stone at that stage is unavoidable. Water depth penetration seems solely partially predictable and connected to the W-value of the substrate. Gravitation effects and teh water release properties of the poultice are effects much more to be regarded. Thus for successively progressive maintaining deeper zones it is adviseable to start with thinner (less water) poultices in the beginning and increase the layer thickness for cycle to cycle to increase the effective cross section stepwise.

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