

TU/e TPM

Salt remediation by electro-kinetics

Leo Pel
Kashif Kamran, Alison Sawdy-Heritage

Faculty of Applied Physics
Transport in Permeable Media
Eindhoven University of Technology
The Netherlands

www.phys.tue.nl/nfcmr
l.pel@tue.nl

Transport in Permeable Media

TU/e TPM


Poultice/substrate systems Limitations

- Pore size
 - » Limited range of materials
- Effective depth
 - » 5-10 cm ... in practice up to 1m
- Not a permanent solution
 - » Decay often starts again
- Laborious
 - » Poultice... from preparation to application

Transport in Permeable Media

TU/e TPM

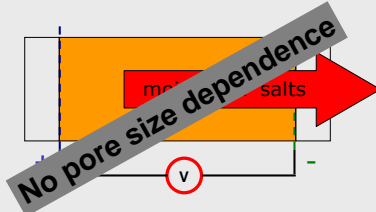
Electro-Remediation



Transport in Permeable Media

TU/e TPM

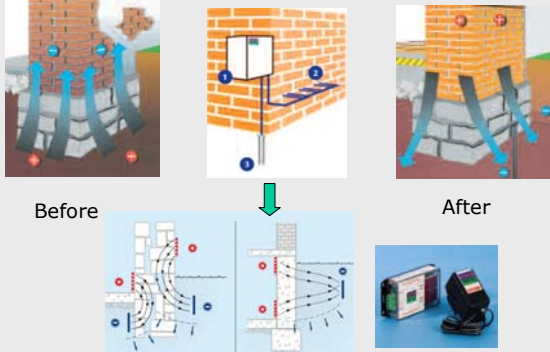
Electro-Remediation



Fired-clay brick, mortar, gypsum, concrete

Transport in Permeable Media

TU/e TPM




Before After

Transport in Permeable Media

TU/e TPM

electro osmosis the certain cure




Transport in Permeable Media

TU/e TPM

Before



After

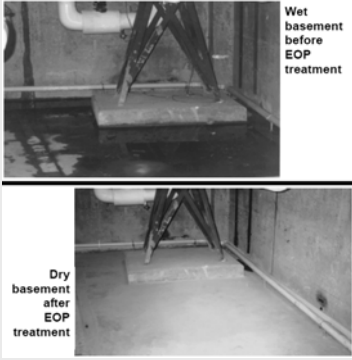


After 269 days

Transport in Permeable Media


TU/e TPM

US Army corps
of engineers



Transport in Permeable Media

TU/e TPM



Transport in Permeable Media

TU/e TPM

Electrokinetic desalination:
can it work ?

electro osmosis: drying
electro kinetics: salts


Transport in Permeable Media

TU/e TPM

Comparison: Transport Processes

- Diffusion
– Concentration gradient
- Advection
– Pressure gradient
- Electro-migration
– Potential gradient
- Electro-osmosis
– Potential gradient

} Alison Sawdy



Transport in Permeable Media

TU/e TPM


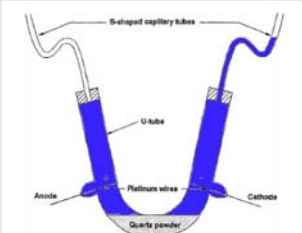
ELECTRO OSMOSIS

Transport in Permeable Media

TU/e **TPM**

F.F. Reuss, Sur un nouvel effet de l'électrique glavanique, Mém. Soc. Impériale Naturalistes de Moscow 2 (1809)

Ferdinand Friedrich von Reuß (1778–1852)

voltaic pile by Volta 1800

Transport in Permeable Media

TU/e **TPM**

Rediscovered

No. 8. ANNALEN 1861.
DER PHYSIK UND CHEMIE.
BAND CXIII.

I. Ueber die Fortführung materieller Theilchen durch strömende Electricität; von G. Quincke.

I.

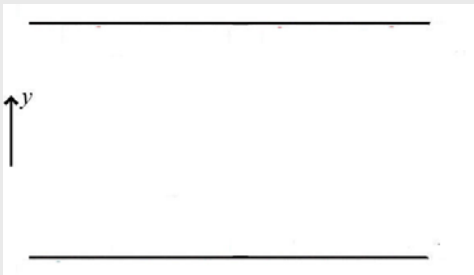
Reuss¹⁾ in Moskau beobachtete zuerst, im Jahre 1807 dafs ein galvanischer Strom Flüssigkeiten in der Richtung des positiven Stromes mit sich fortführte, wenn die Flüssigkeit an einer Stelle durch eine poröse Scheidewand unterbrochen war. Seine Beobachtungen schienen jedoch bis in die neueste Zeit hinein wenig bekannt geworden zu seyn, so dafs oft Porret²⁾, der 1816 ganz ähnliche Versuche beschrieben hat, als der Entdecker dieser später auch wohl mit dem Namen »elektrische Endosmose« bezeichneten Er-

Development theory
M. Smoluchowski
(1882-1917)

Transport in Permeable Media

TU/e **TPM**

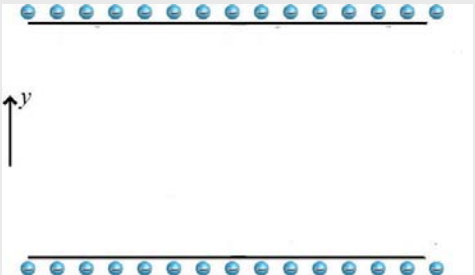
conceptual model



Transport in Permeable Media

TU/e **TPM**

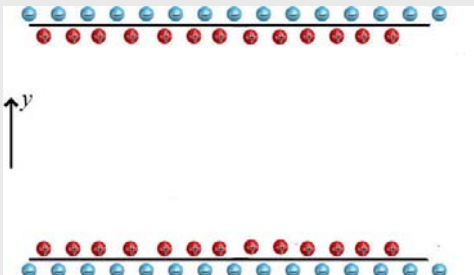
conceptual model



Transport in Permeable Media

TU/e **TPM**

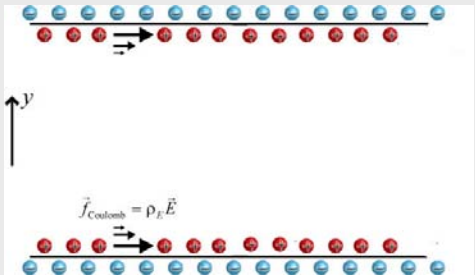
conceptual model



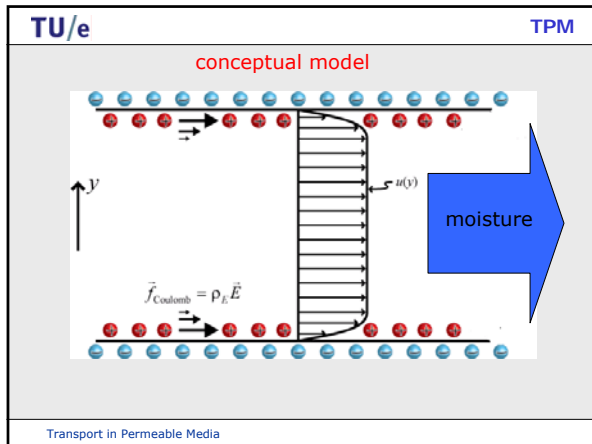
Transport in Permeable Media

TU/e **TPM**

conceptual model



Transport in Permeable Media



TU/e TPM

Lets do a calculation!

$$\Delta P = \frac{8\varepsilon\xi}{r^2} V$$

Where

ξ : Zeta potential	45 mV	} $\rightarrow \Delta P_{EO} = 250 \text{ Pa}$
ε : Permittivity	80	
r : Pore size	1 μm	

Transport in Permeable Media

TU/e TPM

Non-saturated porous materials

For building materials
capillary pressure \gg electro osmotic pressure

$\Delta P_{cap} = 146000 \text{ Pa}$
for 1 μm

much larger \rightarrow $\Delta P_{EO} = 250 \text{ Pa}$

Transport in Permeable Media

TU/e TPM

Other effects

- Surfaces charge is dependent
 - Mortar \leftrightarrow Brick
- Heating
 - 10 Watt
 - 36000 J/hour
 - Water 4200 J/Kg $^\circ\text{C}$
 - 1 hour 8 $^\circ\text{C}$

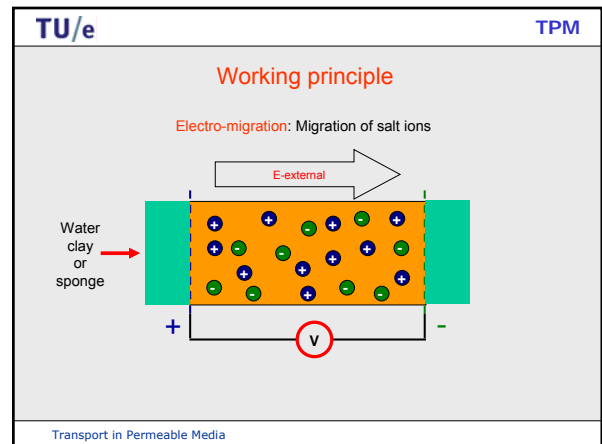
Transport in Permeable Media

TU/e TPM

~~ELECTRO OSMOSIS~~

ELECTRO KINETICS

Transport in Permeable Media



TU/e **TPM**

Working principle

Electro-migration: Migration of salt ions

Transport in Permeable Media

TU/e **TPM**

Diffusion

SLOW

Advection

FAST

Transport in Permeable Media

TU/e **TPM**

Measurement moisture + ion transport ???

Example x-ray images

Transport in Permeable Media

TU/e **TPM**

Moisture
Na-ions

For research

Transport in Permeable Media

TU/e **TPM**

NMR

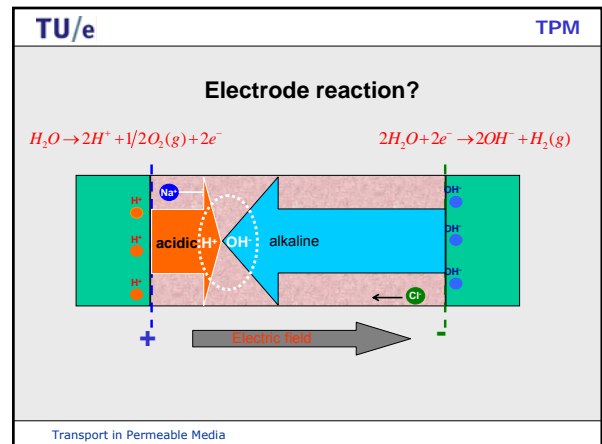
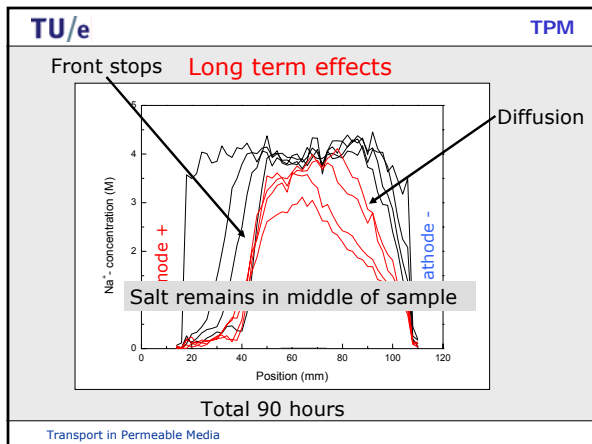
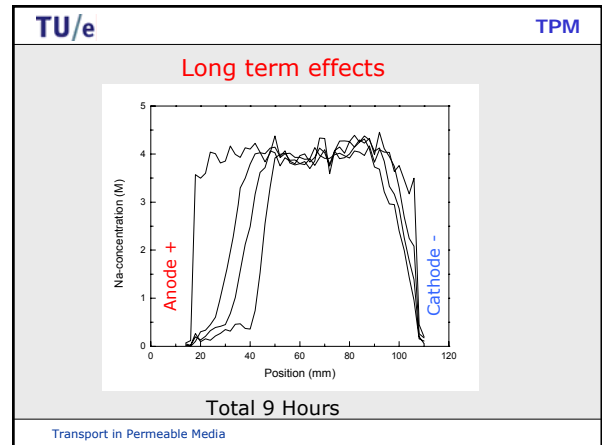
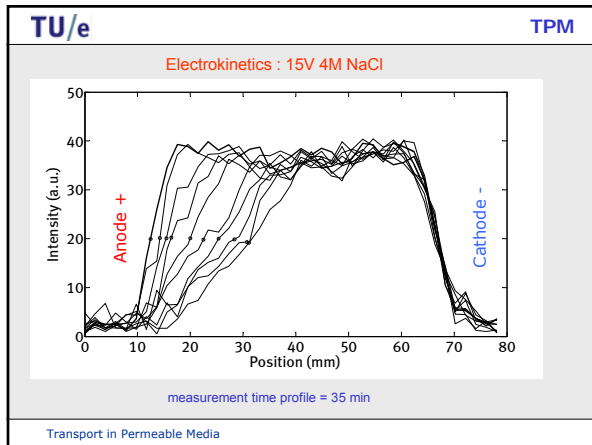
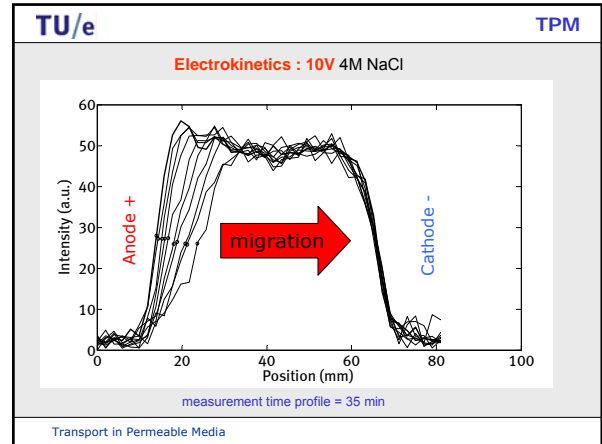
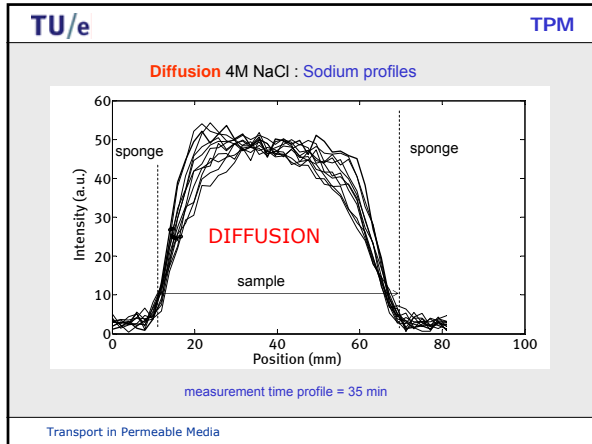
Transport in Permeable Media

TU/e **TPM**

Experimental Setup

Length=6 cm, $\varnothing=20$ mm
4M salt solution

Transport in Permeable Media



TU/e TPM

pH variation

Litmus paper

pH change: chemical reaction, porosity, color

Transport in Permeable Media

TU/e TPM

US Army corps of engineers

Transport in Permeable Media

TU/e TPM

Conclusion

Precipitation of salts (CaOH) in pores: Shut off

Transport in Permeable Media

TU/e TPM

Advection

FAST

Electro kinetics

?

Transport in Permeable Media

TU/e TPM

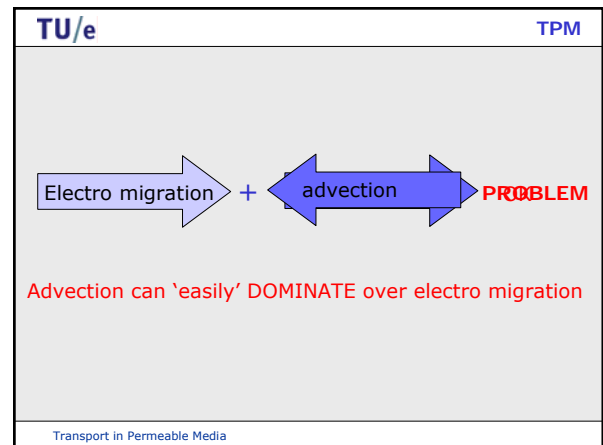
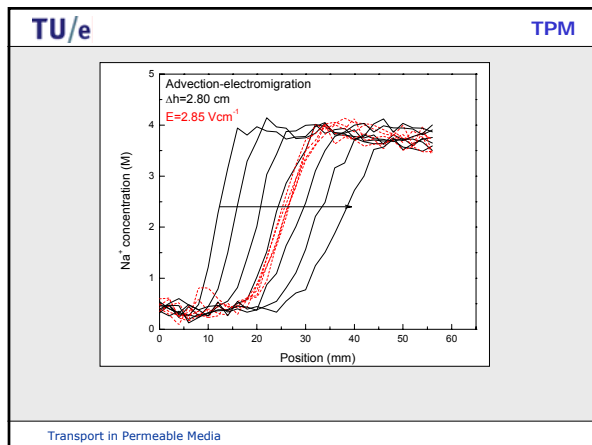
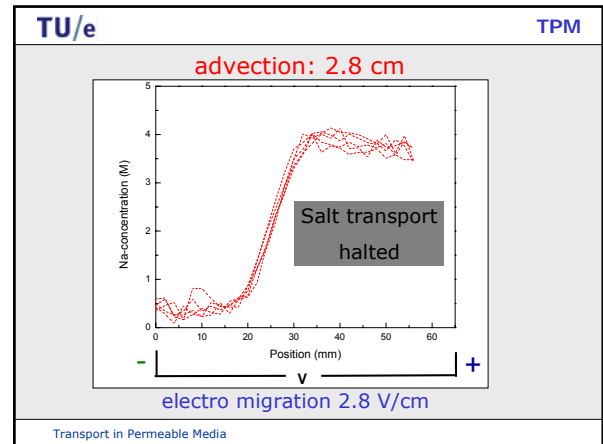
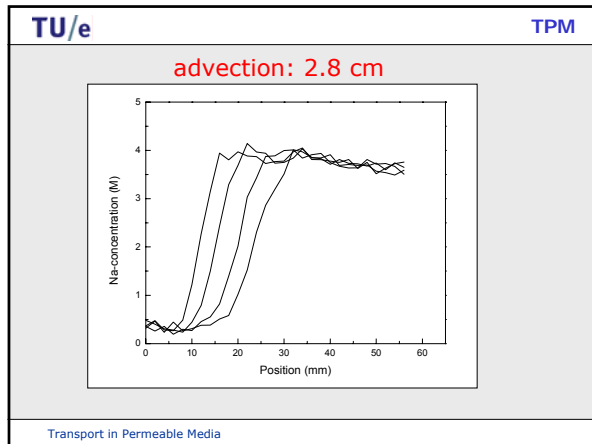
Experimental Setup

Transport in Permeable Media

TU/e TPM

Only advection: 2.8 cm

Transport in Permeable Media



TU/e TPM

Conclusions

electro osmosis

- no effect for building materials (non saturated >proof: articles)
- probably due to side effects

Transport in Permeable Media

TU/e TPM

Conclusions

electro osmosis

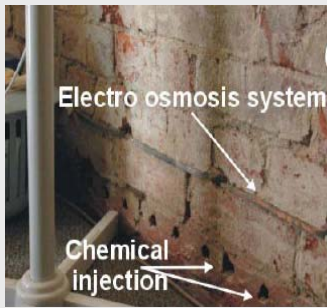
- no effect for building materials (non saturated >proof: articles)
- probably due to side effects

electro kinetics

- not faster than advection
- process stops due to pH
- problem pH: chemical reactions !!!
- if unsaturated ???

Transport in Permeable Media

Australia



Questions ?