



INSTITUT FÜR  
UMWELTPHYSIK

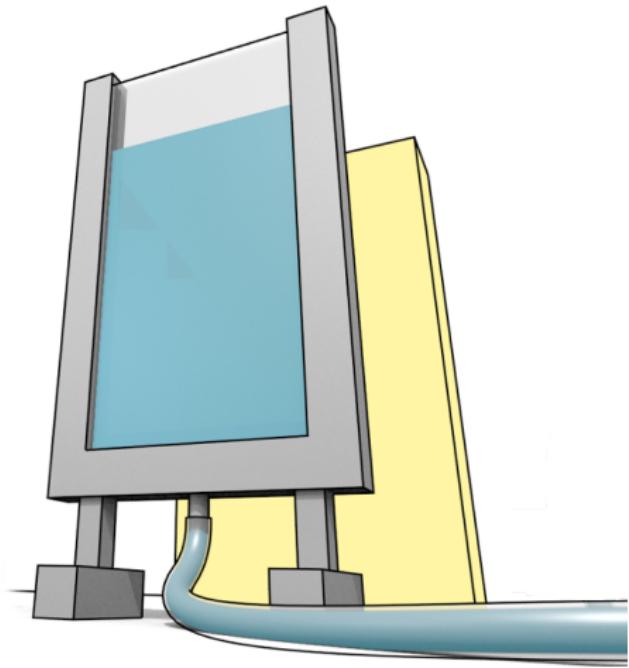
# DENSITY DRIVEN FLOW IN POROUS MEDIA

## status and goals

16.02.2015

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University of Heidelberg



# MOTIVATION

# MOTIVATION

→ Update on my work

# MOTIVATION

- Update on my work
- Feedback for me

# OUTLINE

1. Evaporation

2. CO<sub>2</sub>

3. Future

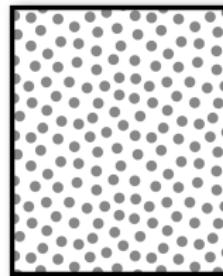
4. Danke

5. Literature

# EVAPORATION

# GENERAL IDEA

→ heterogeneous, porous medium

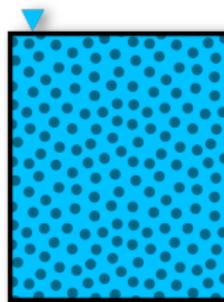


Selfmade graphic

**Figure:** Heterogeneous, porous medium

# GENERAL IDEA

- heterogeneous, porous medium
- saturated with water

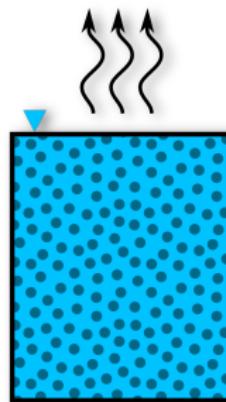


Selfmade graphic

**Figure:** Heterogeneous, porous medium with water

# GENERAL IDEA

- heterogeneous, porous medium
- saturated with water
- evaporation

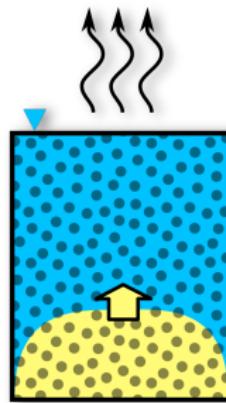


Selfmade graphic

**Figure:** Porous medium with water and evaporation

# GENERAL IDEA

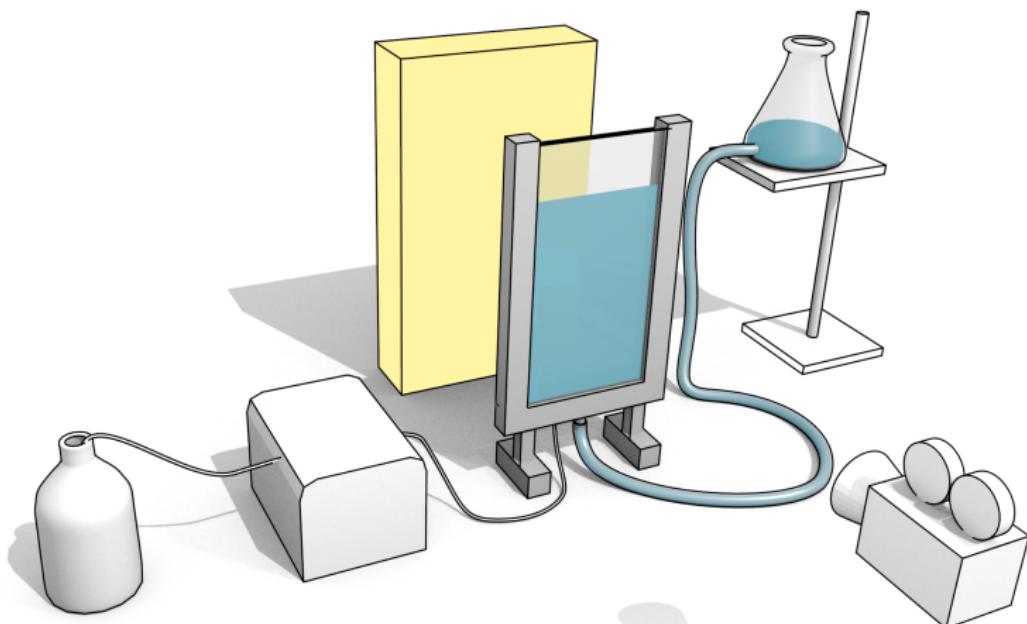
- heterogeneous, porous medium
- saturated with water
- evaporation
- water is pumped up



Selfmade graphic

**Figure:** Porous medium with water and evaporation

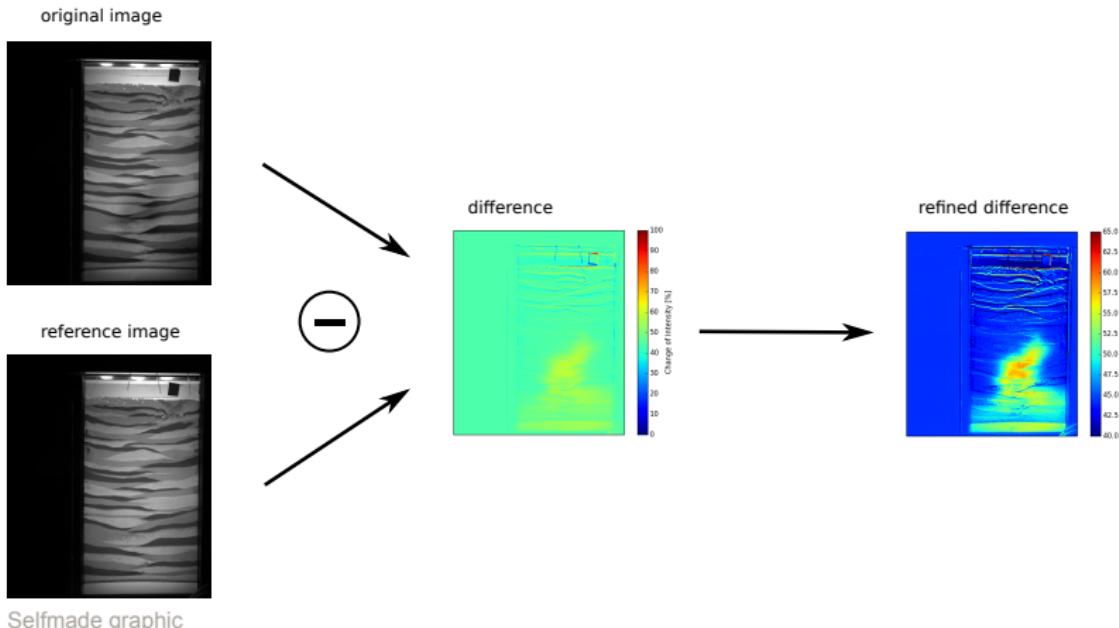
# SETUP



Selfmade graphic

**Figure:** Experimental setup

# IMAGE ANALYSIS



**Figure:** Image analysis

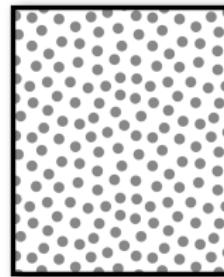
# VIDEO

Let's have a look.

CO<sub>2</sub>

# GENERAL IDEA

→ heterogeneous, porous medium

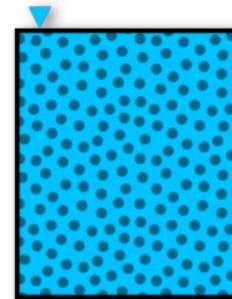


Selfmade graphic

**Figure:** Heterogeneous, porous medium

# GENERAL IDEA

- heterogeneous, porous medium
- saturated with water

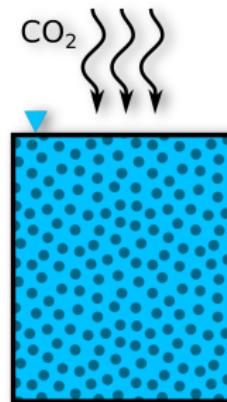


Selfmade graphic

**Figure:** Heterogeneous, porous medium with water

# GENERAL IDEA

- heterogeneous, porous medium
- saturated with water
- CO<sub>2</sub> on top

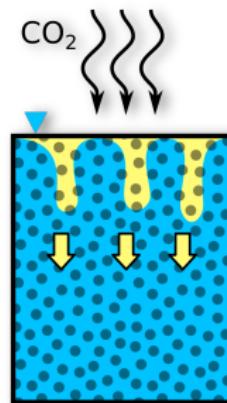


Selfmade graphic

**Figure:** Porous medium with water and CO<sub>2</sub>

# GENERAL IDEA

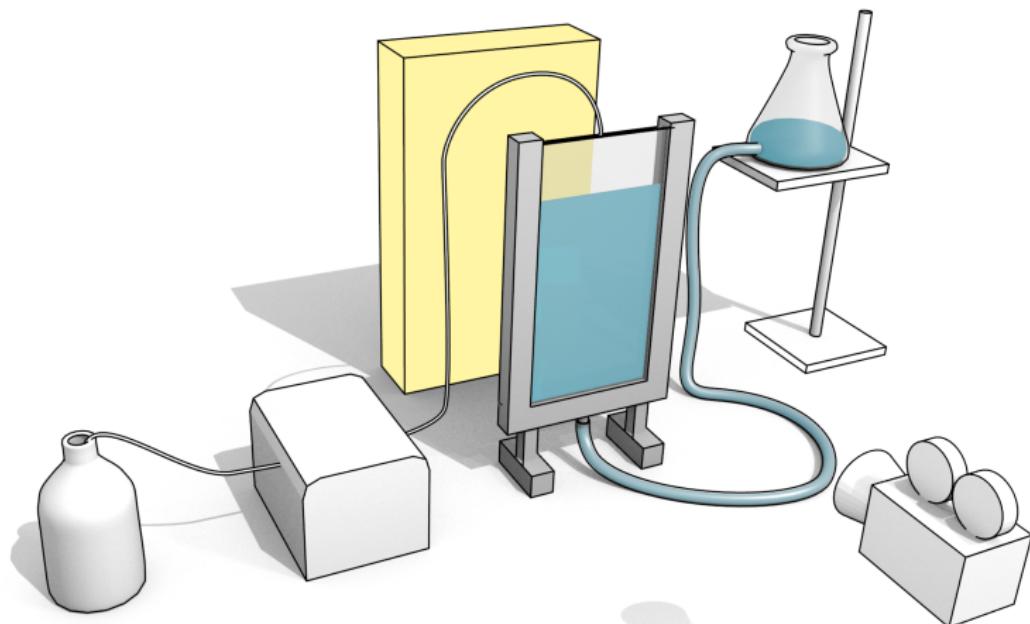
- heterogeneous, porous medium
- saturated with water
- CO<sub>2</sub> on top
- Fingering



Selfmade graphic

**Figure:** Porous medium with water and CO<sub>2</sub>

# SETUP



Selfmade graphic

**Figure:** Experimental setup

# INDICATOR

To see where the dissolved CO<sub>2</sub> is, a pH-Indicator can be used.

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CO<sub>2</sub> in equilibrium with water:



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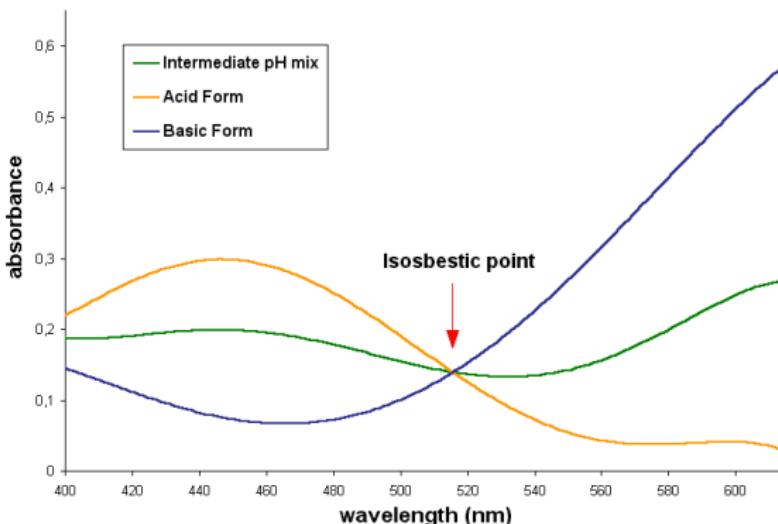
CO<sub>2</sub> in equilibrium with water:



$$\text{pH}(\text{water} \rightleftharpoons \text{air}) \approx 5.6$$

$$\text{pH}(\text{water} \rightleftharpoons \text{CO}_2) \approx 3.9$$

# BROMOCRESOL GREEN



Graph from wikipedia [1]

**Figure:** Experimental setup

# EXPECTATIONS

Dissolved CO<sub>2</sub> is heavier than pure water

# EXPECTATIONS

Dissolved CO<sub>2</sub> is heavier than pure water



Unstable layering

# EXPECTATIONS

Dissolved CO<sub>2</sub> is heavier than pure water



Unstable layering



Diffusice/Convectiv process

# EXPECTATIONS

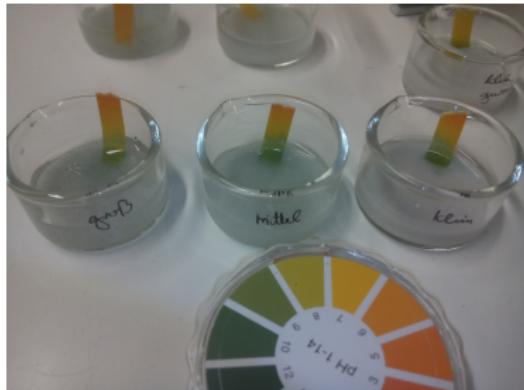
Handle: Rayleigh number as in Kneafsy et al [2]:

$$Ra = \frac{kgh\gamma\Delta C\rho_0}{\mu D}$$

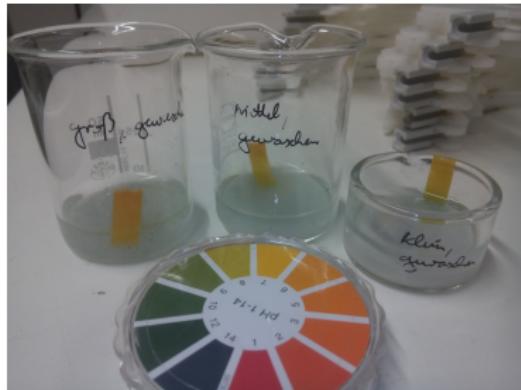
# VIDEO

Let's have a look.

# DEBUGGING



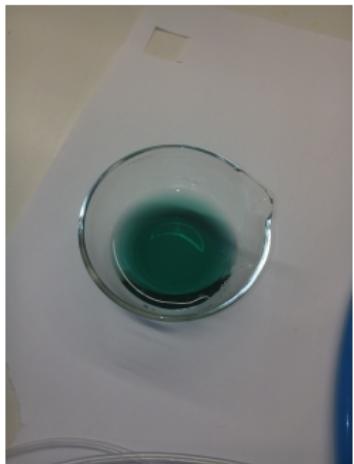
graphic selfmade



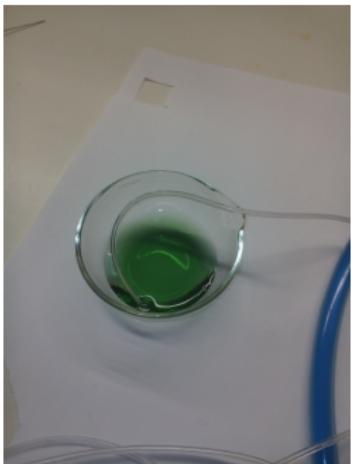
graphic selfmade

**Figure:** Different pH-values for different glass beads

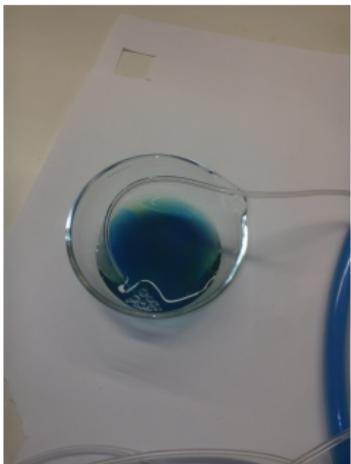
# DEBUGGING



graphic selfmade



graphic selfmade



graphic selfmade

**Figure:** Glas beads in Bromocresol Green

# DEBUGGING



graphic selfmade

**Figure:** Glas beads in Bromocresol Green overview

FUTURE

# FUTURE

»blackboard«

DANKE

# LITERATURE

# LITERATURVERZEICHNIS

-  Wikipedia  
»Bromocresol green«  
[http://en.wikipedia.org/wiki/Bromocresol\\_green](http://en.wikipedia.org/wiki/Bromocresol_green)
-  Springerlink.com  
»Laboratory Flow Experiments for Visualizing Carbon Dioxide-Induced, Density-Driven Brine Convection«  
2010