COMSOL CONFERENCE 2014 CAMBRIDGE

Modelling bioclogging effects in Constructed Wetlands for wastewater treatment

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Intensive WWTPs

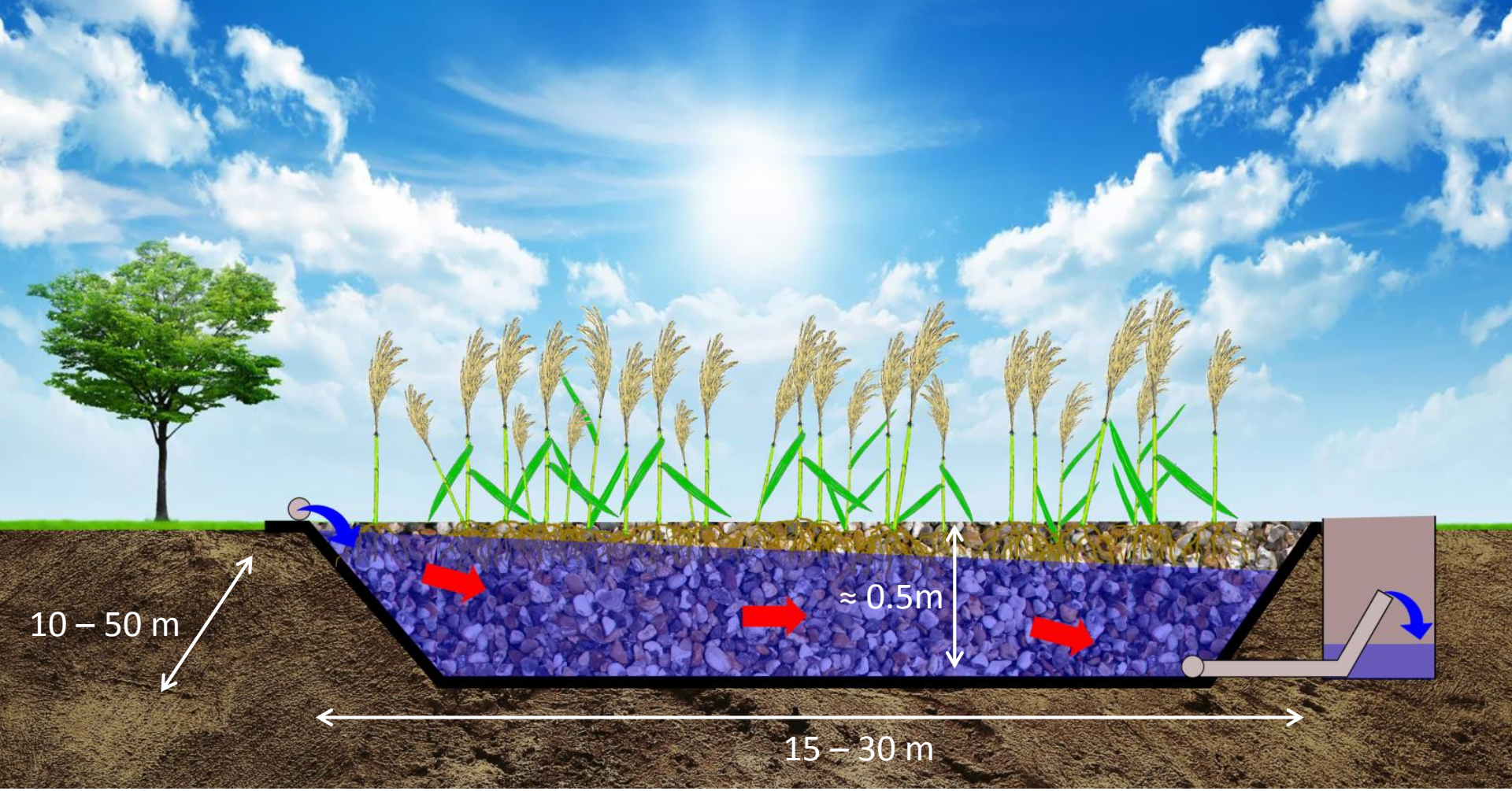
Extensive WWTPs

(based on Constructed Wetlands (CWs))

Verdú (Lleida, Spain)

Close-up of a CW

Missery (Côte d’Or, France)



Impermeable basin

Filled with a porous media (gravel)

Planted with aquatic macrophytes

Fed with wastewater

Main operational problem of CWs

High load of OM and nutrients

High bacterial yields

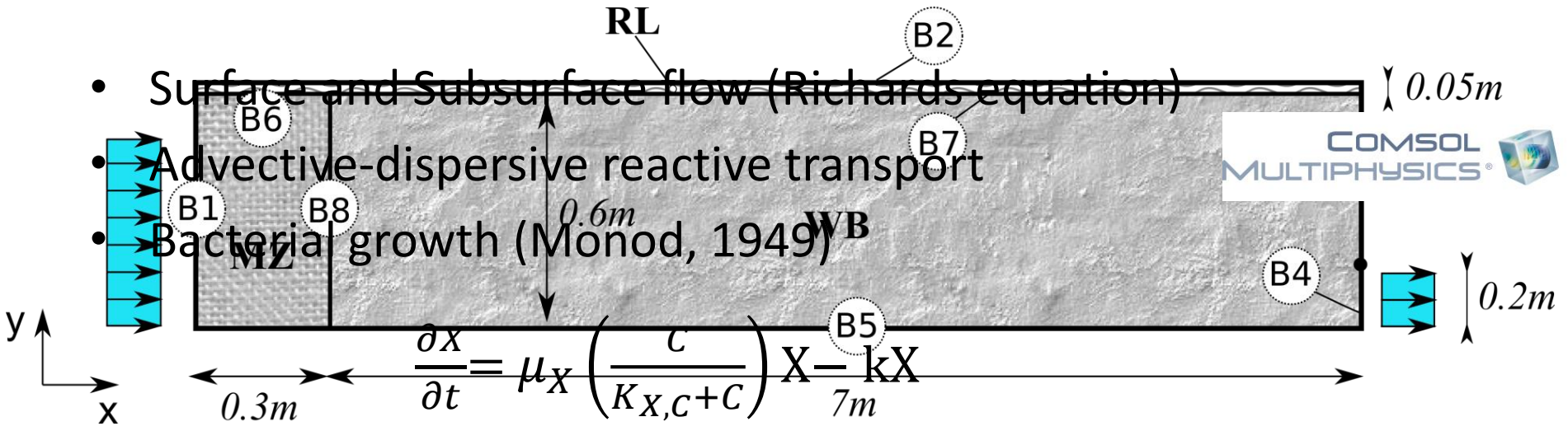
Biological clogging

Objective

To build a **bioclogging** model for **unsaturated** porous media to simulate clogging development and the subsequent **overland flow** in Constructed Wetlands

Model description

- 2D domain (longitudinal section of a CW)
- Surface and Subsurface flow (Richards equation)
- Advective-dispersive reactive transport
- Bacterial growth (Monod, 1949)
- Bioclogging Model (Rosenzweig et al., 2009)

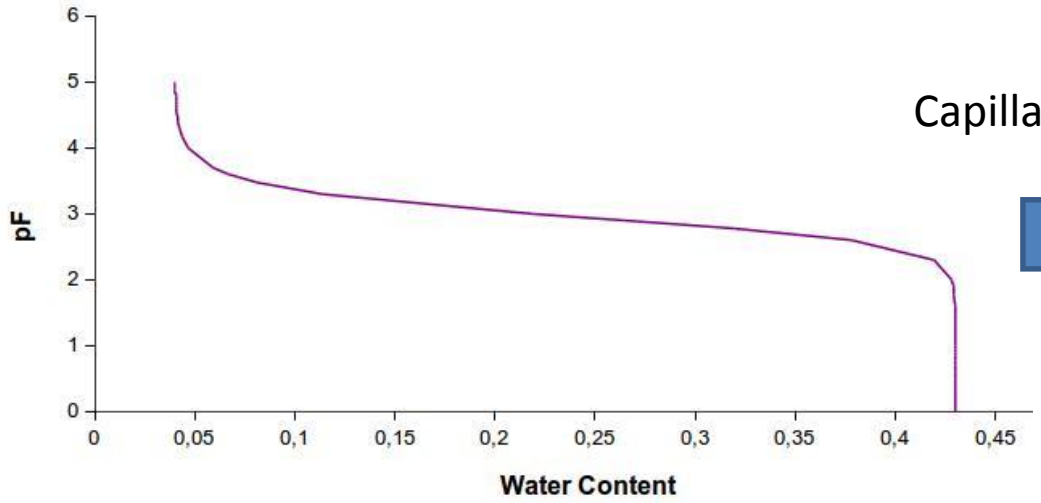


COMSOL MULTIPHYSICS

MATLAB

Bioclogging model
(Rosenzweig et al., 2009)

Van Genucthen (1980)



Capillary model

Initial pore size distribution

$$r = -\frac{2\sigma \cos\beta}{\gamma h}$$

$$N_i = \frac{\Delta\theta}{\pi {r_i}^2}$$

Bacteria volume fraction $\theta_m = X\ \rho_X$

Microbial effective saturation $S_{em} = \frac{\theta_m}{\theta_s - \theta_r}$

Biofilm-affected pore size distribution

$$r_{b,i} = r_{f,i}\sqrt{1 - S_{em}}$$

$$N_{b,i} = N_{f,i}$$

Relative permeability (Hagen-Poiseuille)

Unsaturated, biofilm-affected flow

$$k_b(\theta_{w,j}) = \frac{\sum_{i=1}^{j} N_{b,i}\, r_{b,i}^{\,4}}{\sum_{i=1}^{M} N_{f,i}\, r_{f,i}^{\,4}}$$

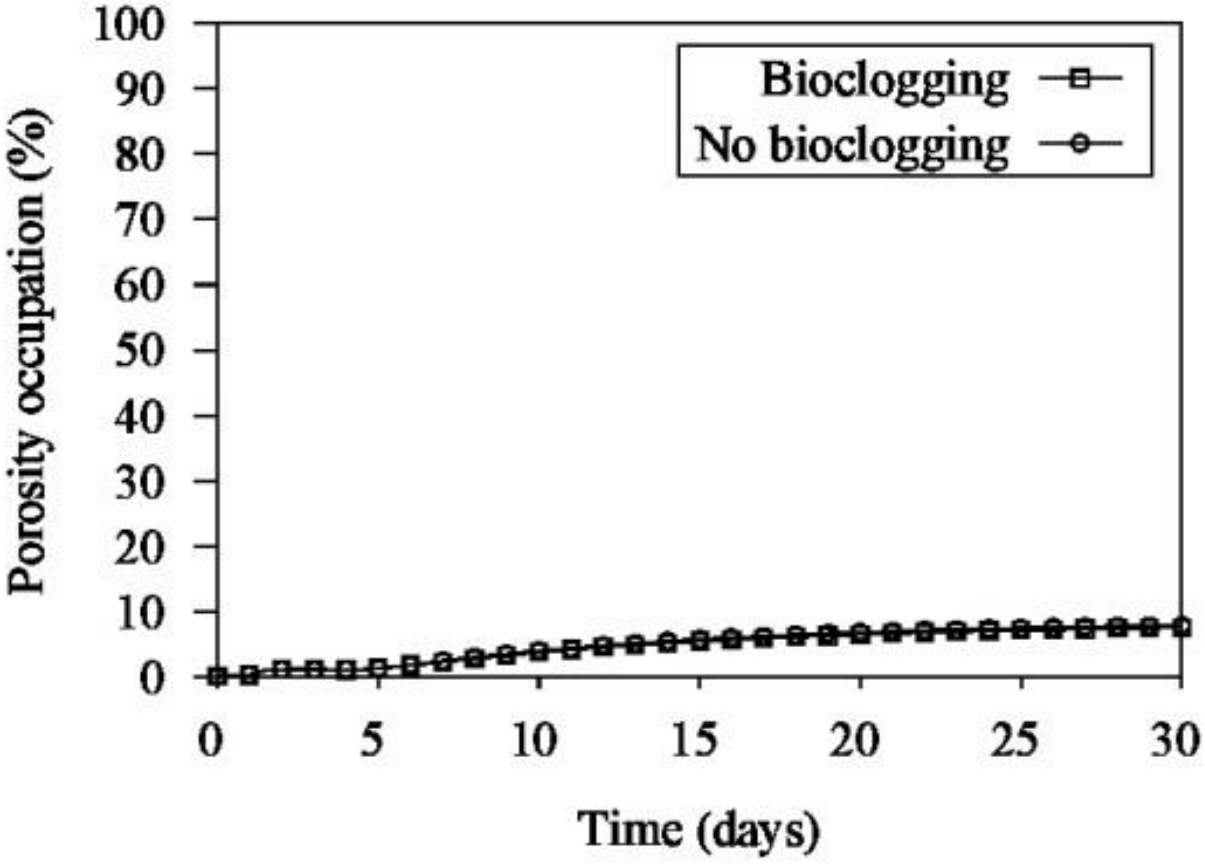
Saturated, biofilm-free flow

Numerical experiment

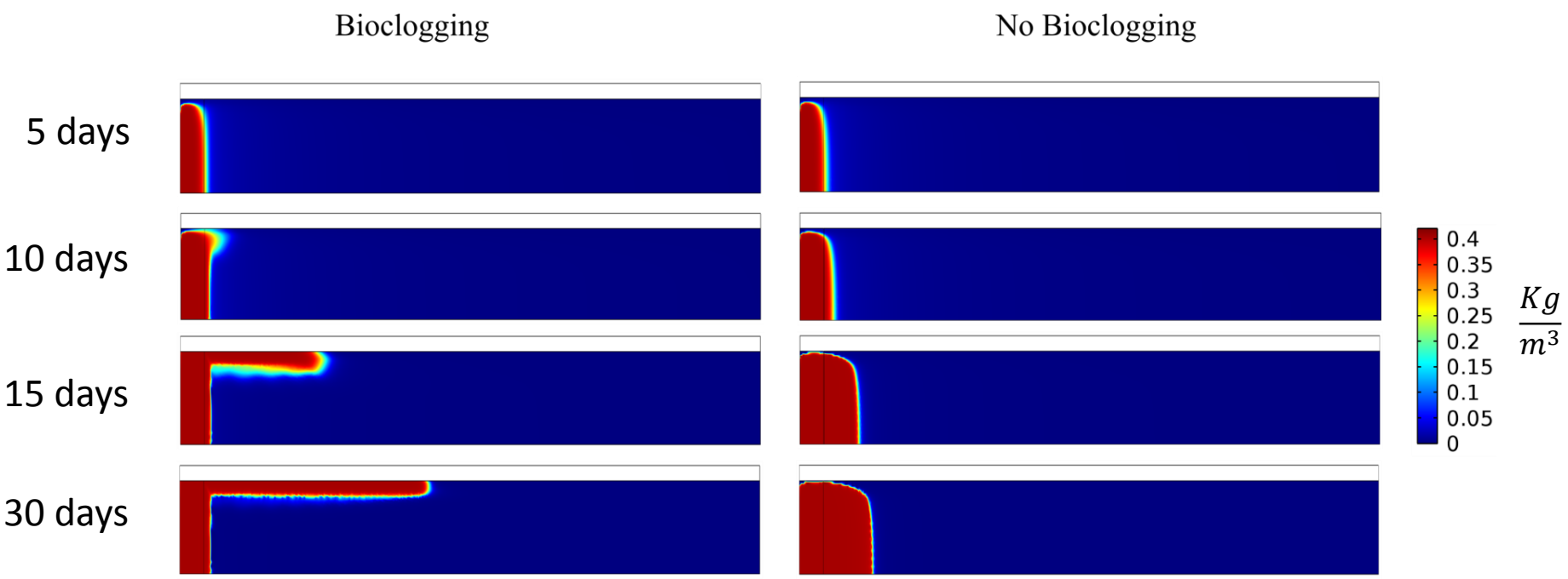
- Two simulations of 30 days
  - Simulation 1: considering clogging
  - Simulation 2: neglecting clogging

- Comparison of different model outputs

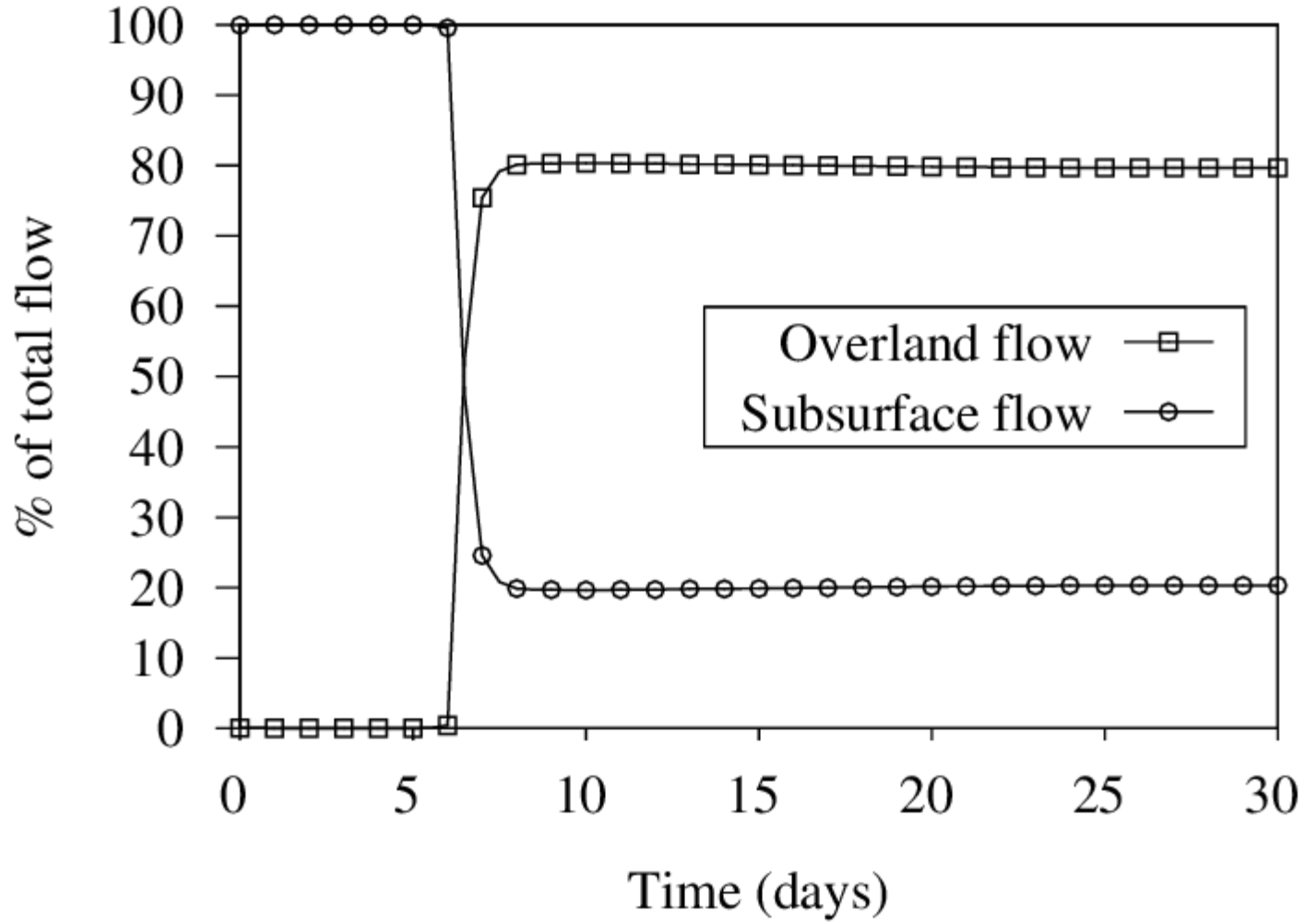
Results (1/3): Porosity occupation



Results (2/3): Bacteria distribution



Results (3/3): Overland vs Subsurface flow



Conclusions

- A new study of bioclogging in unsaturated porous media
- Bioclogging changes bacterial distribution and causes overland flow, reducing CWs lifespan
- Still a work in progress

Further development

- The model of Rosenzweig et al. (2009) does not include tortuosity!

$$k_b(\theta_{w,j}) = \frac{\sum_{i=1}^{j} N_{b,i}\, {r_{b,i}}^4}{\sum_{i=1}^{M} N_{f,i}\, {r_{f,i}}^4}$$

- Overland flow will be described using the shallow water equations (Saint Venant equations)
- Uncertainty, sensitivity, verification and calibration
- More functional bacterial groups and processes will be included

SWINGS PROJECT

Safeguarding Water resources in India with Green and Sustainable technologies

Aim: to enhance optimized municipal WW treatment concepts by combining green and sustainable technologies for enhancing water recycling and reuse, decreasing energy demand and utilising beneficial by-products from the process as a secondary resource.

Tasks:

- Construction and on-site optimization of Anaerobic digester-Constructed wetland systems.
- Disinfection systems and pathogen monitoring techniques.
- Water reuse (e.g. aquaculture, irrigation, etc.).

SEVENTH FRAMEWORK PROGRAMME

Department of Science and Technology

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Thank you!

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