Modeling Phytoremediation By Mangroves

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Abstract

Metal contaminants and organic pollutants are affecting aquatic environments in urban and industrial zones. Mangrove trees are capable of absorbing metal ions and organic pollutants like PCB and PAH [1]. Located in tidal zones of river estuaries mangrove forests may function as a means for immobilization and removal of pollutants. To estimate the remediation potential, a two dimensional model of water and substance flow in the soil plant system based on porous media equations and on plant architecture is set up (Figure 1), which is based on cohesion-tension theory. Water transport in the soil and tree is conceived as a continuous hydraulic process, which is driven by canopy transpiration [2]. State variables are water potential and contaminant concentrations in the sediment, roots, xylem, core and canopy. The model equations are obtained by application of Richards equations specific for the soil and each plant compartment. The water transport equations are coupled to the contaminant transport equations via the Darcy velocity and the dispersion tensor. In each compartment, contaminant species can occur in liquid and solid phase. Exchanges between compartments are mediated by a diffusion model on the boundary for transport across membranes. Water evaporation from leaf mesophyll cells is taken into account by a transpiration sub model, which comprises stomata regulation and is driven by environmental variables such as air water potential, wind speed, radiation and temperature. Local evaporation depends on the leaf area index density. Boundary conditions at the soil surface are subject to periodical tidal inundations by water with contaminant loads. This typical multiphysics problem was implemented into COMSOL Multiphysics® using the coefficient form of the PDE interface. Because of the extremely high differences in water potential between air and canopy, boundary and initial conditions and net size and structure had to be set up very carefully in order to achieve convergence. Figure 2 and Figure 3 show representative results. The model is capable of simulating the uptake and storage of contaminants in mangrove trees under time varying boundary conditions such as tidal inundations, wind velocity and humidity of the air and thus meets the conditions of our experiments in Vietnam, which are currently carried out. Once the model is validated, it will be applied to trees of different ages in a forest stand and be used to estimate the remediation potential of mangrove forests adjacent to contaminated estuaries.

Reference

[1] Ramos e Silva, C.A.et al., Concentration, stock and transport rate of heavy metals in a tropical red mangrove, Natal, Brazil. Marine Chemistry 99(2006), 2-11
[2] Janott, M. et al.,A one-dimensional model of water flow in soil-plant systems based on plant architecture, Plant Soil (2011) 341:233-256

Figures used in the abstract

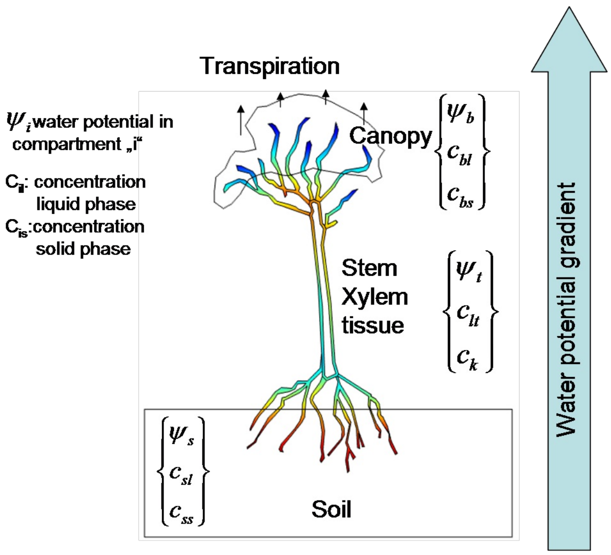

Figure 1: Layout of geometries, state variables and processes

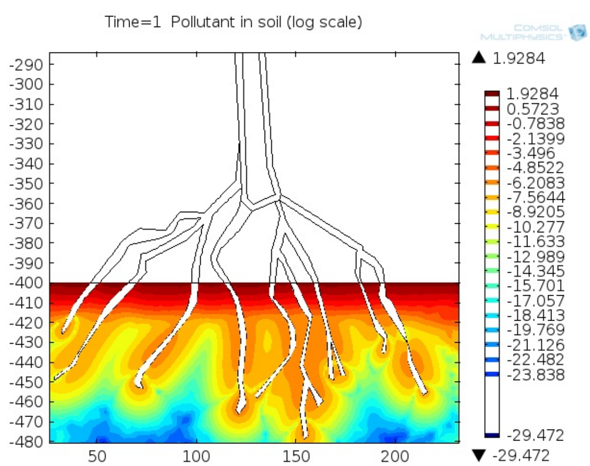

Figure 2: Distribution of a contaminant in soil following an inundation of contaminated water. Scale in cm.

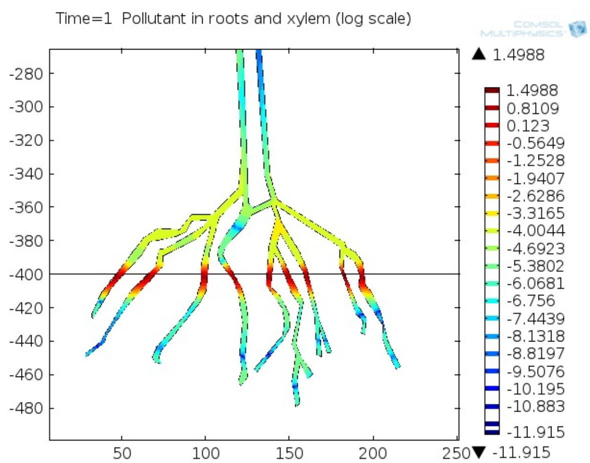

Figure 3: Distribution of a contaminant in root and xylem following an inundation of contaminated water. Scale in cm.