The Delivery of Dissolved Organic Carbon from Forest Soils to a Head Water Stream

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Introduction

The temporal variation of the delivery of dissolved organic carbon (DOC) from hillslopes to the adjacent streams is determined by hydrological and biogeochemical processes that have not been completely quantified. In particular, processes involving differences in the fate and transport of the easily biodegradable fraction of dissolved organic carbon (BDOC) and the more recalcitrant fraction of DOC (NDOC) are of ecological importance.

Our research site is White Clay Creek (WCC) watershed, WCC watershed is a 725 ha, 3rd-order watershed located in southeastern Pennsylvania. The major goal of this research is to estimate the spatial DOC flux distribution within the watershed.

Objectives

➢**Objective 1 :**

Estimate vertical annual DOC flux to groundwater. (*One dimensional treatment*)

➢**Objective 2 :**

Estimate the DOC flux to the stream during precipitation events along the hillslope. (*Two dimensional treatment*)

Model Discprition

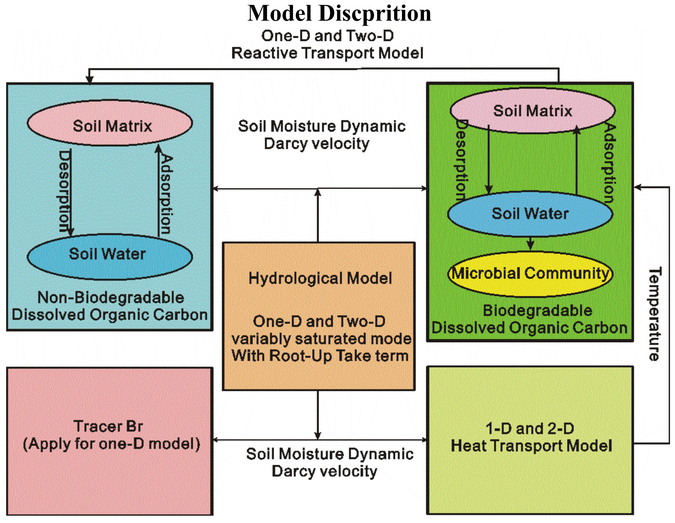


Fig 1. One Dimensional and Two Dimensional Model Structure

1-D dual-permeability unsaturated flow and transport model:

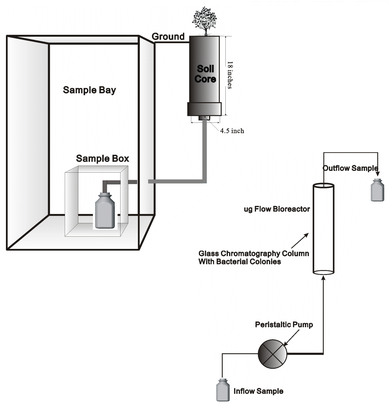
- The one dimensional model was used to estimate vertical flux through soil column.
- The model was first calibrated using the experimental data (Fig 2), then extended to 6 lengths representing different soil lengths above the groundwater table.
- The 1997 meteorology data were used to run the calibrated model for the annual DOC recharging rate to the groundwater.

2-D saturated and unsaturated flow and transport model:

- The two dimensional model was used to calculate DOC flux through the hillslope for a precipitation event. The meteorology data in July,2010 was used here.

One Dimensional Model Equations are Available on Handout

Field and Laboratory Methods *(Objective 1):*



Soil Core Experiments:

➢Applied Bromide-amended solution on the top of in-situ soil core at a controlled speed.

➢Collected water samples at the bottom at fixed time intervals.

➢Kept track the temperature at the top of the soil core and 3 cm into the soil core.

Lab experiments:

➢Plug-flow bioreactor was used to separate BDOC and non-BDOC by running samples through it, DOC and BDOC concentrations were obtained by calculating the difference between the inflow and outflow samples of the bioreactor.

Simulation Results (*Objective 1*)

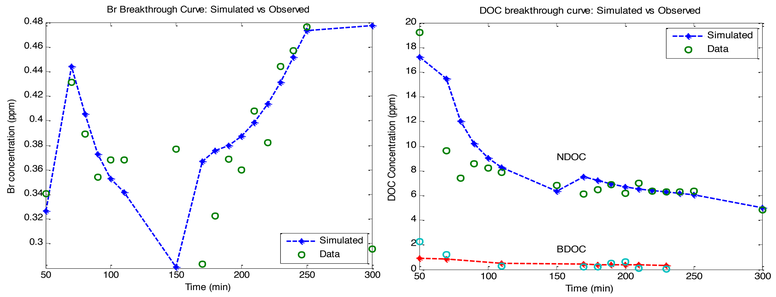


Fig 2. Calibration of one-D model from soil core experiments

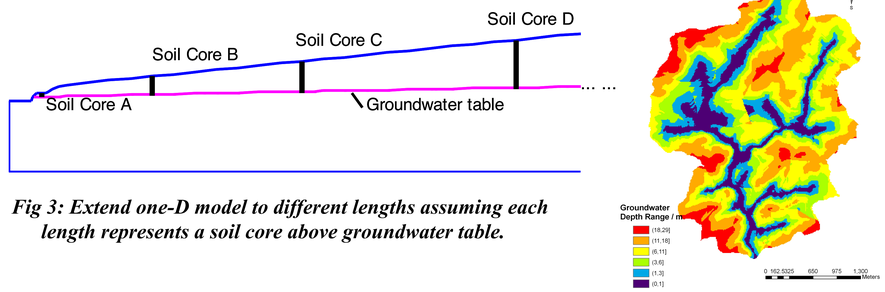


Fig 3: Extend one-D model to different lengths assuming each length represents a soil core above groundwater table.

Fig 4. Groundwater depth distribution across the watershed, the whole watershed was divided into 6 sub-regions

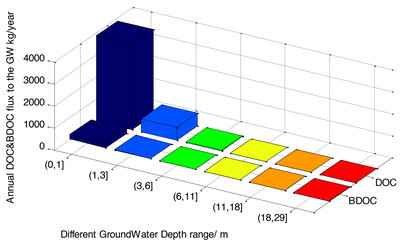


Fig 5. Calculation results of NDOC and BDOC flux to groundwater in each specific groundwater depth region (Each region uses a representative soil core length)

- In WCC watershed, simulation results show that the riparian zone (groundwater depth less or equal to 1m) contributes 87% DOC to the groundwater. The area of groundwater depth from 1 to 3m contributes 21% ,and the rest of the area contributes less than 1% .
- The model output of total DOC recharge to groundwater in 1997 is about 4700 kg C/year. The estimated DOC export from WCC in 1997 is about 7000 kg C/year. This indicates that about 67% of the exported DOC was from baseflow.

2-D hillslope hillslope approach *(Objective 2)*

Fig 6 Riparian zone

Fig 7 Middle hillslope

- A hillslope transect located on the east bank of the third order stream of White Clay Creek was selected to explore horizontal DOC flux along groundwater flow path.
- This transect is nearly perpendicular to the stream and almost parallel to the flow direction of shallow phreatic groundwater (Fig 6 and Fig 7).

Method: numerical model

Saturated-unsaturated flow

$$\nabla\cdot\left[\mathbf{K}_s k_r\left(\nabla h+\mathbf{k}\right)\right]-R=\left(C+\frac{\theta}{n}S_s\right)\frac{\partial h}{\partial t}$$

DOC and BDOC transport

$$\frac{\partial}{\partial t}\left(\theta c_b+\rho s_b\right)=\frac{\partial}{\partial x_i}\left(\theta D_{ii}\frac{\partial c_b}{\partial x_i}+\theta D_{ij}\frac{\partial c_b}{\partial x_j}\right)-q_i\frac{\partial c_b}{\partial x_i}-S$$

- A 2-D vertical finite element model was used to solve for flow and DOC transport along this 120 m hillslope in WCC watershed.

Simulation results *(Objective 2)*

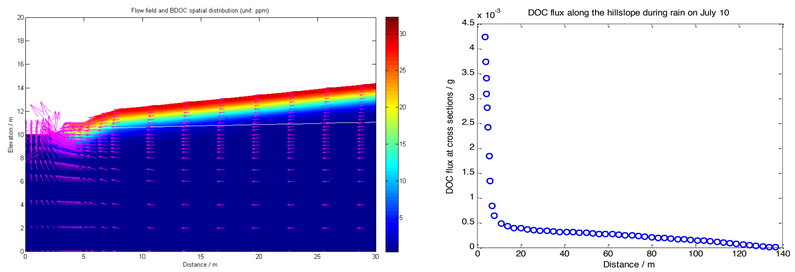


Fig 8. DOC concentration spatial distribution and DOC flux along the hilllslope

- The 2D model simulation results show that DOC flux is high near the stream and declines rapidly in the upland area (Fig 8).

Discussion

➢As DOC is "flushed" from its terrestrial sources to the stream, the riparian zone has a much more significant effect on the DOC and BDOC concentrations in the adjacent stream than do sources from the upper hillslope. The groundwater level is very close to the top soil layer in the riparian zone, and when the stream stage rises rapidly during the rain, the ground water level in the riparian zone rises accordingly and reaches major DOC sources in the upper soil layers.

Future Research

- Collaboration with the PennState CZO group has been initiated. The PennState Integrated Hydrological Modeling System (PIHM), a physically-based fully distributed hydrology model, will be extended to simulate the DOC dynamics at a whole catchment scale. The Christina Basin will be the test bed for the model.

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