Research Experience on Understanding Water and Chemical Transport in the Earth's Vadose Zone

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Introduction

- For the summer of 2018 four students from two different universities embarked on an international research exchange at the Czech Technical University in Prague, Czech Republic.
- Students arrived in Prague May 25th for an eight week research program.
- Throughout these eight weeks, students had lectures on soil physics, vadose zone modeling, groundwater modeling, and mathematical groundwater modeling.
- The focus of this research was contaminant transport through the vadose zone.
- One of the major factors that was researched was the importance of how pore size distribution and preferential flow in soils leads to varied water infiltration.
- Students went on two different field excursions: one to the Uhlriska catchment in the Jizera mountains near Liberec and one to a site near Zaksin.
- Each student was assigned one of four different tasks to focus on for the summer.
  - Alexa: Geophysics and particle analysis
  - Davida: CT image analysis
  - Jordan: Ponded infiltration analysis
  - Liz: Infiltration modeling
- The students ended their stay with a presentation to the Civil Engineering faculty at CTU and Dr. Ray along with writing a technical report on the activities performed.

Geophysics

- Geophysical resistivity measurements were conducted at the Zaksin village, northern Czech Republic originating at 50.5268764N, 14.4930081E.
- Measurements were done by using an ARES device equipped partly with a multiplexor.
- The measurements were done at three profiles; One on a span of 510 m (consisting of 4 rearrangements of the 275 long multicable), using 5m intervals, along the road. The second span of 130 m using 1 m intervals along the road (each measurement was 47m long). The third profile being a span of 130m using 1m intervals in a garden (with two overlapping installations of 95m and 80m.

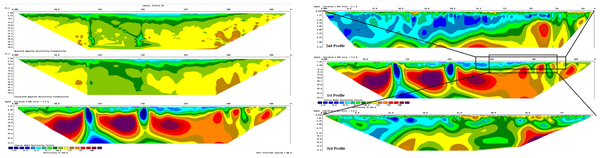


Figure 1. Resistivity values for prolife 1 (Left) and combined profiles (Right)

Pore Size Analysis

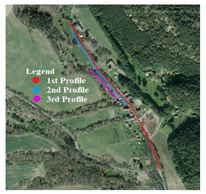


Figure 2. Geographic visual of combined profiles

- Distributed soil sample from the topsoil (Sample A) and subsoil (Sample B) was collected in a village in lower northern Bohemia as eolic deposited Orthic Luvisol. Sample A 0-30 cm, Sample B 30-40 cm were collected at 50.5298286N, 14.4904908E.
- This was done by using a densiometric method, sand sieving and determining solid density. Sample A has a particle density of 2.53 g/cm^3 and Sample B has a slightly higher particle density of 2.67 g/cm^3
- When combined with a USDA soil texture triangle the soil texture of sample A, it's on the border of silt and silt loam while sample B is a silt loam.

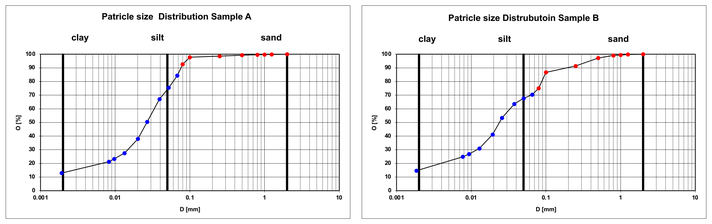


Figure 3. Particle size distribution for samples A and B

CT Image Analysis

- Soils Cores were collected from the Uhlirska catchment in the Jizera Mountains and the St. Ann Church in Viznov, Czech Republic.
- Each Core was approximately 14 cm in diameter, 14 cm in height, and 3077 cm^3 in volume.
- CT scanning occurred in summer 2017 at CEITEC in Brno, Czech Republic.
- Images were analyzed to determine the stone content, pore size distribution, and total porosity of the core.

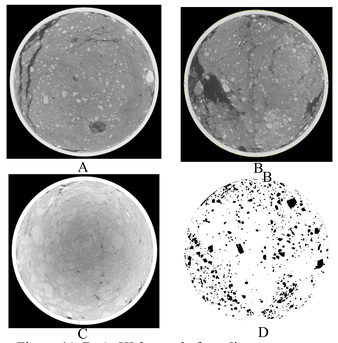


Figure 4A-D. A. HL2 sample from Jizera Mountains, B. HL3 sample from Jizera Mountains, C. Viznov sample, D. Segmentation for stone isolation in HL2

Table 1. Total porosity of each sample

	HL2	HL3	Viznov
Total Porosity	46.90 %	18.88 %	11.17 %

Table 2.Stone content of the Jizera soil cores

	HL2	HL3
Stone Content	8.91 %	9.63 %

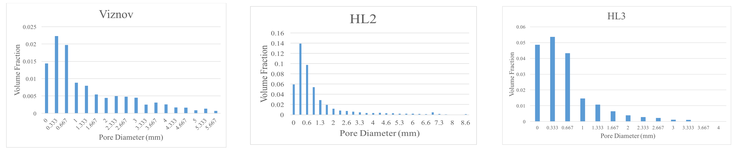
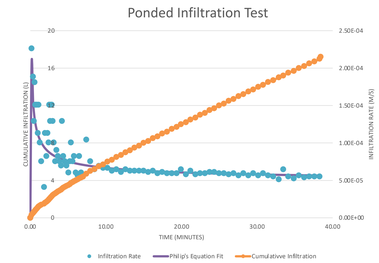


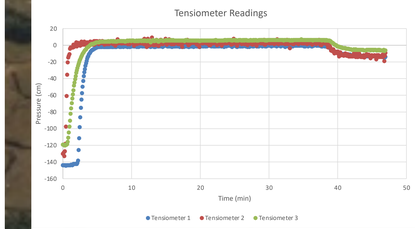
Figure 5. Histograms of the pore size distribution for each soil core sample

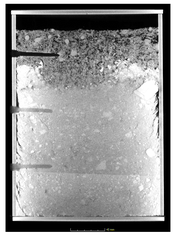
Ponded Infiltration Analysis

- A 20 cm diameter and 25 cm tall soil core was collected in 2016 for a laboratory experiment in ponded infiltration
- The soil core was collected from the Uhlriska catchment in the Jizera Mountains in the northern part of the Czech Republic
- A constant water head was maintained; input was recorded, bottom flux was recorded, three tensiometers were inserted at depths of 5 cm, 12 cm, and 19cm to record the pressure changes as the wetting front moved down the profile
- Infiltration rate, flux, cumulative infiltration, and pressure gradient changes were recorded



K_s	0.49 cm/min
K_s	702.48 cm/day
K_s	8.13E-03 cm/s
K_s	8.13E-05 m/s
Phillip:	
S	1.015E-03 ms(-1/2)
A	4.598E-05 m/s
K	6.850E-05 m/s
Indicator Height	0.022 m
Cylinder Height	0.04 m
Cylinder Diameter	0.375 m
Cylinder Area	0.11045 m^2

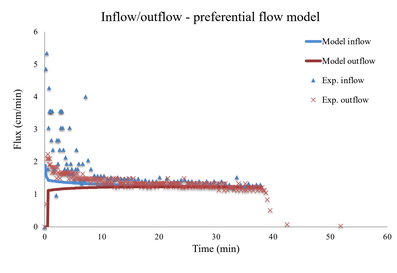


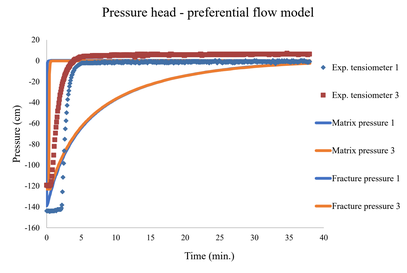


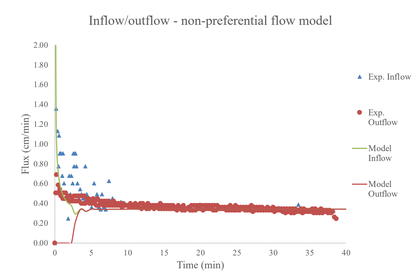
Above: Laboratory results. Above right: the ponded infiltration experimental setup. Right: a cross section of the core with the tensiometers from a CT scan.

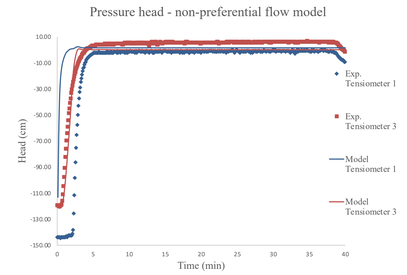
Infiltration Modeling with Hydrus-1D

- The same lab ponded infiltration experiment was modeled in 2016 and 2018. The 2016 model considered preferential flow, while the 2018 model did not. These charts show how that these models fit the data.
- The 2016 model was created in S1D, and the 2018 model was created in Hydrus-1D. While it would have been preferable to create both models in the same program, S1D did not produce reasonable results when modeling under non-preferential flow conditions.
- Preferential flow modeling appears to moderately outperform non-preferential flow modeling with regard to inflow and outflow. This demonstrates the importance of preferential flow modeling in structured soils.
- Fracture and matrix pressure head curves were not as close to the experimental data as the non-preferential flow curves were. However, the fracture and matrix pressure head curves more accurately modeled the position of the experimental curves relative to each other.









Conclusions

- Understanding hydraulic properties of soils in the vadose zone are important and influence water transport, biological, and chemical processes in the soil
- Hydraulic properties are directly depended on pore size distribution, soil structure, bulk density, texture, and initial water content
- Quantifying these properties can help explain how readily water and contaminants are transported through the soil profile
- Soil core analyses and electrical resistivity measurements are two good methods used to examine soil structure and composition
- Using computer modeling for hydraulic properties is a relatively cheap and efficient method for quantifying infiltration
- A multidisciplinary approach to science allows for a better collection of ideas and viewpoints to address a problem

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