10th International Groundwater Quality Conference (GQ2019)

Submission ID 171:

# Laboratory Investigation on Characterizing the Source Zone Geometries of Dense Non- Aqueous Phase Liquids (DNAPLs): The Impact of Fluid and Aquifer Properties

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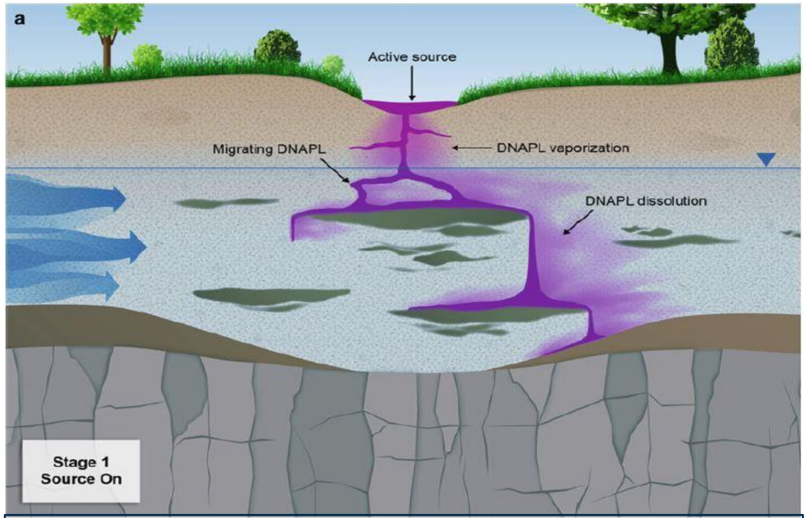
# Background and Motivation

- DNAPL = **D**ense **N**on-**A**queous **P**hase **L**iquid
- $\rho_{DNAPL} > \rho_{Water}$
- Less degradation → Longer persistant in groundwater (up to decades)
- Previous studies based on:
  - Plume migration (dissolved phase)
  - Simplied assumption (point/line/rectangular) for plume length estimation

(Kueper et al., 2014)




Principles of DNAPL distribution in the subsurface

⇨ **Improve current understanding of complex Source Zone Geometries (SZGs) for DNAPL contamination**

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# Previous Studies

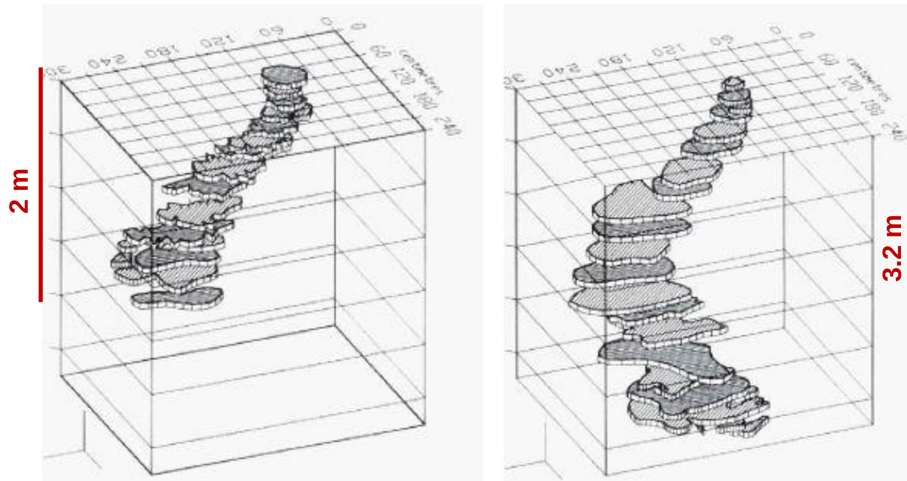
## (Poulsen and Kueper, 1992)

- Field Scale – Unsaturated Zone
- Mainly investigated phase distribution due to **Release methods** of DNAPL
- Summary:
  - Overall migration of SZGs
    - Release area at ground surface
    - Source strength
    - Angle of bedding
  - Slow release promotes deeper migration

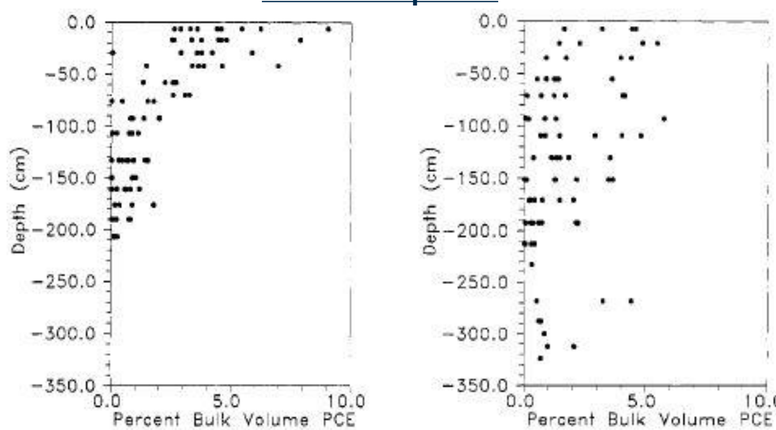
Instantaneous release

Drip / slow release

**Overall migration**




**Saturation profile**

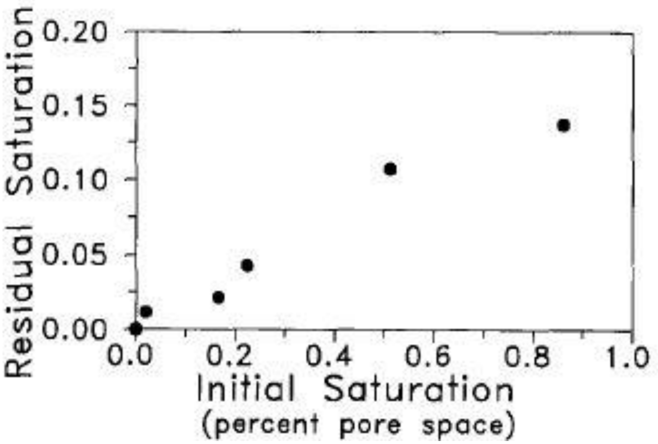


# Previous Studies

## (Kueper et al., 1993)

- ❑ Field Scale – Saturated Zone
- ❑ Investigated **initial-residual saturation** relationships and **pool formation**.
- ❑ Summary:
  - Residual saturation is a direct function of initial saturation.
  - Pool forms in laminations and lenses

**Initial-residual saturation**

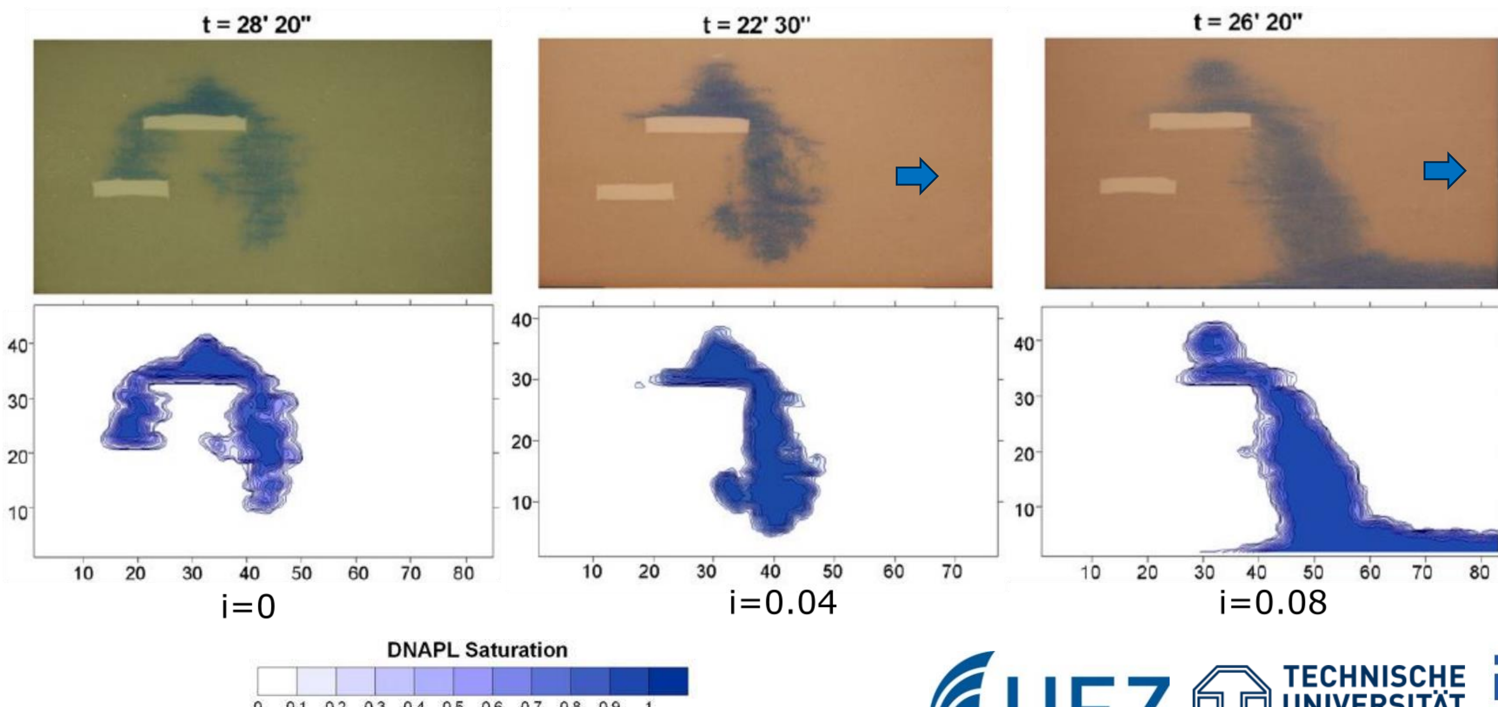


# Previous Studies

## (Luciano et al., 2009)

- Laboratory Scale – Saturated Zone
- Investigated the influence of **hydraulic gradient** on source migration with enhanced imaging analysis.

- Summary
  - Hydraulic gradient (i) promotes both downward and lateral movement of source migration.



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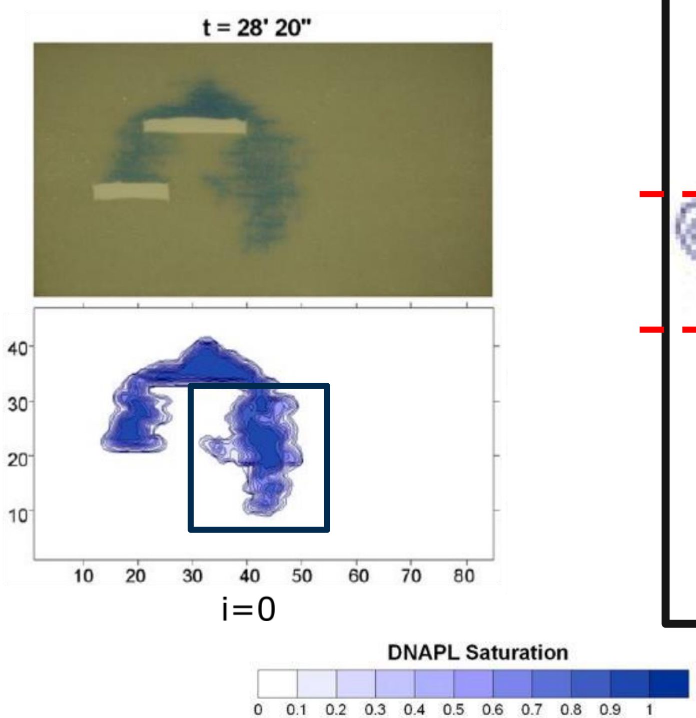
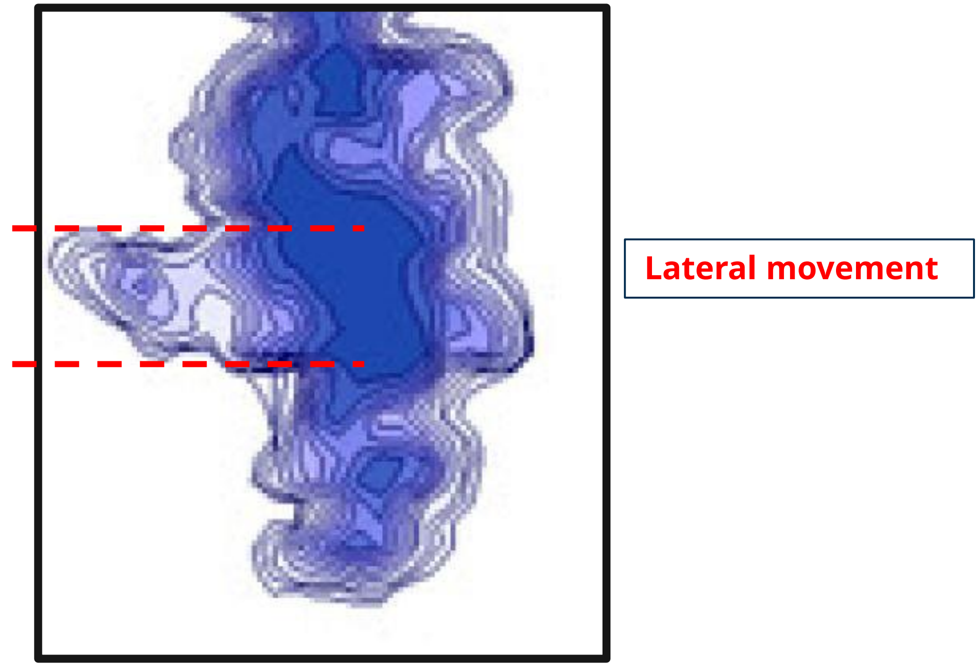
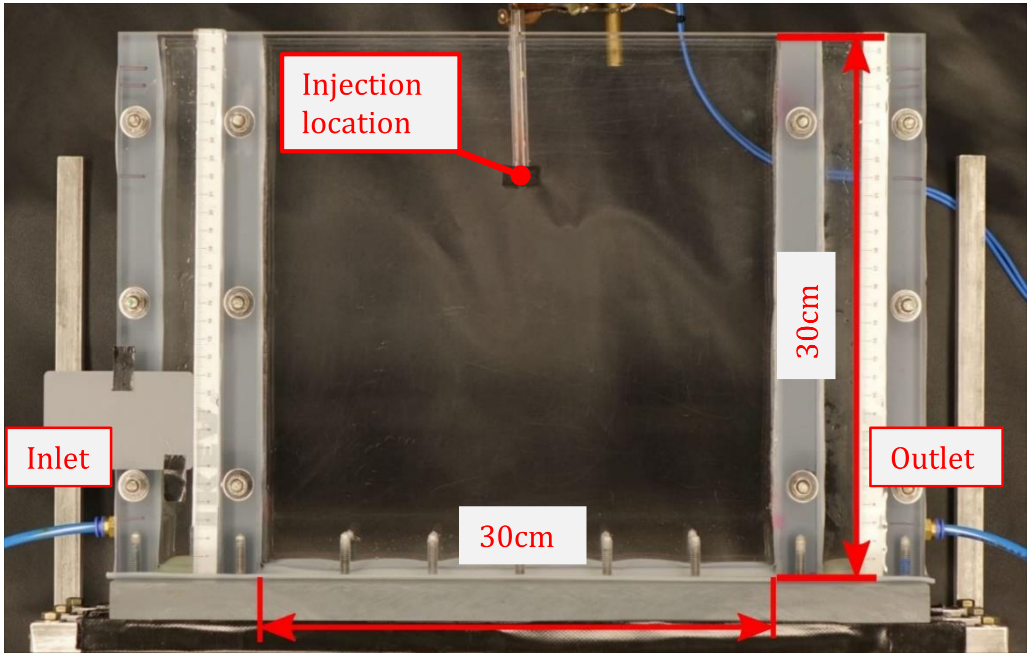


# Laboratory Experiments

## ❑ 2D Tank Setup [2]

- Detachable PMMA Tank
- Dimension: 30 x 30 x **2** $cm^3$
- Porous Medium -
  - → Natural Sand Fraction
  - → Sieved Size: 1 – 2 mm
- Surrogate DNAPL(HFE-7100) dyed with red coloured dye.




[2] Engelmann et al., (manuscript in prep.)

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# Laboratory Experiments

## ❑ Migration of DNAPL Source Zone

- Fully homogeneous
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- No hydraulic gradient (i=0)
- Injection head: Falling;
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→ Migration started after overcoming the entry pressure.

→ Non-uniform SZGs in full homogeneous soil system.

→ *Compaction* was done manually by hand compactor with fixed height increment.
**<u>Position of pools</u>** is strongly correlated with that height.

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## ❑ Migration of DNAPL Source Zone

→ Compaction was done by vibration with rubber hammer

→ Pools tends to form during downward migration

→ Non-uniformity of source zone prevails

30cm

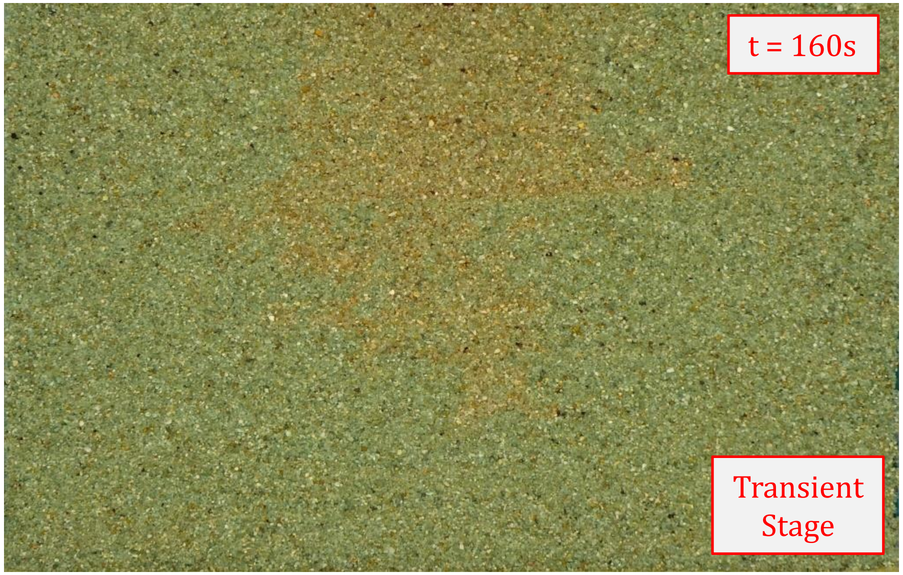
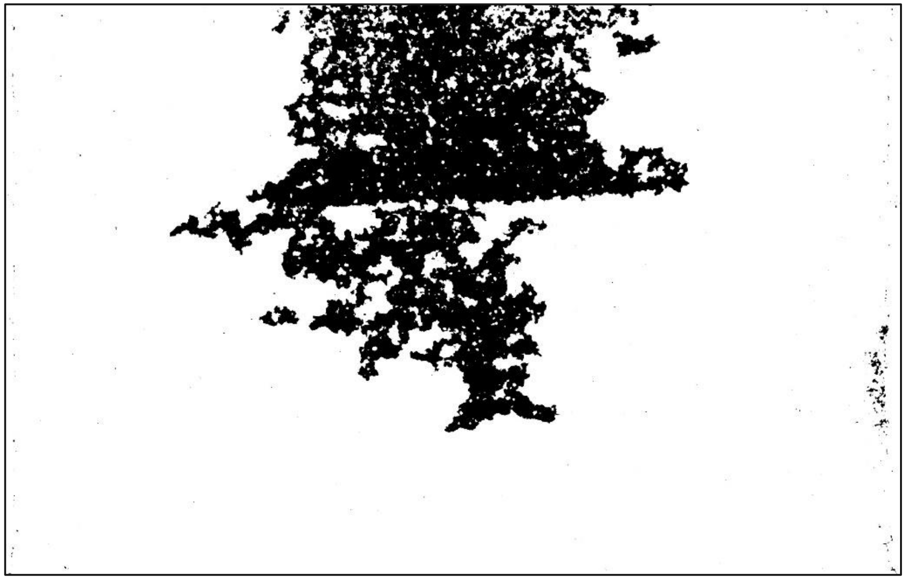



Image aquired by digital camera (cropped) [1] [8]

30cm



Source phase with binary image (cropped) [1] [8]

[8] Visit **poster no. 167** for more on image processing and analysis

[1] Engelmann et al., (manuscript in prep.)

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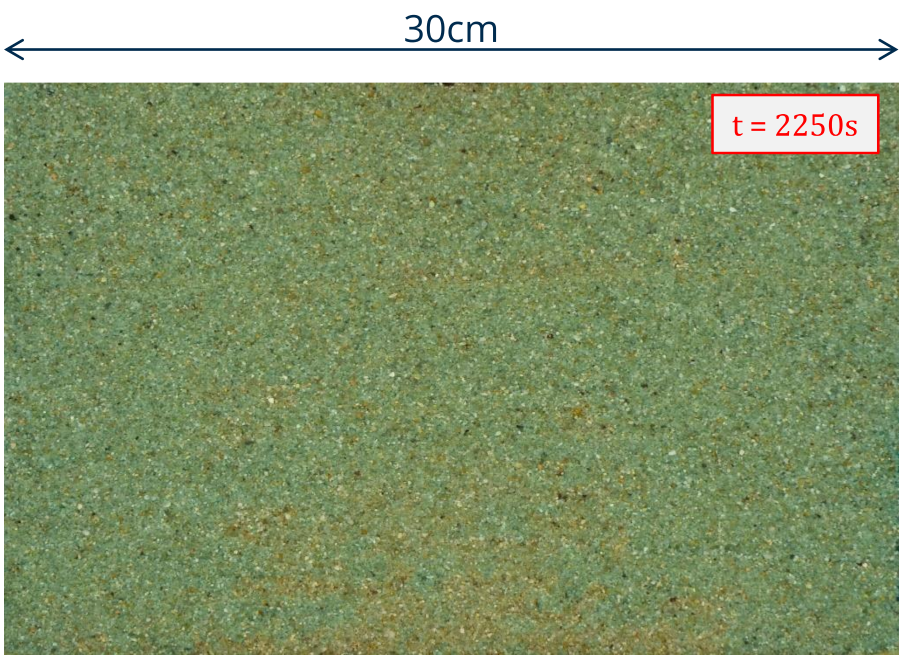


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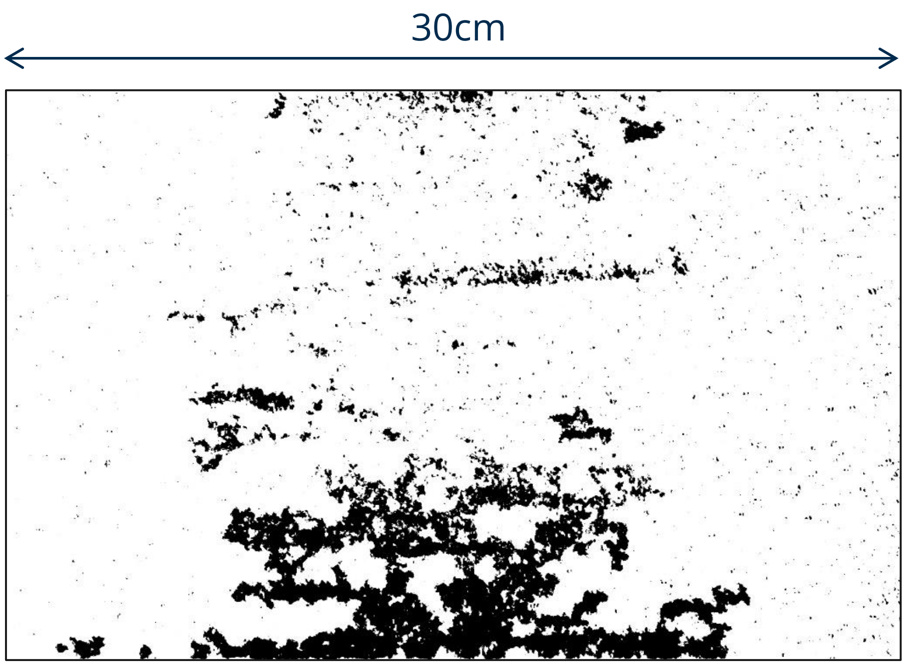


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# Conclusion and Outlook

## ❑ Conclusion:

- Migration of source phase and their investigation are extremely uncertain processes even in the most suitable and controlled environment
- Strength of source controls the infiltration of DNAPL into porous media
- Pool forms even in homogeneous media with defined size ranges
- Current knowledge on how to characterize the shape of source zone need much more improvement

## ❑ Outlook:

- More attempts with repetitions to further understand the pool and residual formation
  - *How this distinct pool forms in laminations and lenses in homogeneous system?*
  - *Why it gives different SZGs with each repetition? is there any pattern we can follow?*
- Improvement of methods to measure the expected observations for phase detection.
- Comparison and validation by numerical investigations

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[9] **Acknowledgement: Presence and guidance of Prof. Dr. Charles J. Werth**, Associate Chair for Environmental Engineering, University of Texas at Austin, during the initial trials of experiments.

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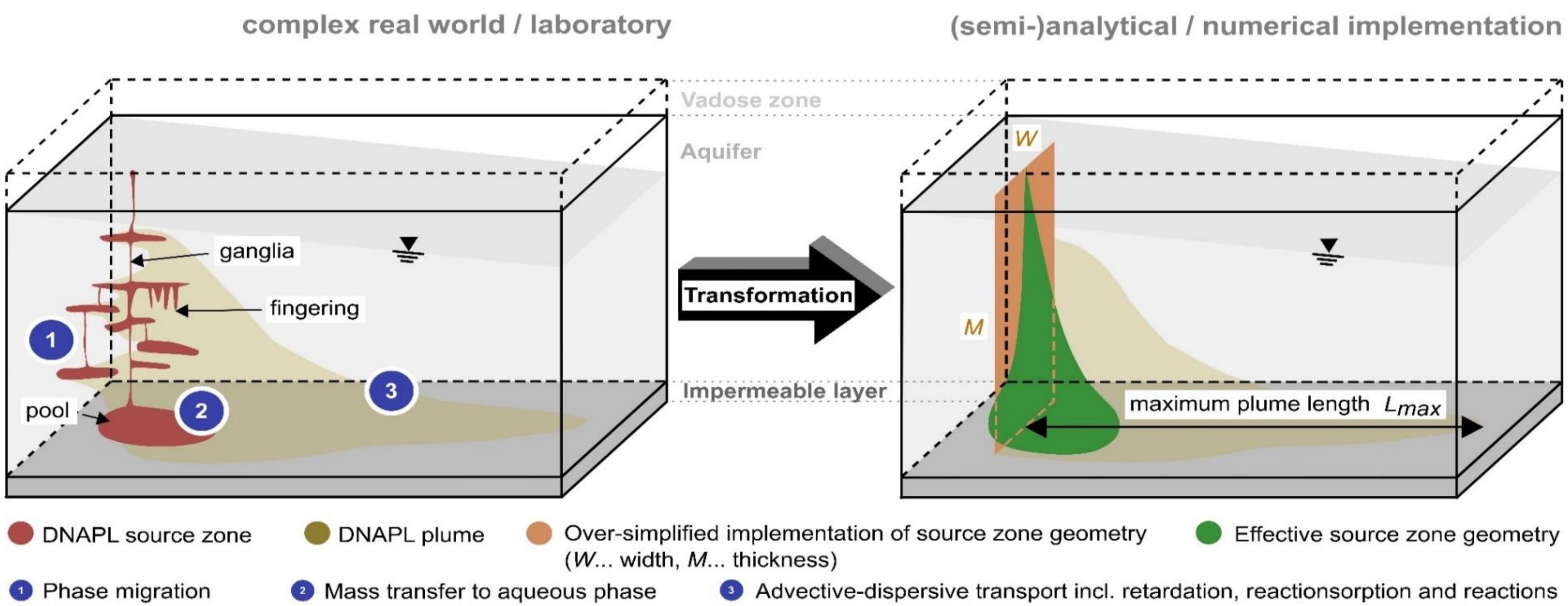
# Backup Slides

# Background and Motivation

## Objective/Goal:

- ❑ Complex Source zone geometries (SZGs) → Effective SZGs
- ❑ Effective SZGs → easier and better implementation for plume assessment ($L_{max}$)

(Engelmann et al., 2019)



# Background and Motivation

## Source Zone Geometires (SZGs)

- Residual Formation:
  - Blobs & gangila between pores/pores throat due to snap-off and trapping mechanisms
  - Typically occupies between 1% to 43% (pore space)
  - Important factors –
    - Initial-residual saturation relationship
    - Release methods
    - Pore geometry (aspect ratio)
    - Viscosity & density ratio

# Background and Motivation

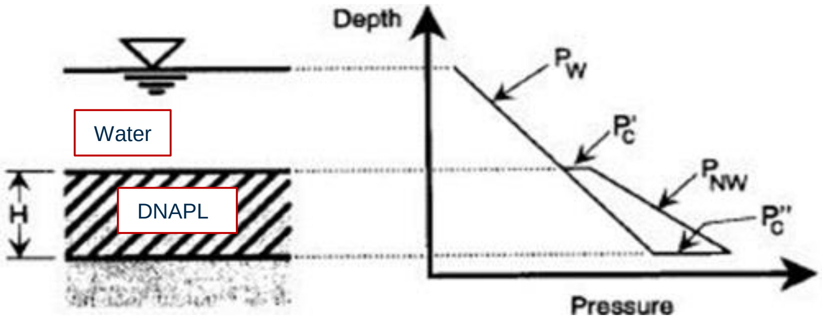
## Source Zone Geometires (SZGs)

- <u>Pool Formation:</u>
  - Capilary resistance by porous media
  - Maximum pool height is given by:

$$H = \frac{P_c'' - P_c'}{\Delta\rho g}$$

Where,
$P_c''$ = capilary pressure at the base of pool
$P_c'$ = capilary pressure at the top of pool
$\Delta\rho$ = density difference between DNAPL and water
g = gravity

  - Important factors –
    - Bedding angle
    - Interfacial tension
    - Hydraulic gradient
    - Preferrential pathways

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