Uptake and Loss of Vapor Phase PCE by Plants: Impacts to Phytoremediation

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Why Phytoremediation?

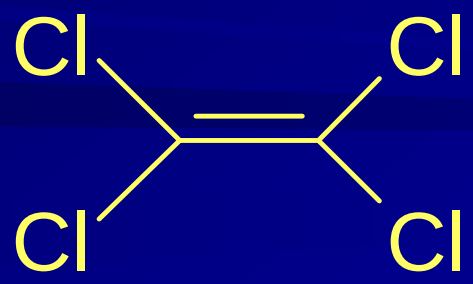
- When phytoremediation works it is very cost effective.
  - Hydraulic control
  - Immobilization
  - Degradation

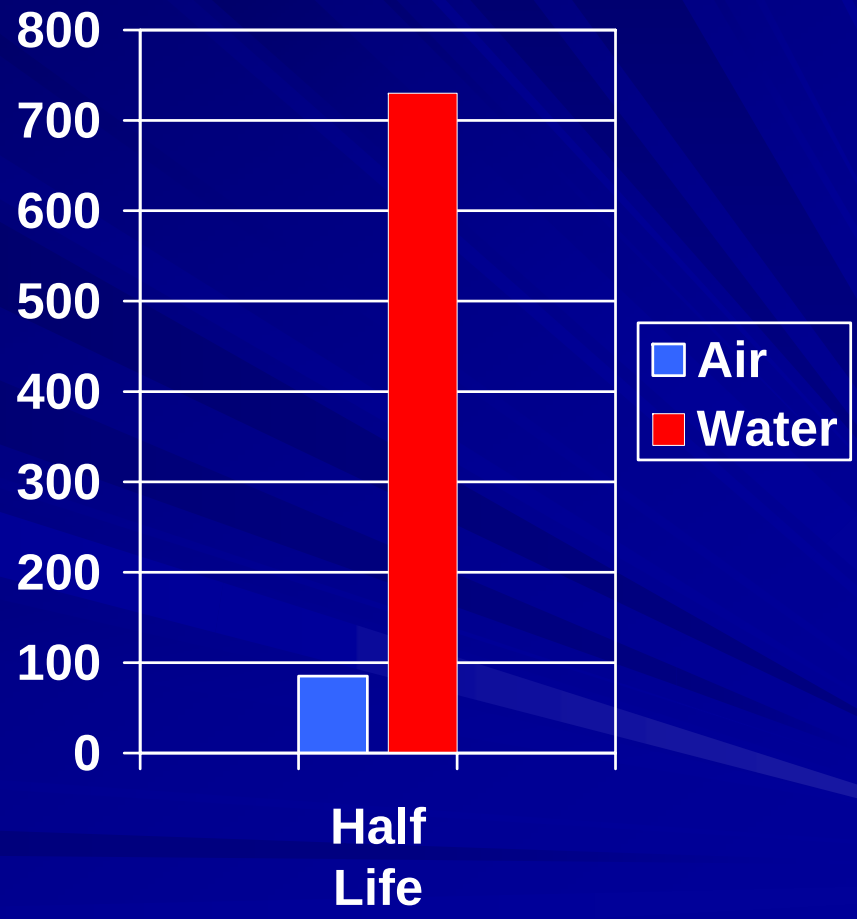
Before and 4 yrs after in Oregon

Courtesy Lou Licht, Ecolotree®

Tetrachloroethylene (PCE)

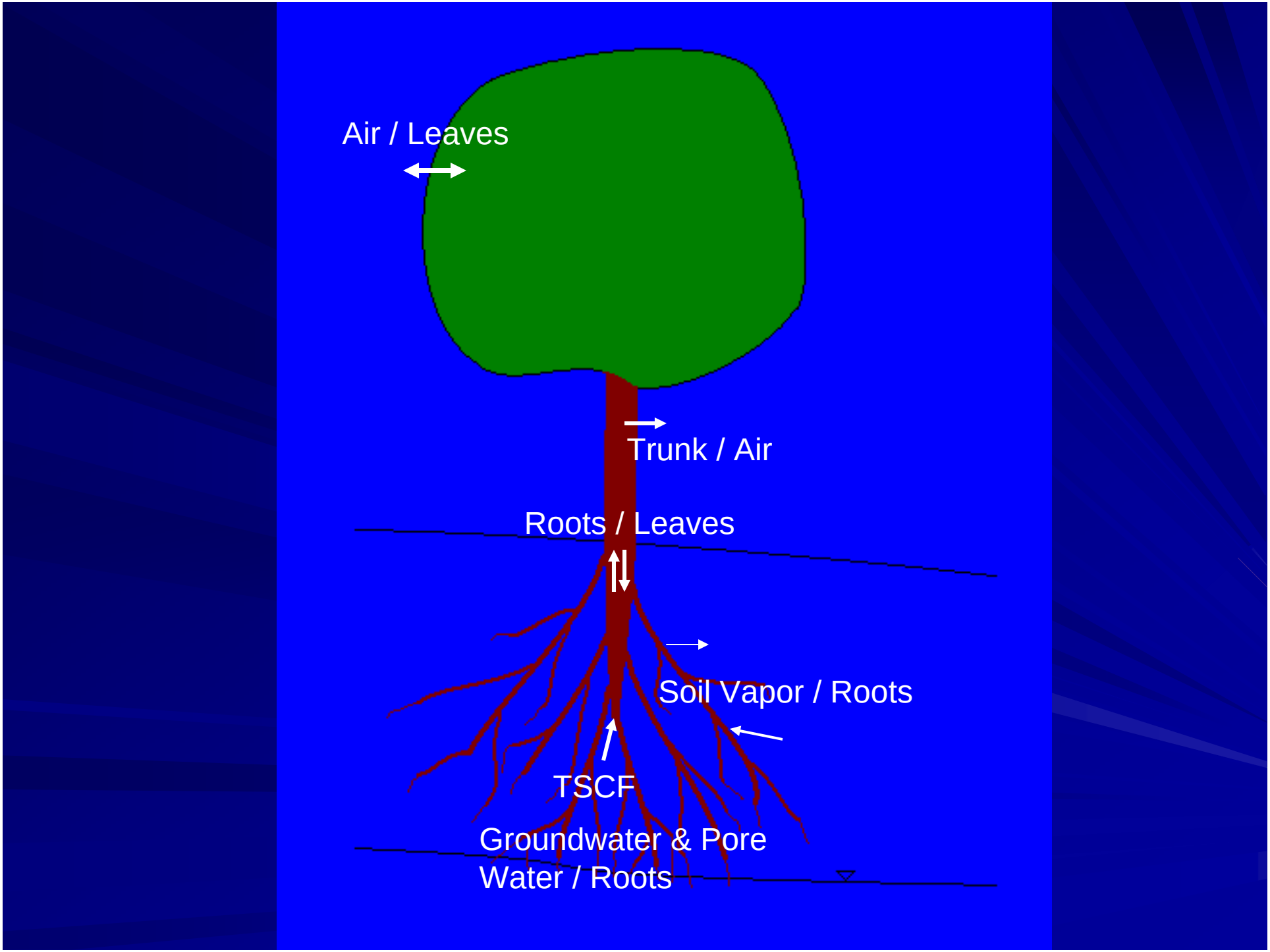
- Recalcitrant chlorinated solvent
- Used in textile and metal industries
- Found in abundance at the field site studied



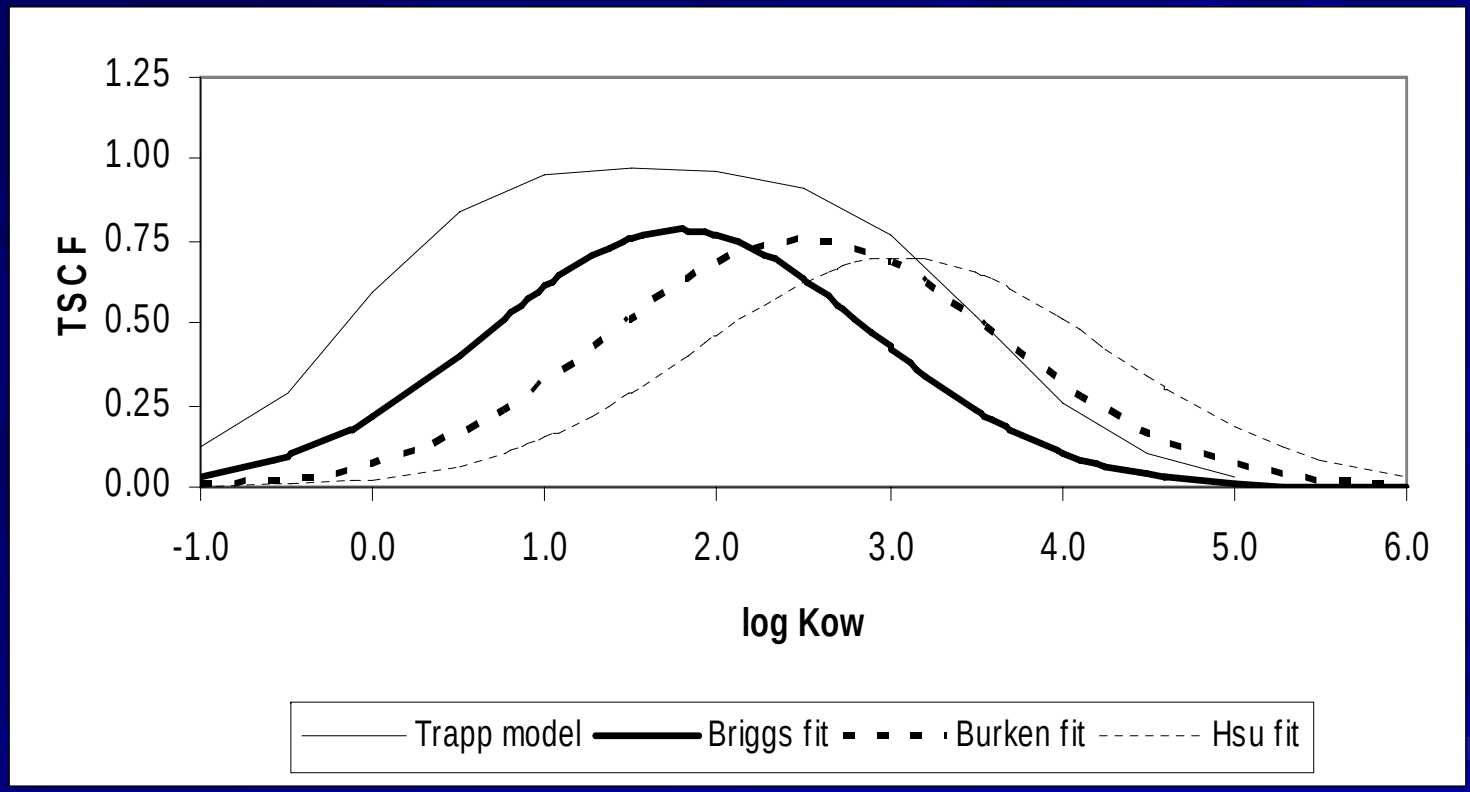


Derived from ToxProbe, Inc. report of Ten Carcinogens in Toronto

http://www.city.toronto.on.ca/health/pdf/cr_appendix_b_tetrachloroethylene.pdf


Air / Leaves
Trunk / Air
Roots / Leaves
Soil Vapor / Roots
TSCF
Groundwater & Pore Water / Roots

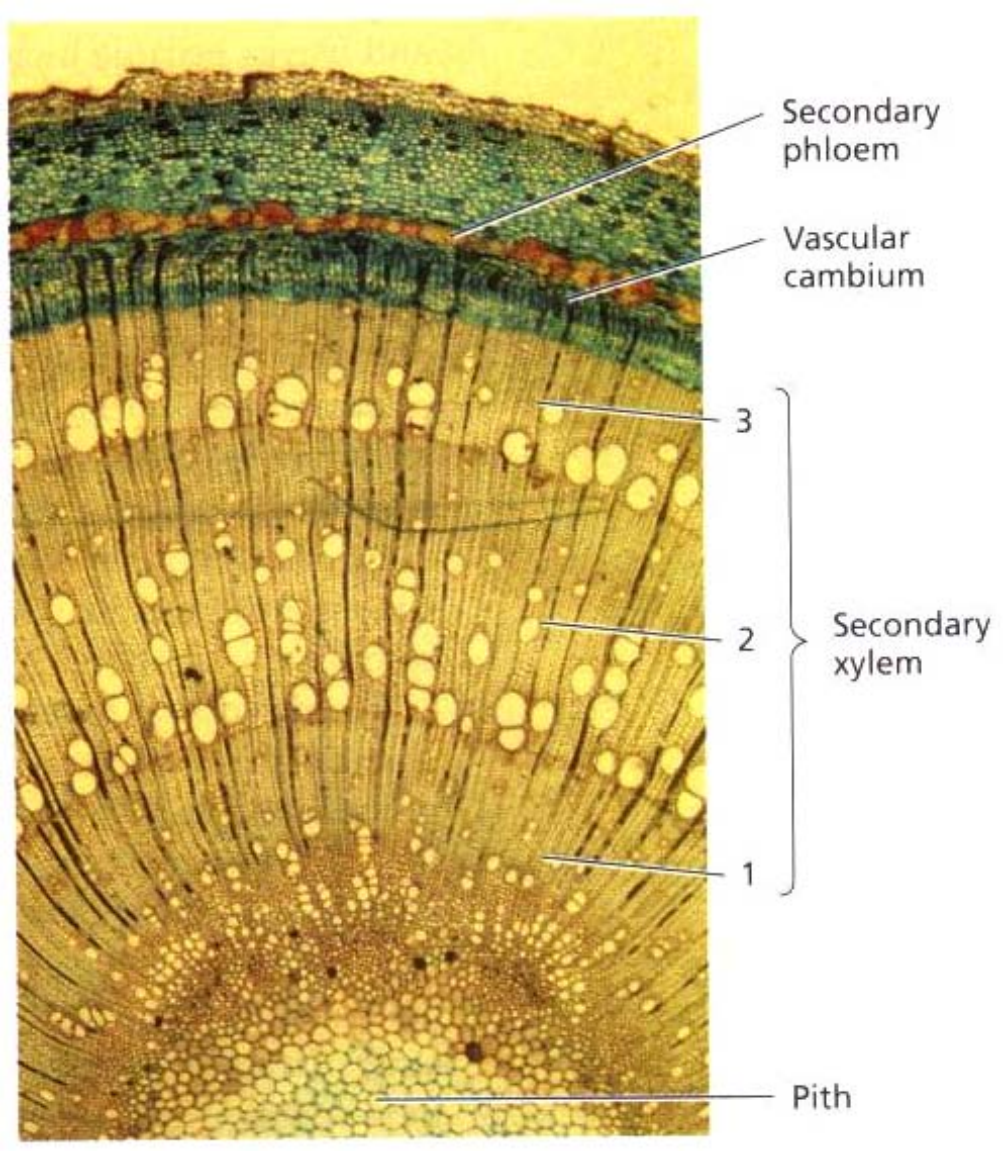
Transpiration Stream Concentration Factor (TSCF)



Why do results vary thus?

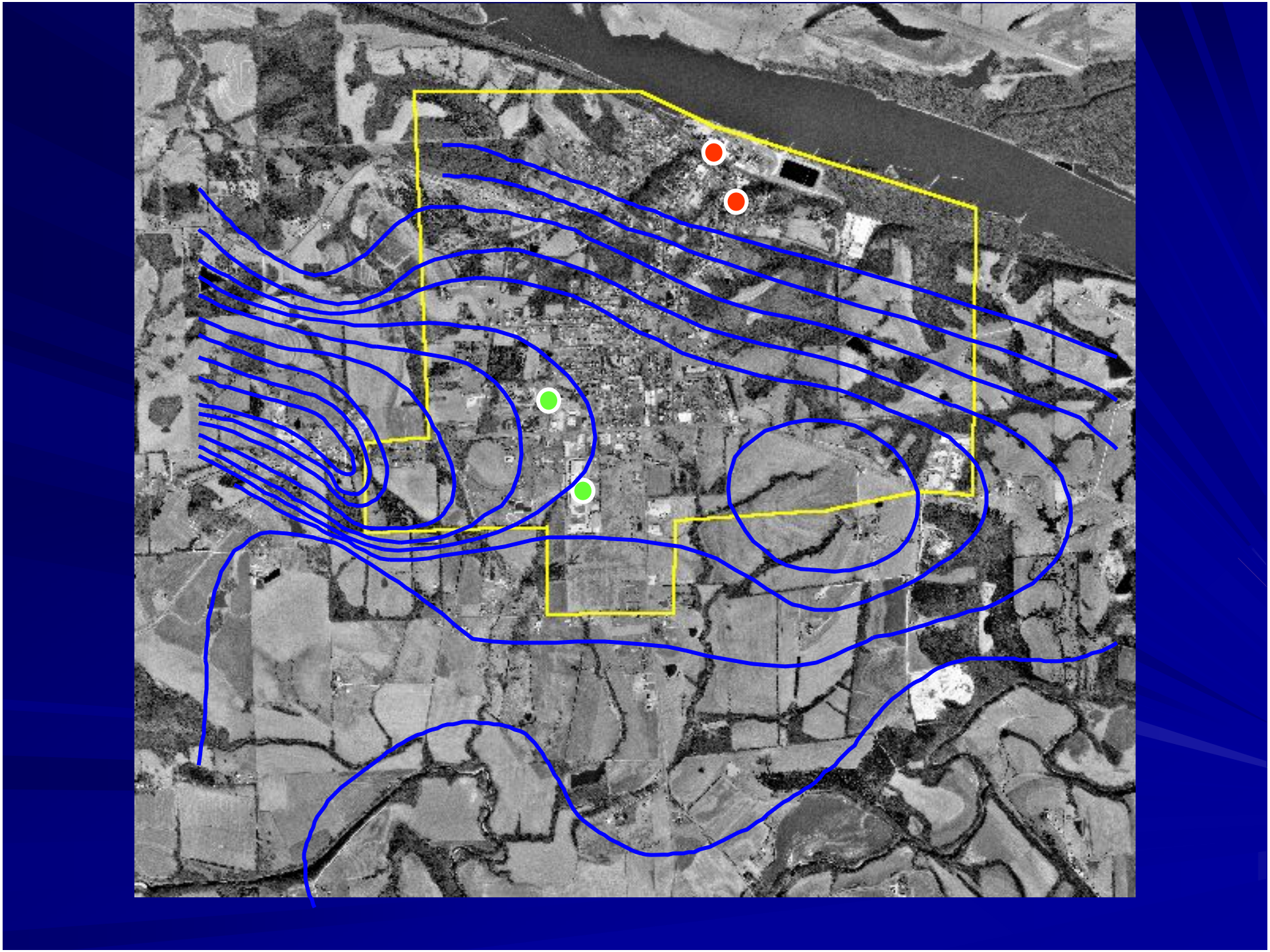
Stefan Trapp. Modeling Uptake into Roots and subsequent translocation of neutral and ionisable organic compounds. *Pest. Manag. Sci.* 2000, *56*, 767-778

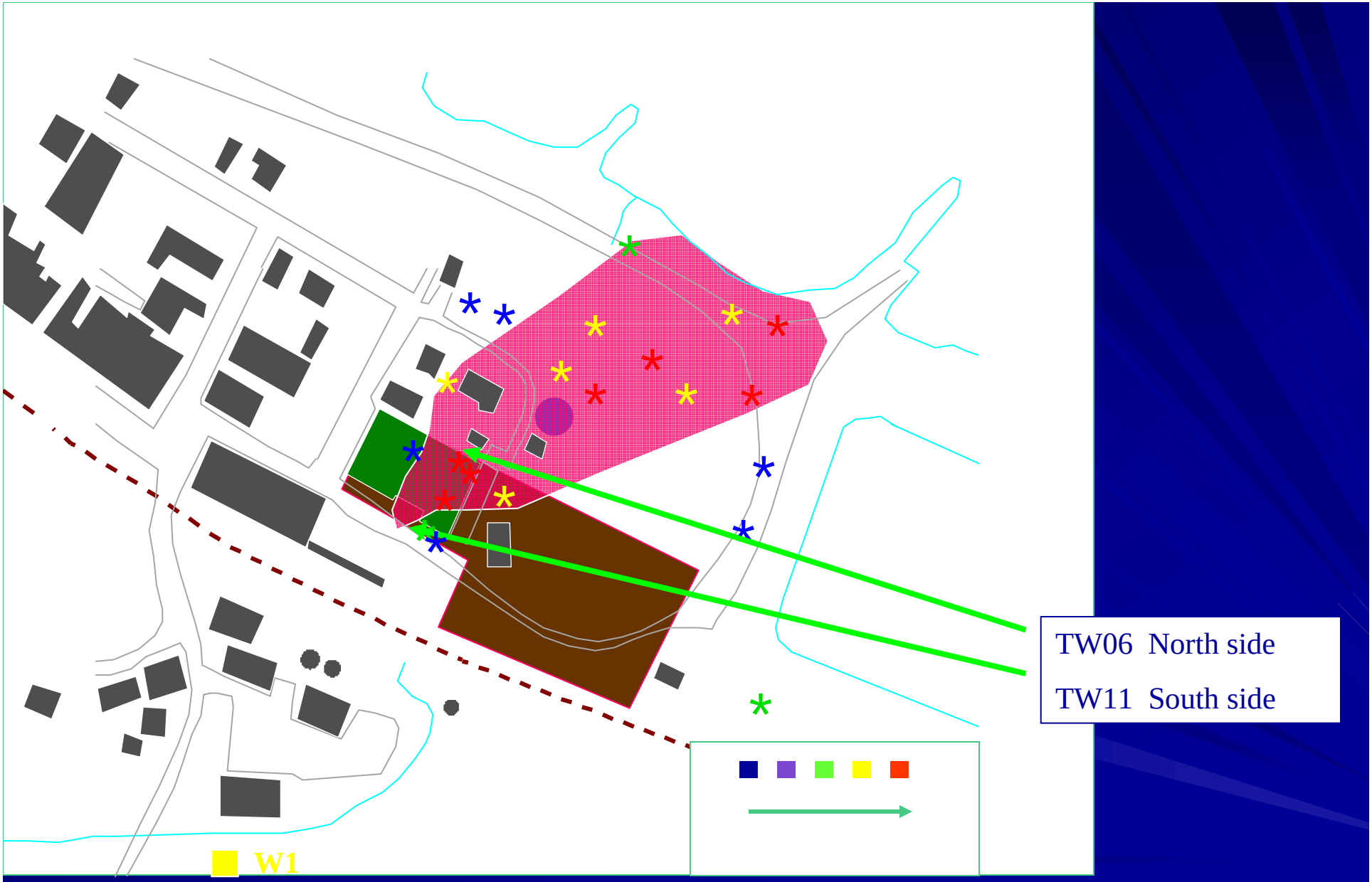
Do soil vapor phase VOCs, or the lack thereof, have a significant impact on contaminant uptake, loss, and translocation?



PLANT PHYSIOLOGY, Third Edition, Figure 10.2 © 2002 Sinauer Associates, Inc.

- Xylem – Transports water, minerals, and subsurface contaminants to the plant
- Phloem – Transports photoassimilates (fixed carbon) from the leaves to the rest of the plant





The plume is from tree core data *= GW sample

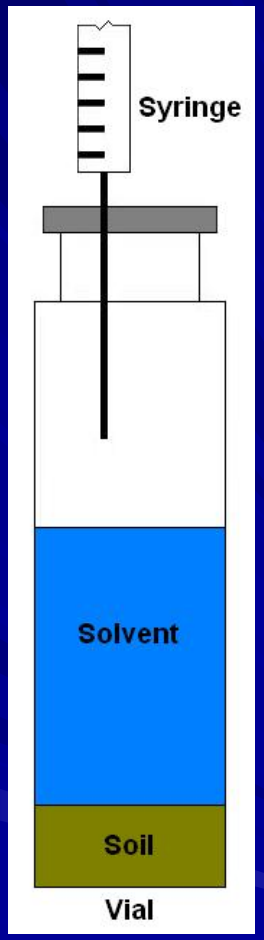
Methods

http://fri.sfasu.edu/

Tree coring and tree stem sectioning

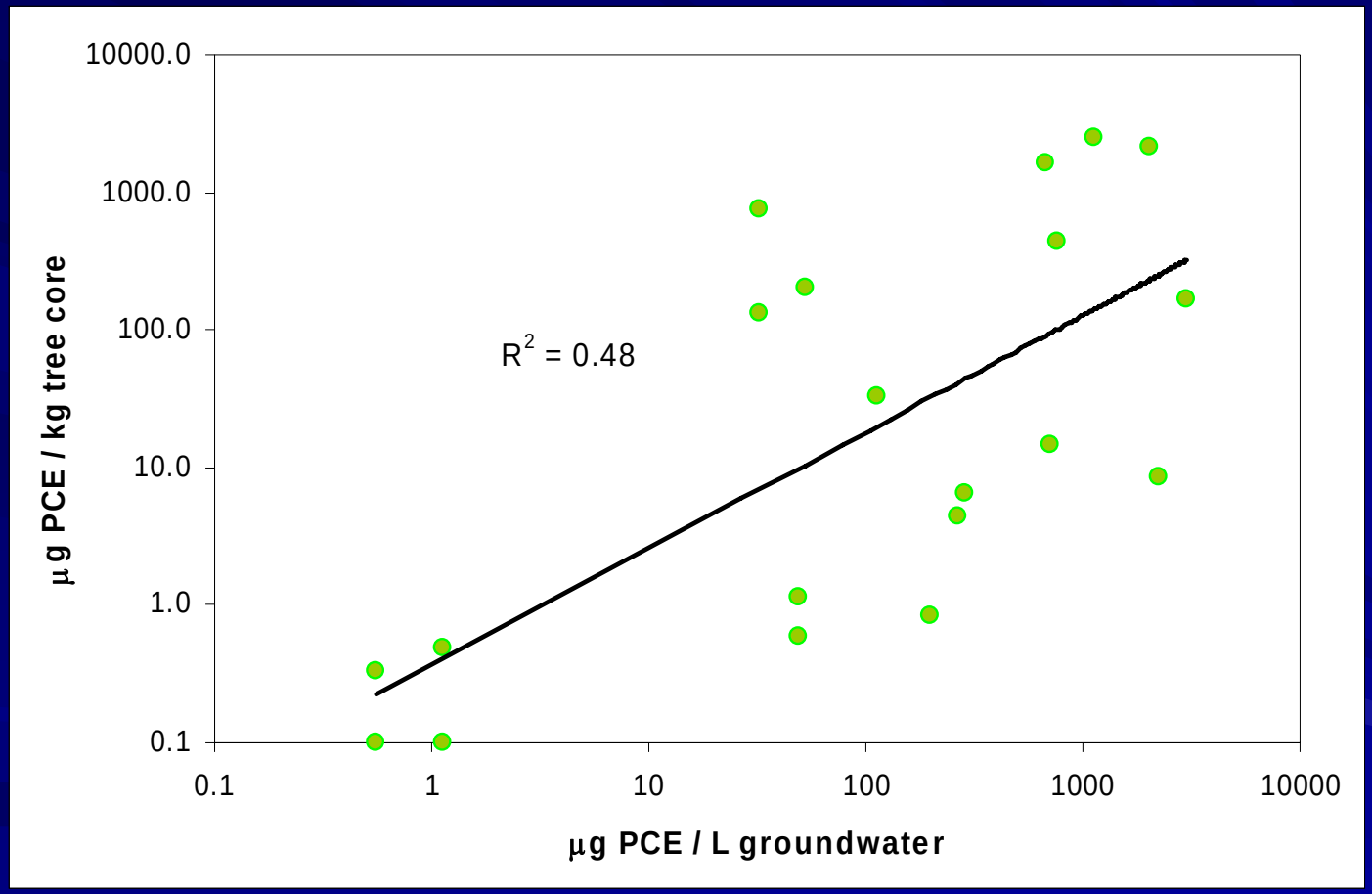
Direct Push

http://www.geoprobe.com

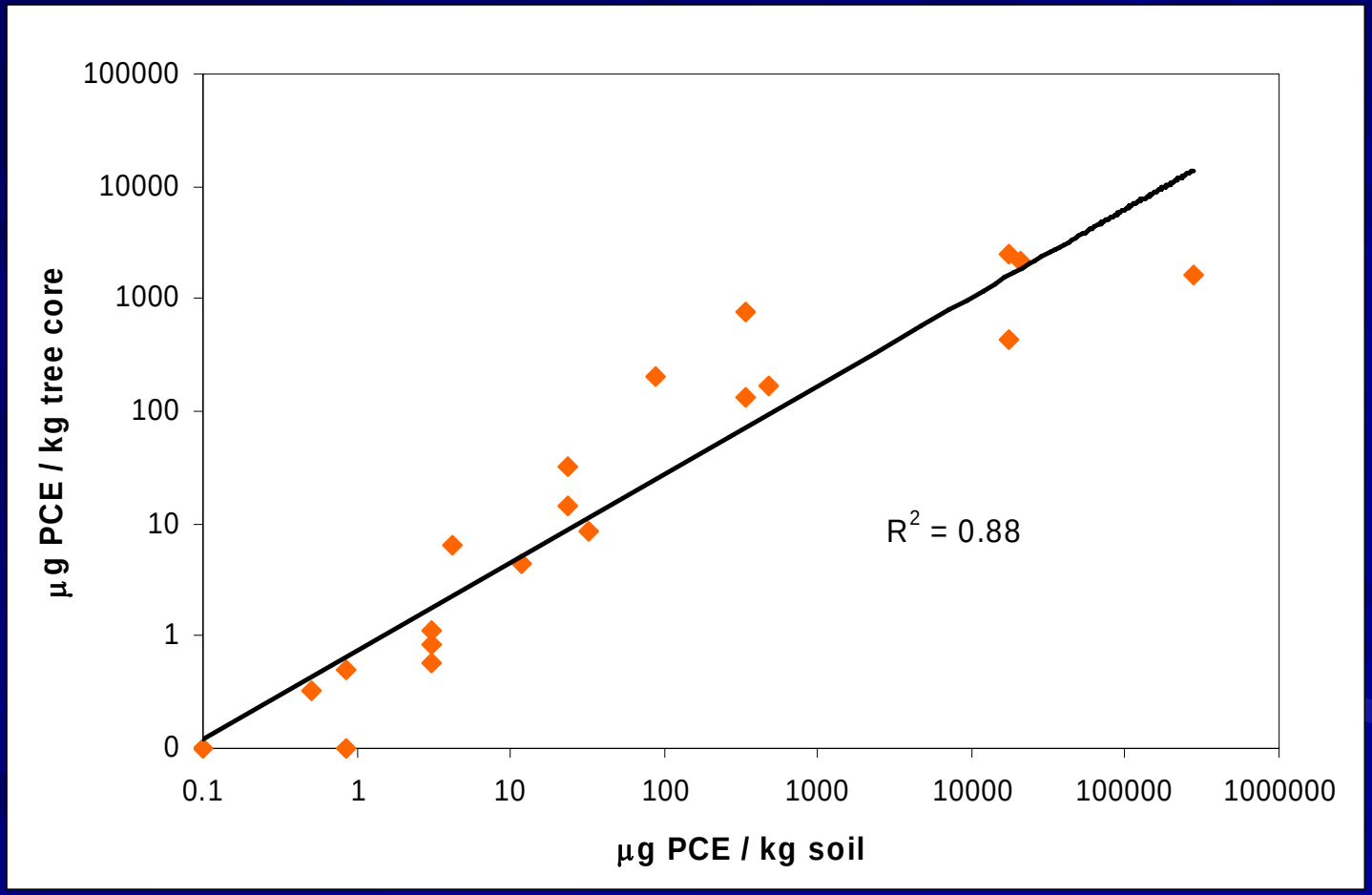


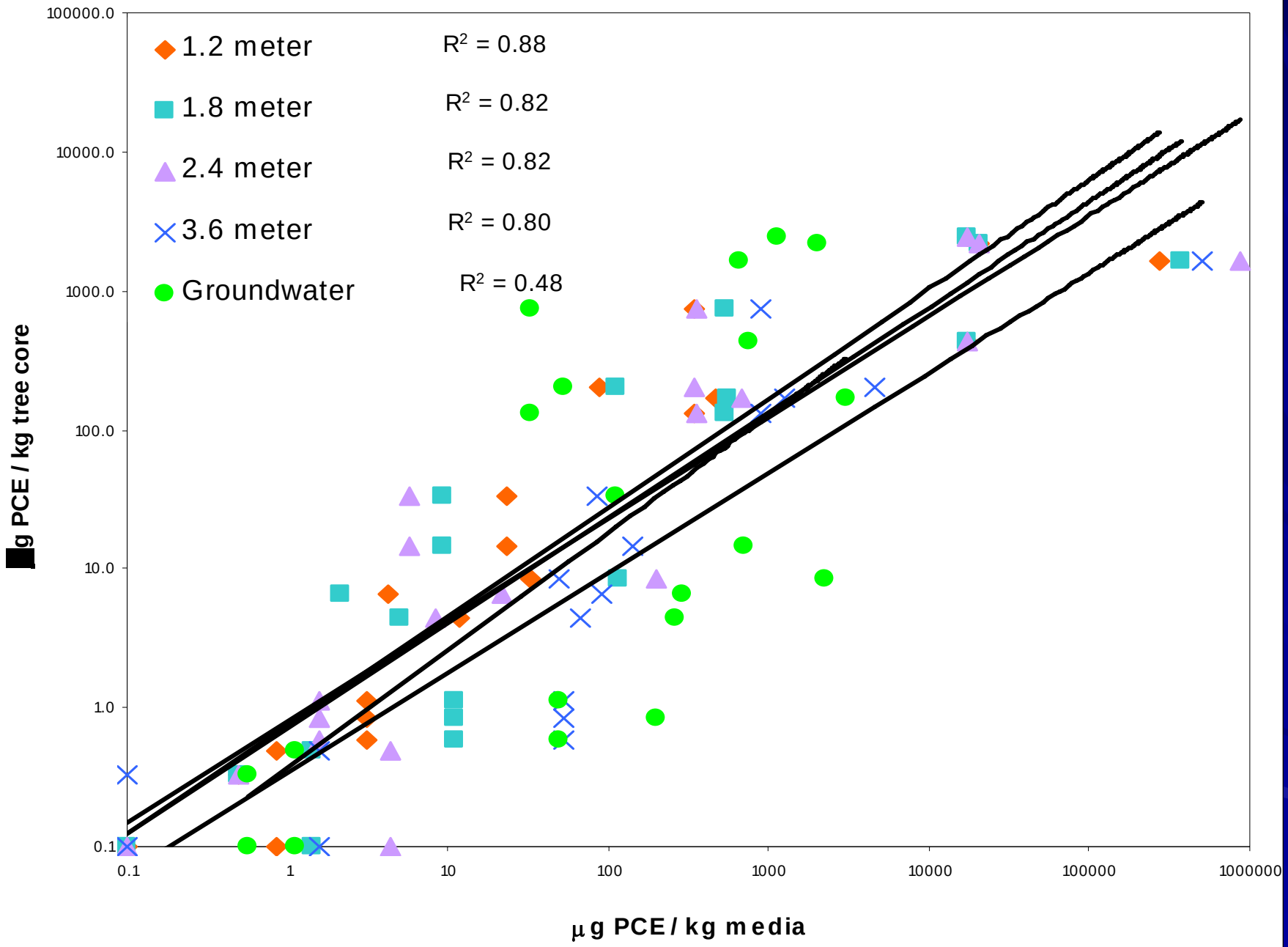
Soil samples

Field Data:
Tree vs. Groundwater (6 – 7.6 m)



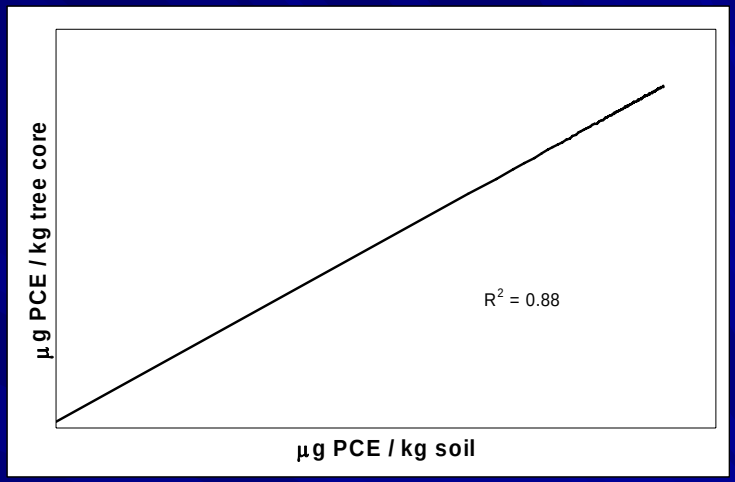
Field Data:
Tree vs. Soil 1.2 m deep



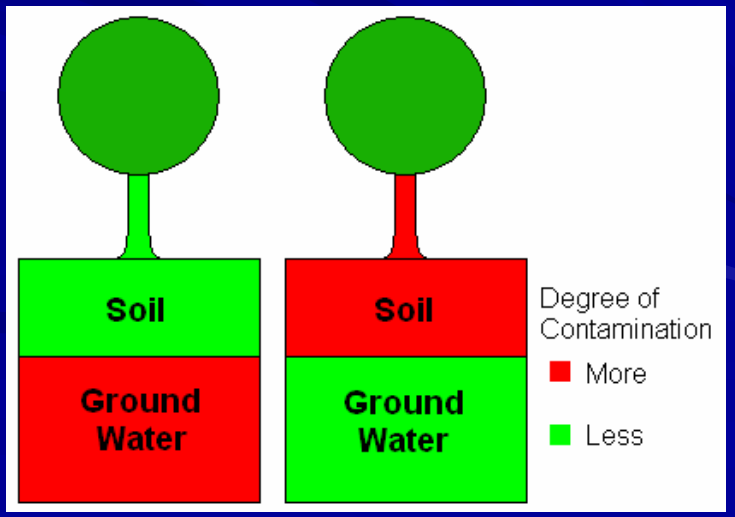

1.2 meter
1.8 meter
2.4 meter
3.6 meter
Groundwater
R2 = 0.88
R2 = 0.82
R2 = 0.82
R2 = 0.80
R2 = 0.48
100000.0
10000.0
1000.0
100.0
10.0
1.0
0.1
0.1
1
10
100
1000
10000
100000
1000000
g PCE / kg tree core
µg PCE / kg media

Hypotheses

- VOCs can freely and reversibly diffuse between tree roots and soil

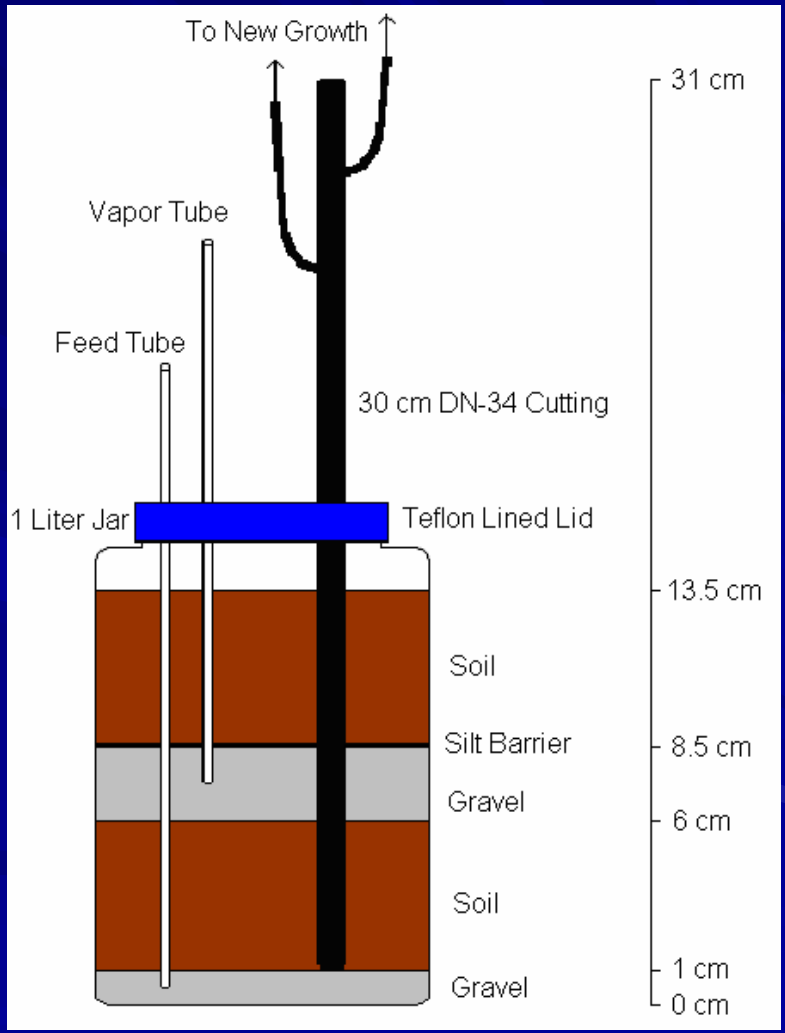


- Soil-PCE can have a greater effect on tree tissue PCE levels than groundwater PCE.



Methods – Batch Reactors

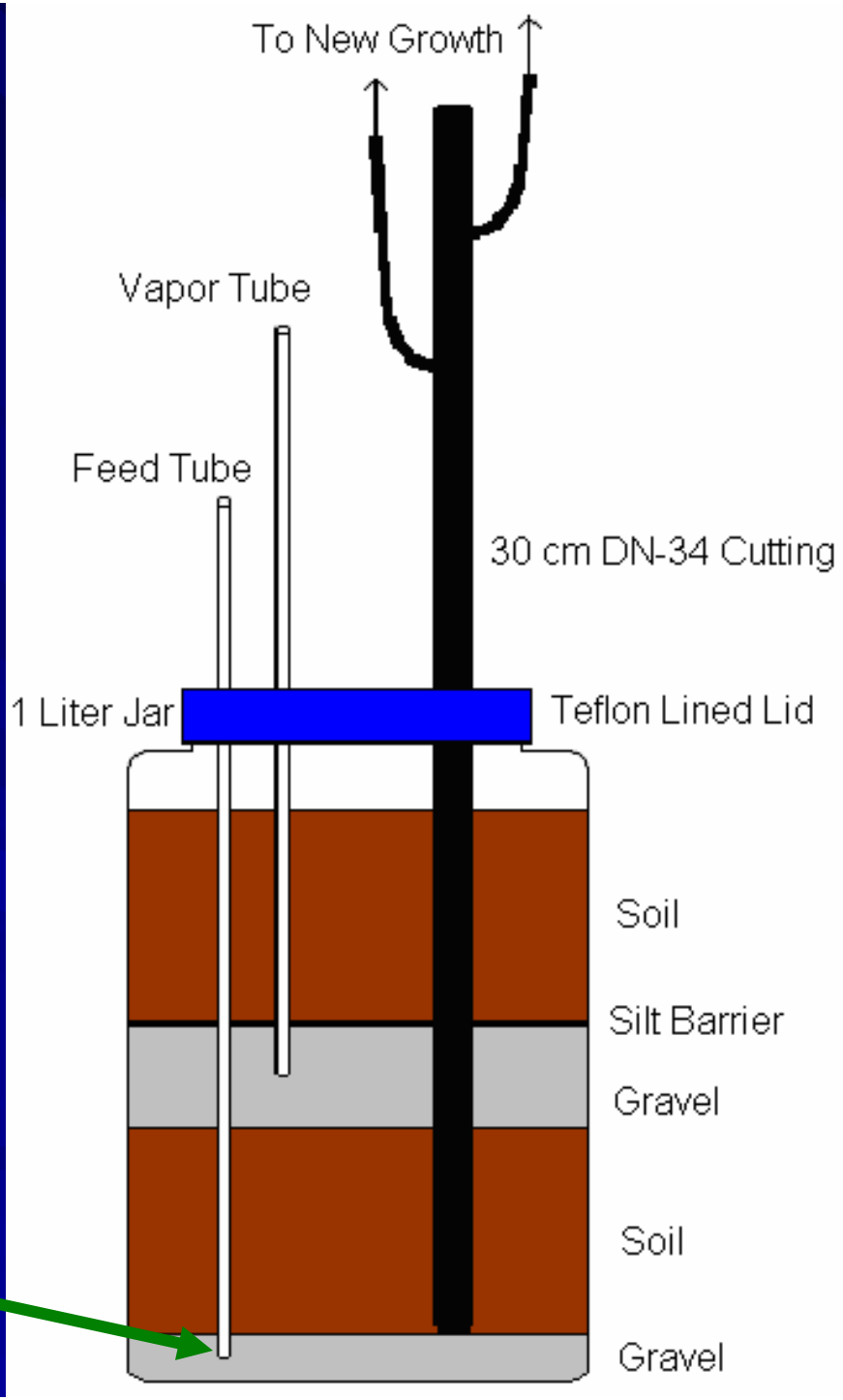
- Hybrid poplar (DN-34) cuttings were planted into soil in 1-liter glass jars
- Capillary barrier
- Watered gravimetrically



Contaminated Water / Stagnant Air Dosing Method

Nothing added to the vadose zone

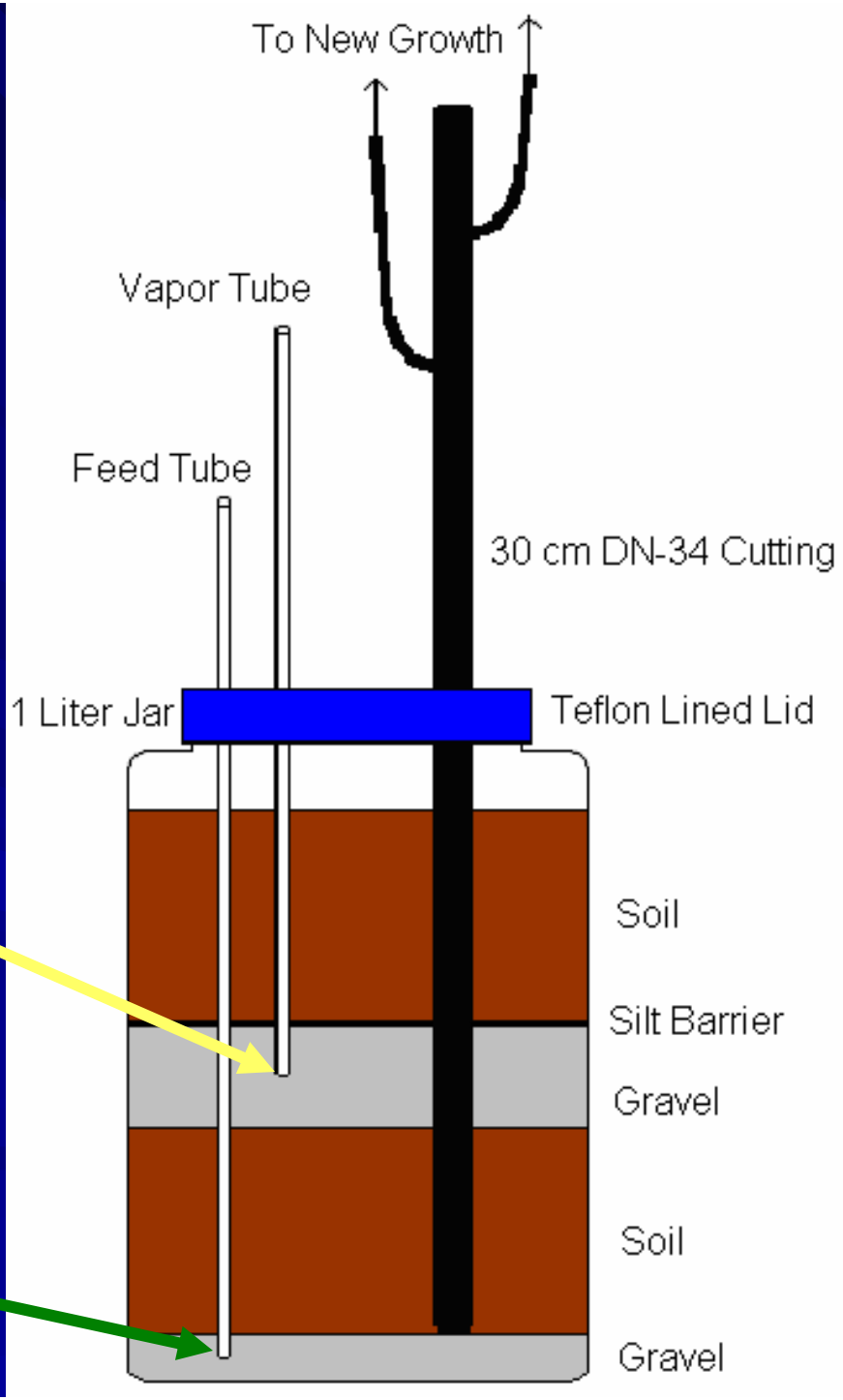
5 ppm PCE solution injected into reactor



Contaminated Water / Clean Air Dosing Method

Clean air vented through the vadose zone

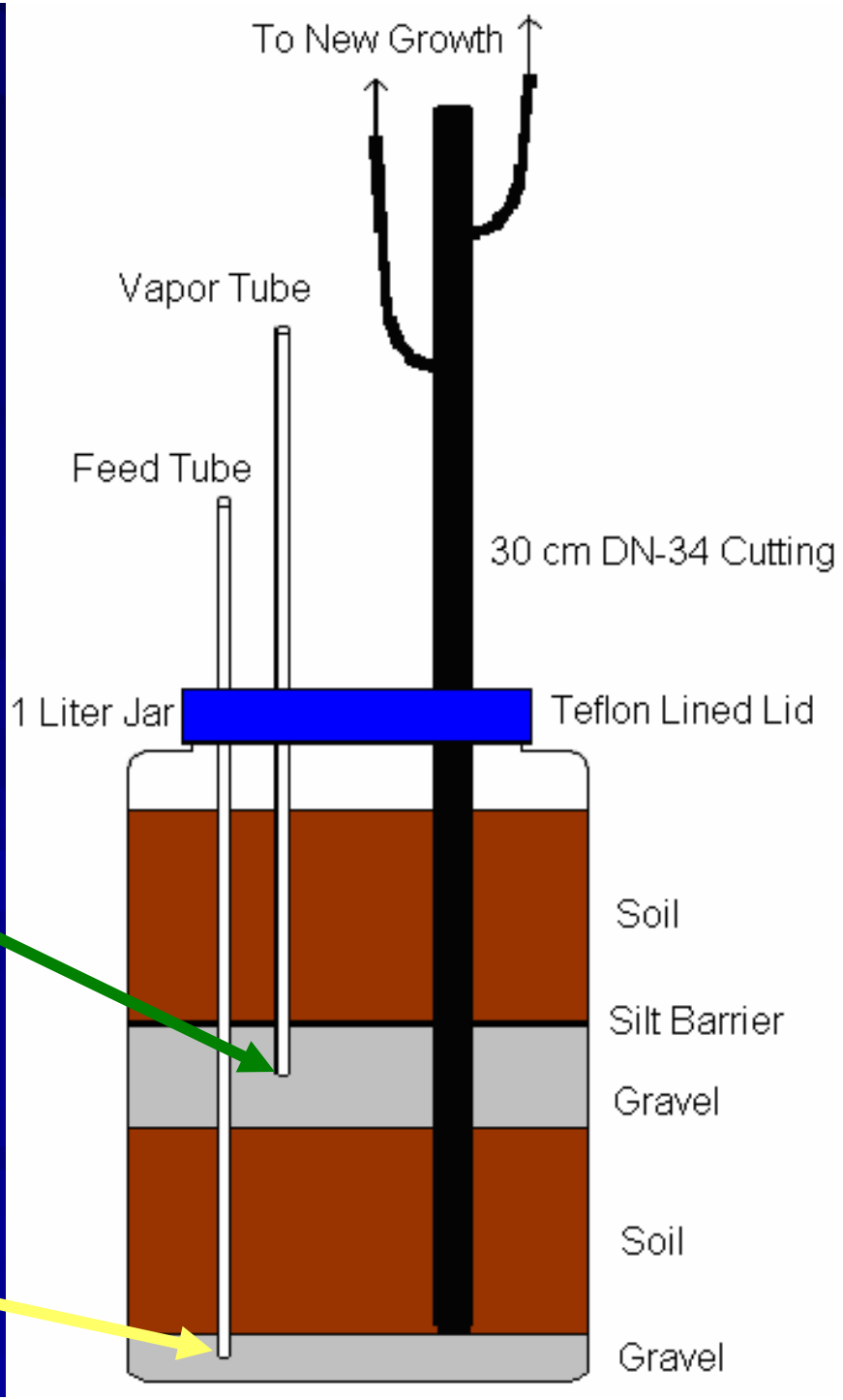
5 ppm PCE solution injected into reactor



Clean Water / Contaminated Air Dosing Method

Pure PCE vapor added to vadose zone

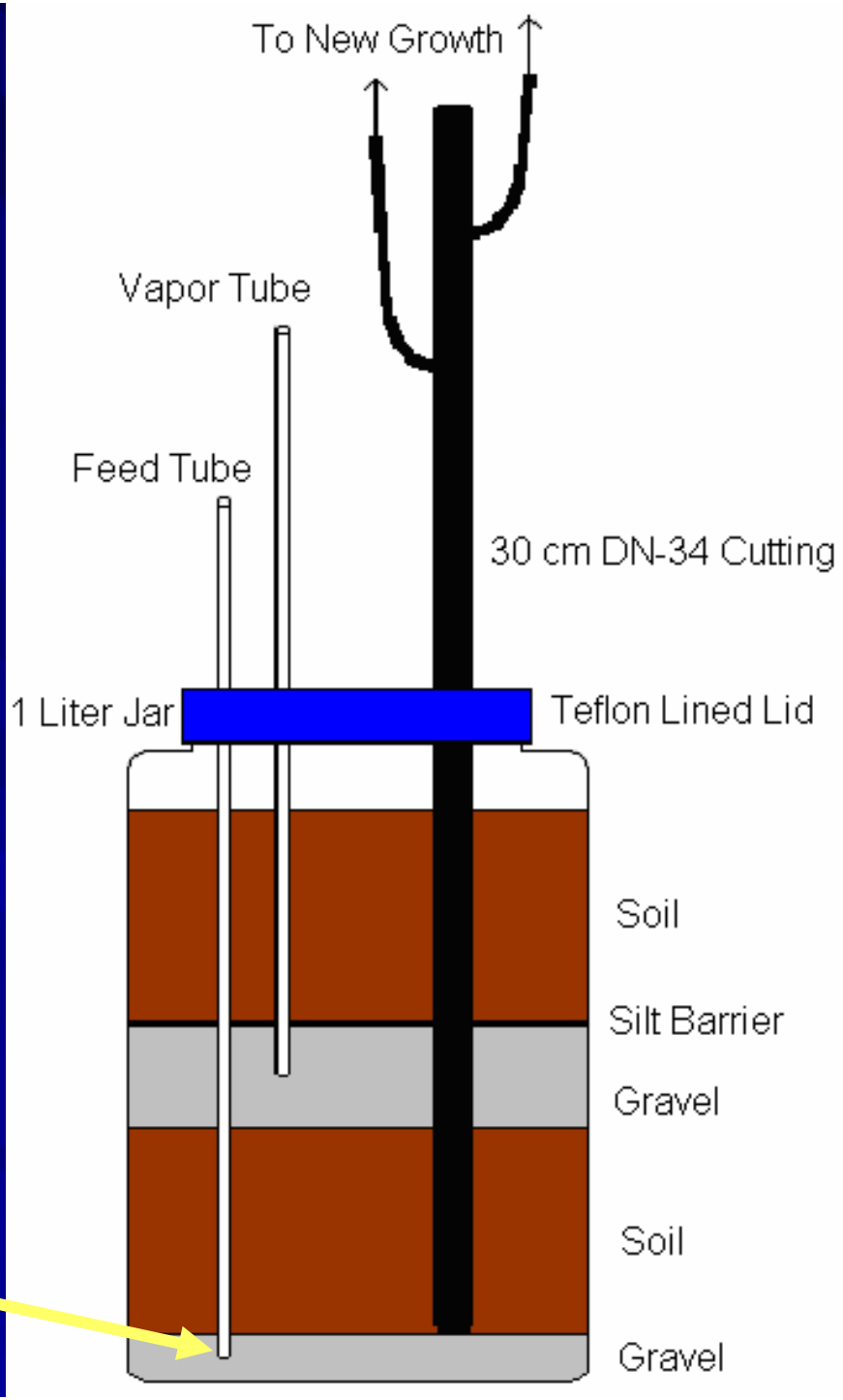
DI water injected into reactor



Clean Water / Clean Air Dosing Method (Negative Controls)

Nothing added to vadose zone

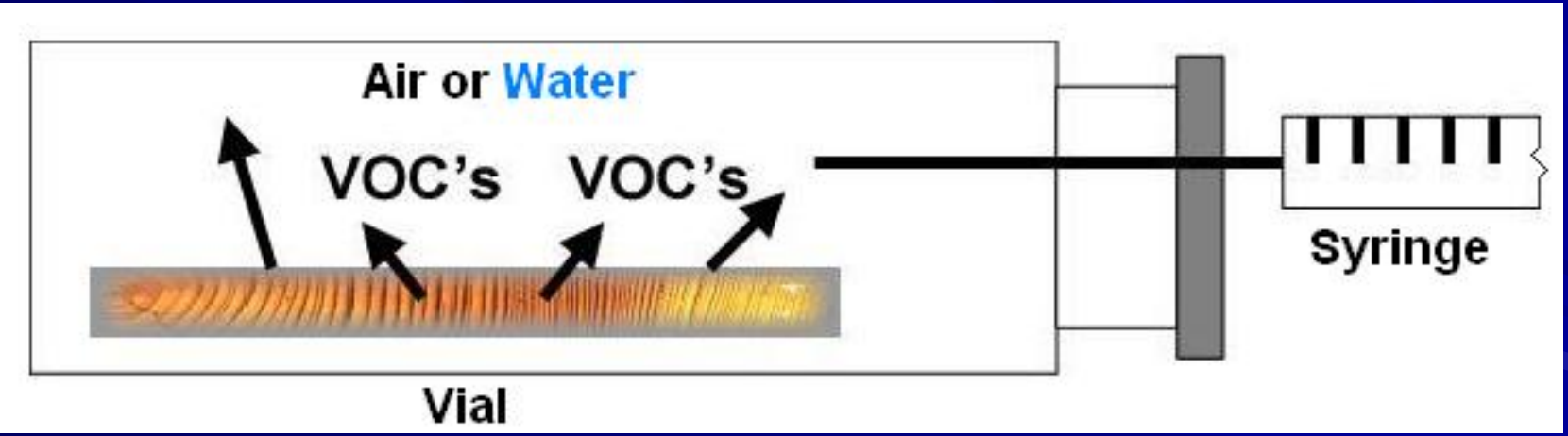
DI water injected into reactor



Partitioning Coefficients

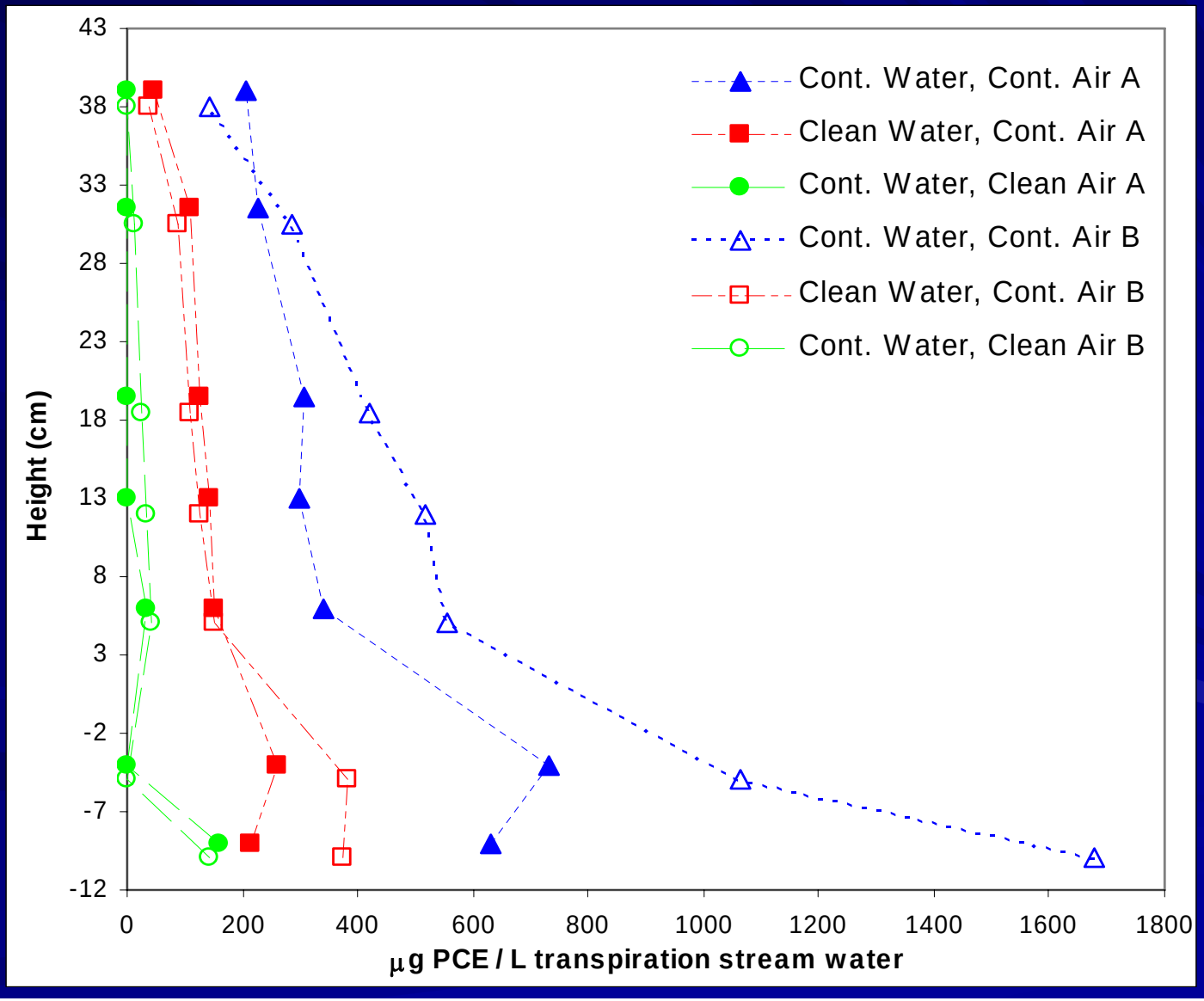
$K_{liquid\text{-}wood} = 0.049$ L/g

$K_{air\text{-}wood} = 0.0081$ L/g

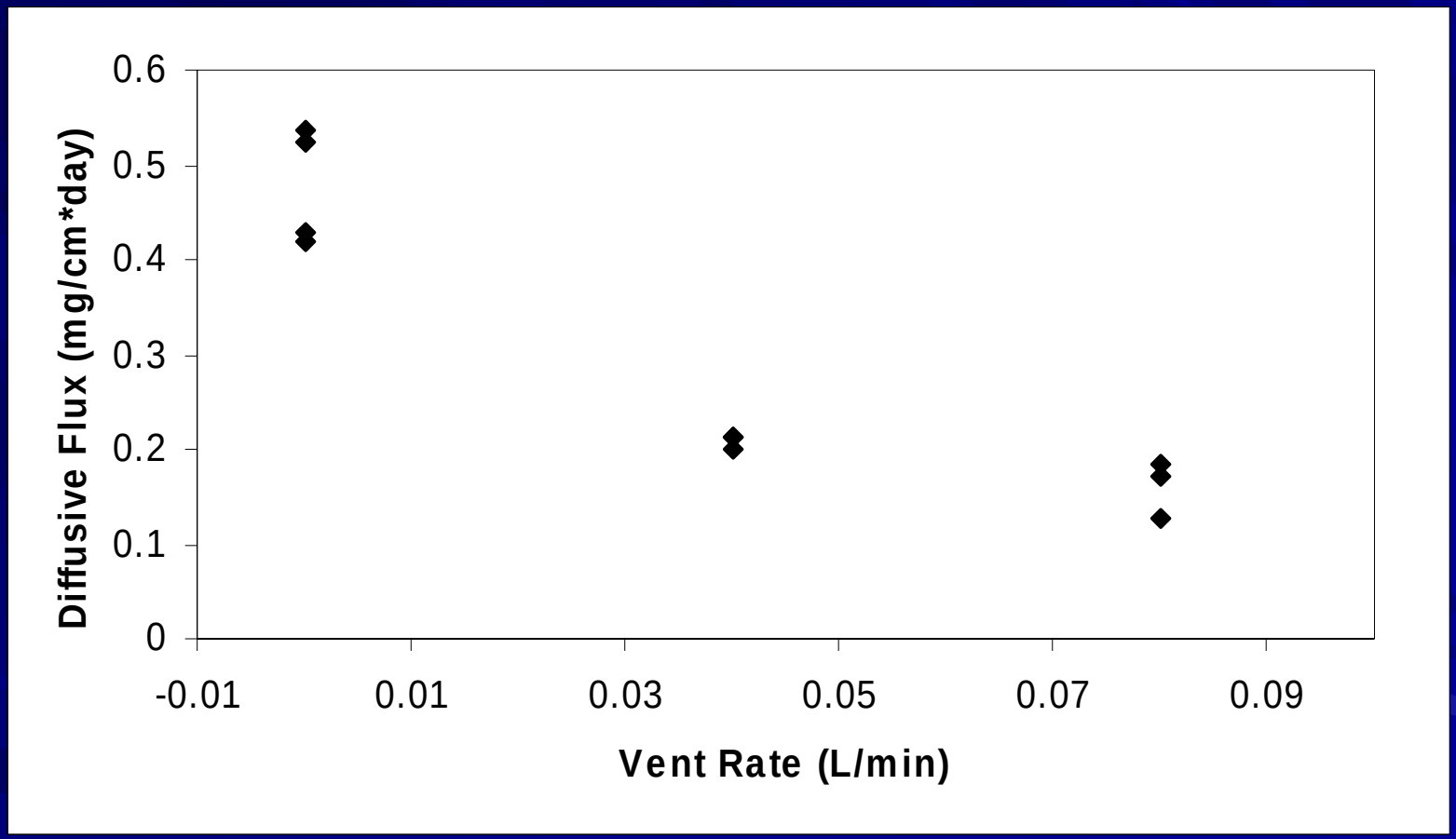


Modified from: http://toxics.usgs.gov/

Results – Batch Reactors



Results – Batch Reactors



Summary

- Soil vapor PCE affects uptake and translocation within plants
- Soil and tree PCE concentrations are linked in natural settings
- The TSCF relationship is not valid for PCE because PCE is not conserved within plants

Recommendations

- Reconsider the use of TSCF relationships with nonconservative contaminants
- Keep diffusion in mind when analyzing tree core data, especially if using them to quantify subsurface conditions

Publications

- Struckhoff, G. C.; Burken, J. G. Vapor-Phase Exchange of Perchloroethene between Soil and Plants. *Environ. Sci. Technol.* 2005, *39* (6), 1563 -1568

- Schumacher, J. G.; Struckhoff, G. C.; Burken, J. G. *Assessment of Subsurface Chlorinated Solvent Contamination Using Tree Cores at the Front Street Site and Former Dry Cleaning Facility at the Riverfront Superfund Site, New Haven Missouri, 1999-2003*. U.S. Geological Survey Scientific Investigations Report 2004-5049; Reston, VA, 2004; 35pp.

- Struckhoff, G. C.; Burken, J. G.; Schumacher, J. G. Effect of Soil PCE on Uptake and Loss by Plants. Proceedings of the Fourth International Conference on Remediation of Chlorinated and Recalcitrant Compounds (Monterey, CA; May 2004). ISBN 1-57477-145-0, published by Battelle Press, Columbus, OH.

Acknowledgements

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- Xingmao Ma and Paul Brendan
- My current mentor, Gene F. Parkin

Questions / Comments?

Check out Ms. Sally Breite's poster, which presents similar research for TCE and other compounds!