Transient Processes in the Vapor Intrusion Problem

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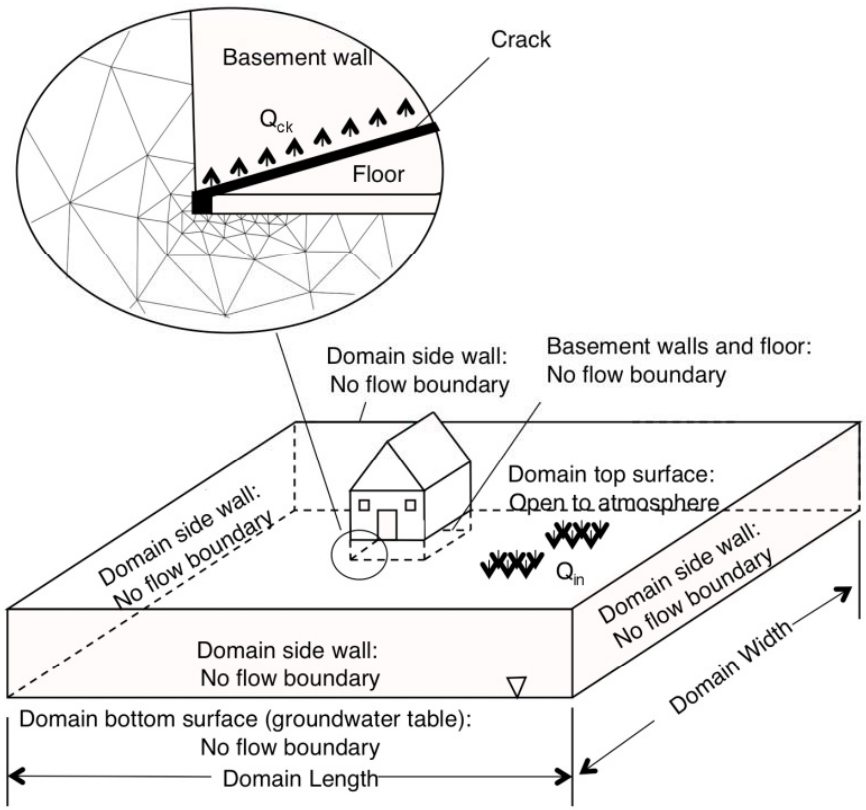
Outline

- Scenario Considered and Governing Equations
- Approach to the Steady State Solution-New Source
- Transient Process with Source Removal @ t=0
- Transient Process with 1-day cycle of Indoor Pressure Variation
- Transient Process with Heating Season cycle

Scenario Considered



Governing Equations

- Darcy's Law

$$\left(x_p\left(1-\eta_g\right)+x_f\eta_g\right)\frac{\partial p}{\partial t}=\nabla\left(\frac{k}{\mu_g}\left(\rho_g g\nabla z+\nabla p\right)\right)$$

- Convection and Diffusion

$$\frac{\partial C_{ig}}{\partial t}+\nabla(q_g C_{ig}-D_{ig}\nabla C_{ig})+R_{ig}=0$$

Indicators of indoor air quality

- Mass flux through the crack
- (Rapid attainment of steady state within crack assumed)

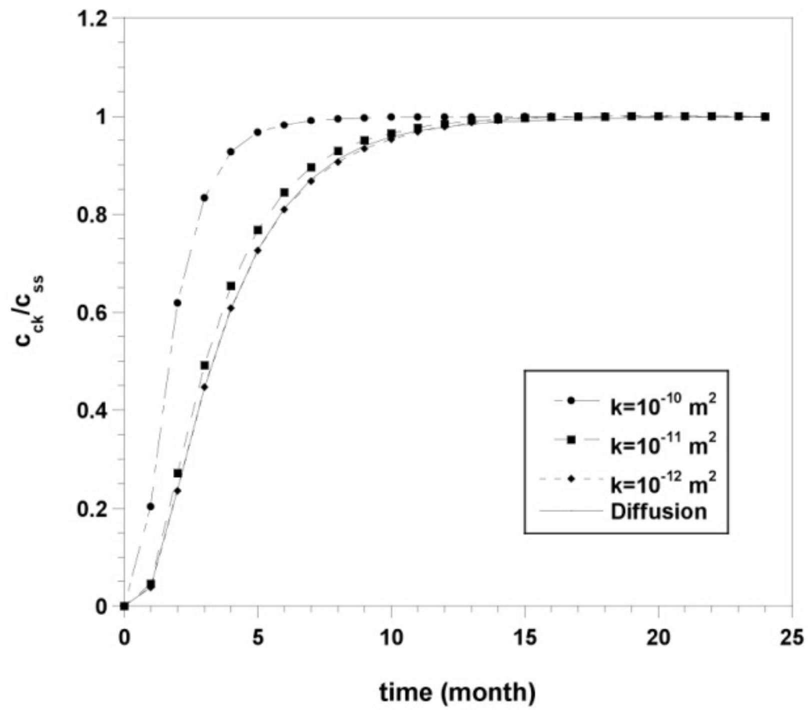
$$J_{ck} = q_{ck} \frac{\exp(\frac{q_{ck} d_{ck}}{D^g}) c_{ck} - c_{indoor}}{\exp(\frac{q_{ck} d_{ck}}{D^g}) c_{ck} - 1} \approx q_{ck} \frac{\exp(\frac{q_{ck} d_{ck}}{D^g}) c_{ck}}{\exp(\frac{q_{ck} d_{ck}}{D^g}) c_{ck} - 1}$$

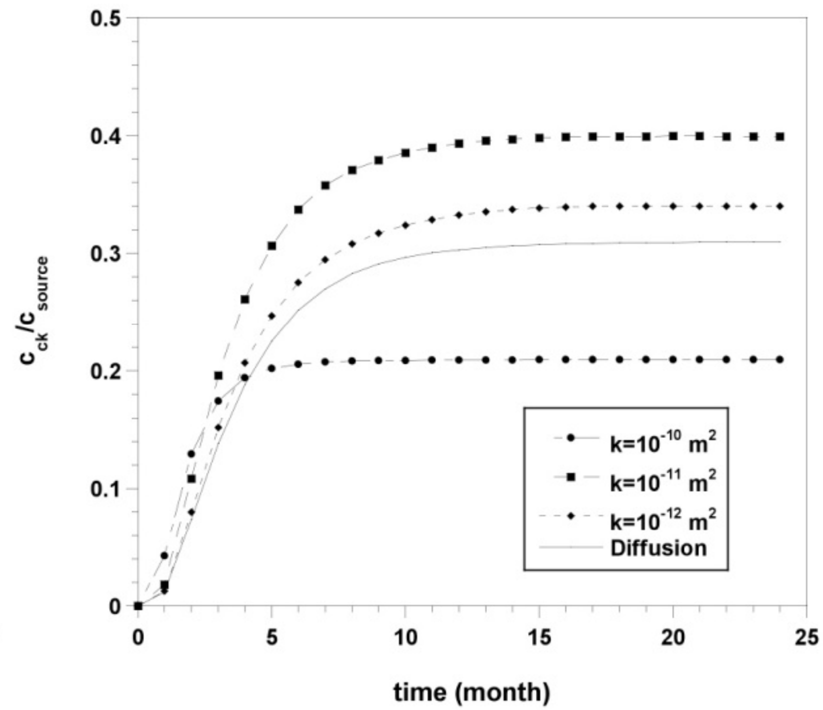
- Indoor air concentration

$$c_{indoor} = \frac{M_{ck}}{Q_{ck} + V_b A_e} \approx \frac{M_{ck}}{V_b A_e} = \frac{J_{ck} A_{ck}}{V_b A_e}$$

- **M_{ck} better indicator of problem than C_{indoor}**

Approach to the Steady State Solution

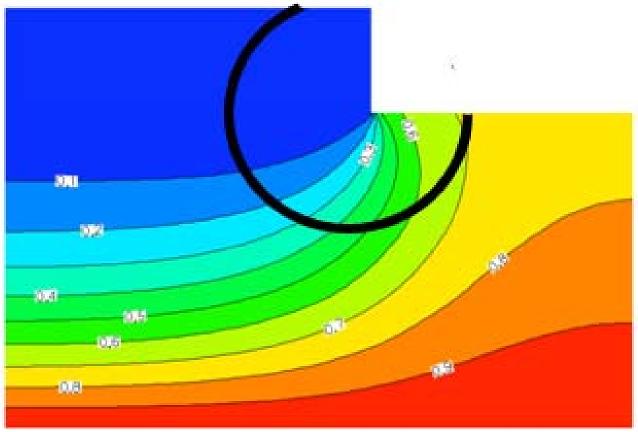




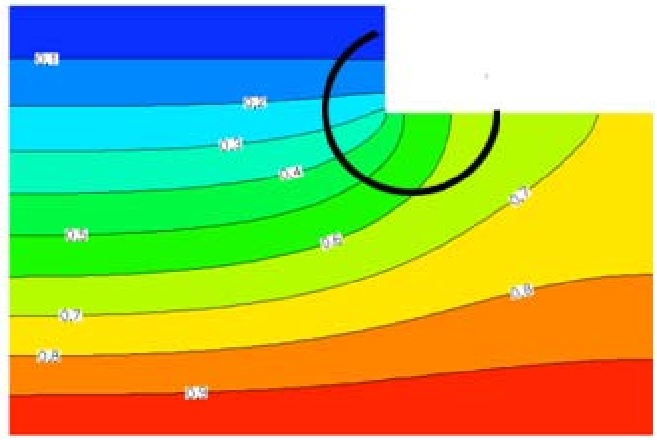
$k=10^{-10}m^2$: 0.5 year
(Advection dominated)
$k<10^{-11}m^2$: 1 year
(Diffusion important)

Highest concentration for $10^{-11}m^2$

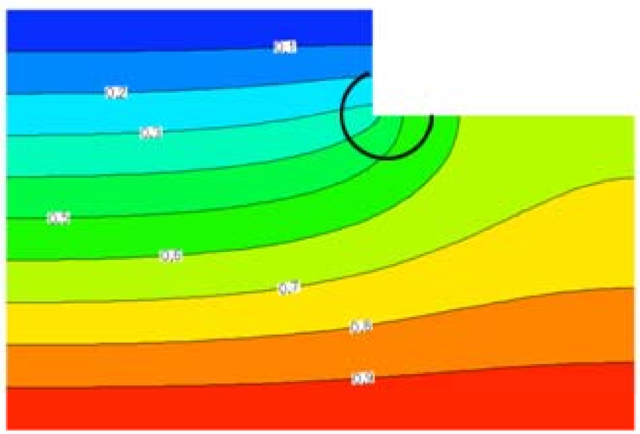
Ability to Draw in Air *vs.* Contaminant, a Key Factor of Advective Transport



k=10^{-10}m^2

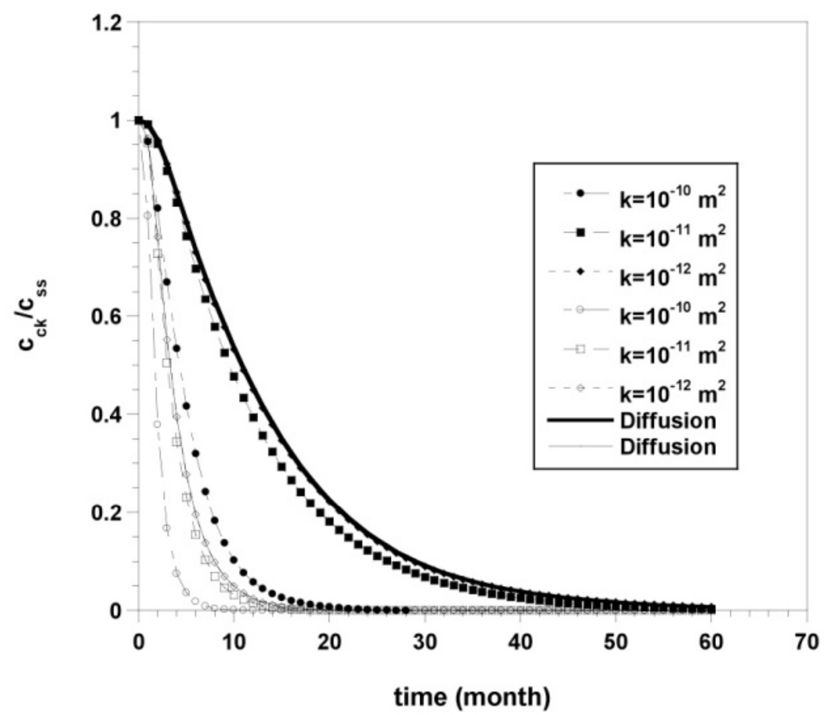


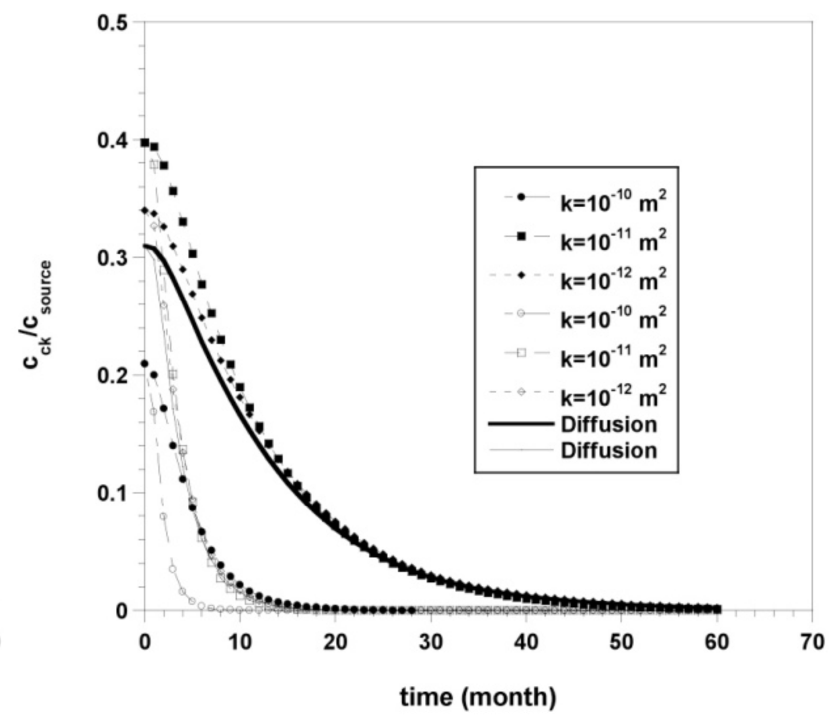
k=10^{-11}m^2



k=10^{-12}m^2

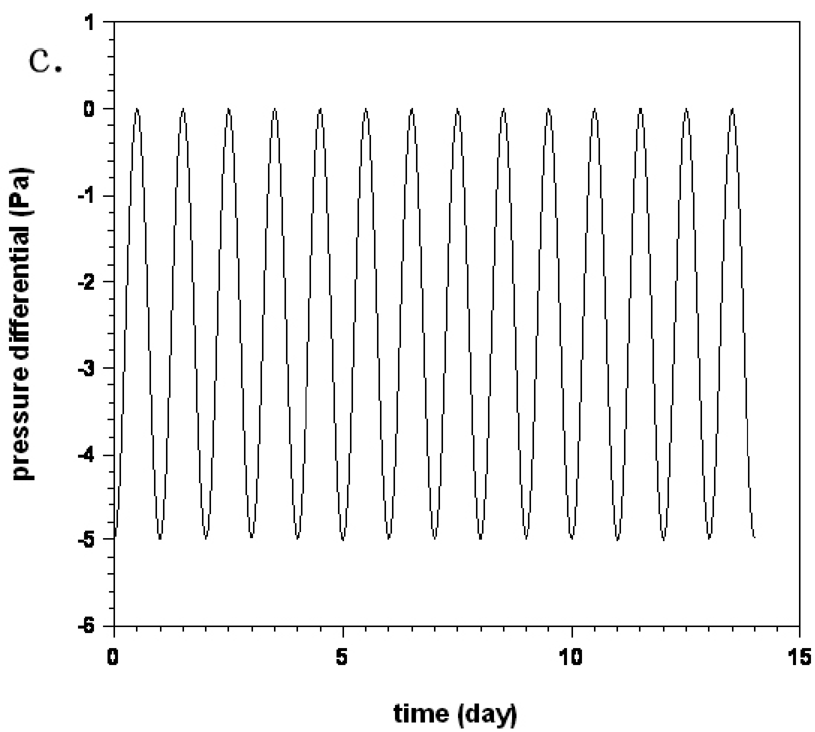
Source Removal @ t=0 (How long does it take to see a response to GW remediation?)

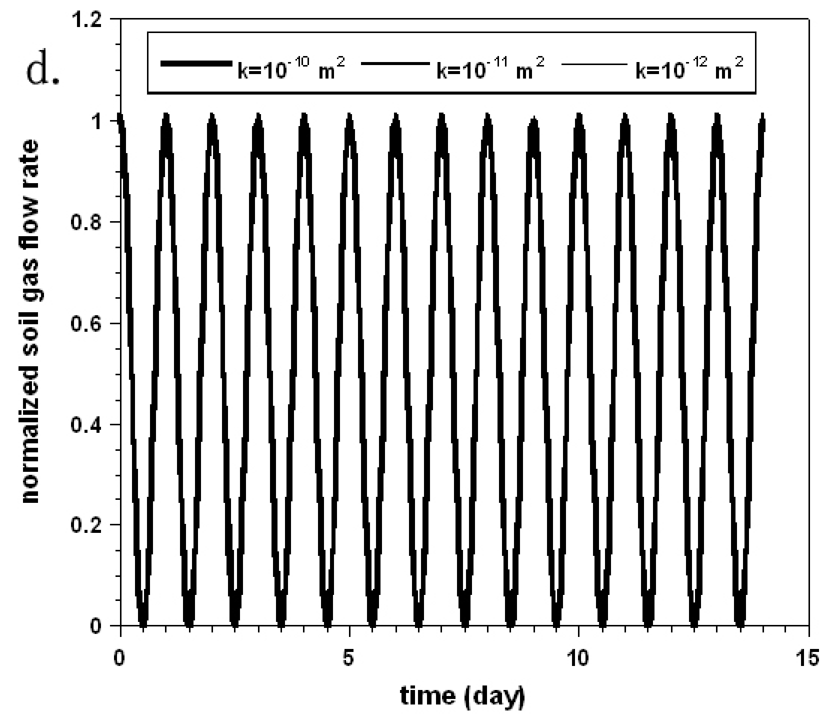




	GW as Sink	“Impermeable “GW
$k=10^{-10}m^2$	0.5year	2 year
$K<10^{-11}m^2$	1 year	4 year

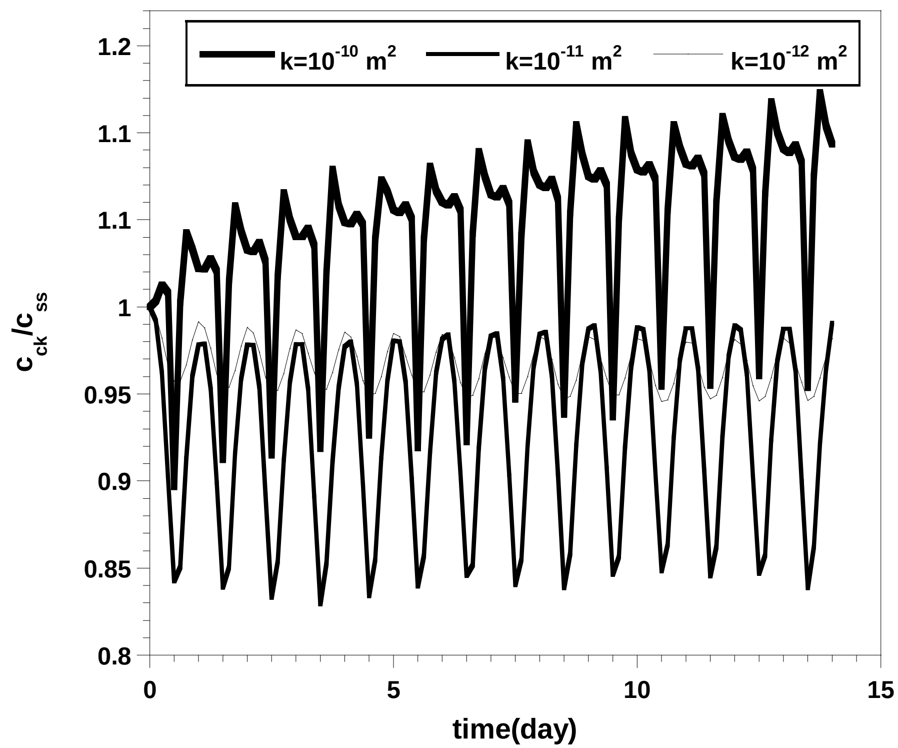
Results for 1-day cycle of Indoor Pressure

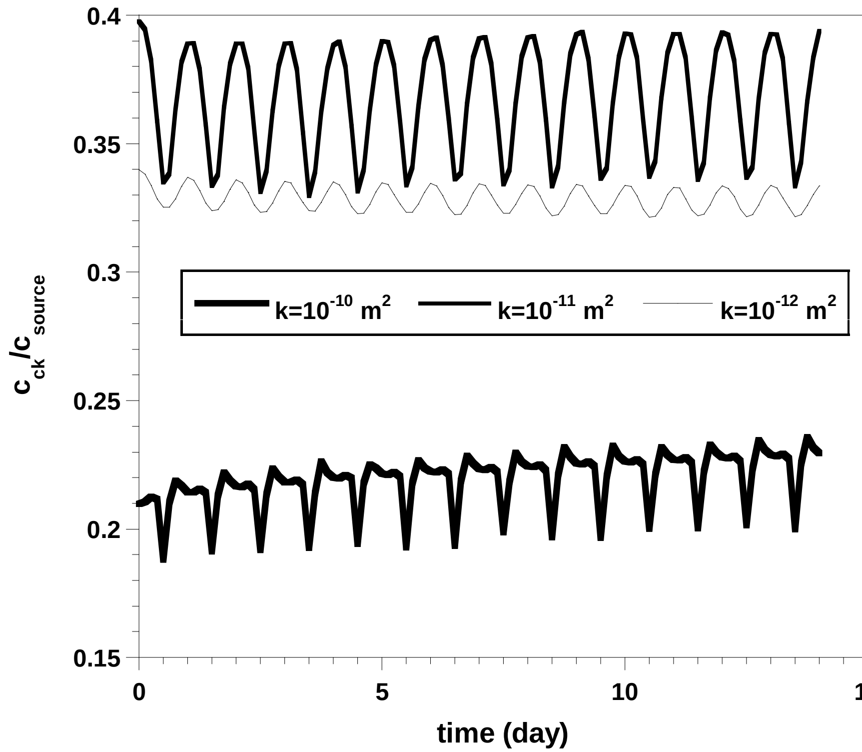




Pressure disturbance:-5Pa~0
Flow responds quickly

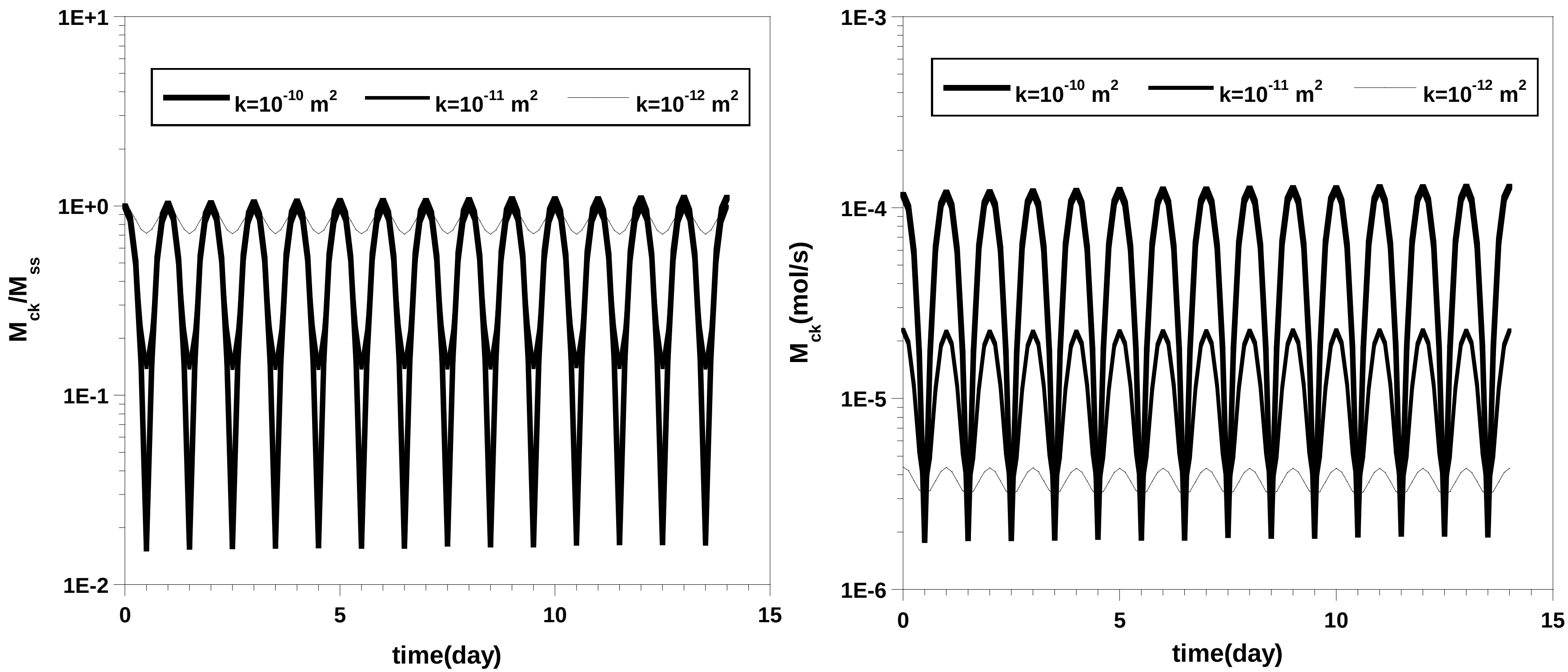
Subslab crack Concentration for 1-day cycle





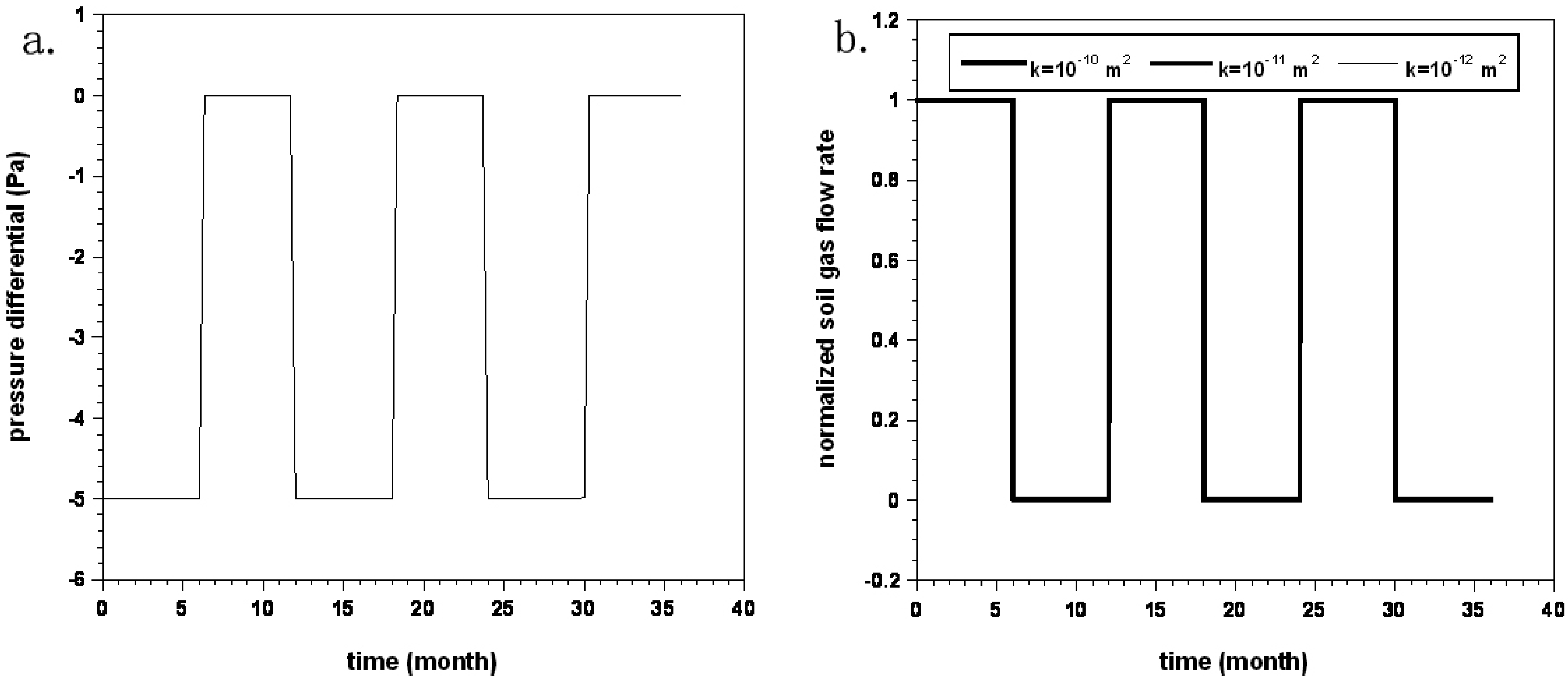
The concentration variation is not significant in all three cases.

Variation in Mass Flow Rate into the house for 1-day pressure cycles



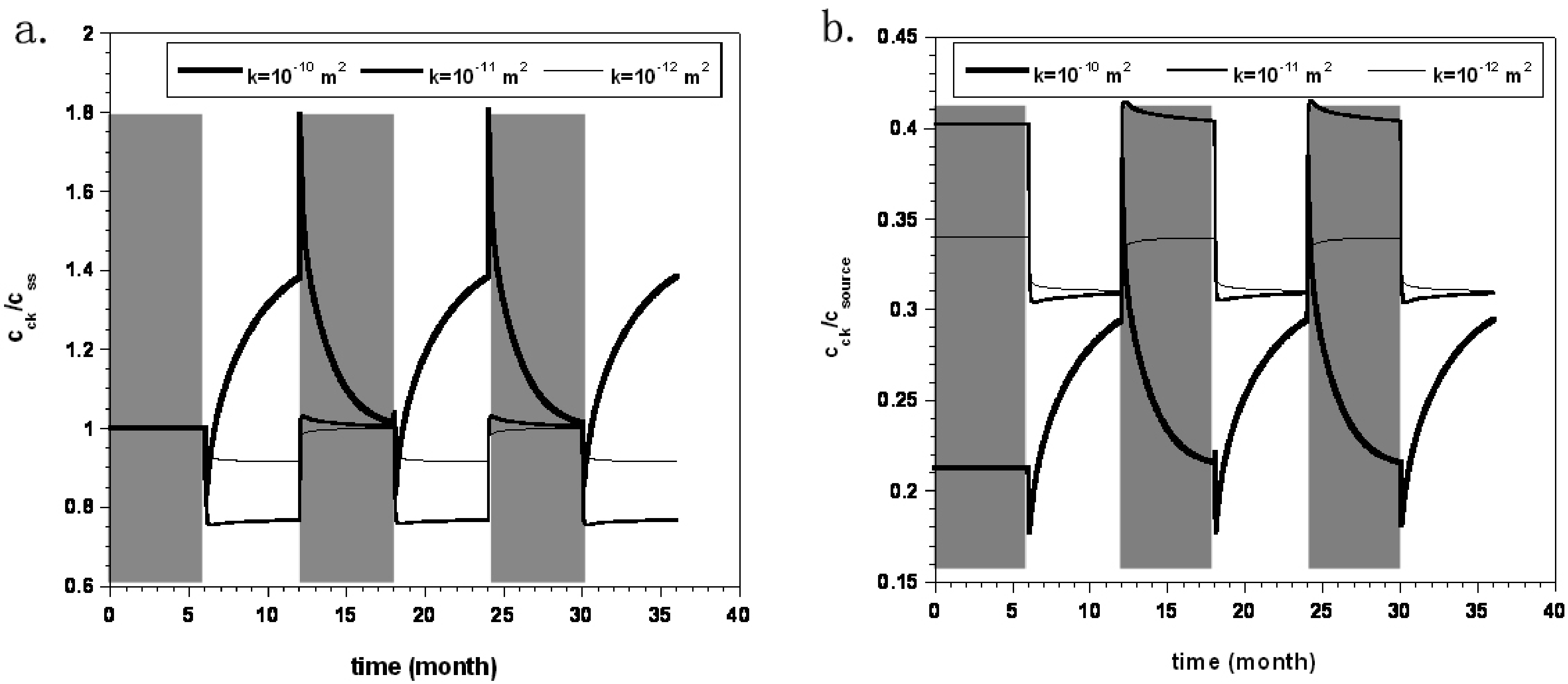
$k=10^{-10}m^2$: 2 o.o.m.
$k=10^{-11}m^2$: 1 o.o.m.
$k=10^{-12}m^2$: almost no change

Results for heating season cycle of Pressure



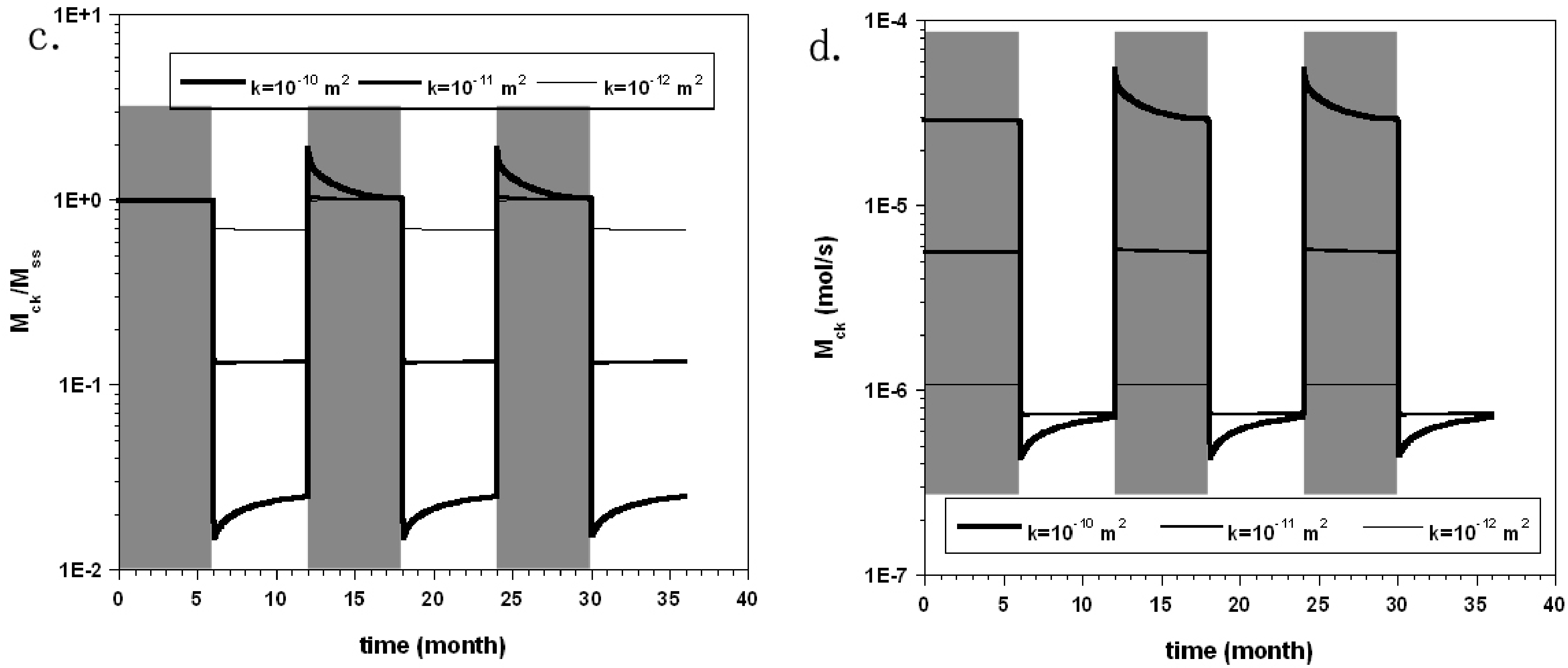
Pressure disturbance:-5Pa~0
Flow responds quickly

Subslab Crack concentration for for heating season cycle



High permeability leads to large transients, low permeability damps out transients.

Mass Flow Rate into the house for heating season cycle



Almost instantaneous response, and small magnitude change in low permeability soils

Summary

- Contaminant mass flow rate into a structure is more suitable as an indicator of indoor air quality than is C_{indoor}.
- Subslab concentration at crack would reach max for $k=10^{-11} m^2$ as a result of balance in advective transport between dilution air and contaminant.
- The flow always responds quickly to pressure change.
- For short cycle indoor pressure variation, the subsurface concentration profile would not change much, while in long term pressure variations the effect is small except for very high soil permeabilities.

Our current research

- Comparison between J-E model with 3D simulation and the introduction of mass conservation ratio to J-E model.
- Developing generalized results, for example, for a homogenous steady state model, the geometry, the ratio of foundation depth to the source depth, determines the subslab concentration at the crack. Based on that, a new 2D analytical model has been created.
- Considering other transient factors.