Mass Flux Evaluations of Soil Vapor Extraction Remediation Systems

Prepared for the Maryland Statewide Brownfield Conference by

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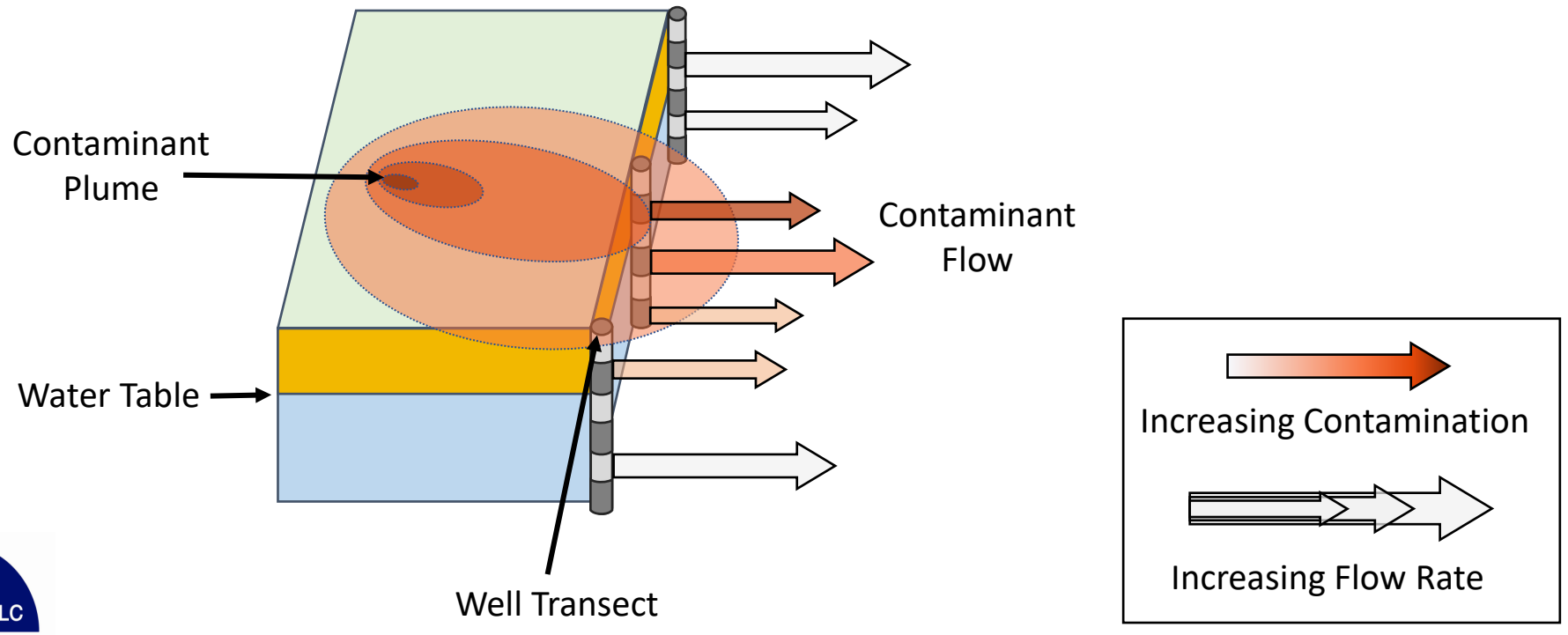
What is Mass Flux?

Mass Flux (MF)

- MF is movement of mass through a specified area over time
- Concentration of subsurface contaminant is mass/volume (eg. µg/m^3)
- Flow rate is velocity * area (eg. m^3/s)



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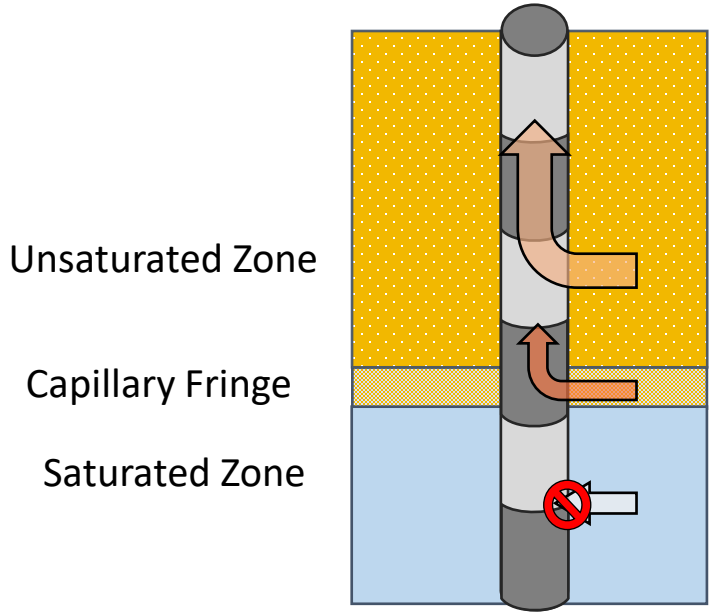
What is Soil Vapor Extraction?

Soil Vapor Extraction (SVE)

- Remediation system for contaminated soil vapor
- Remove vapor via vacuum pressure, discharge to treatment system
- Greatly affected by soil permeability and water table



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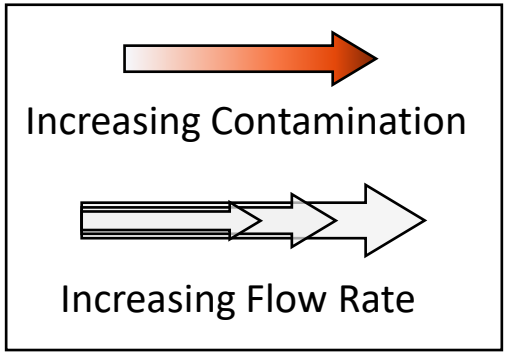

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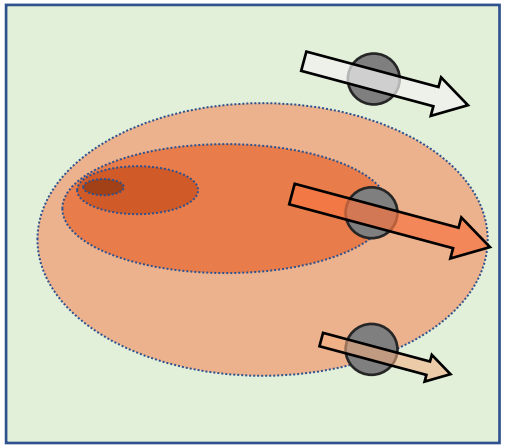
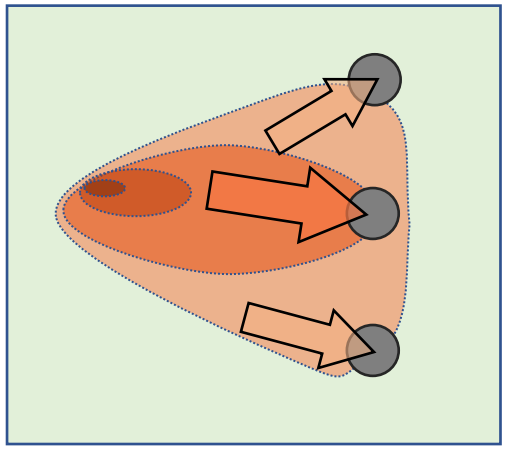
SVE and Mass Flux

SVE affects Mass Flux:

- Direction – vacuum pressure overcomes subsurface flow
- Magnitude – pressure increases flow rate; removing vapor reduces concentration
- Area – reduces contaminated area



SVE Off



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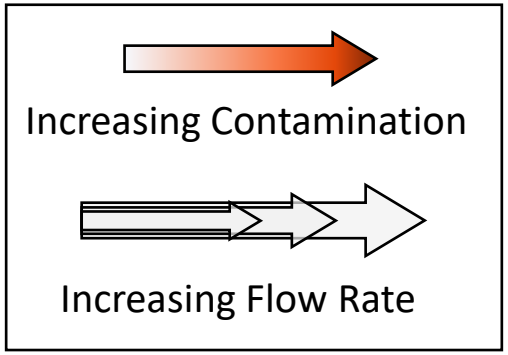

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Subsurface Zones

Recharacterize subsurface relative to system (instead of water table)

Advective Zone

- Vapor flows readily
- Accessible by system during operation
- High mass flux

Recalcitrant Zone

- Inaccessible by system during operation
- Mass flux is limited by diffusion to advective zone

Cyclic or Periodic System Operation

Evaluate changes in subsurface conditions

- Have contaminant concentrations decreased?
- Has the source area been decreased?
- How quickly does the advective zone recharge?

Evaluate system efficacy

- Are there inaccessible areas of contamination?
- Is the system continually removing mass, or only containing?
- How quickly is the advective zone swept?

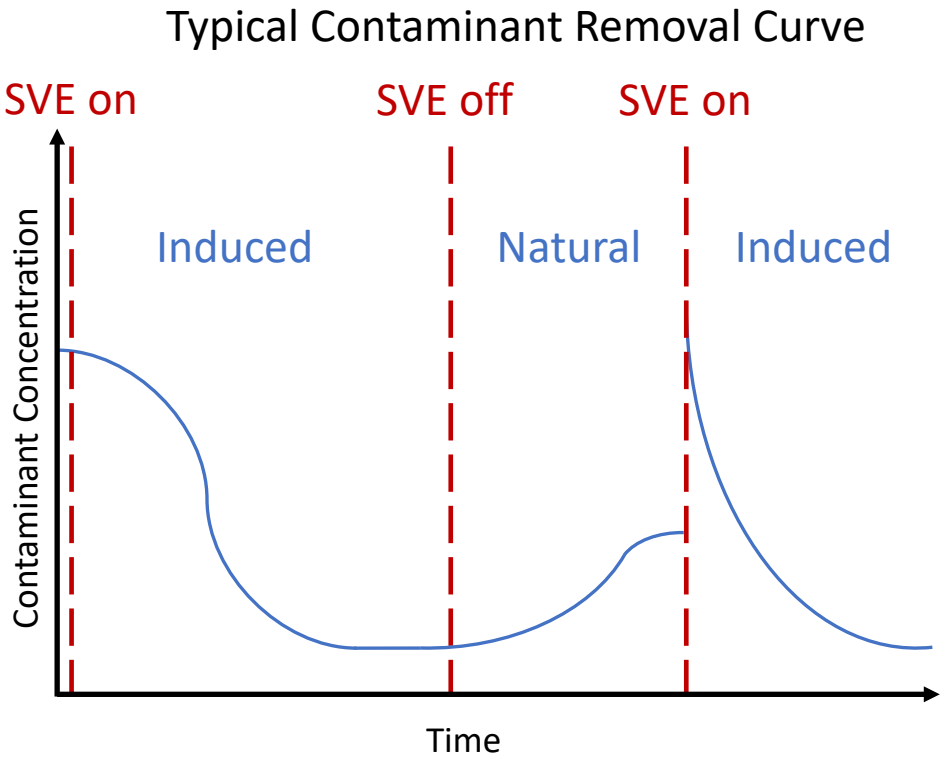
Mass Flux Parameters

Induced-Gradient

- System operational
- Removal of contaminated soil vapor
- Contaminant concentrations decreasing

Natural-Gradient

- System non-operational
- Accumulation of contaminated soil vapor
- Contaminant concentrations decreasing



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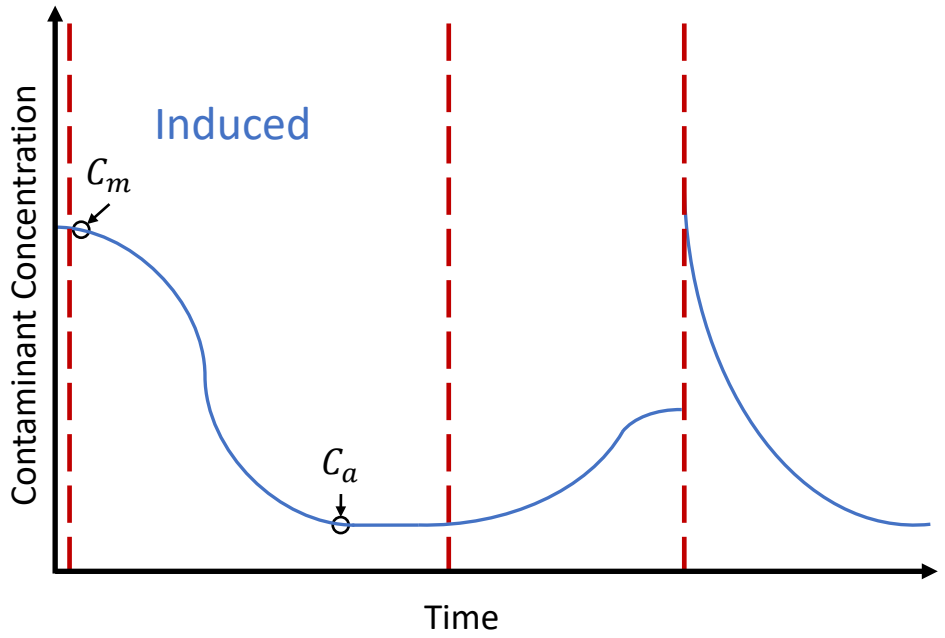
Mass Flux Parameters

Induced-Gradient

- MFm - maximum mass flux
  - C_m (maximum contaminant concentration) * average flow rate
- MFa – asymptotic mass flux
  - C_a(asymptotic contaminant concentration) * average flow rate

Typical Contaminant Removal Curve



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Mass Flux Parameters

Natural-Gradient

- Mpv – mass removed from first "pore-volume"
  - $\sum_1^n CQT_s$
    - C = Contaminant concentration
    - Q = Flow rate
    - T_s = Sample time interval
- MFr – rebound mass flux
  - Mpv / non-operational time

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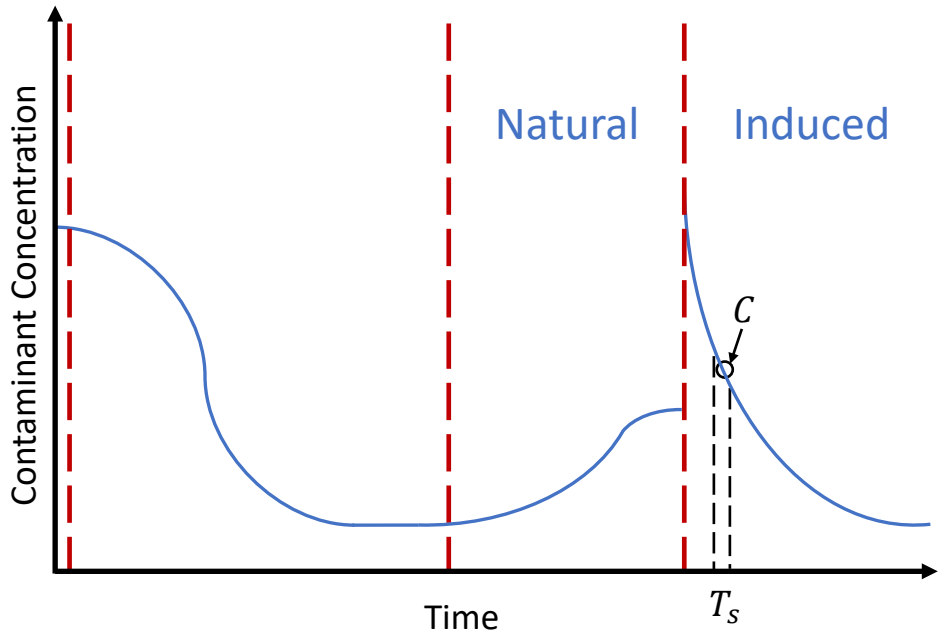

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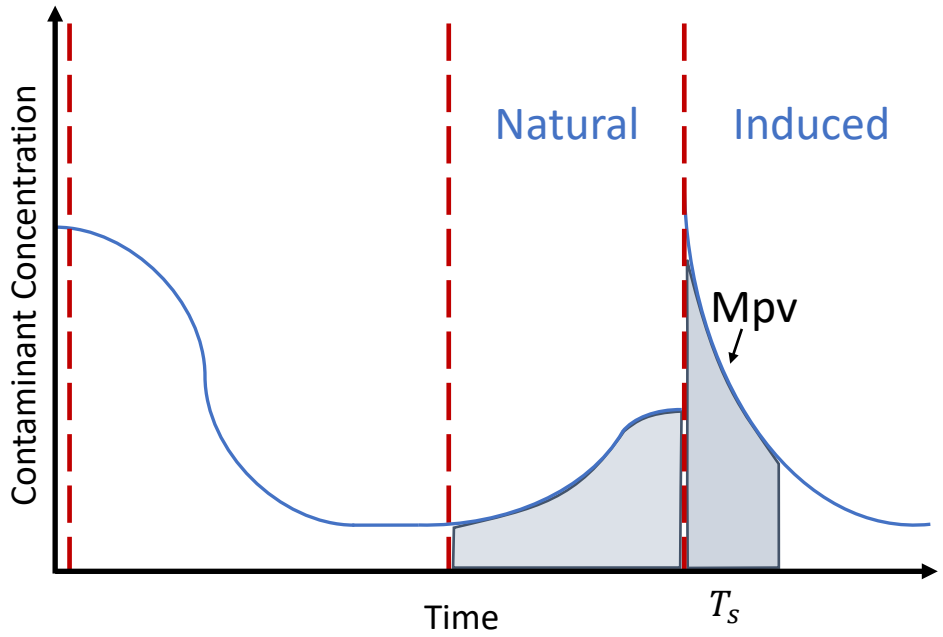

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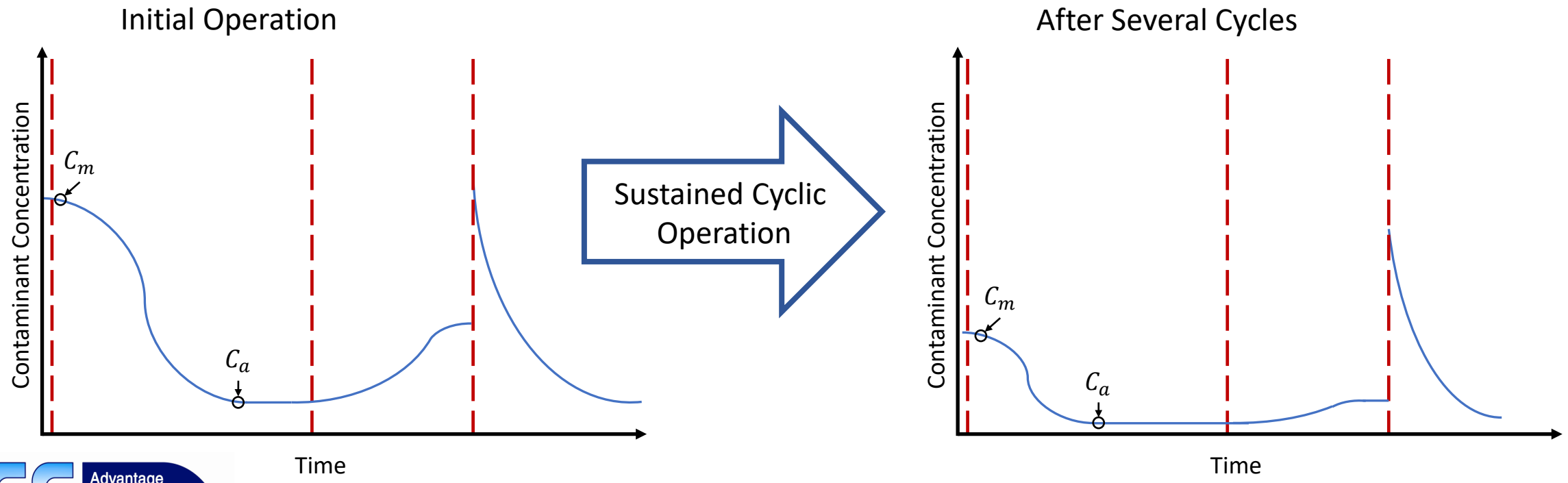
Comparing Parameters Between Cycles

Reduction in maximum (C_m) and asymptotic (C_a) concentrations

Decreased time to reach asymptotes (in each stage)



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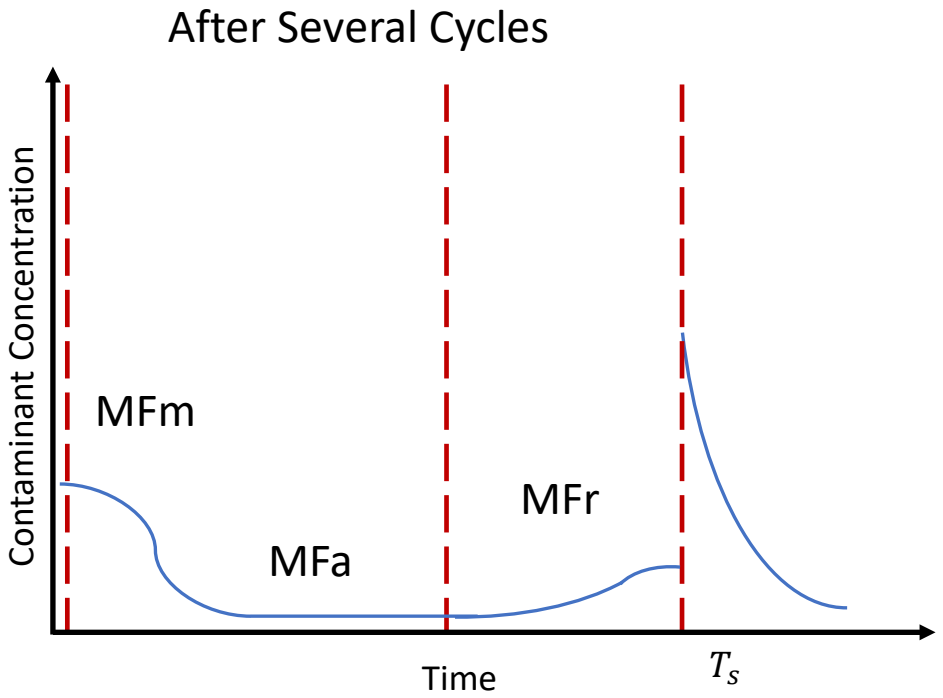
Comparing Parameters Between Cycles

Convergence of MF parameters

- Caused by:
  - Reduction in concentrations
  - Decreased time to asymptotic values

Conclusions to draw:

- Reduced source contamination
  - MFm compared to initial
- Advective zone recharging slower
  - MFm compared to MFa
- System efficiency decreasing
  - MFr compared to MFa



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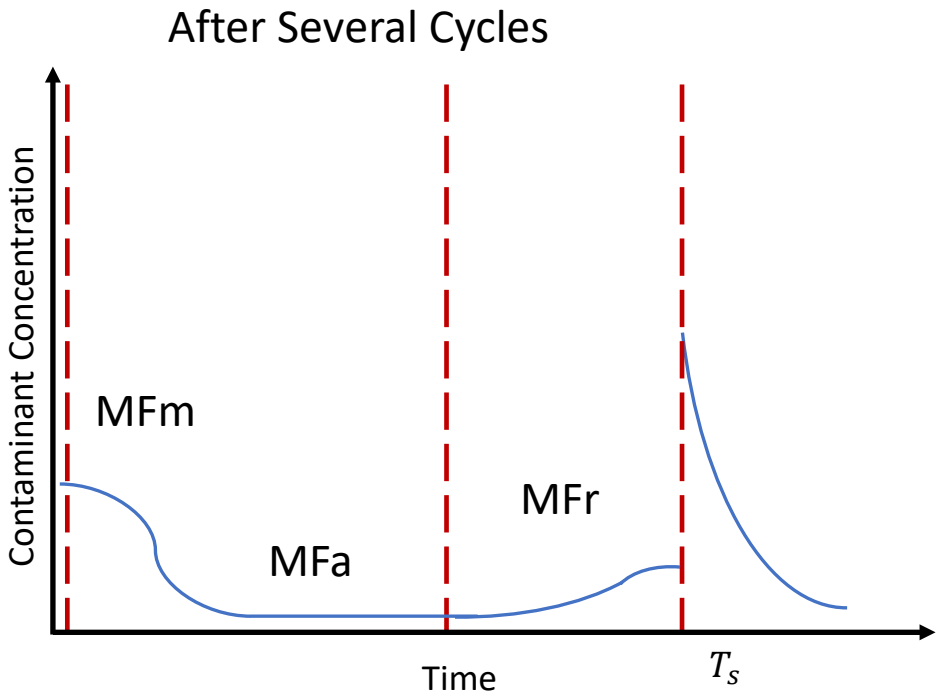
Comparing Parameters Between Cycles

Further Exploration

- Reduced source contamination
  - Compare SVE points to evaluate area
- Advective zone recharging slower
  - Limited by diffusion from recalcitrant zone
- System efficiency decreasing
  - Sustained asymptote is only containment, insignificant mass removal



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References

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- Stewart, L., R. Truesdale, J. Redmon, Ed Barth, C. Northeim, AND J. McKernan. Engineering Issue: Soil Vapor Extraction (SVE) Technology. U.S. Environmental Protection Agency, Washington, DC, EPA/600/R-18/053, 2018.
- ITRC (Interstate Technology & Regulatory Council). 2010. Use and Measurement of Mass Flux and Mass Discharge Washington, D.C.: Interstate Technology & Regulatory Council, Mass Flux Team.