Comparison of Leaching of PAHs from two Contaminated Soils under Varying Hydraulic Retention Time

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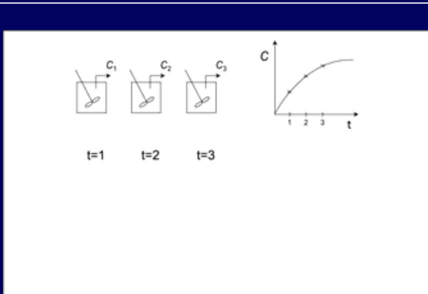
Background

- Hydraulic retention time, HRT, is an important parameter when conducting leaching experiments
- HRT = the contact time between the liquid and the solid phase

Background



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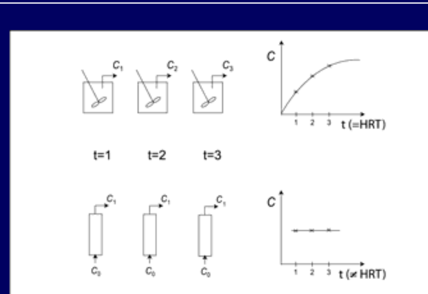

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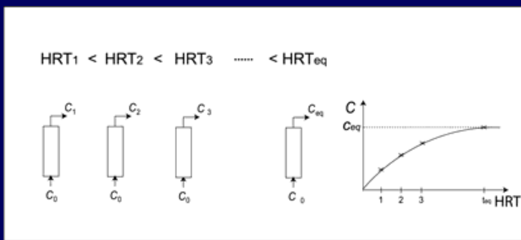


Objectives

- To investigate which processes control leaching of PAHs from aged contaminated soil
- To investigate if leached concentrations from field contaminated soil, obtained by dynamic column leaching, can reach equilibrium concentrations at very short contact times
- To demonstrate that leaching of PAHs from aged contaminated soils can show significant differences in leaching behaviour, leachable concentrations and available amounts

Soil samples

1. Husarviken, Stockholm, Sweden
   - former gasworks plant (1893-1972)
   - **coal tar**, heavy metals, cyanide

2. Holmsund, Umeå, Sweden
   –former impregnation facility (1943-1983)
   –**creosote**, As, Cu, Cr

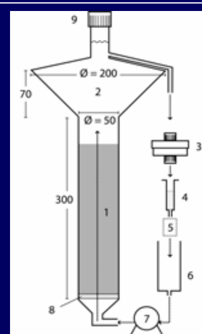
Soil data

Parameters	**Coal tar cont. soil**	**Creosote cont. soil**
TOC %	16	3
pH water (1:10)	7.62	5.64
Density kg/L (d.w.)	1.36	1.06
Composition of soil	**(%)**	
Coarse sand (>0.2 mm)	54	62
Fine sand (0.02-0.2 mm)	20	23
Silt (0.002-0.02 mm)	21	10
Clay (<0.002 mm)	5	5

Initial amounts

PAH	Abbreviation	Coal tar cont. soil	Creosote cont. soil
		(mg/kg soil)	
Fluorene	FLU	7 ± 1	110 ± 12
Phenanthrene	PHE	61 ± 3	240 ± 43
Anthracene	ANT	60 ± 3	226 ± 101
Fluoranthene	FLU	221 ± 43	1066 ± 36
Pyrene	PYR	177 ± 34	521 ± 24

Design of the leaching experiment



1. Glass column
2. Sedimentation chamber
3. Filter
4. SPE cartridge
5. Drop counting detector
6. Reservoir
7. Peristaltic pump

Experimental set up

•Glassware and stainless steel

•Sterilization, $HgCl_2$

•0.7 µm filter

•0.5 kg soil

Experimental flow rates and HRTs

Husarviken (coal tar contaminated soil)

•Elevation difference of 38 m!

•Large proportion of medium to coarse material

⇩

High groundwater velocities

Experimental flow rates and HRTs

Flow rates chosen for the experiments: 0.1 – 0.5 L h^{-1}
(Darcy velocities: 450 – 2200 m $year^{-1}$)

$$HRT = \frac{m_{d.w.} \cdot \varepsilon}{Q \cdot \rho_{d.w.}}$$

Q = flow rate
$m_{d.w.}$ = amount of sample material
ε = porosity
$\rho_{d.w.}$ = density

$\Rightarrow$ HRT: 0.3 – 1 h

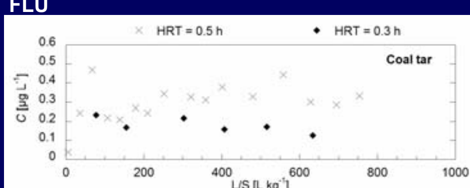
HRTs, Husarviken

Husarviken, coal tar

HRT = 0.3 h x 2
0.5 h x 2
1.0 h x 1

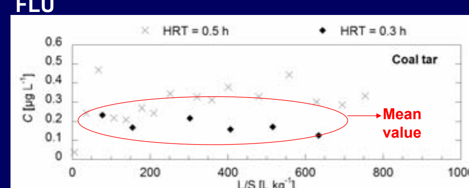
Leached concentrations, Husarviken

FLU

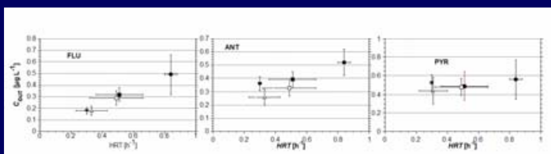


Leached concentrations, Husarviken

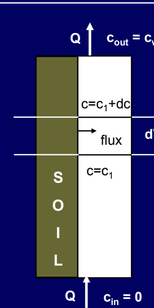
FLU

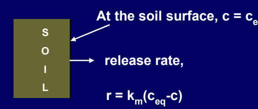


Leached concentrations, Husarviken



Modelling the column leaching





$$C_w = C_{eq}(1 - e^{-k_m * HRT})$$

Modelling results

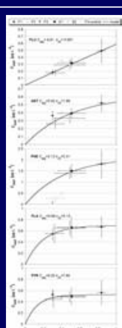
FLU $k_m = 0.006$

ANT $k_m = 1.99$

PHE $k_m = 2.31$

FLA $k_m = 5.13$

PYR $k_m = 7.60$



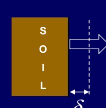
188 $cm^3\ mol^{-1}$

Le Bas molar volume

217 $cm^3\ mol^{-1}$

Interpretation of k_m

$$k_m \propto \frac{D \cdot A}{\delta \cdot V}$$



$r = k_m(c_{eq} - c)$

k_m = mass transfer coefficient (h^{-1})

D = the diffusivity of the solute ($cm^2\ s^{-1}$)

A = the sorbent surface area (cm^2)

V = the pore water volume (cm^3)

δ = the distance of the mass transfer (cm)

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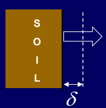

$r = k_m(c_{eq} - c)$

Conclusion: The leaching is not a result of dissolution of PAHs from a free phase of coal tar!

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D differ approx. 1.1 between the PAHs studied

Interpretation of k_m

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Conclusion: The leaching may be a result of mass transfer resistance within the solid phase!

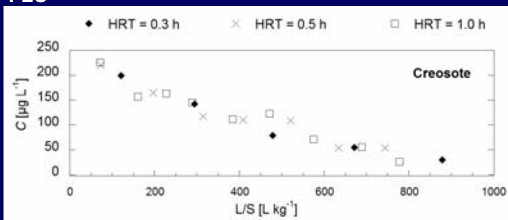
HRTs, Holmsund

<u>Holmsund, creosote</u>

HRT =0.3 h x 1
0.5 h x 1
1.0 h x 1

Leached concentrations, Holmsund

FLU



Leachable amounts

PAH	Creosote cont. soil	Coal tar cont. soil
	% leached of total amount	
Fluorene	77	1.84
Phenanthrene	32	0.46
Anthracene	6	0.64
Fluoranthene	4	0.18
Pyrene	4	0.16

Solubility limitations?

PAH	Creosote cont. soil	
	C_{max}	S
	[µg L^{-1}]	
Fluorene	215 ± 14	440
Phenanthrene	166 ± 8	870
Anthracene	26 ± 2	51
Fluoranthene	85 ± 4	68
Pyrene	35 ± 2	47

Conclusion: The leaching may be a result of dissolution of PAHs from a free phase of creosote!

Solubility limitations?

PAH	Creosote cont. soil		Coal tar cont. soil	
	C_{max}	S	C_{mean}	S
	[µg L^{-1}]		[µg L^{-1}]	
Fluorene	215	440	0.31	220
Phenanthrene	166	870	1.36	190
Anthracene	26	51	0.35	53
Fluoranthene	85	68	0.59	18
Pyrene	35	47	0.42	15

Conclusions

- The leaching from the creosote contaminated soil, collected from Holmsund, was probably governed by dissolution.
- Desorption processes most likely controlled the release of PAHs from the coal tar contaminated soil from Husarviken.
  - -Leached concentrations of the heavier PAHs seemed to be close to distribution equilibrium concentrations, despite the rather short HRT
- Significant differences in leaching behaviour, leached concentrations and available amounts –although initial concentrations were similar and both samples were aged
- Leaching tests for organic contaminants can provide valuable information for risk assessments!