Electroosmosis enhances the release of PAH from nanoporous geo-matrices

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Limited HOC-Bioavailability in Soil

Homogenization Enhances Bioavailability

- Non-bioavailable
- Bioavailable

Enhancement of contact probability

Mobilization
Objectives

Release and mobilization of chemicals

Wick et al., 2007, Electrochim Acta, (52), 592
Electroosmosis

Direct current (DC) – Electric Field

$K^{-1} \quad r$

$cathode \quad anode$

$H_2 \quad OH^- \quad H^+ \quad O_2$

Electroosmosis
Influence of pore size on electroosmotic flow velocity

\[ K\eta = \frac{r}{K^{-1}} \]

Rice & Whitehea. R, 1965
Hydraulic water flow only

Electroosmotic water flow

Acuna and Wick (unpublished)
DC promoted release

Aqueous phenanthrene concentration (mg/L)

Effluent phenanthrene concentration (mg/L)

Time (hours)

- Control
- Switch DC
Mono- vs. biphasic PHE release from aluminium oxide

$q(t)$ is the solid-phase sorbate concentration at a given time, $q_0$ is the initial solid-phase sorbate concentration, $k_s$ and $k_r$ are apparent first-order rate constants for the slowly and rapidly desorbing fractions, respectively.

\[ y = 0.4 \cdot \exp(-5.3 \cdot 10^{-3} \cdot x) + 0.6 \cdot \exp(-2 \cdot 10^{-5} \cdot x) \]

\[ \frac{M_t}{M_0} = \phi_s \exp(-k_s t) + (1 - \phi_s) \exp(-k_r t) \]
Hypothesis: DC influences kinetics of PHE release

Kaolinite embedded in alginate beads

Phenanthrene
Sorbent (Kaolinite)
Alginate

Hydraulic Flow
'No' release
EOF Flow
Release
Kaolinite

Release rate ($\mu g/h$) vs Time (h)

Bentonite

Release rate ($\mu g/h$) vs Time (h)

Phenantrene release percentage (%) with and without DC treatment.

Remaining fraction (%) vs Time (h)

$y = \exp(-2.3 \times 10^{-3} x)$

$y = \exp(-1.3 \times 10^{-4} x)$

$y = \exp(-3.4 \times 10^{-3} x)$

$y = \exp(-2.4 \times 10^{-4} x)$
Kd has minor effect on EOF promoted release in Silica

Silica 40Å

\[ y = \exp(-3.1 \times 10^{-3} x) \]

Silica 60Å

\[ y = \exp(-7.2 \times 10^{-3} x) \]

Silica 100Å

\[ y = \exp(-8.3 \times 10^{-3} x) \]

Release fraction (%)

Time (hours)

Pore size: 4nm

6nm

10nm
Kd has minor effect on EOF promoted release in Silica

Silica 40Å

Silica 60Å

Silica 100Å

Release fraction (%)

y = exp(-0.016x)

y = exp(-3.1 × 10^{-3}x)

y = exp(-8.3 × 10^{-3}x)

y = exp(-0.025x)

y = exp(-7.2 × 10^{-3}x)

y = exp(-0.021x)

Pore size: 4nm 6nm 10nm

Enhancement: ×5.2 ×3.5 ×2.5
Electroosmotic flow vs. PHE release rate

[Graph showing the relationship between EOF and PHE release rate for different materials such as Water EOF, Silica 40Å, Silica 60Å, Silica 100Å, Zeolite 13X, Zeolite 3Å, and Aluminum Oxide.]
Conclusions

- EOF-enhanced release is monophasic and reversible
- EOF enhance of the release of PHE from nanopores
- EOF-enhanced release is most effective from small (nano-)pores
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Thank you for your attention