Effects of soil texture and flow rate on leaching of arsenic from historically contaminated sites

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Introduction

- Arsenic (As) contamination in the environment is a global health issue.
- Rainfall, flooding, and irrigation can mobilize arsenic, a carcinogen, in soil, causing it to enter groundwater supplies.
- Mobilized arsenic typically occurs as arsenic(III), which is more toxic than arsenic(V), the form usually found in oxic soils.
- A soil column experiment was carried out to determine leaching of arsenic from a historically contaminated site in Berkeley, CA that is prone to winter flooding.

Fig 1. Flooded field site.

Objective

To determine the effect of soil texture and flow rate on leaching of As from historically contaminated soil.

Methods

- Two soils of different textures (Table 1) were excavated from an arsenic-contaminated railroad grade.
- Soils were packed at field site density into columns (5cm diameter and 27.5 cm length) (Figure 2).

Fig 2. Soil column study.

- Tap water was eluted through the soil columns in one of three flow regimes (fast, pulse, and slow flow rates; Table 2) designed to simulate flooding, flooding plus typical regional precipitation, or just typical regional precipitation, respectively.
- Effluent was collected for 21 days for the fast flow rate columns, and about 200 days for the slow and pulse columns.
- Post-flow through arsenic speciation was investigated with thin sections of aggregates from Col E (filled with the loam soil, which had a distinct leachate profile) using X-ray absorption spectroscopy (µX-ray fluorescence chemical mapping and X-ray absorption near edge spectroscopy (XANES)) at the Advanced Light Source.

Table 1. Soil characteristics.

Soil	Texture	% clay	Porosity	Bulk density
Soil 1	Loam	22	54.57	1.204
Soil 2	Clay loam	27	60.08	1.058

Table 2. Soil column study flow regimes.

Column	Soil Type	Flow rate (ml/hr)
A	Loam	3.8
B	Clay loam	3.8
C	Loam	3.8 pulse, then 0.38
D	Clay loam	3.8 pulse, then 0.38
E	Loam	0.38
F	Clay loam	0.38

Results: Arsenic breakthrough curves

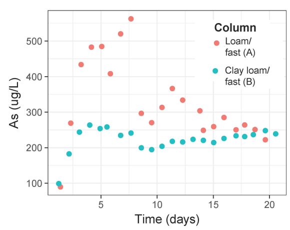

Fig. 3. Arsenic breakthrough curve from columns subjected to fast flow rate.

- Under the fast flow regime, the peak in arsenic at the beginning of the loam column (A), in contrast to the clay loam column (B), suggests a pool of As the in the loam soil that is available to leach initially.

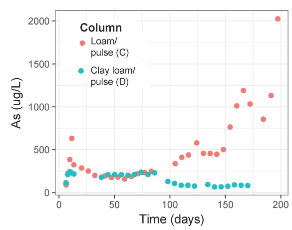

Fig. 4. Arsenic breakthrough curve from columns subjected to fast flow rate during a 21 day pulse, then slow the flow rate.

- During the fast pulse, the initial peak in the loam column (C) effluent (at 7 days) is similar to the peak in the loam/fast column (A) around 7 days.
- When the loam (C) and clay loam (D) columns were switched to the slow flow rate at 21 days, leaching from the two soils is similar until 80 days.
- The peak in the loam column (C) arsenic at 100+ days suggests reduction occurring in loam soil.

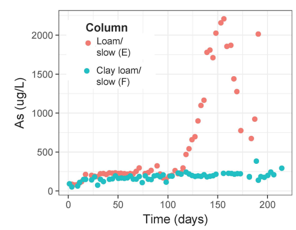

Fig. 5. Arsenic breakthrough curve from columns subjected to the slow the flow rate.

- Under the slow flow regime, over 0-100 days, arsenic leaches from loam (E) and clay loam (F) soils in similar amounts, regardless of the percent clay or arsenic concentration in the soil.
- After 100 days, arsenic peaks in loam (E) effluent, suggesting (like in loam/pulse (C)) that reducing conditions occurred in the loam (E), mobilizing the arsenic.

Results: Post-leaching arsenic speciation

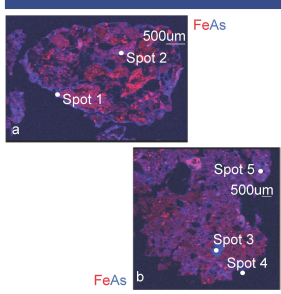

Fig 6 a and b. Chemical maps of Col E aggregate. 20 µm pixel size, 12 keV.

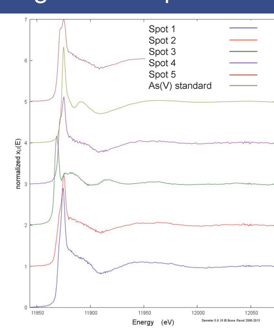

Fig. 7. Arsenic XANES spectra.

- Chemical maps (Figure 6) show arsenic present after leaching on the surface (Figure 6a) and within (Figure 6b) aggregates from the loam/slow flow rate column (E).
- XANES spectra (Figure 7) from spots within and on the surface of leached aggregates indicate the presence of mixed 50% arsenic(III) and 50% arsenic(V).
- Linear combination fitting of spectroscopic data suggests arsenic(III) is associated with hydrous ferric oxide (HFO). Arsenic could be mobilized for leaching when it reduces from arsenic(V) to arsenic(III), with arsenic reducing before iron in the system.

Conclusions and Future Directions

- More clay, and possibly a better aggregate structure related to the clay content, lowers leaching of arsenic from clay loam soil, although some arsenic is still lost to leaching from the clay loam.
- The loam (Col A, C, and E) could have a less well defined aggregate structure than the clay loam, such that small particles mobilize and fill larger pores, thus reducing pore size, blocking flow, and causing reducing conditions that mobilize arsenic at high concentrations at time scales >100 days.
- To promote oxic conditions and decrease arsenic leaching, good drainage should be maintained in arsenic contaminated soils.
- Arsenic(V) reduction, and subsequent mobilization, is not necessarily correlated with iron(III)oxide reduction.
- Future work will determine the chemical form of arsenic and iron in post-leaching aggregates from the clay loam soil, and propose mechanisms for arsenic mobilization from both soils.

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