Arsenic Fate and Transport in Red Cove, Fort Devens

Fort Devens Superfund Site
OU01 – Shepley’s Hill Landfill
OU11 – Plow Shop Pond

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Site access and coordination of field activities made possible by: Robert Simeone (Dept of Army - BRAC), Dave Reault (ECC), Marc Grant (AMEC)
Site Characterization

View of Red Cove from SE Shoreline

Plow Shop Pond Sediment
(<0.3 m)
Arsenic Concentration (mg/kg)

Red Cove:
Geom. mean
1400 mg/kg
n = 12

Max:
6800 mg/kg

Whole Pond:
Geom. mean
217 mg/kg
n = 107

GW discharge appears to be the primary source of elevated arsenic contamination in Red Cove sediments.
**Conceptual Model**

*Sediment Contamination*

**GROUNDWATER:**
- HIGH As
- HIGH Fe
- LOW ORP

**PLOW SHOP POND “RED COVE”**

**O₂**

**ACCUMULATION IN SEDIMENT**

**REDOX INTERFACE**

**DISCHARGE**

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**Project Objective**

*Site Characterization to Support Cleanup*

- **Project Goals**
  - Identification of the mobile form of arsenic in groundwater
  - Identification of the process(es) controlling arsenic uptake onto Red Cove Study Area sediments
  - Evaluation of the stability of arsenic associated with Red Cove Study Area sediments

- **Site Characterization**
  - GW hydrology and chemistry in Red Cove Study Area
  - Sediment chemistry including arsenic speciation in Red Cove
  - SW chemistry in Red Cove

- **Provide recommendations for GW & sediment remedies, where applicable**
Site Characterization
Area of EPA/ORD Study

GW Monitoring Network
- Screened at water table or nested 5-ft screens across saturated overburden
- Flow gradient across sediment layer
- Temperature of RSK GW and sediment pore water (1 ft depth)

Red Cove Study Area
**Flow Gradients**

- **GW wells**
- **PZ Flow Potential**
- **Across Sediment Layer**
  - **Up**
  - **Negligible**
  - **Down**

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**Groundwater Discharge into Red Cove**

*Discrete Measurements with Seepage Meter*

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[http://www.epa.gov/nrmrl/pubs/600r06122/600r06122.pdf](http://www.epa.gov/nrmrl/pubs/600r06122/600r06122.pdf)
**Sediment Pore Water Temperature**

**Classed Posting Map – Temperature Buttons**

- Groundwater temperature range was 49-51 °F (transducers).
- Select locations where the seepage meter was deployed in Red Cove are plotted as white diamonds.

**Water Chemistry Comparison**

**RSK Groundwater vs. Red Cove Surface Water**

- Highest As in upgradient GW wells generally associated with high K concentration.
- Shallow SW has consistently low K concentration.
Flux of As from Overburden Aquifer
RSK Well Clusters

- Groundwater
  - As Flux (g/d)
  - K Flux (g/d)

- Sediment
  - <1500 mg/kg As
  - >1500 mg/kg As

33 mg/kg As
Ecological Probable Effect Conc.

Red Cove Surface Water – As & Fe

- High particulate Fe in SW from GW discharge of Fe²⁺ (adjacent to PZ5)
- Oxidation & precipitation of Fe²⁺ captures As, but only after contact with DO in SW

Reddish Floc (next slide)

Water Column
Sediment Layer
Shallow Aquifer
### Red Cove Surface Water

**Relationship between Suspended Solids & Shallow Sediments**

- Significant correlation between Fe and As in sediments
- Concentration of As in suspended solids from Fe precipitation consistent with highest concentrations in shallow sediments

![Graph showing the relationship between acid extractable Fe and As](image1)

### Shallow Red Cove Sediments

- Sediment As associated with Fe-bearing minerals (mostly ferrihydrite)
- Predominantly As(III) in western & central transect; As(V) more significant in eastern transect
- High As concentrations and greater As(V) in eastern transect due to less GW discharge and more oxidizing condition (ferrihydrite more stable)

![Map showing sediment surface layer locations](image2)
Site Characterization: Chemistry
Specific Conductance vs. Arsenic in SW

- Difference in specific conductance between deep & shallow SW a good indicator of plume discharge
- Arsenic in deep SW water affected by plume & sediment dissolution

![Graph of specific conductance vs. arsenic in SW]

Fate of As from GW Discharge

Sequestration, but potential instability...

![Diagram of fate of arsenic from GW discharge]

GW Discharge
High As, Fe, K
Low DO

Sediment Recycling
High As, Fe – Low K
Variable DO
**Project Findings**

Q: Does groundwater discharge into Red Cove?
Yes - measured flow gradients around and within cove demonstrate potential for discharge.

Q: What is the spatial extent of arsenic plume discharge into Red Cove?
Mapped concentrations of arsenic in groundwater around cove perimeter (RSK well clusters) along with GW flux measurements show greatest flux from west of cove; data from RCTW wells underlying cove show maximum concentration in central portion of cove.

Q: What is the magnitude of arsenic flux discharging into Red Cove?
Calculated flux from measured distribution of hydraulic conductivity, flow gradients, and arsenic concentration in saturated overburden indicate flux of 20-60 g/day.

Q: What are the chemical forms of arsenic within the plume and sediments?
Arsenic in GW and deep SW predominantly As(III); dominantly As(III) or As(V) bound to iron oxides in sediments (limited association of As(III) with iron sulfides in central part of Red Cove).

**Fortuitous Findings**

Q: Does the groundwater extraction system at the north end of the landfill capture arsenic plume discharge at Red Cove?
Extraction system operation initiated March 2006 with an increased extraction rate beginning July 2007. Measured groundwater potentiometric surface and seepage within Red Cove from April 2007 to Sept 2008 indicates plume at Red Cove is not captured.

Q: What is the distribution of arsenic concentrations as a function of depth within surface water of Red Cove?
Arsenic above AWQC only within deep surface water (<2 ft above sediment surface); dominantly As(III).

Q: Are there physical or chemical parameters that can be used to map groundwater discharge into Red Cove?
Temperature, specific conductance & K concentration; concurrence between multiple parameters better, limited validation w/ direct measure best.

Q: What is the source of “reddish floc” observed in water column and shallow sediments?
Precipitation of ferrous iron (Fe^{2+}) following GW discharge and/or diffusion from sediments. (Not re-suspension of sediments.)
Current Status – Risk Characterization in Plow Shop Pond by Army

• Hydrologic and chemistry data from Red Cove Study Area used to design approach to select locations for risk characterization to assist differentiating between sediment contamination zones within and outside of locations of plume discharge

• Sampling points include: 1) locations with & without plume discharge, and 2) locations with As(III) vs. As(V) in sediments

• Risk characterization derived from weight-of-evidence approach based on chemistry, survey of macroinvertebrate populations, and sediment toxicity tests

• Graded approach for selection of locations for sediment toxicity – visual observations for “floc” or “no floc” followed by contaminant concentrations in surface water and sediment pore water.