Seepage from an Oil Sands Tailings Pond: Laboratory and Field Investigation

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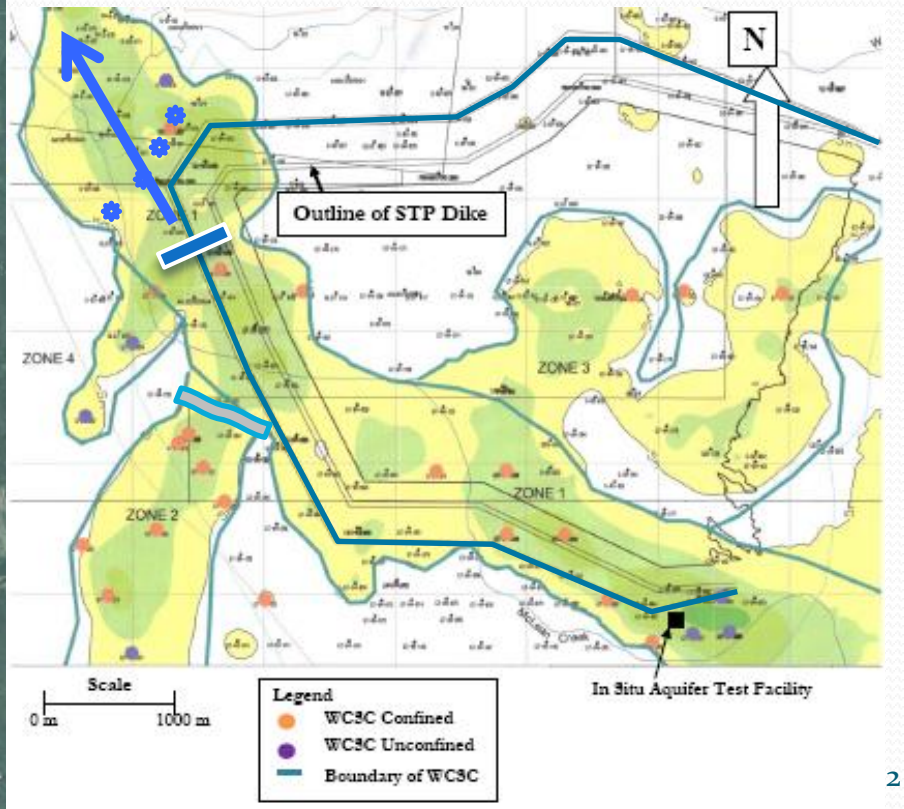
South Tailings Pond



Goals

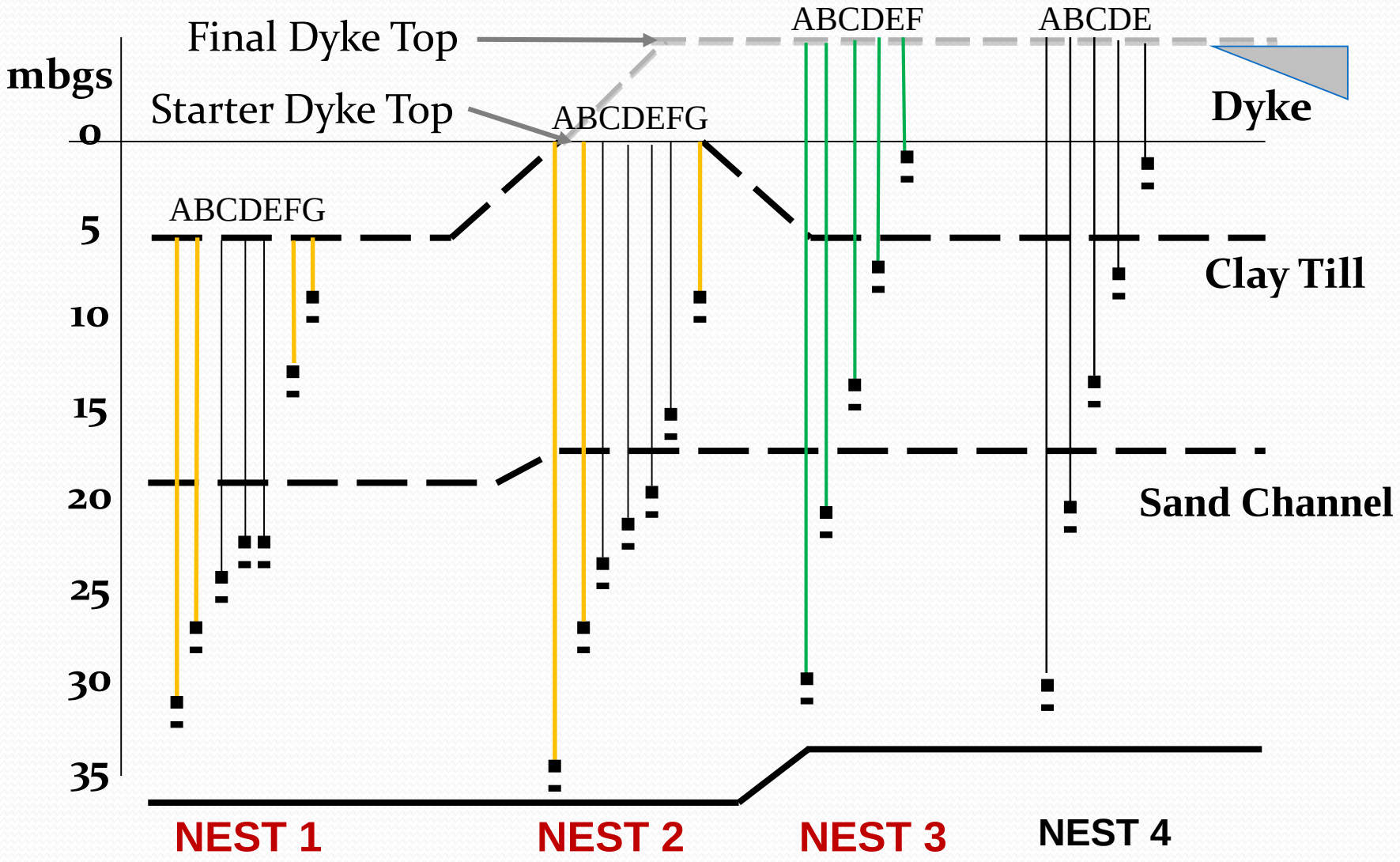
1) Clarify fate & transport of
   - **trace metals** (Si, B, Fe…)
   - **ions** (Na, Cl, SO_4, Ca…)
   - **organics** (NAs, BTEX…)
2) Develop remediation strategy
   - **Chemical oxidants + biodegradation**

Field Investigation

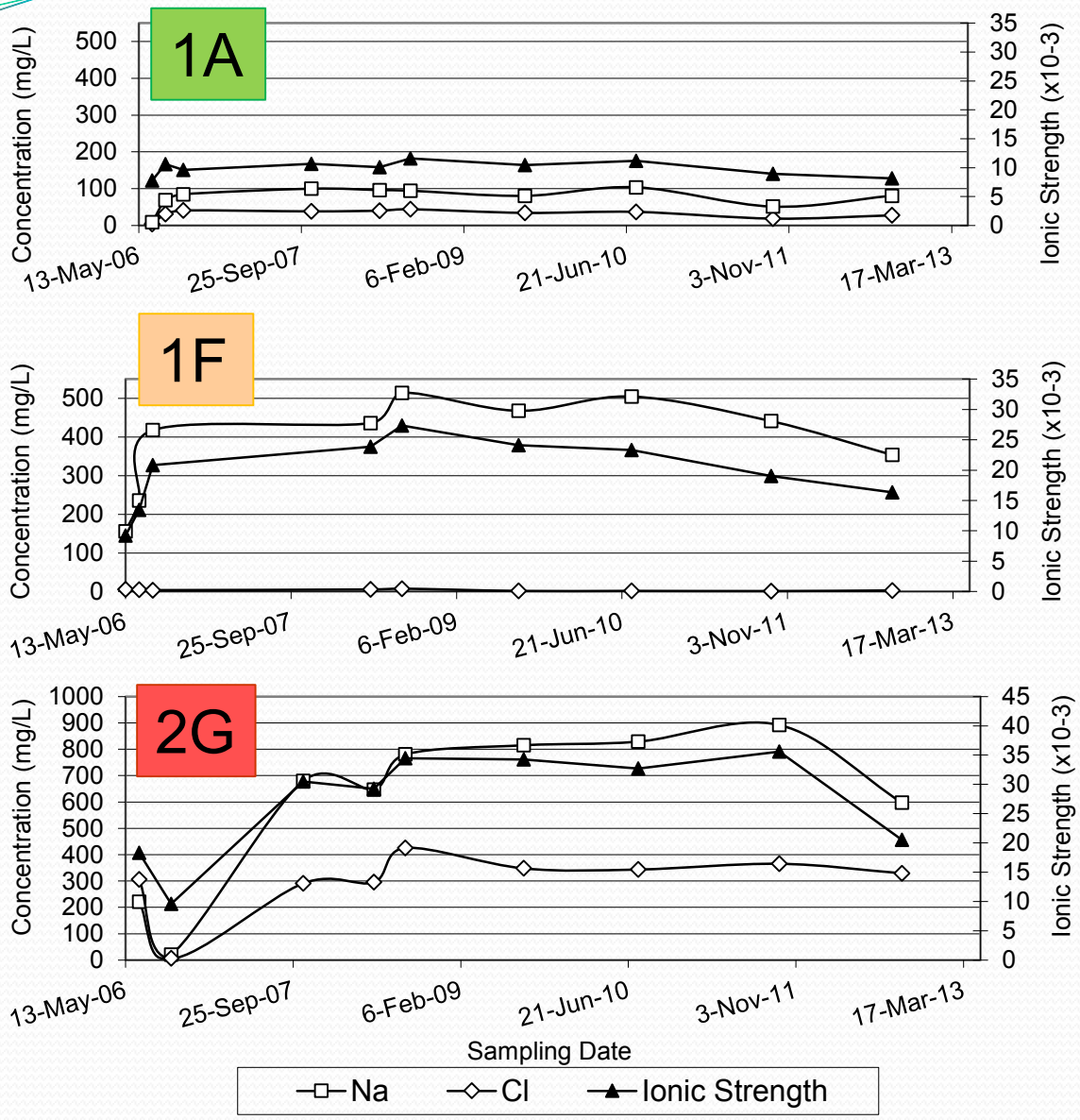
Methodology

- Annual groundwater sampling
- Measurement of field parameters
- Analysis of samples
  - NAs
  - BTEX/F1-F2
  - Major ions
  - Trace metals
  - Etc.

Monitoring Well Network



Trends of Potential Indicator Species

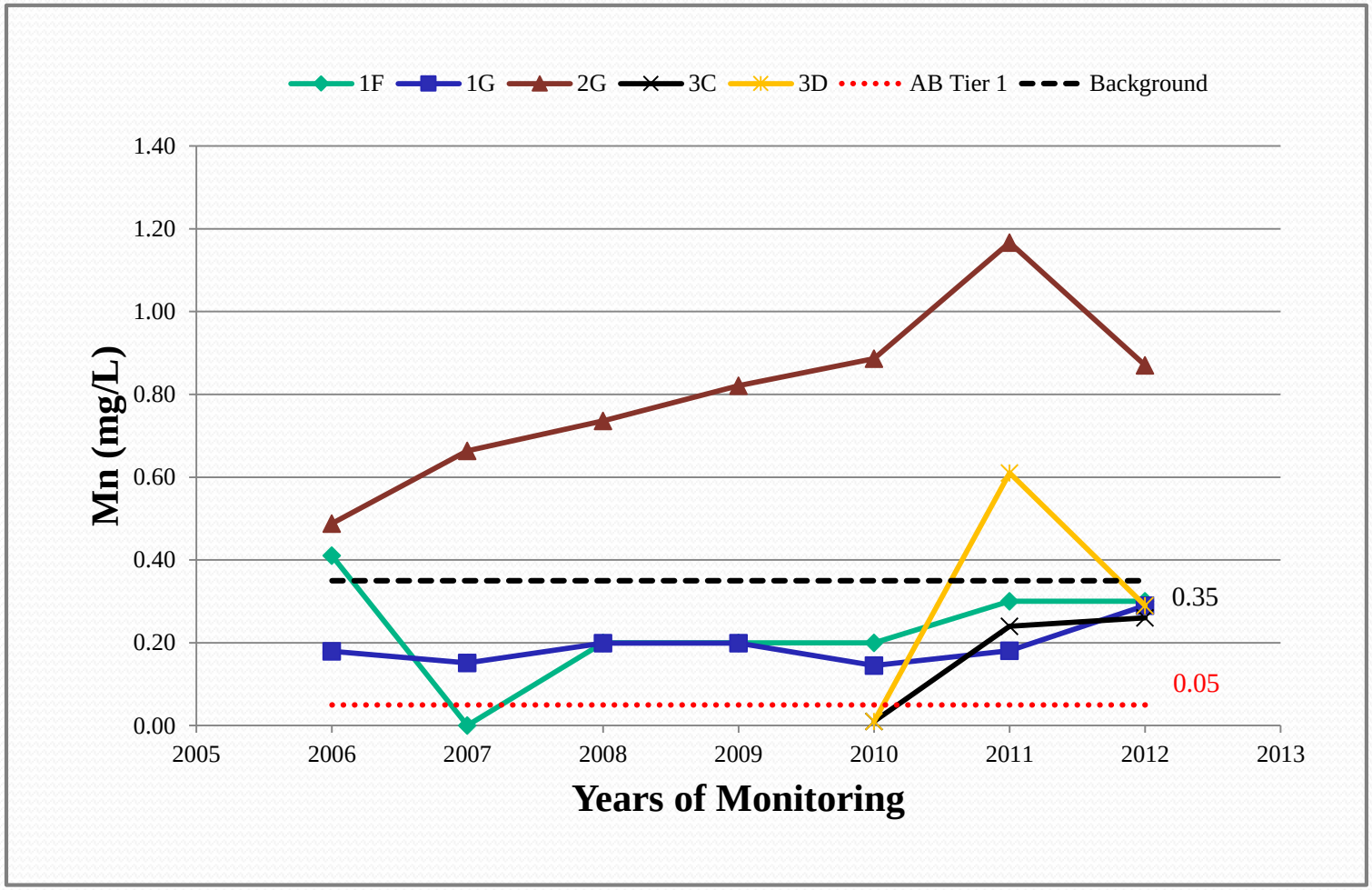


Not impacted

Contaminated, not impacted?

Seepage-impacted

Metals of Concern



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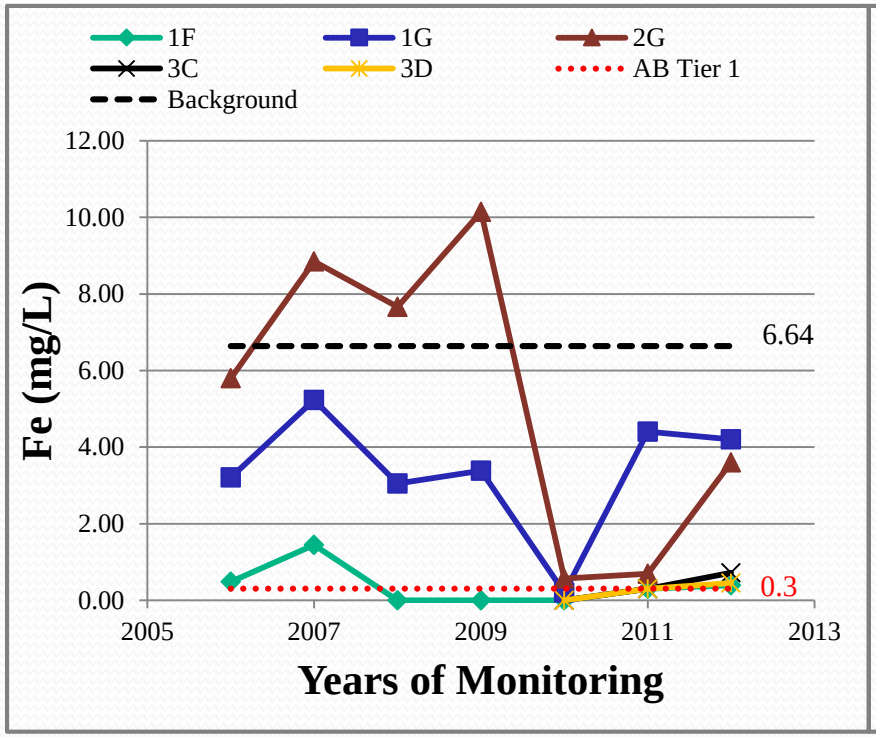
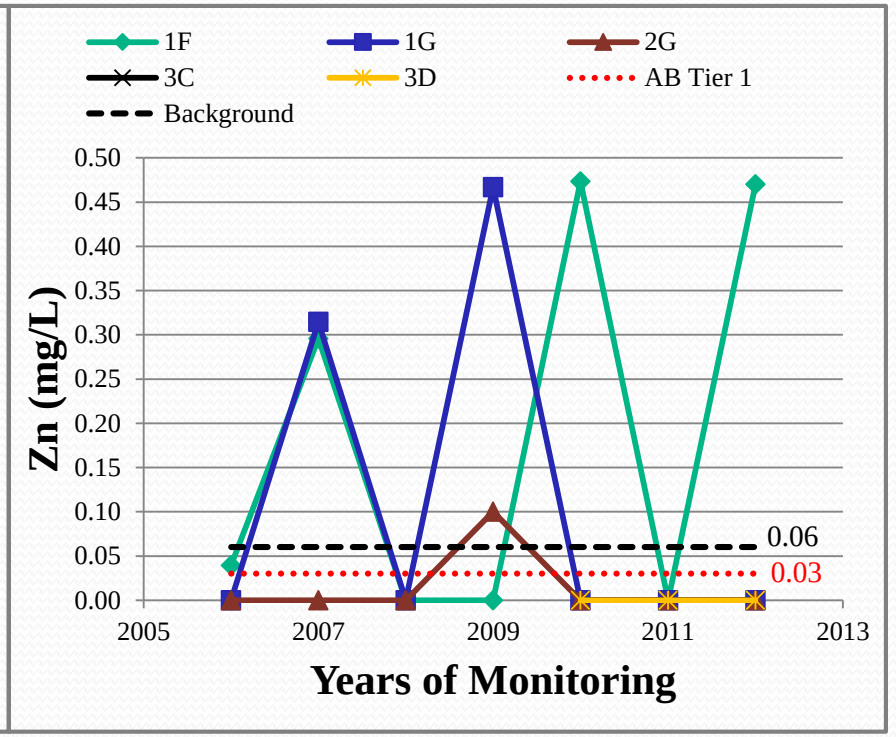
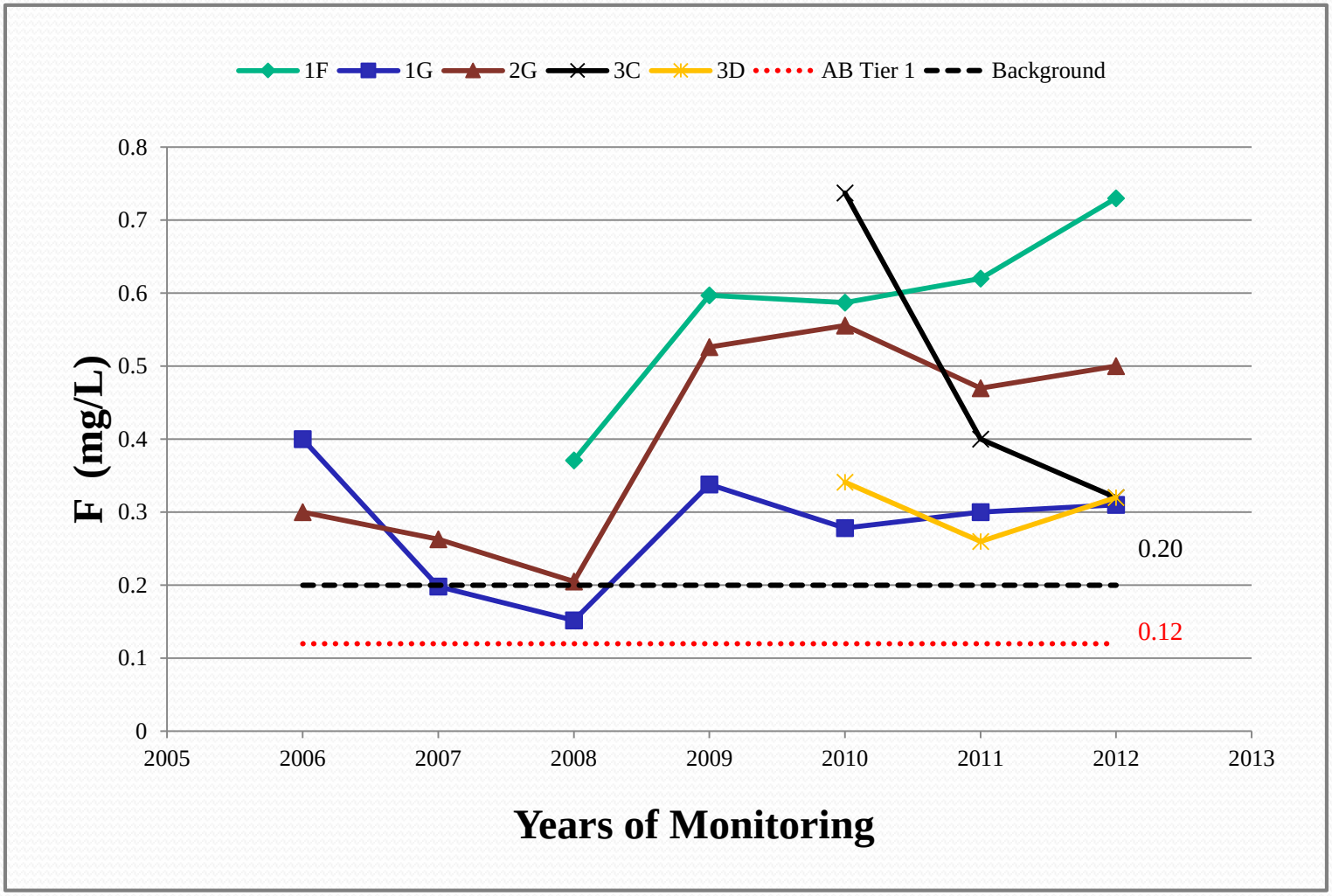
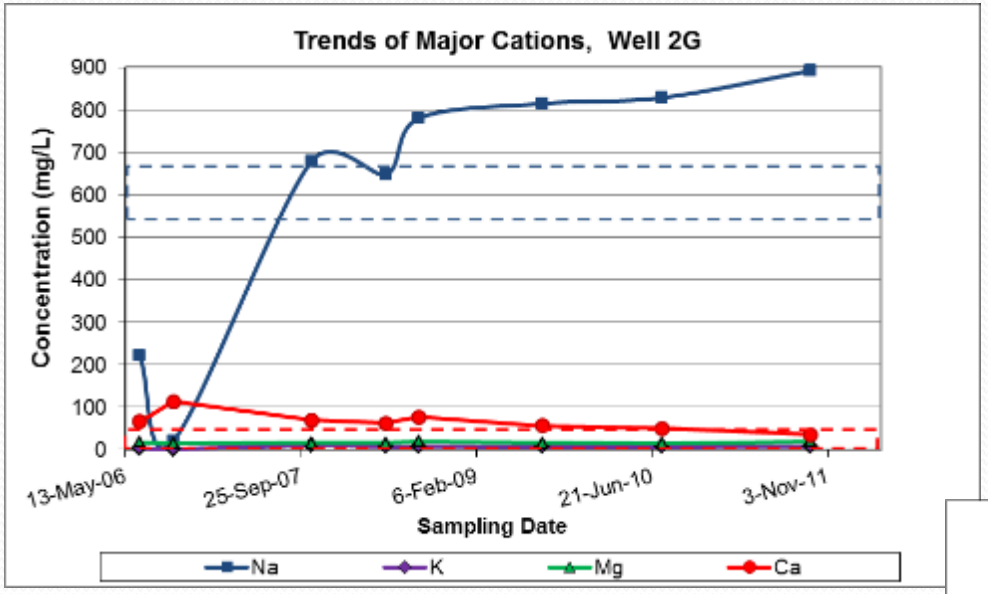




Ions of Concern

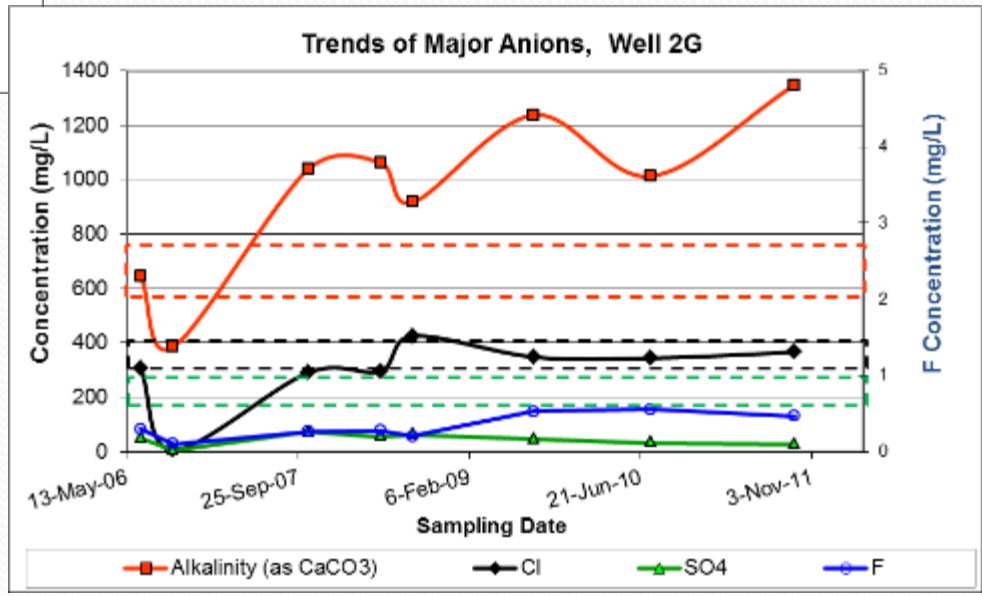


Well 2G: Major Ions

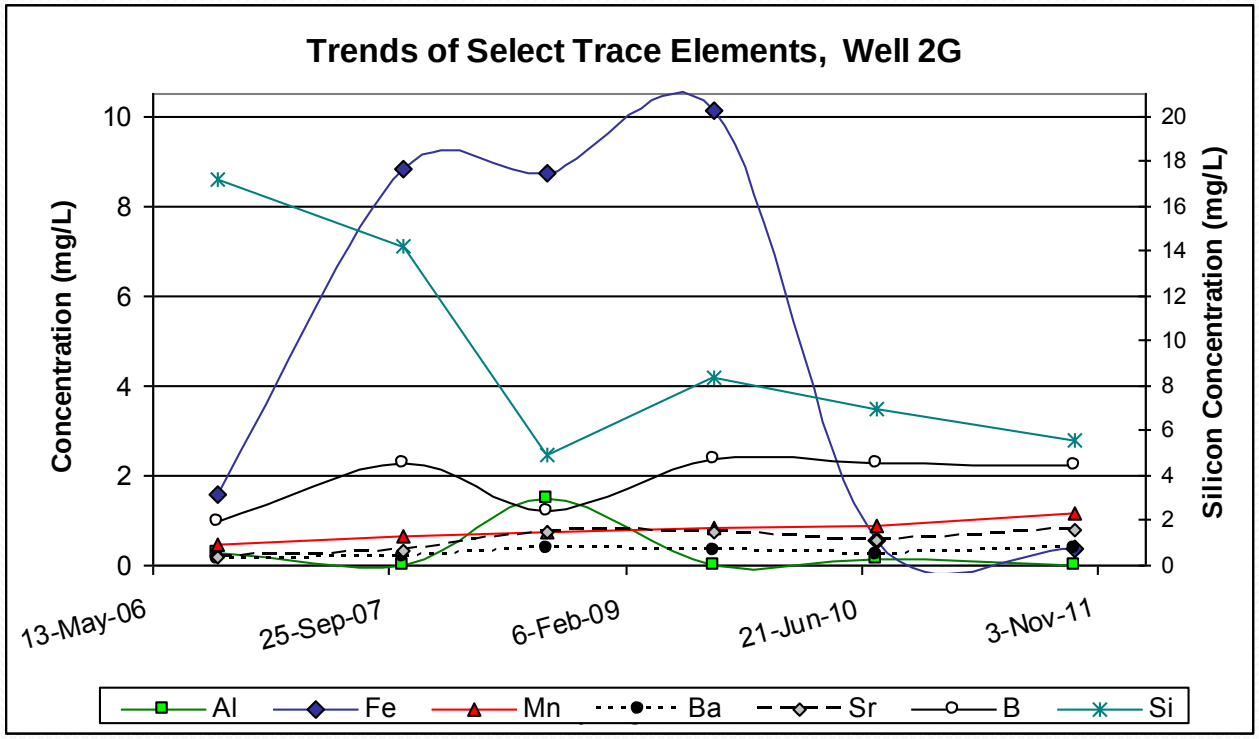


- Cl↑, F↑, Alkalinity↑, SO_4↓
- Cl conservative
- Biodegradation (SO_4)

- Na ↔ Ca, Mg
- Ca, Mg salt dissolution, later precipitation



Well 2G: Trace Metals



- Variable Fe,
- Si↓,
- Mn, (Ba), Sr↑

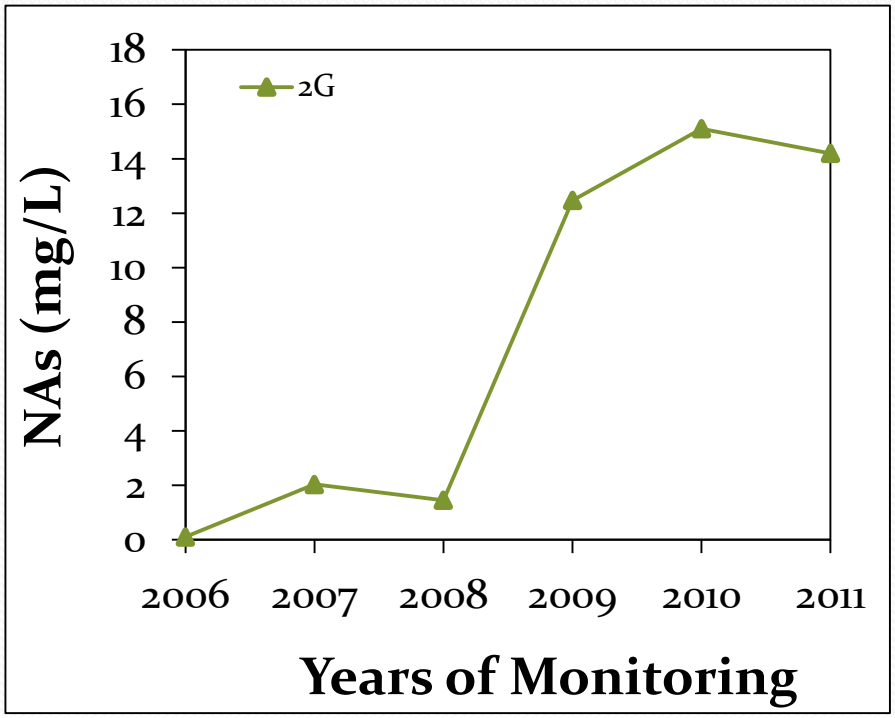
Organics of Concern

No exceedances for:

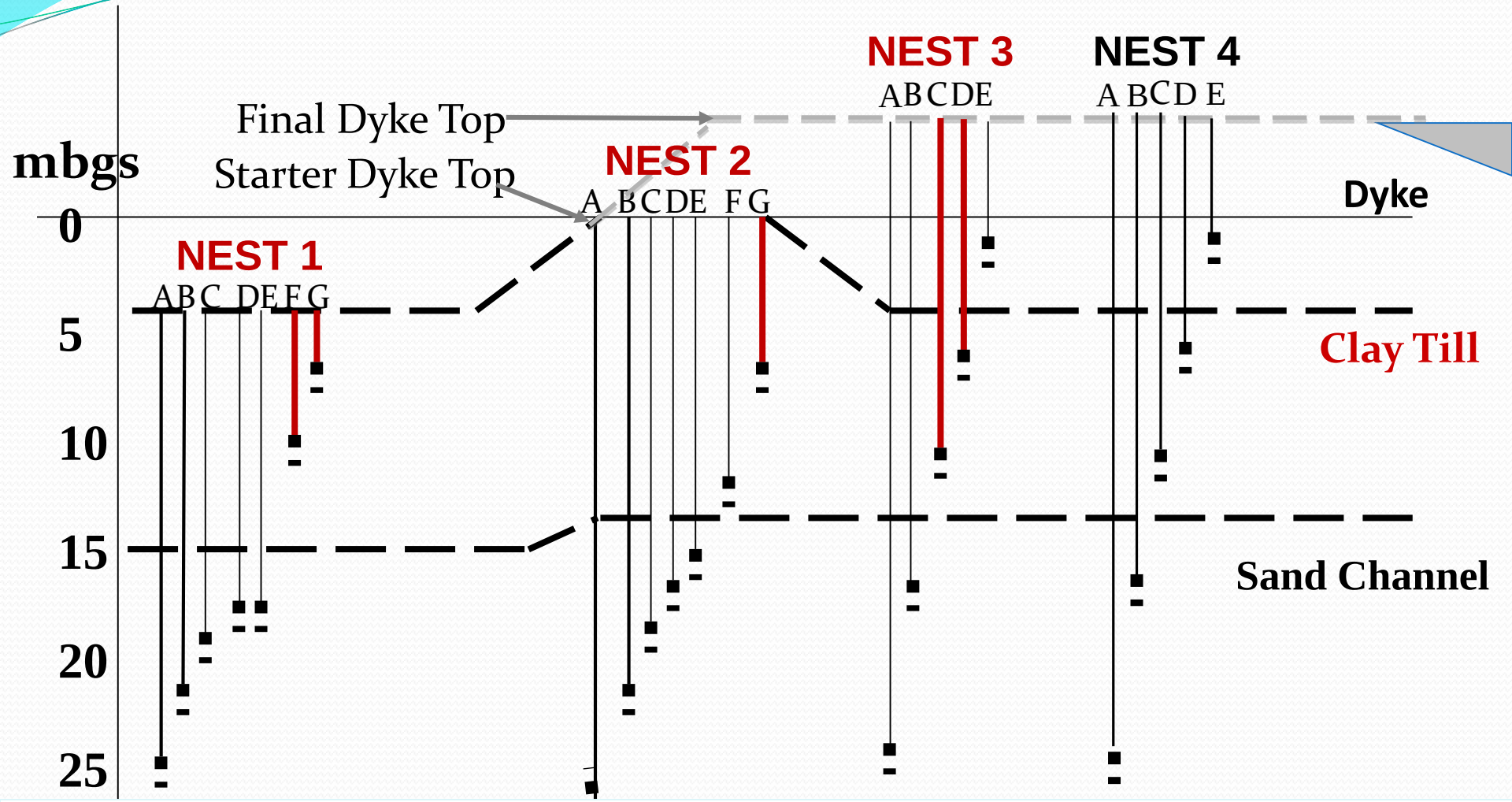
- BTEX
- PHC F1-F2

Increasing trend in 2G

- NAs



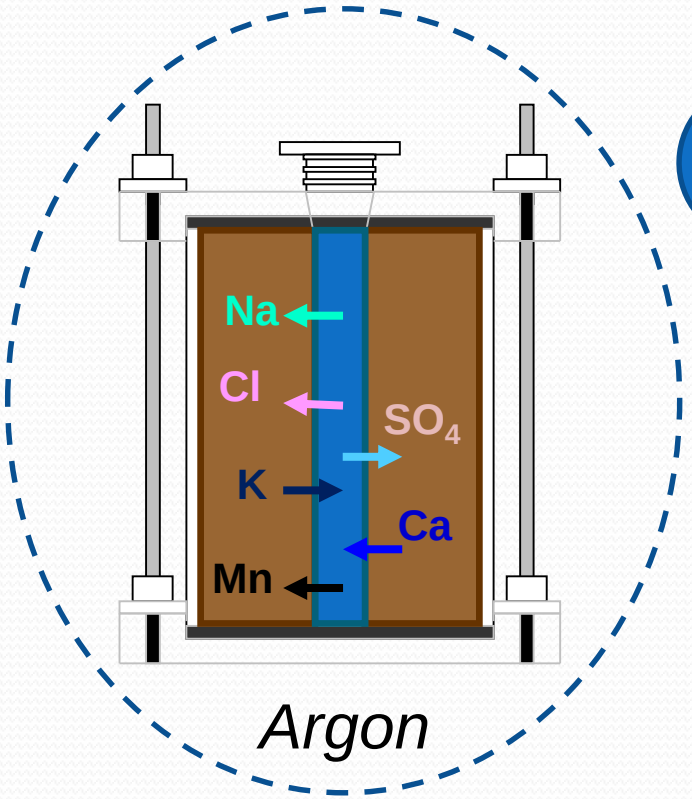
Conclusions



- Releases of NAs, F, Na, Cl, Mn, Fe, Zn
- Contaminants confined most frequently in shallow clay till (1F, 1G, 2G, 3C, 3D)

Laboratory Experiments

Radial Diffusion Cells – Clay



Observations:

Fe(2), B release
Na, SO_4 uptake
Ca, Mg release

Processes:

Reductive dissolution of Fe(3) => Fe(2)

SO_4^{2-} reduction to S^{2-}

Metal release from solids

Na ⇔Ca, Mg Exchange

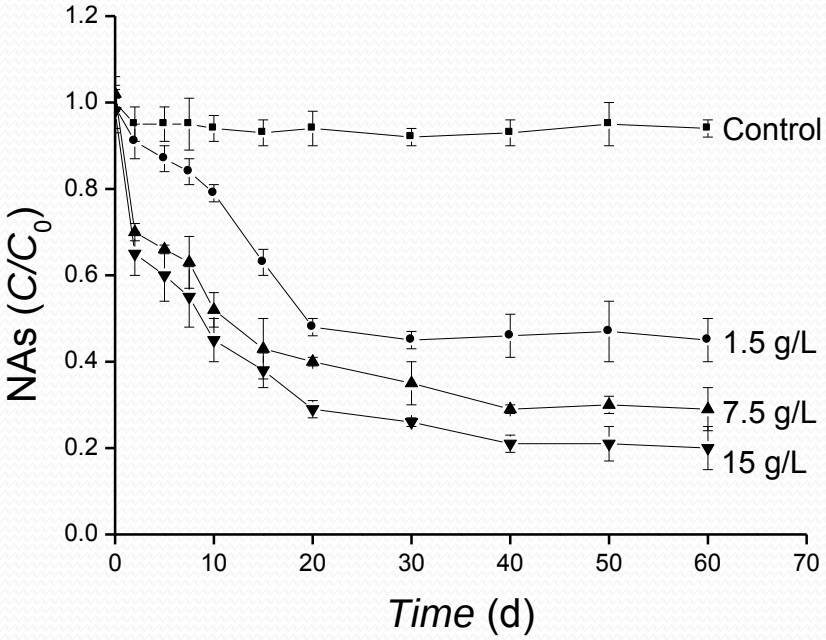
Holden et al. (2013) Biogeochemical processes controlling the mobility of major ions and trace metals in aquitard sediments beneath an oil sand tailings pond: laboratory studies and reactive transport modeling. *J. of Contaminant Hydrology*.

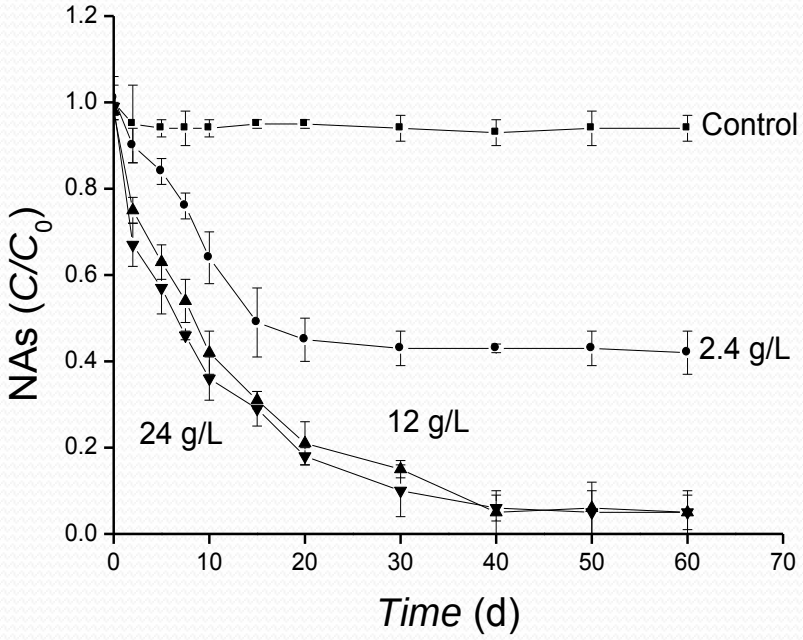
Remediation of NAs?

- In-situ chemical oxidation
- Bioremediation

} Can we couple these?

Removal of NAs from groundwater





$KMnO_4$: 77% removal

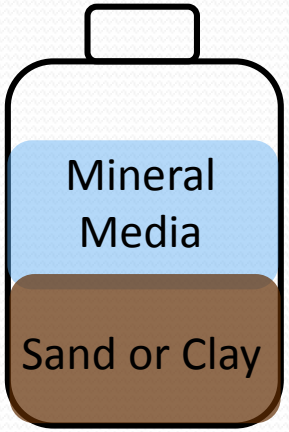
$Na_2S_2O_8$: 95% removal

Effect on microbial community

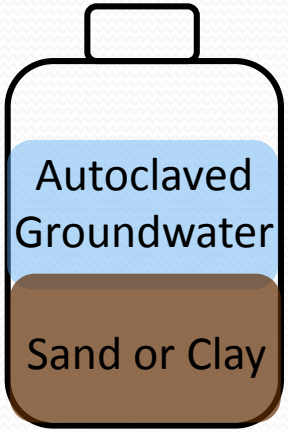
Samples	Total Bacteria (copies/g soil)
4B	**9.82E+04**
4B after oxidation with SP	**5.28E+04**
4D	**5.68E+04**
4D after oxidation with SP	**2.75E+04**

- Chemical oxidation has no significant detrimental effect on total bacteria
- Coupling chemical oxidation & biodegradation is possible

Naphthenic Acid Microcosms



Electron Acceptor:
NO_3^-, SO_4^-, or Fe(III)



	NO_3^-	SO_4^-	Fe(III)	NO_3^-	SO_4^-	Fe(III)
Clay	✓	✓	✓	✓	✓	✓
Sand	✗	✗	✗	✓	✓	✓

**Based on e- acceptor measurements only.

Conclusions

- NAs appear persistent and mobile
- Initial flush of metals does not appear to be persistent
- Remediation efforts
  - NAs removal with sodium persulfate or potassium permanganate
  - Oxidative degradation of NAs not affecting microbial community
  - In-situ bioremediation – may be possible

Thanks for your attention!

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