Accumulation of Contaminants in the Distribution Systems

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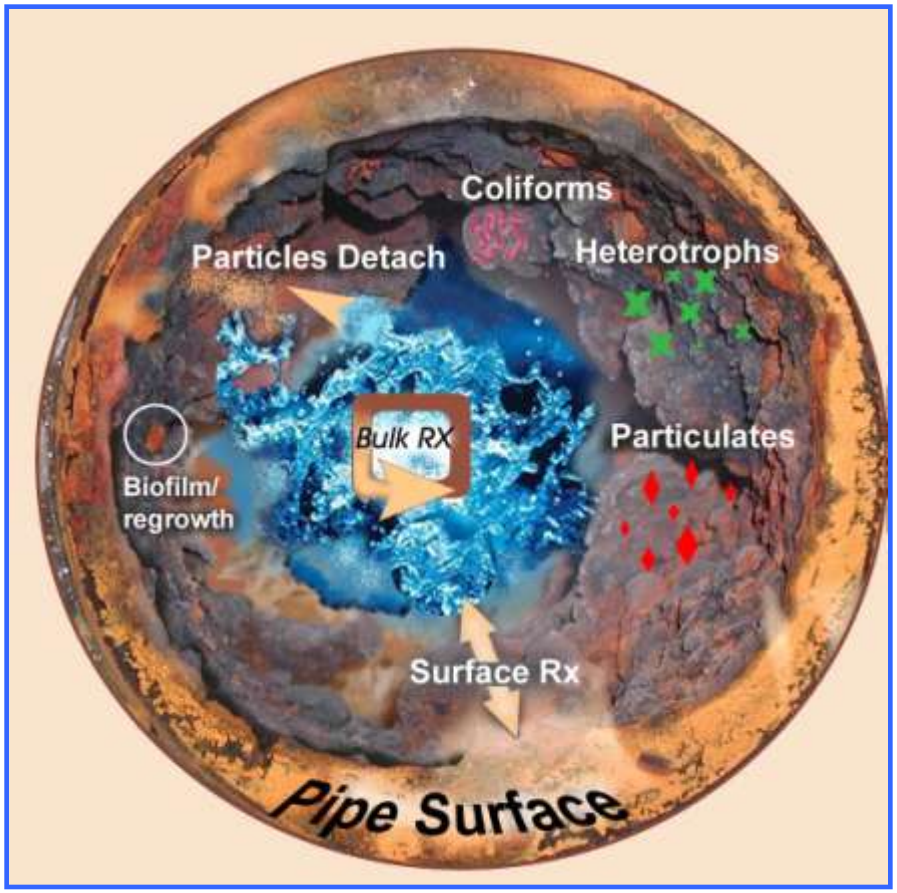
Corroding Pipes are Complicated Reactors that can Accumulate Trace Contaminants



General Nature of Metallic Pipe Surfaces

- **Oxides, hydroxides, hydroxycarbonates, carbonates, hydroxysulfates, etc. from corrosion**
- **Similar compounds from deposition or post-precipitation (particularly Fe, Mn, Al), may include silicates**
- **Phosphates from corrosion control**
- **All may be mixed with NOM**
- **Biofilms present in some areas and some materials**

Practical Issues of Contaminant Accumulation

- **What contaminants are involved (health risk?)**
- **What is the “equilibrium” mass of deposit?**
- **Where are the contaminants located**
  - ***Relative to consumer ingestion?***
  - ***Relative to regulatory monitoring locations?***
  - ***Relative to types of mains/pipes?***

Accumulation of Contaminants in the DS

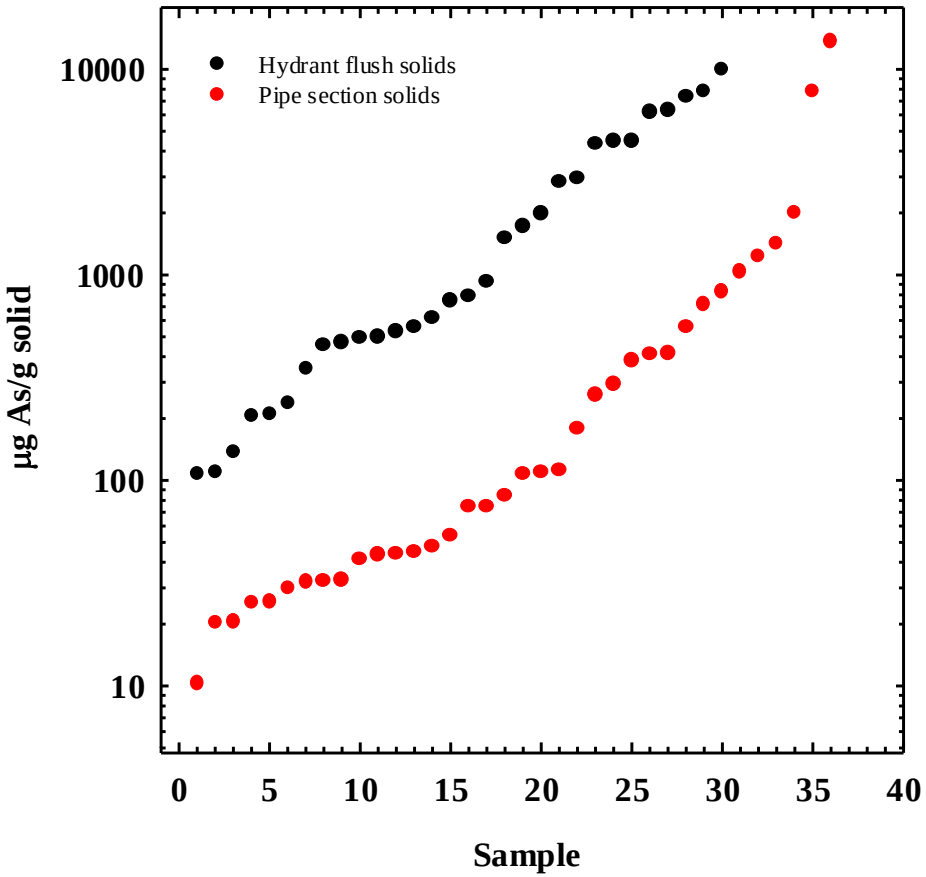
Corrosion deposits, sediment, and other solids that collect in the DS can accumulate contaminants if in the water

Solids Analysis

- Acid digestion/ICP-MS (Battelle)
  - *Ca, Mn, Fe, Mg, P, Si, As, others*
  - *Units*
- XRD
  - *Mineral phases*
- Electron microprobe-WDS (Battelle)
  - *Quantitative elemental mapping*
- SEM-Wavelength dispersive spectrometer- imaging and elemental mapping

Arsenic Accumulation in the DS

ICP-MS Analysis



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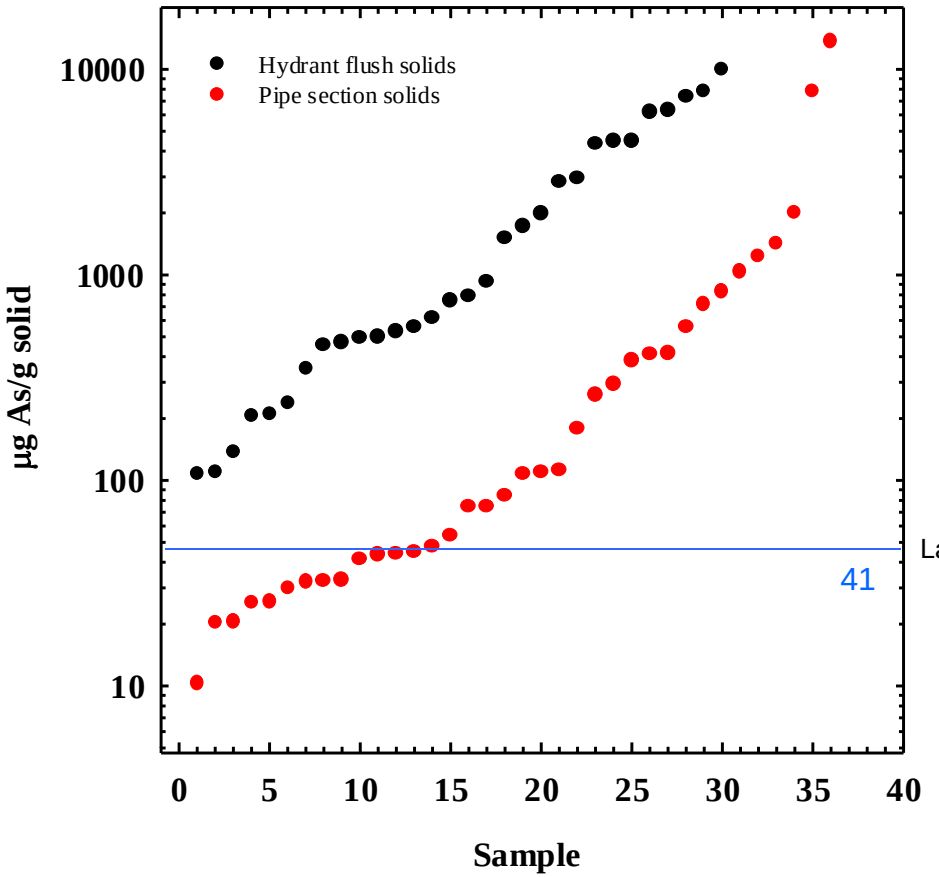

Land Application of “clean sludge”

Arsenic Accumulation in the DS

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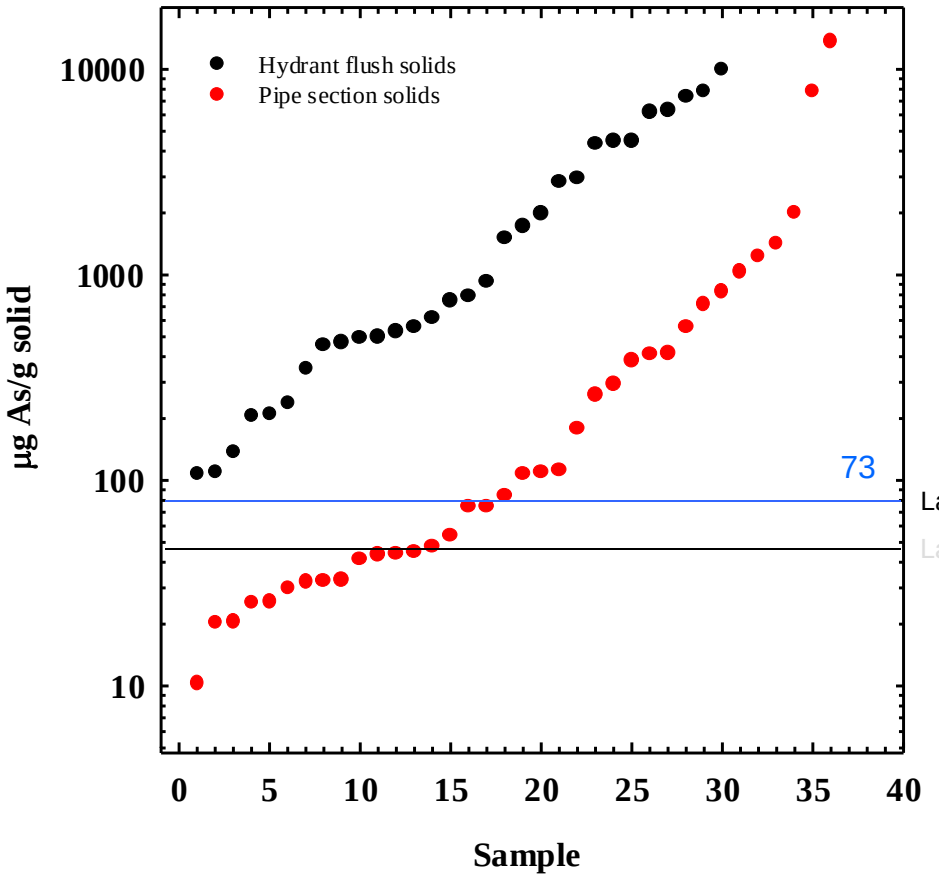
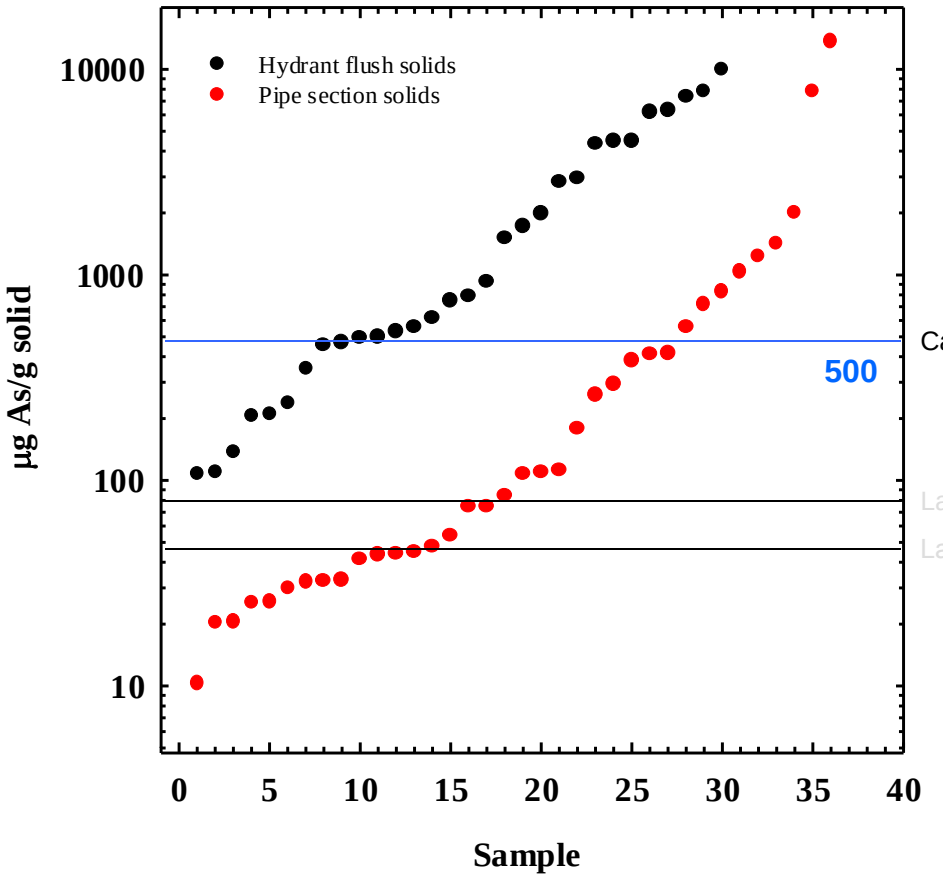


Land Disposal Limit, Dedicated Land Disposal sites

Land Application of "clean sludge"

Arsenic Accumulation in the DS

ICP-MS Analysis



California definition of hazardous waste

Land Disposal Limit, Dedicated Land Disposal sites

Land Application of “clean sludge”

Arsenic Accumulation in the DS

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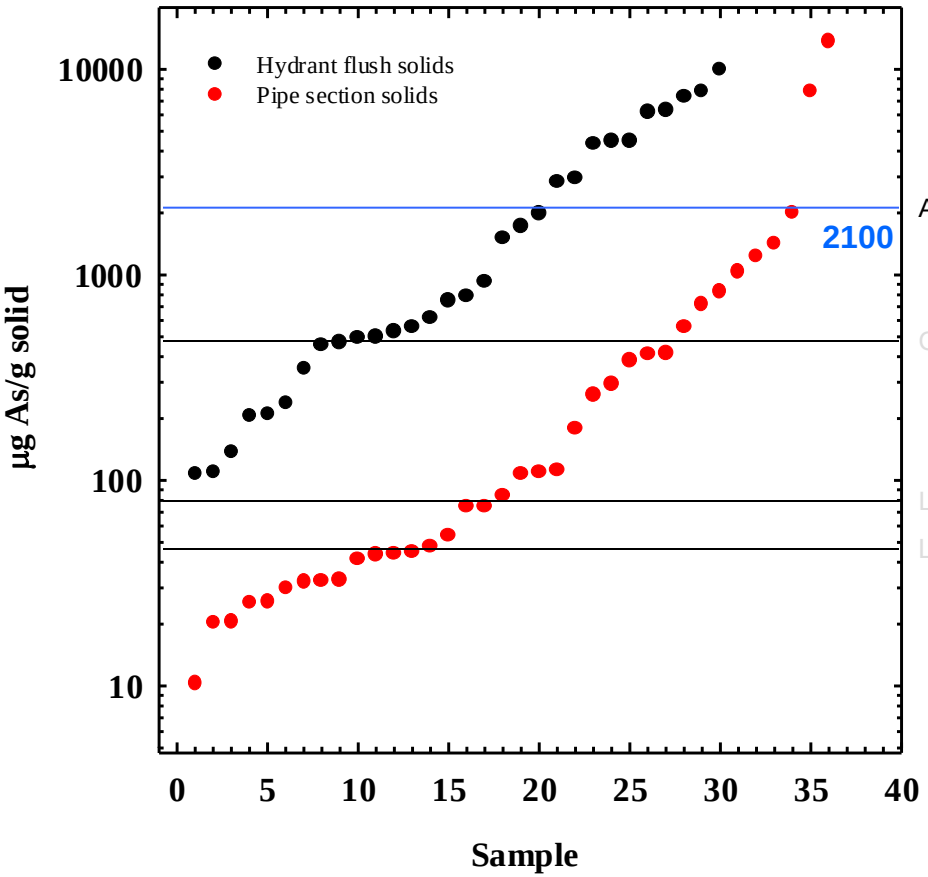

Arsenic Accumulation in the DS

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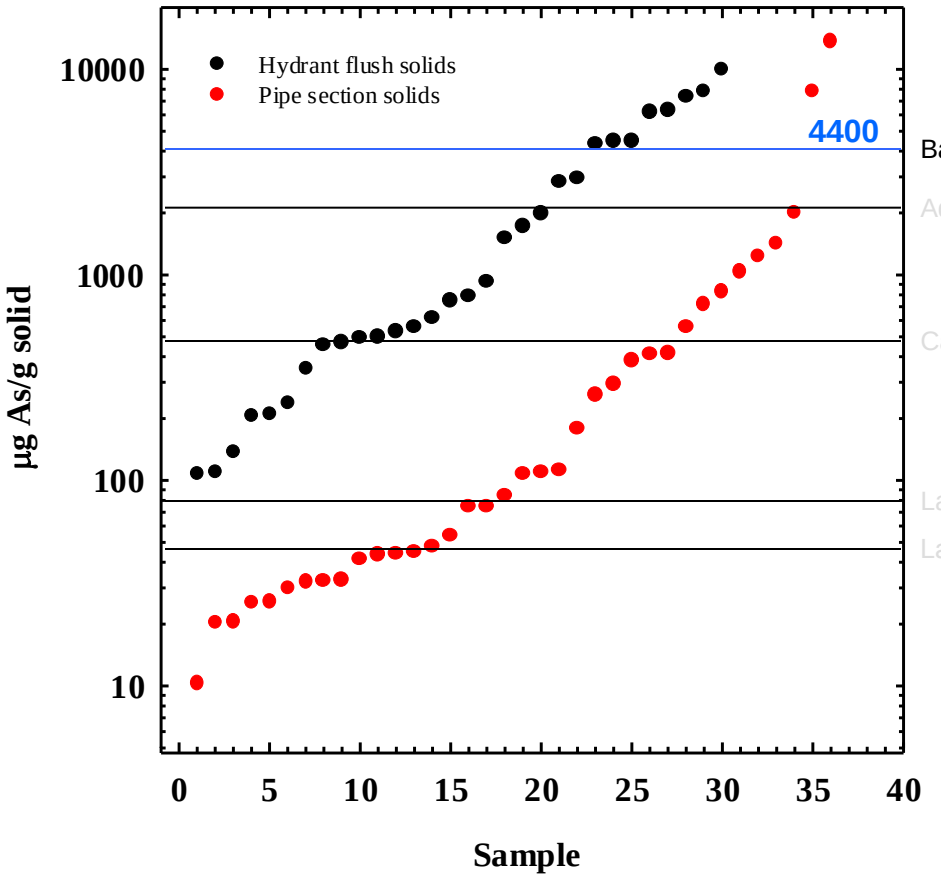

Backwash solids (ave., 56 samples)

Adsorption media (ave., 28 samples)

California definition of hazardous waste

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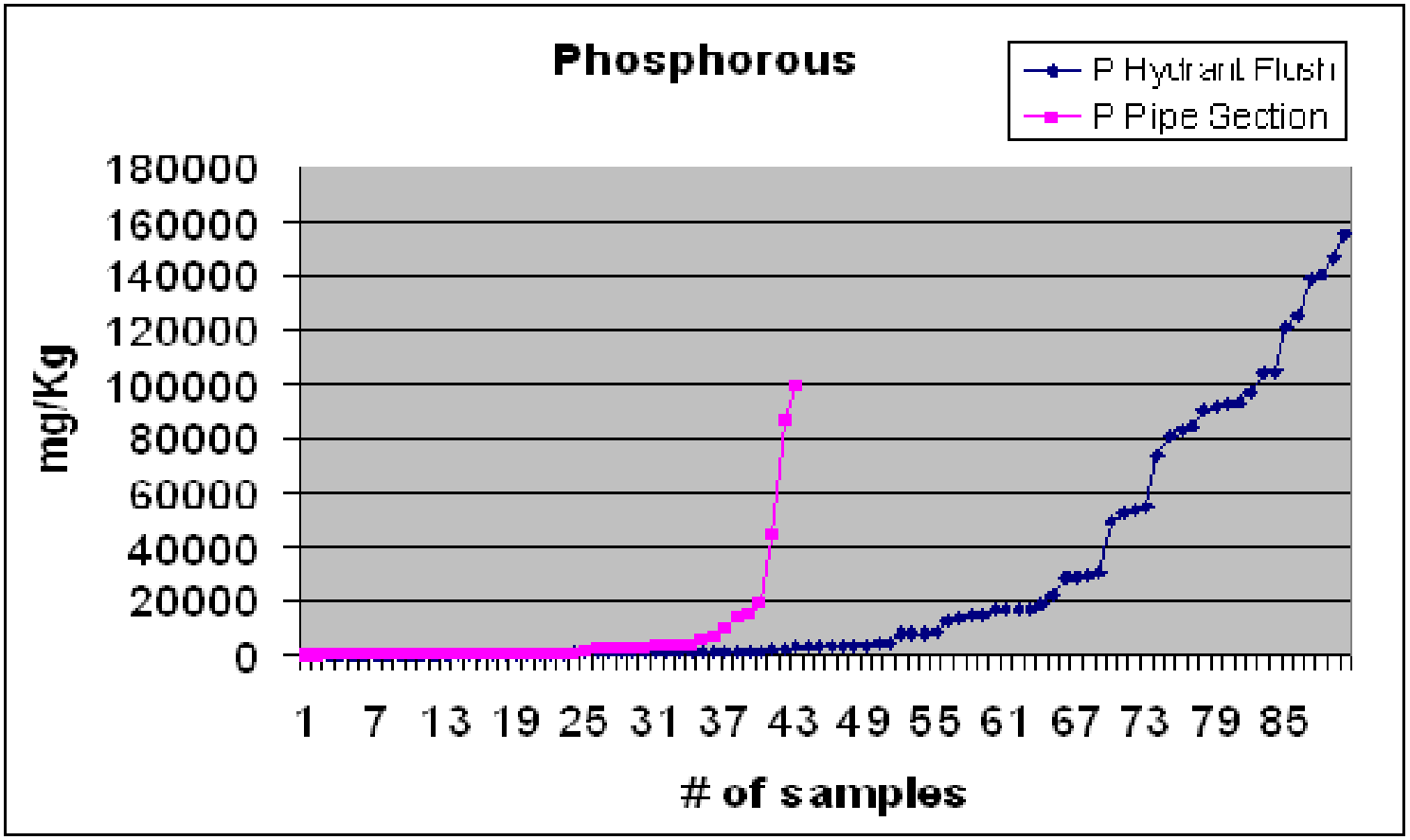
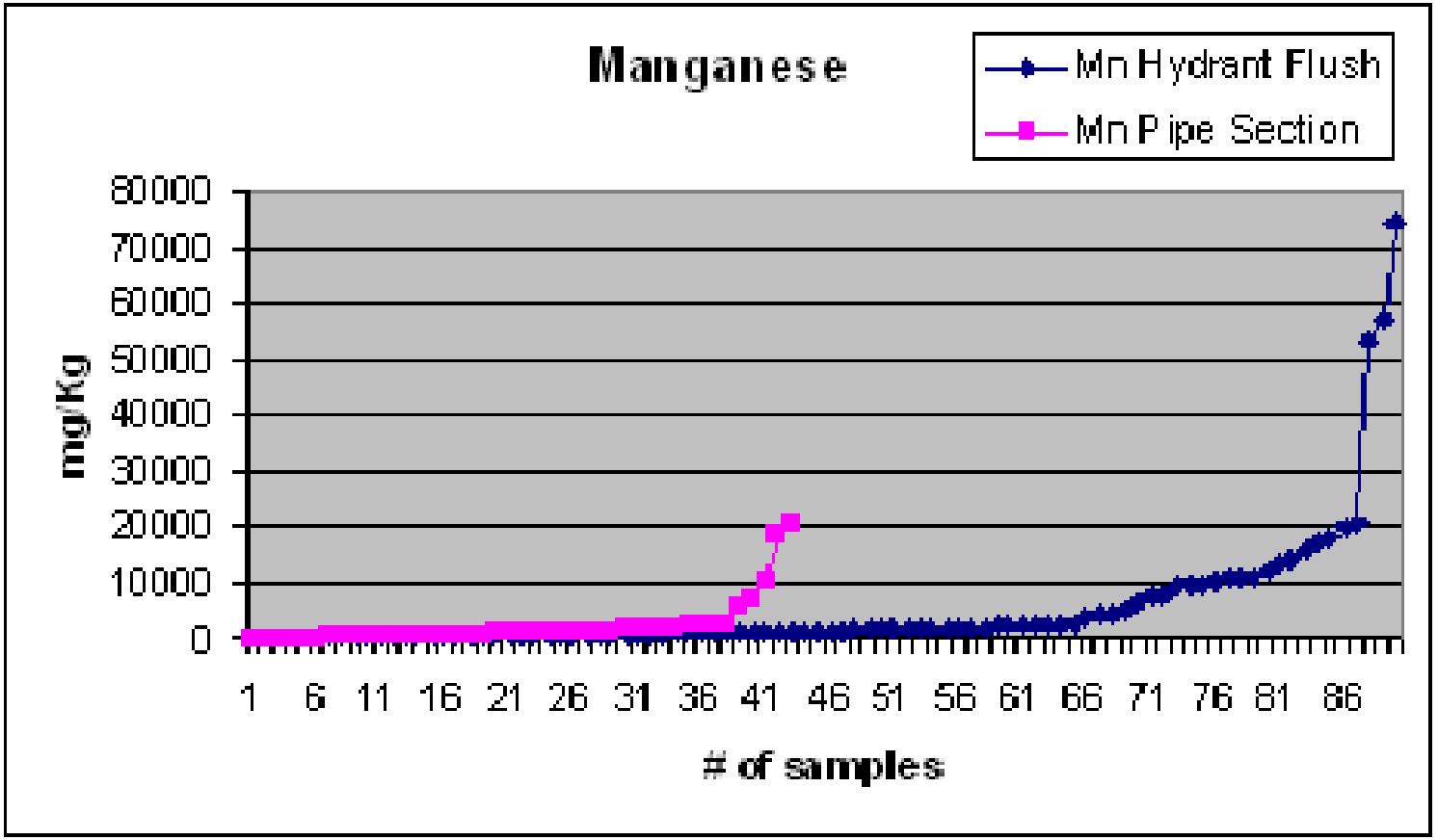
Phosphorus Accumulation



Manganese Accumulation



Practical Issues of Contaminant Accumulation

- **How easily is it destabilized?**
  - ***How is the contaminant bound?***
    - **Solid mineral phase?**
    - **Sorbed?**
  - ***Phosphates: Do they***
    - **"Seal" the surfaces?**
    - **Dissolve or displace the surface compounds and layers?**
    - **Mobilize sediment particles?**
    - **Any or all of the above?**
  - ***Hydraulic factors: pressure or flow changes***

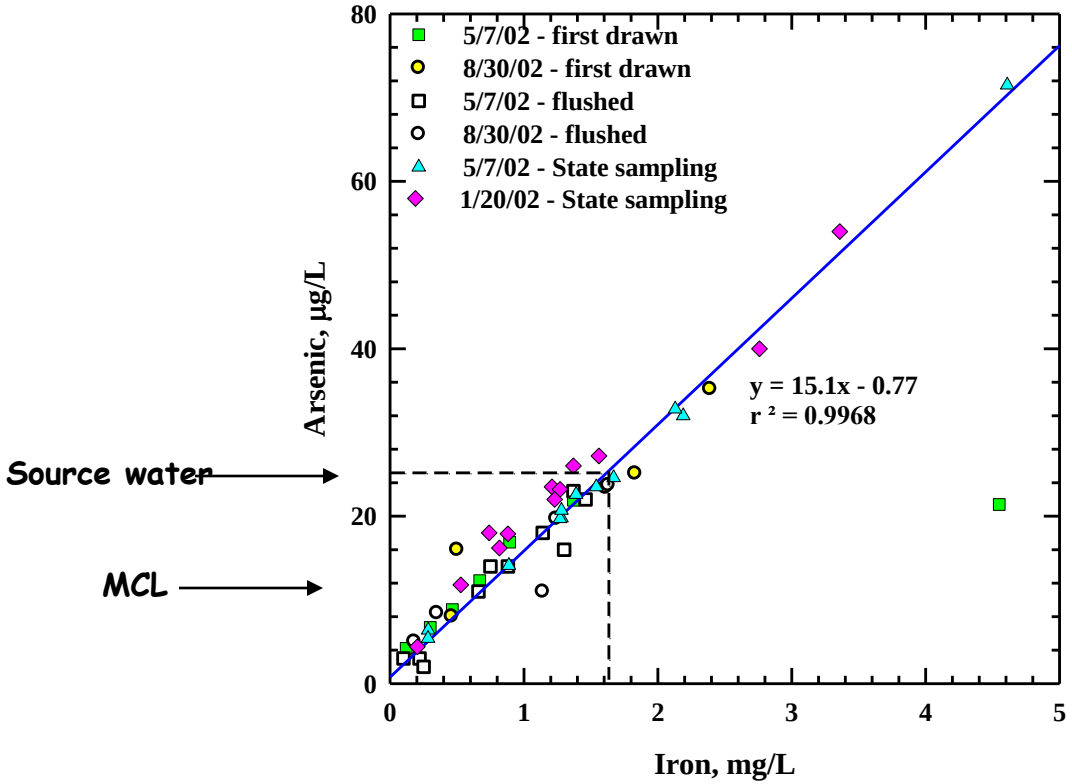
Particle Mobilization

Case Study 1: Particulate Release of Arsenic in Distribution Systems

- Colored water events led to sampling and the finding that As levels (>100 µg/L)
- Also high iron levels (>15 mg/L)
- Lawsuit and media attention
- 73 mg Ca/L, 32 mg Mg/L, 17 mg SiO_2/L, pH mid 7's
- 24 µg As/L, 1.6 mg Fe/L
- Chlorination

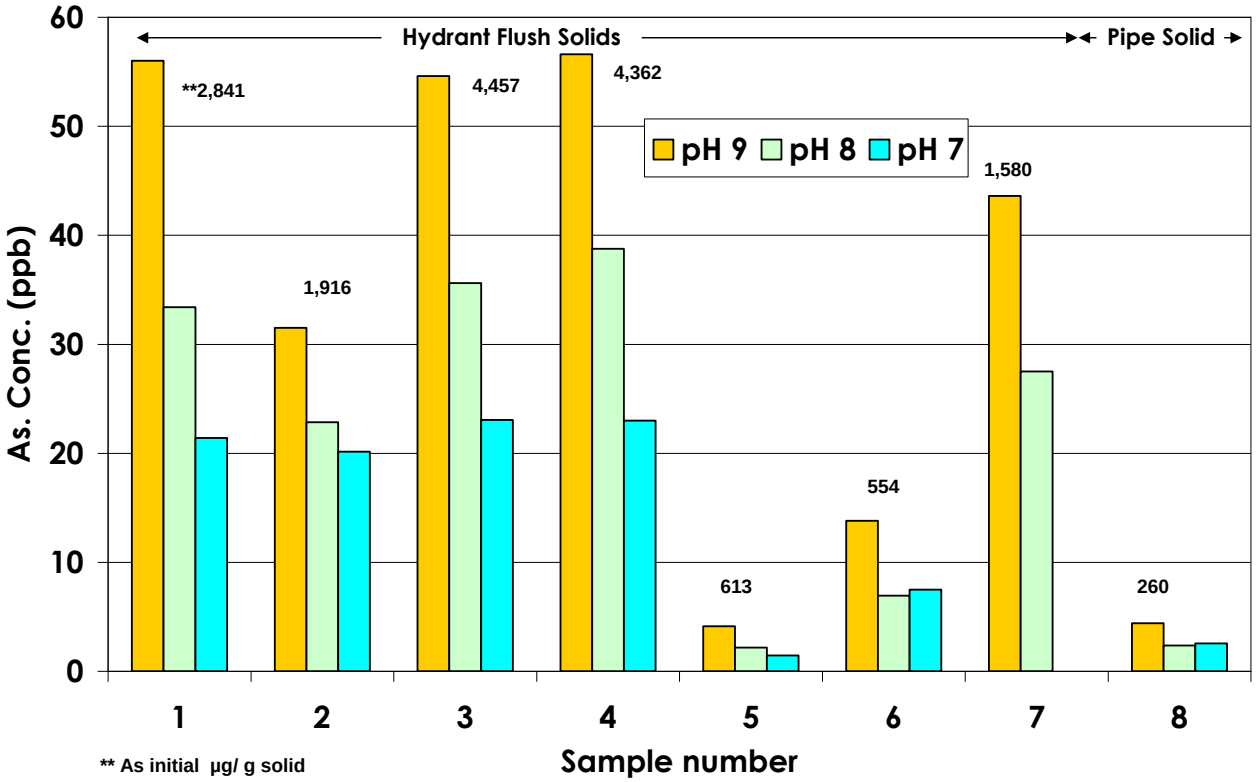
Particle Mobilization

Case Study 1: Relationship Between Arsenic and Iron in Distribution System Samples



Desorption

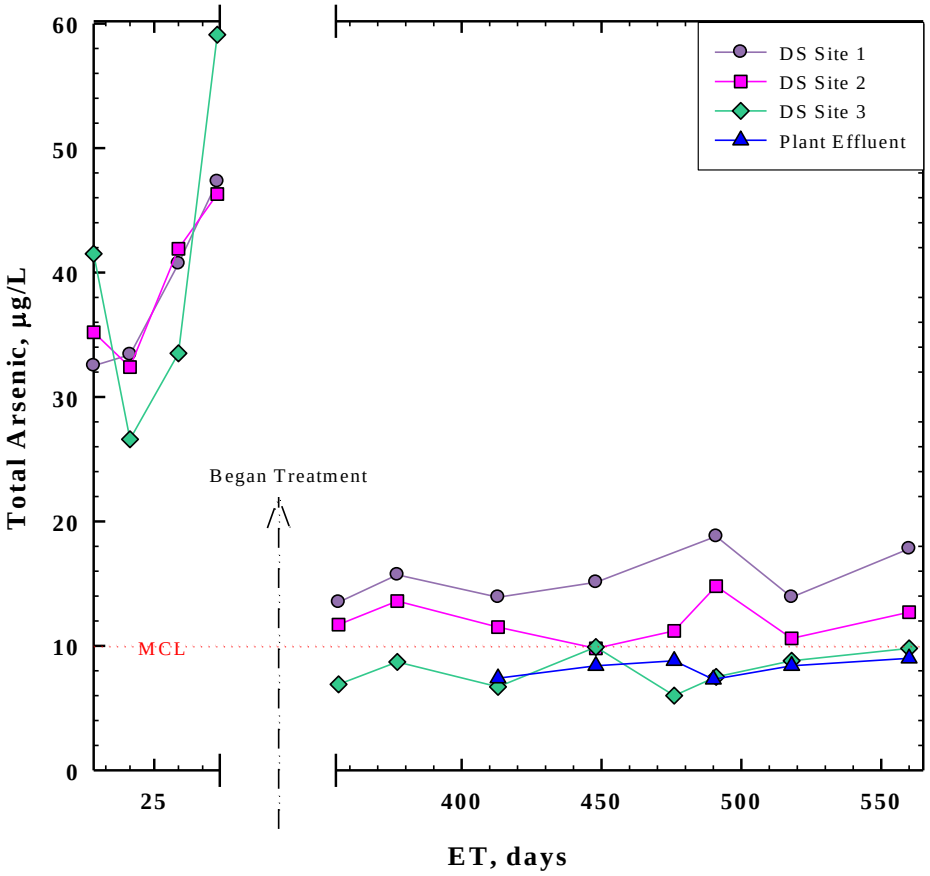
Research: Desorption from Drinking Water Distribution System Solids



- **Samples 1, 2,3,4 and 7 correspond to the same Utility**
- **The majority of these solids are hydrant flush material**

Desorption

Lidgerwood, ND



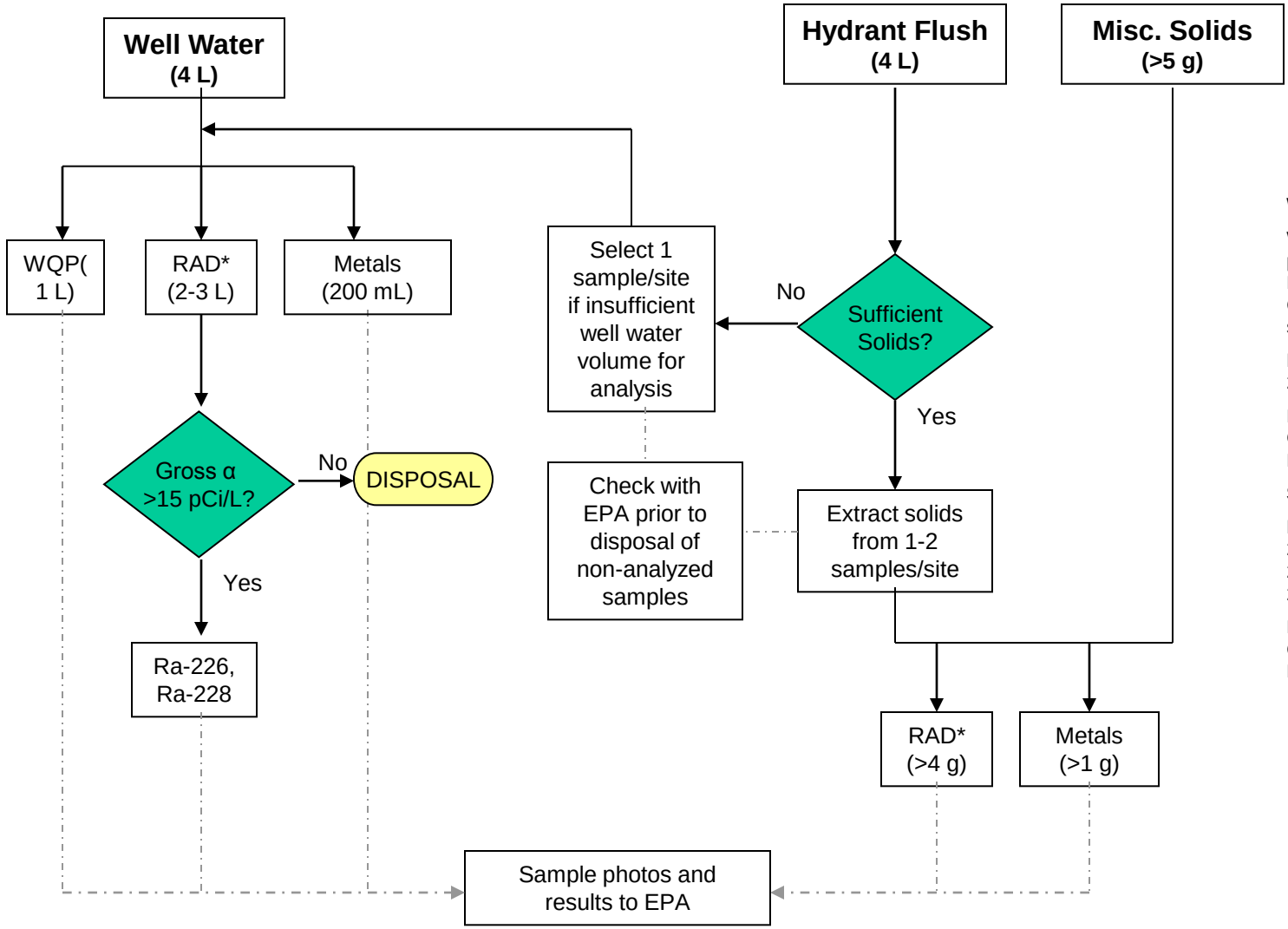
Initial soluble As concentration:

125 µg/L (reduced to approximately 35 µg/L prior to DS)

Accumulation of Radium and Uranium in Distribution Systems

- Battelle Contractor
- Pipe sections and fire hydrant flush samples
- Midwest, Texas water systems
- Status: samples concentrated currently being analyzed

Radium and Uranium Sample Flow Chart



Water analysis

WQP (20): alkalinity, pH, turbidity, TDS, SiO_2, PO_4, NO_3, NO_2, SO4, F, Cl, NH_4, TOC (Belmont), sulfide (DHL)

RAD (15): Gross α, Ra-226, Ra-228

Metals (20): Al, As, Ca, Cd, Cu, Fe, Mg, Mn, Ni, P, Pb, Si, Zn, V, Sb

Solids analysis

RAD (40): Gross α, Ra-226, Ra-228, U, Th-228, 230, 232, U-233/234, 235/236, 238

Metals (80): Al, As, Ca, Cd, Cu, Fe, Mg, Mn, Ni, P, Pb, Si, Zn, V, Sb

WQP = water quality parameter analyses; RAD = radiological isotopes analyses; Metals = ICP/MS analyses; TBD = to be determined.

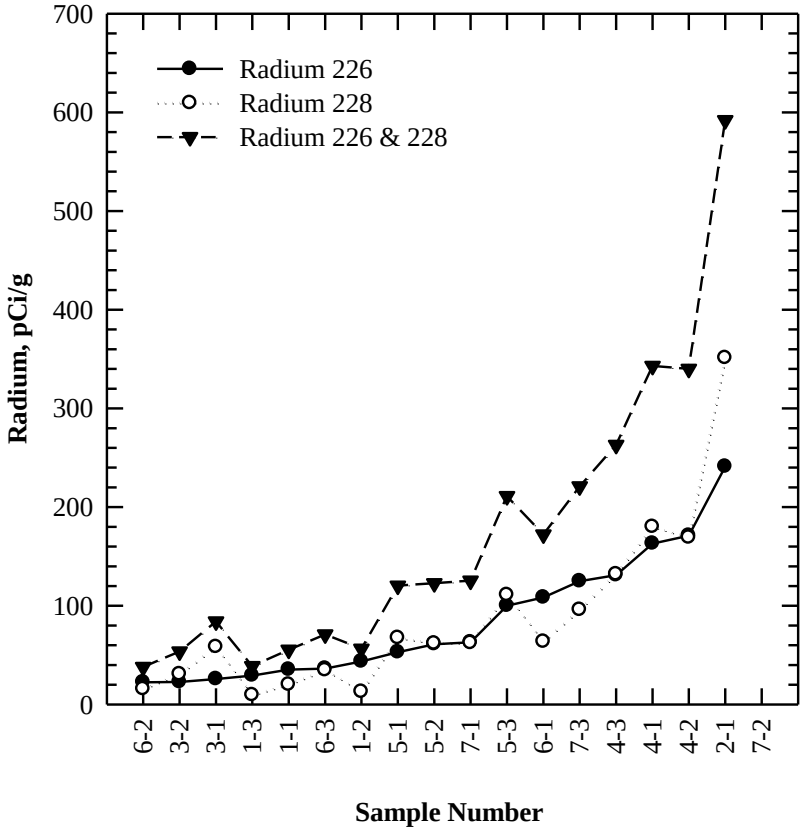
* = first priority for analysis.

All samples will be screened by Radiation Safety Services for proper handling and storage guidelines.

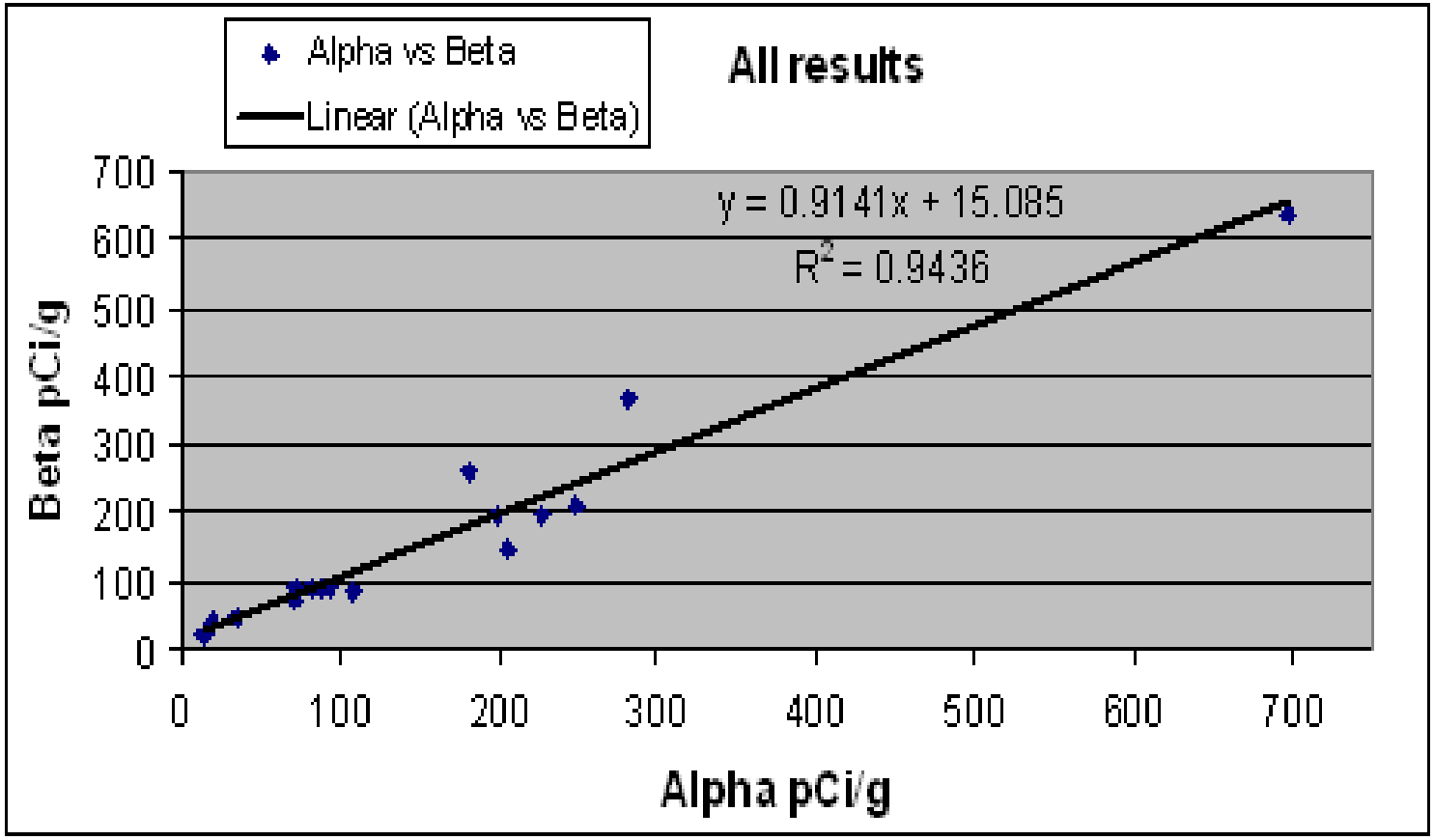
Accumulation of Contaminants in the DS

- Mg, Al, Si, P, Ca, V, Mn, Fe, Ni, Cu, Zn, As, Cd, Sb, Ba, Pb
- Gross α; gross β; Ra-226 & 228; Th- 228, 230 & 232; U- 233/234, 235, 236 & 238
- 18 sample from 7 location in Midwest
  - 13 to 698 pCi/g gross α
  - 22 to 637 pCi/g gross β
  - 23 to 241 pCi/g radium-226
  - 16 to 351 pCi/g radium-228

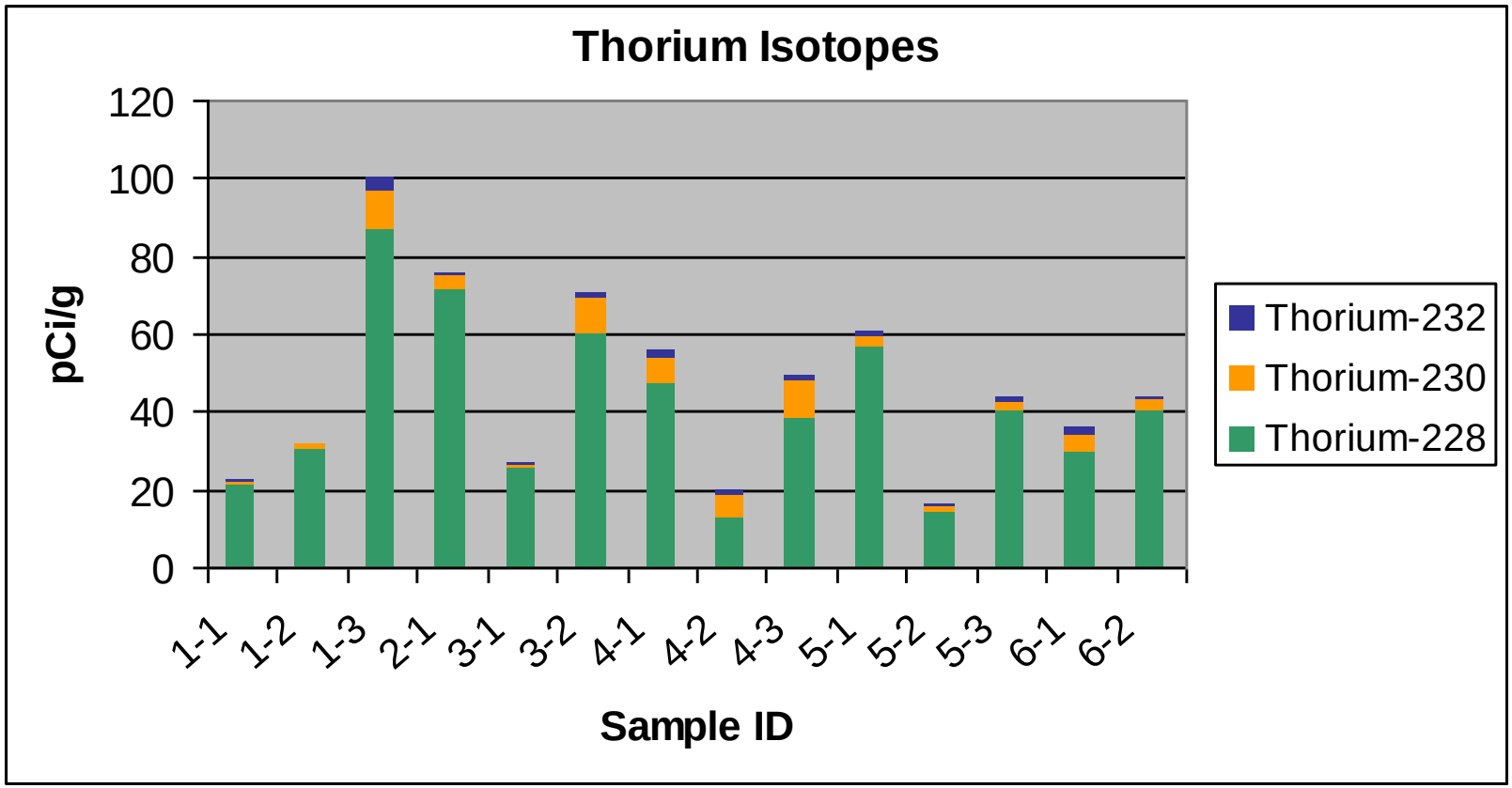
Radium in Distribution System Solids



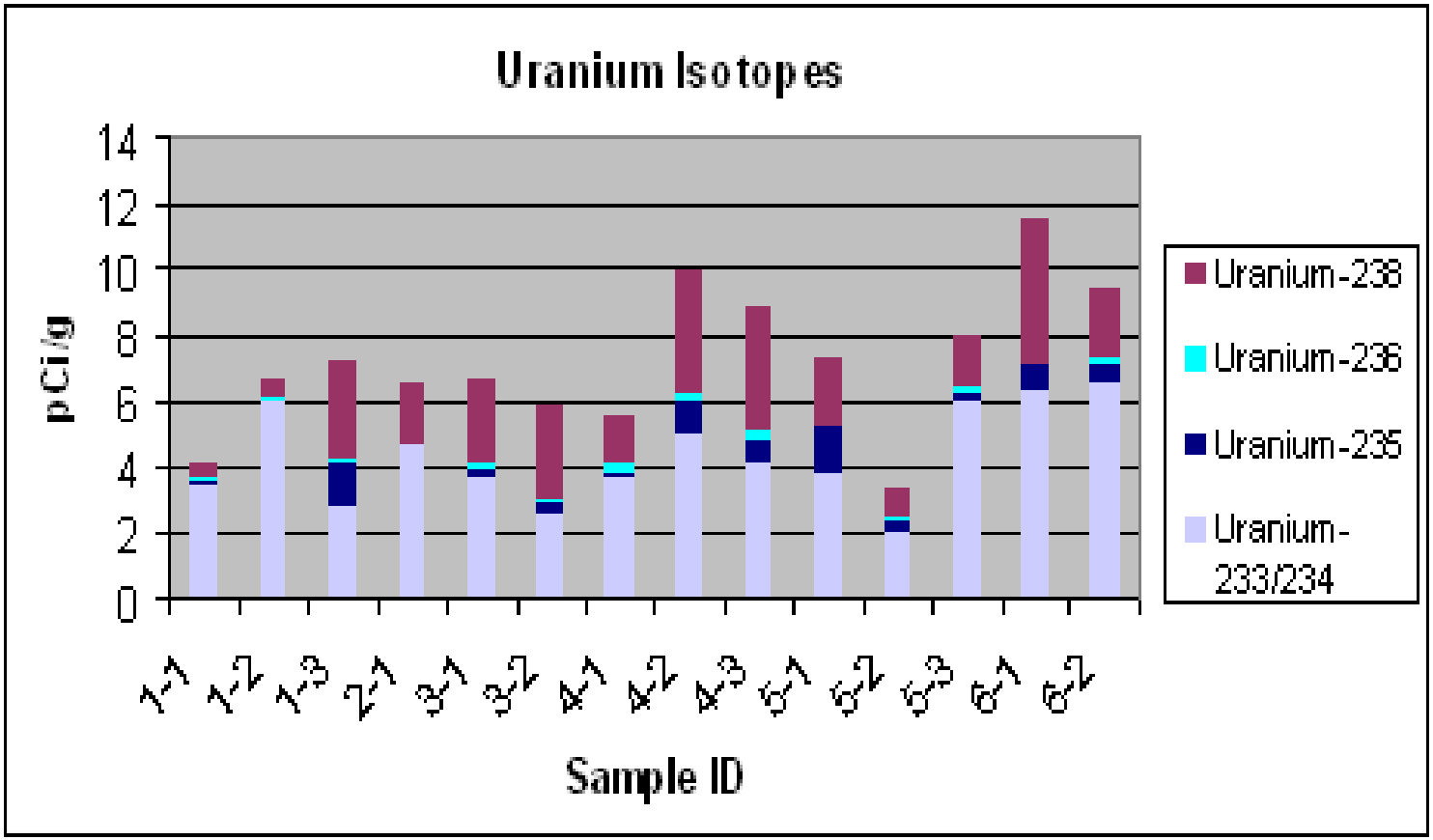
Gross Alpha and Beta Radioactivity in Distribution System Solids



Thorium in Distribution System Solids



Uranium in Distribution System Solids



Conclusions

- Arsenic and some radionuclides can concentrate in DW DS if in water at levels even below respective MCL
- The factors that determine how much accumulates are complex
- Also complex are the factors that impact release back into the distribution system. Disturbances to DS may release arsenic as well as factors such as:
  - *Particle destabilization*
  - *Desorption*
  - *Competitive desorption*
  - *Redox chemistry changes*
  - *Microorganisms*
- Health effects??
- Need for future investigation

Thank-you

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