The Accumulation and Release of Arsenic from Distribution System Solids

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Concentration of Arsenic in DW Distribution Systems Solids

- Source water (natural, contamination)
- Particles that enter and settle in the DS
  - Iron oxides
  - Calcium carbonate?
  - Manganese dioxide?
- Adsorption on corrosion deposits (Fe, Cu, Zn, Pb)
- Adsorption on sediment
- Precipitation of arsenic mineral phase

Background

- AWWA Opflow report by Reiber (2000)
  - Midwestern utility made treatment change
  - As < 7 µg/L
  - Colored water event
  - Water samples very high As (>300 mg Fe/L)
  - Presumably arsenic tied to iron deposits
- Is the potential for similar occurrences widespread?
- Arsenic Rule does not consider As levels in the distribution system

Objective

To provide an overview of research related to the accumulation and release of contaminants in DW DS solids (fire hydrant flush solids and pipe sections).

Solids Collection Approach

- Identify and contact utilities (Battelle, State Agency, past relationships)
- Coordinate sample collection
  - Hydrant flush (5 liter bottles)
  - Pipe section (when available)
  - Water chemistry (As speciation, iron speciation, general water chemistry)
- Describe system
- Analyze solids

Fire Hydrant Flush

- Normal hydrant flushing schedule
- Simply place 5 L bottle in flush stream
- Concentrate sample by sedimentation and centrifugation
- Grind (75 µm sieve)
- Dry

Fire Hydrant Flush

Pipe Material

- Took what we could get when we could get it
- Any material was acceptable (PVC, AC, cast iron, copper, etc..)
- Scrape (layering if possible), grind

Iron pipe

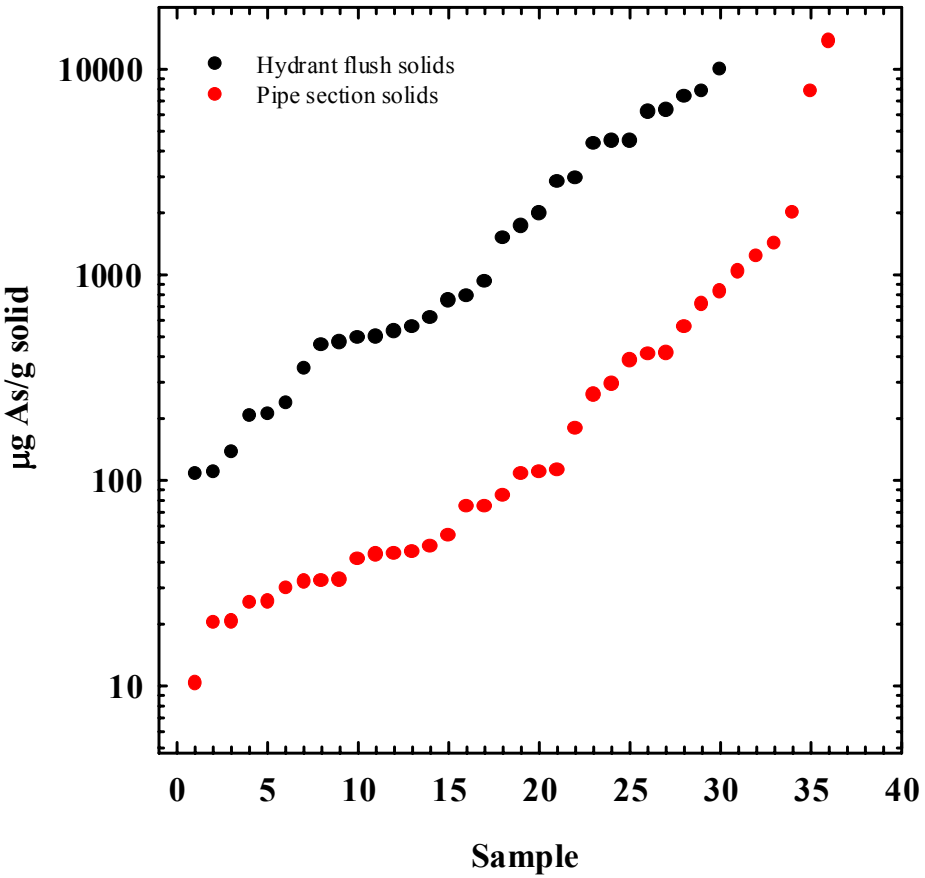
PVC pipe

Solids Analysis

- Acid digestion/ICP-MS (Battelle)
  - Ca, Mn, Fe, Mg, P, Si, As
  - Units
- XRF (Univ. of Cincinnati Geology Dept.)
  - Cl, S, Ba, Ca, Mn, Mg
- 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



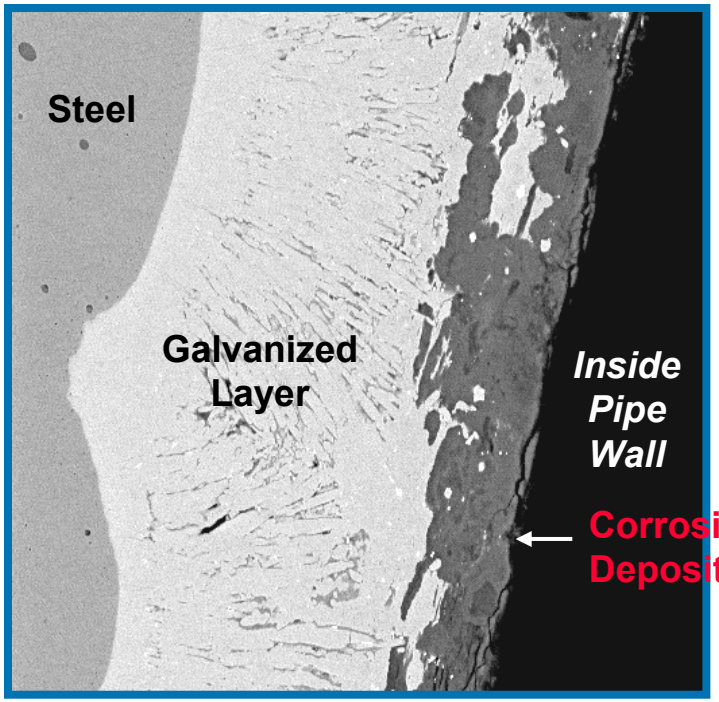
Distribution Pipe With Accumulation

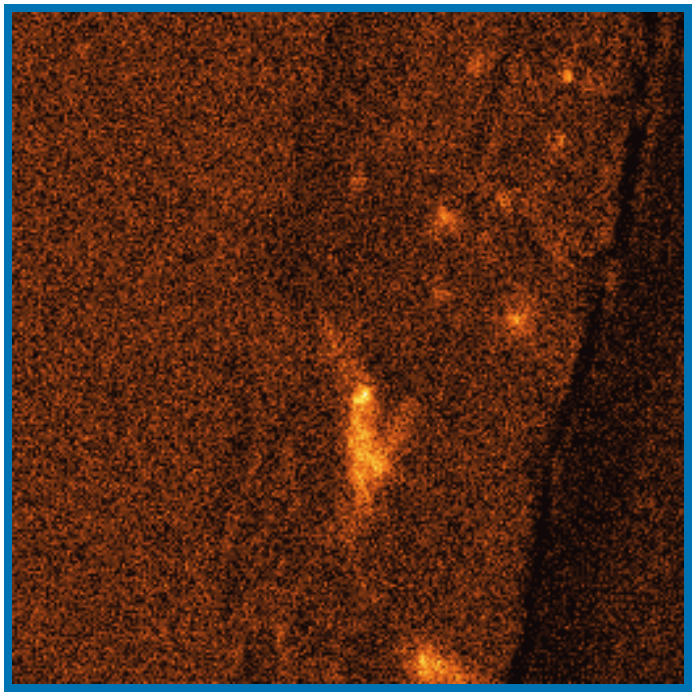
PVC Pipe- Sample 3-1

Analysis showed 13,000 µg As/g solid

Elemental Mapping

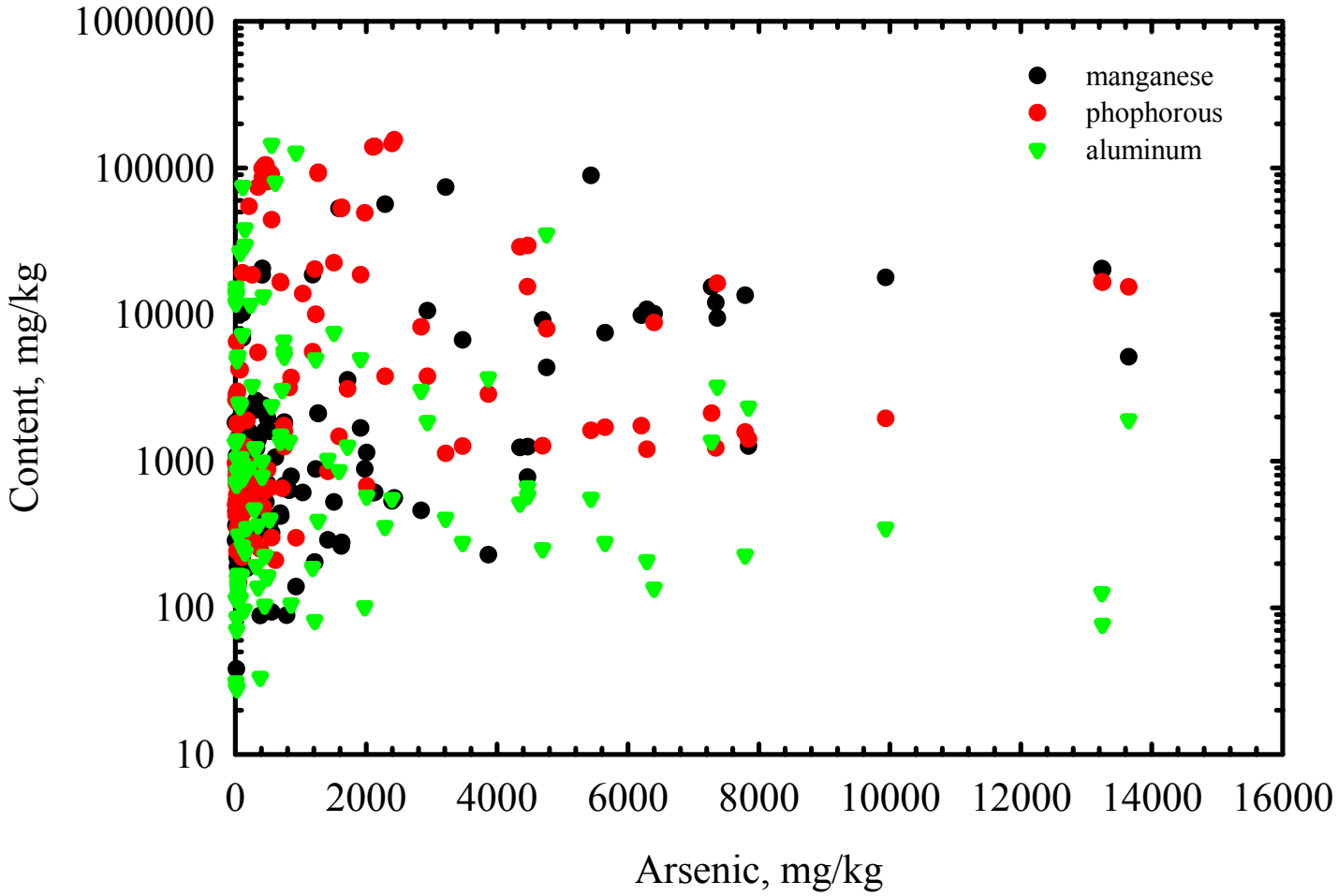
Microprobe-WDS analysis





Arsenic distribution

Al, As, Mn, and P Content of Distribution System Solids



Arsenic Release

- Particle mobilization
  - Hydraulic changes
  - Water chemistry changes
  - Hydrant flushing
- Desorption
  - Water chemistry changes
  - Treatment changes

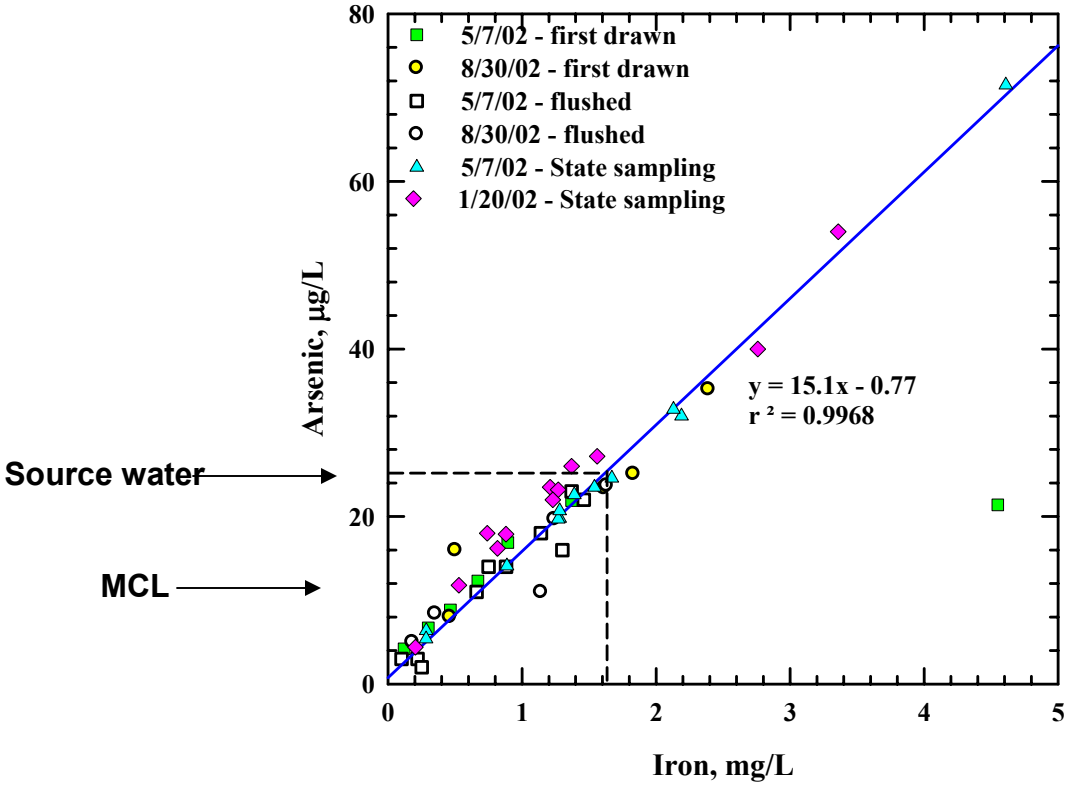
Particle Mobilization

Case Study 1: Particulate Release of Arsenic in Distribution Systems

- Colored water events led to sampling and the finding that As levels (>100 :g/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

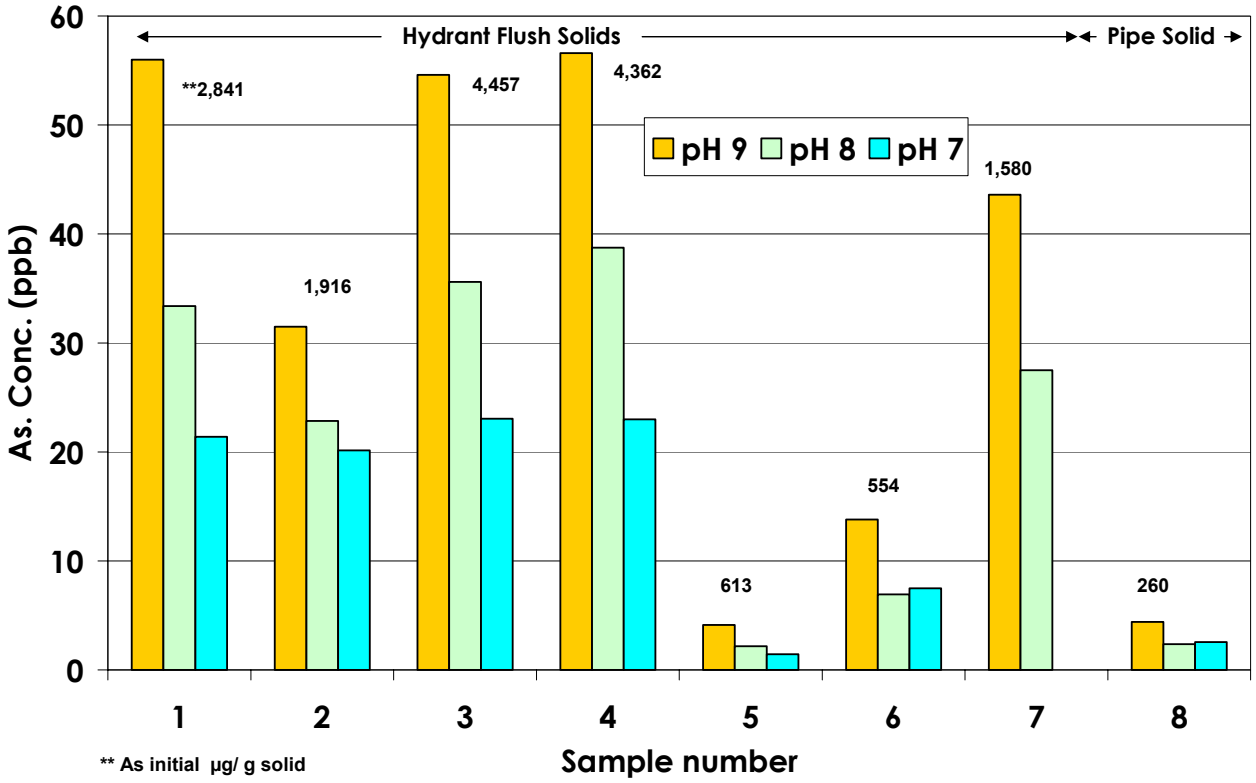
Particle Mobilization

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



Desorption

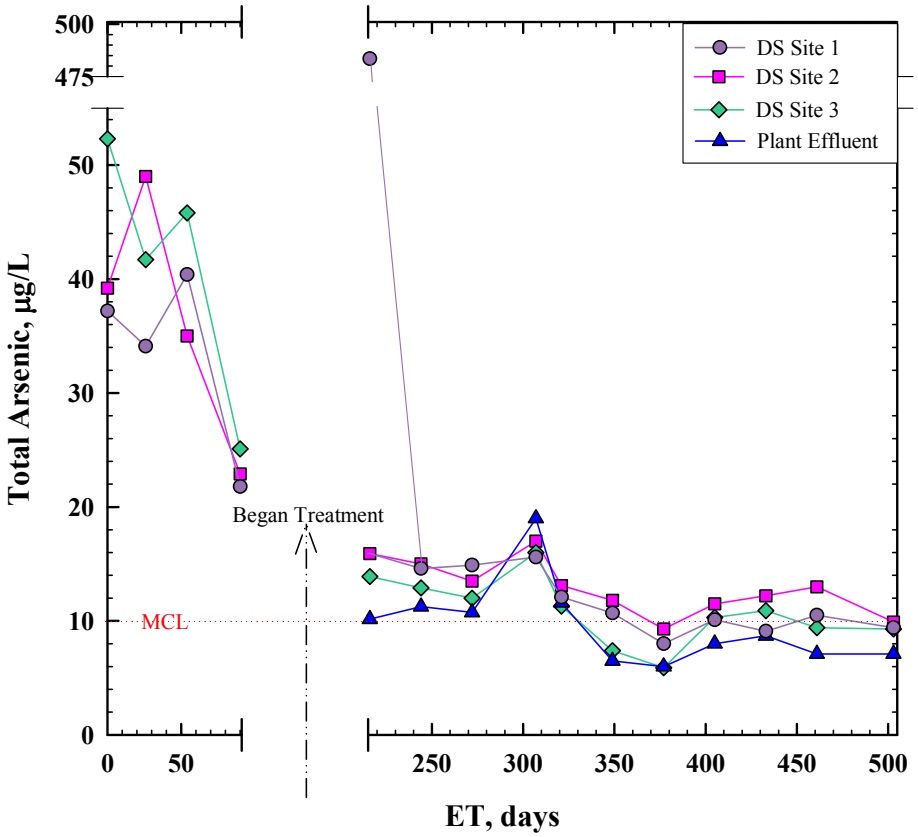
Research: Desorption from Drinking Water Distribution System Solids



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

Desorption

Climax, MN



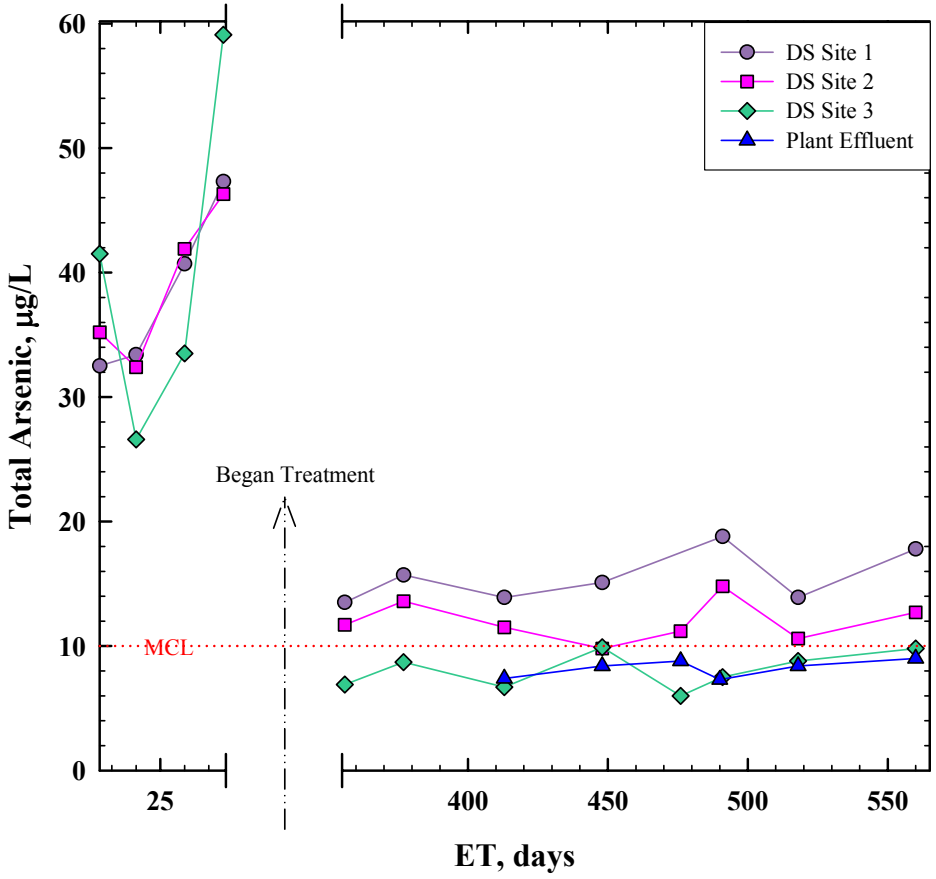
Initial soluble As concentration:

34-45 µg/L

*At distribution site 1 the first sample after treatment had an arsenic value of 483.5 µg/L. The homeowner reported a fulsh of red water during sample collection.

Desorption

Lidgerwood, ND



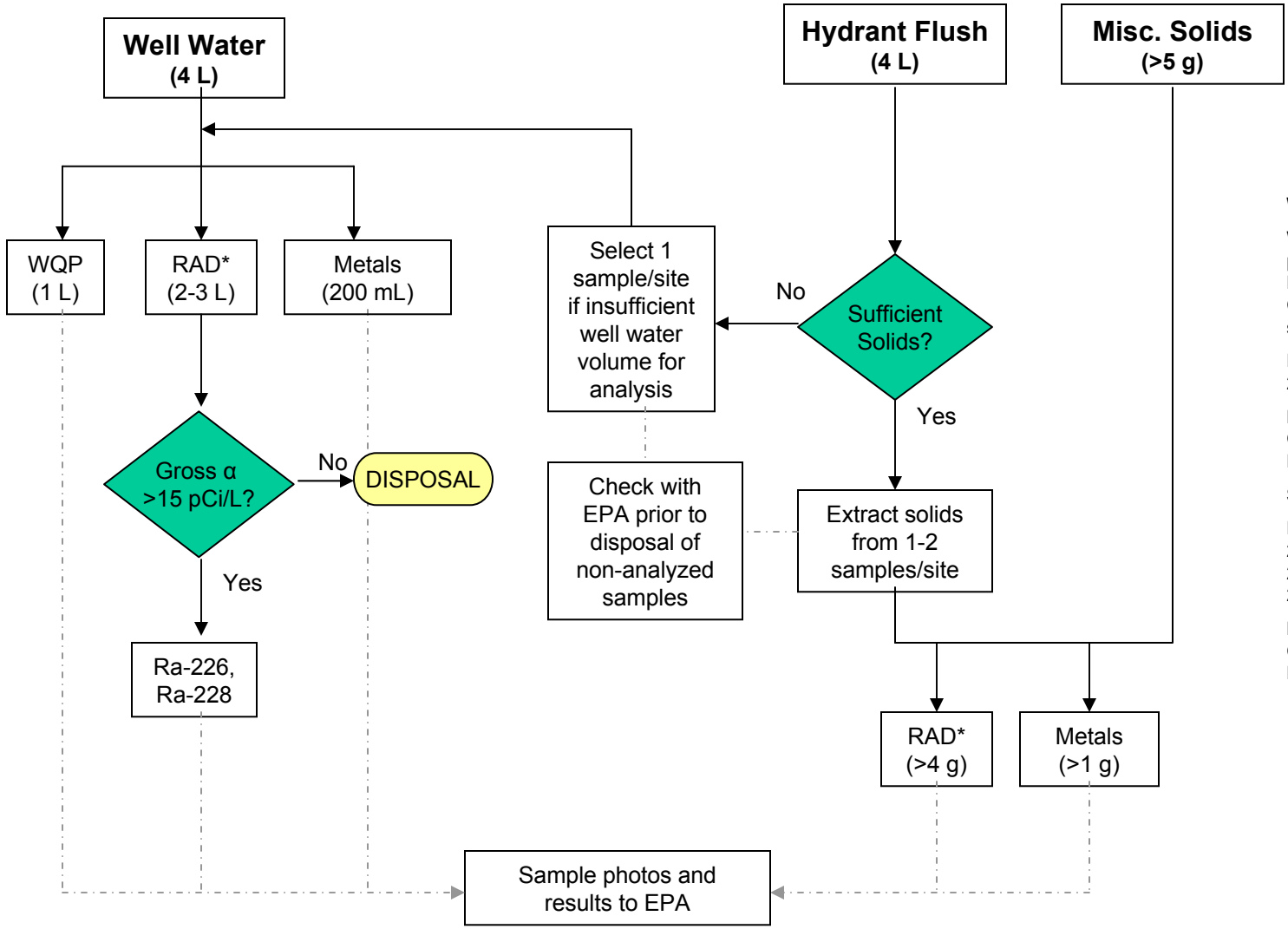
Initial soluble As concentration:

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.

Conclusion

- Arsenic does concentrate in DW DS
- Amount of arsenic in solids did not follow any trends
- Turbidity and color were indicators of arsenic release when particulate iron was involved
- Particulate transport and desorption were sources of arsenic release
- More research is needed

Acknowledgements and Contact

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Arsenic web site:
http://www.epa.gov/ORD/NRMRL/arsenic/