The Presence of Arsenic in Drinking Water Distribution Solids

By

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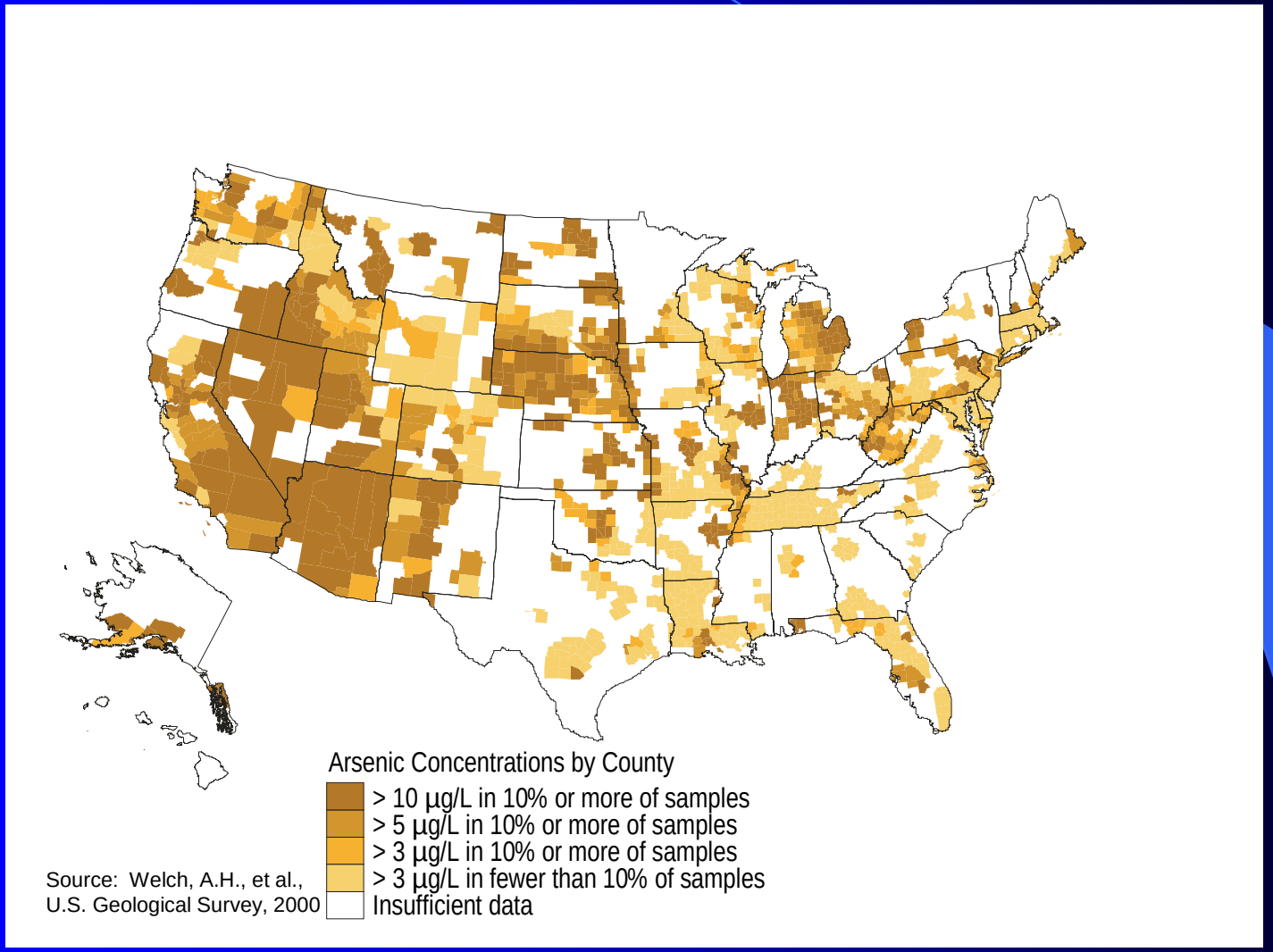
Acknowledgements

- Abraham Chen, Bruce Sass, Lili Wang- Battelle Memorial Institute
- Christy Frietch, Son Cao, Ian Lasacke, Cheryl James, Jeff Causey- U.S. EPA
- Utility managers and personnel

Iron-Based Arsenic Removal Processes

- Adsorptive properties of iron mineral toward arsenic are well known
- That knowledge is the basis for many arsenic treatment processes
  - Iron removal
  - Coagulation with iron coagulant
  - Iron-based adsorption media
- Reasonable that iron-containing corrosion deposits and sediment will also adsorb As
- Other solids??


Arsenic Concentrations by County
> 10 µg/L in 10% or more of samples
> 5 µg/L in 10% or more of samples
> 3 µg/L in 10% or more of samples
> 3 µg/L in fewer than 10% of samples
Insufficient data
Source: Welch, A.H., et al.,
U.S. Geological Survey, 2000

Iron-Based Adsorbent Media

GFO Bayoxide E33

Modified activated alumina

Zero valent iron

Concentration of Arsenic in DW Distribution Systems Solids

- Source water (natural, contamination)
- Particles that enter and settle 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 g/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.

Project Objective

Determine the composition of solids collected from DW DS where measurable amounts of arsenic in the finished water

- pipe sections (corrosion products, deposits, etc.,)
- fire hydrant flush (loose particles, corrosion products, etc.,)

Project 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)
- System description
- Analyze solids

Utility Selection

- Battelle, State assistance, past relationships
- Arsenic in raw/treated water
- 8 utilities- Ohio, Michigan, and Indiana
- Range of treatment
  - Aeration/softening/chlorination
  - Fe & Mn removal (3)
  - None
  - Chlorination
  - Chlorination/polyphosphate (2)

Water Chemistry

- pH 7-8
- 2-31 g As/L
- <detection- 2.77 mg Fe/L
- Relatively hard, 11-116 mg Ca/L
- <detection-0.59 mg Mn/L

Fire Hydrant Flush

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

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

PVC pipe

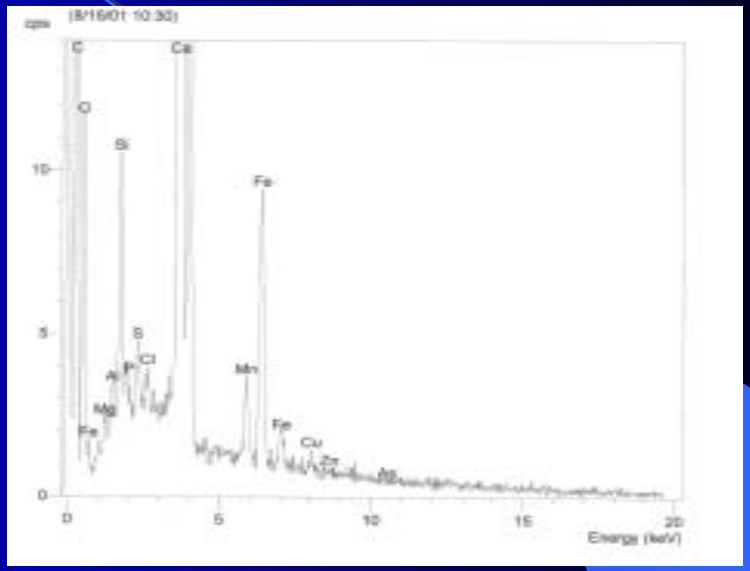
Iron pipe

Pipe Scale Cross Section

Solids Analysis

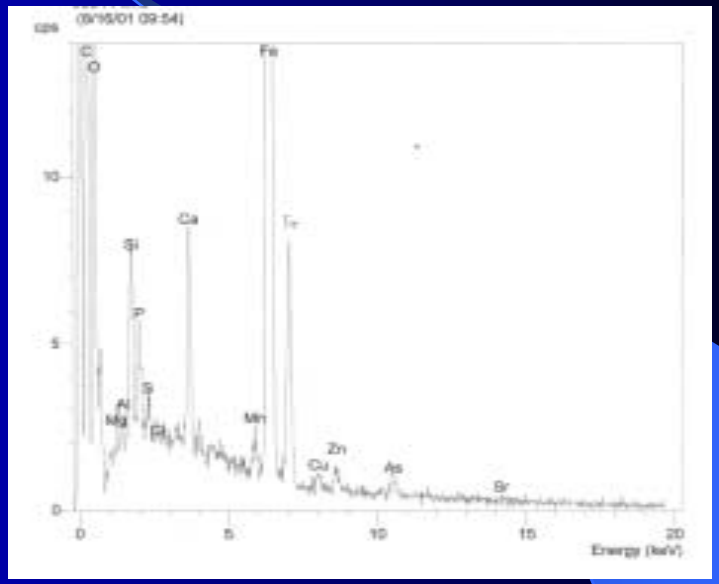
- Acid digestion/ICP-MS (Battelle)
  - Ca, Mn, Fe, Mg, P, Si, As
  - Units
- XRF (Univ. of Cincinnati Geology Dept.)
  - Cl, S, Ba, Ca, Mn, Mg
- XRD
  - Mineral phases
- Electron mircoprobe-WDS (Battelle)
  - Quantitative elemental mapping
- SEM-Wavelength dispersive spectrometer-imaging and elemental mapping

Cement-Lined Iron Main-Sample 2-5



Location	Sample ID	Mg (ug/g)	Si (ug/g)	P (ug/g)	Ca (ug/g)	Mn (ug/g)	Fe (ug/g)	As (ug/g)	ug As/ mg Fe
Utility 2	Sample 2-5	2869	3090	513	308085	10187	40039	108	2.70

PVC pipe- Sample 3-1

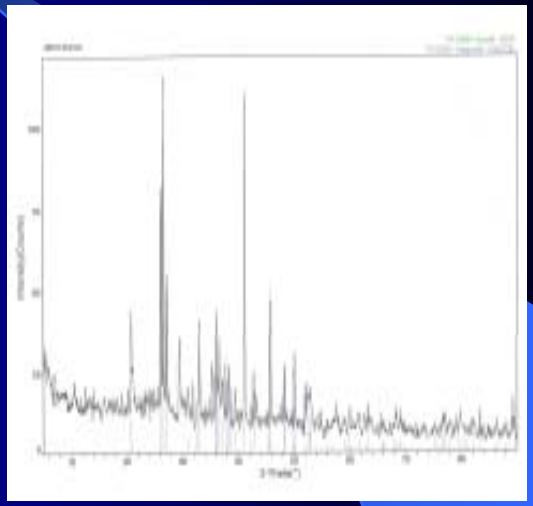


Location	Sample ID	Mg (ug/g)	Si (ug/g)	P (ug/g)	Ca (ug/g)	Mn (ug/g)	Fe (ug/g)	As (ug/g)	ug As/ mg Fe
Utility 3	Sample 3-1	1492	10452	15410	22939	5141	442528	13650	30.85

Cement- DL00040

Location	Sample ID	Mg (ug/g)	Si (ug/g)	P (ug/g)	Ca (ug/g)	Mn (ug/g)	Fe (ug/g)	As (ug/g)	ug As/ mg Fe
Utility	Dl00040	1736	8719	850	28859	290	77030	1416	18.38

Iron- Sample 4-1

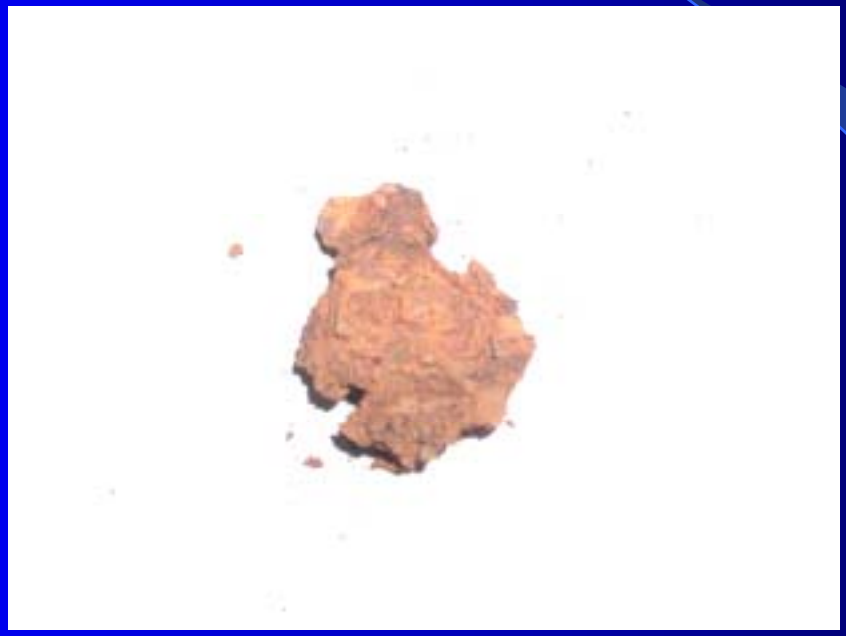


Location	Sample ID	Mg (ug/g)	Si (ug/g)	P (ug/g)	Ca (ug/g)	Mn (ug/g)	Fe (ug/g)	As (ug/g)	ug As/ mg Fe
Utility 4	Sample 4-1	6023	1286	949	106475	638	168757	84.3	0.50

Iron

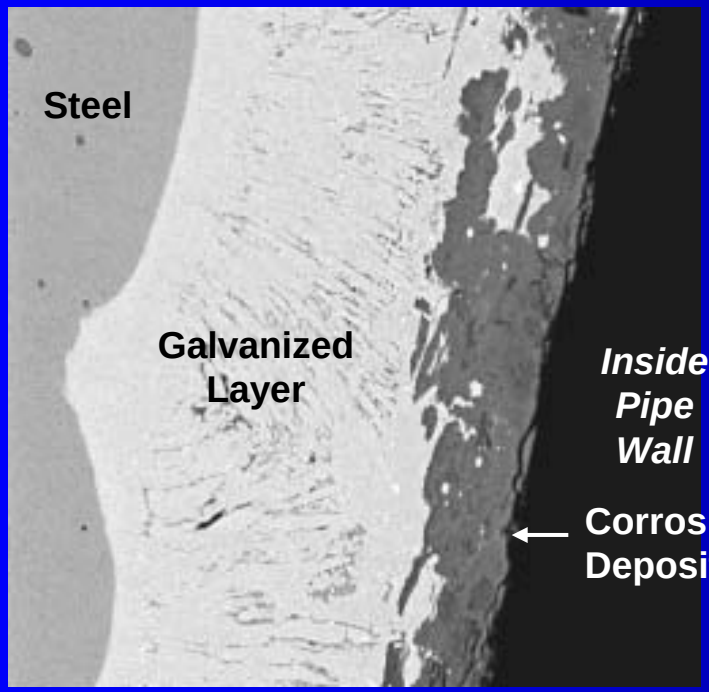
Location	Sample ID	Mg (ug/g)	Si (ug/g)	P (ug/g)	Ca (ug/g)	Mn (ug/g)	Fe (ug/g)	As (ug/g)	ug As/ mg Fe
Utility	Dl00050 a	8620	5223	150	343521	312	79647	53.9	0.68
	Dl00050 b	5023	3042	279	173830	660	300792	294	0.98

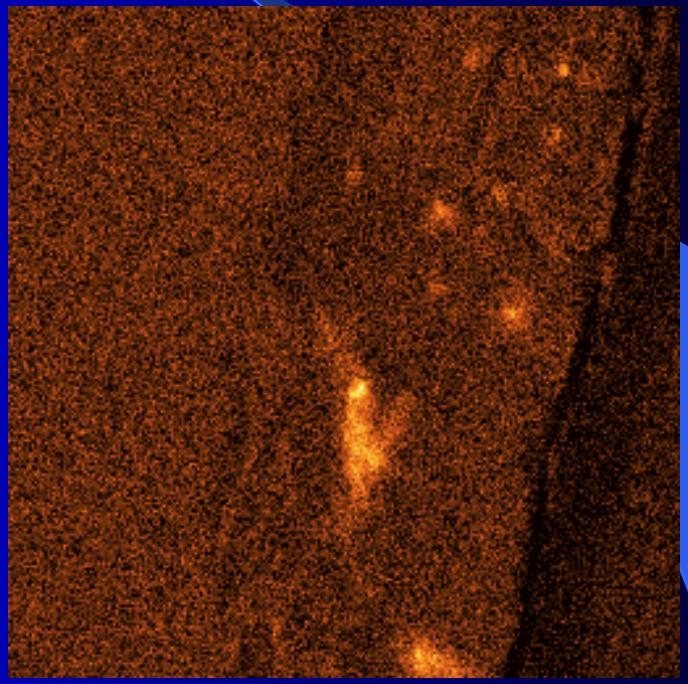
Iron- DL00037



Location	Sample ID	Mg (ug/g)	Si (ug/g)	P (ug/g)	Ca (ug/g)	Mn (ug/g)	Fe (ug/g)	As (ug/g)	ug As/ mg Fe
Utility	Dl00037	119	348	251	2521	88.4	592987	383	0.65

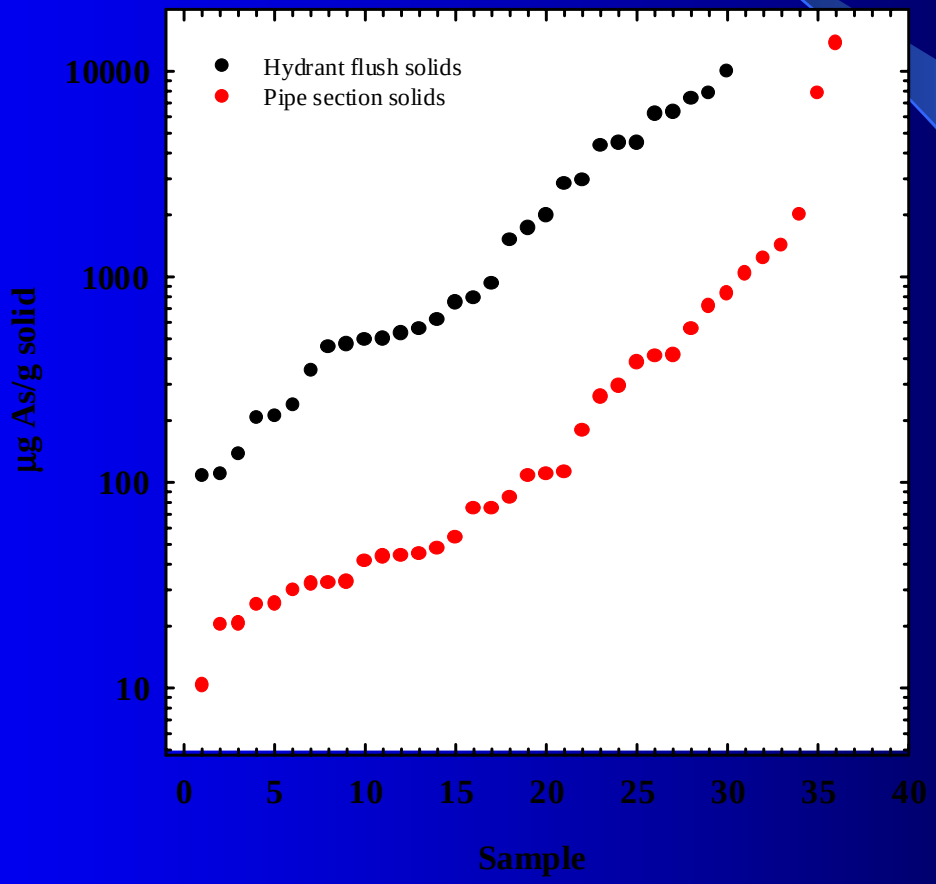
Elemental Mapping- Microprobe-WDS analysis



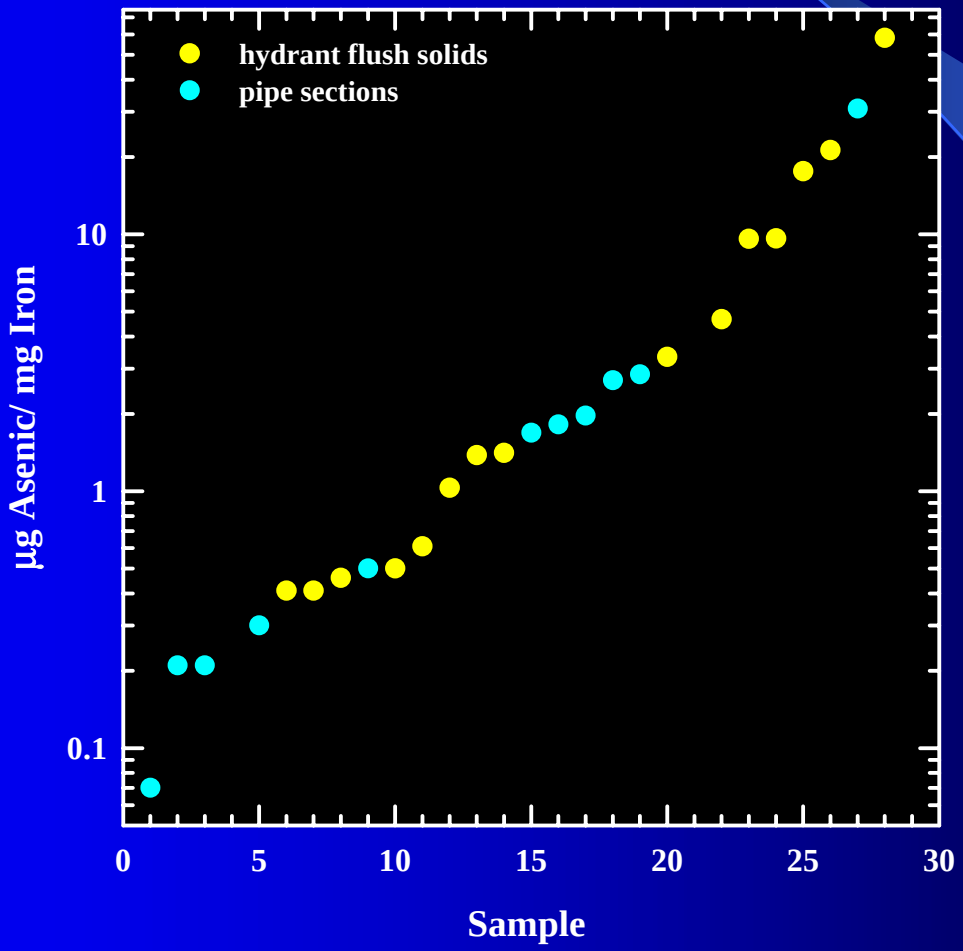


Arsenic distribution

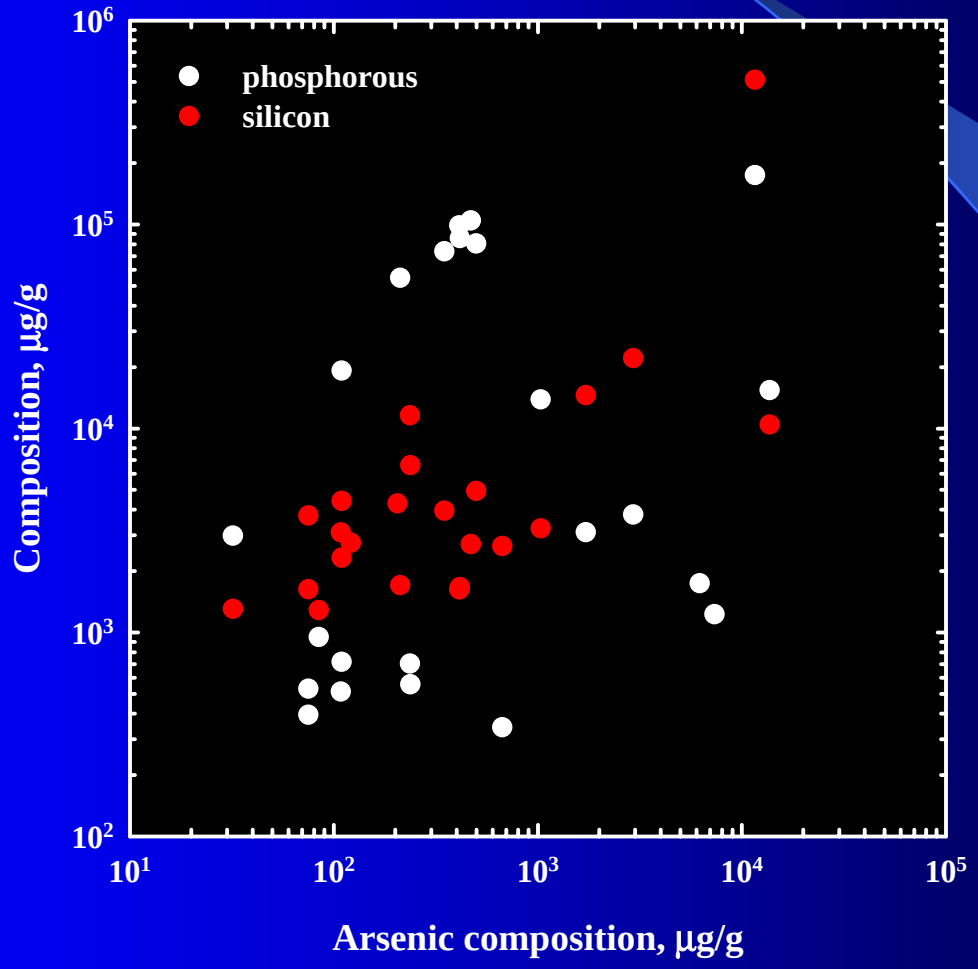
Summary of the Arsenic Composition of Solids



Summary of the Arsenic Composition of Solids Relative to Iron Composition



Arsenic, Silicon and Phosphorous Solid Composition



Arsenic Composition Relationships

- Initial arsenic- no
- Pipe or flush- no
- Water chemistry- no
- Treatment- no
- Material age- ??

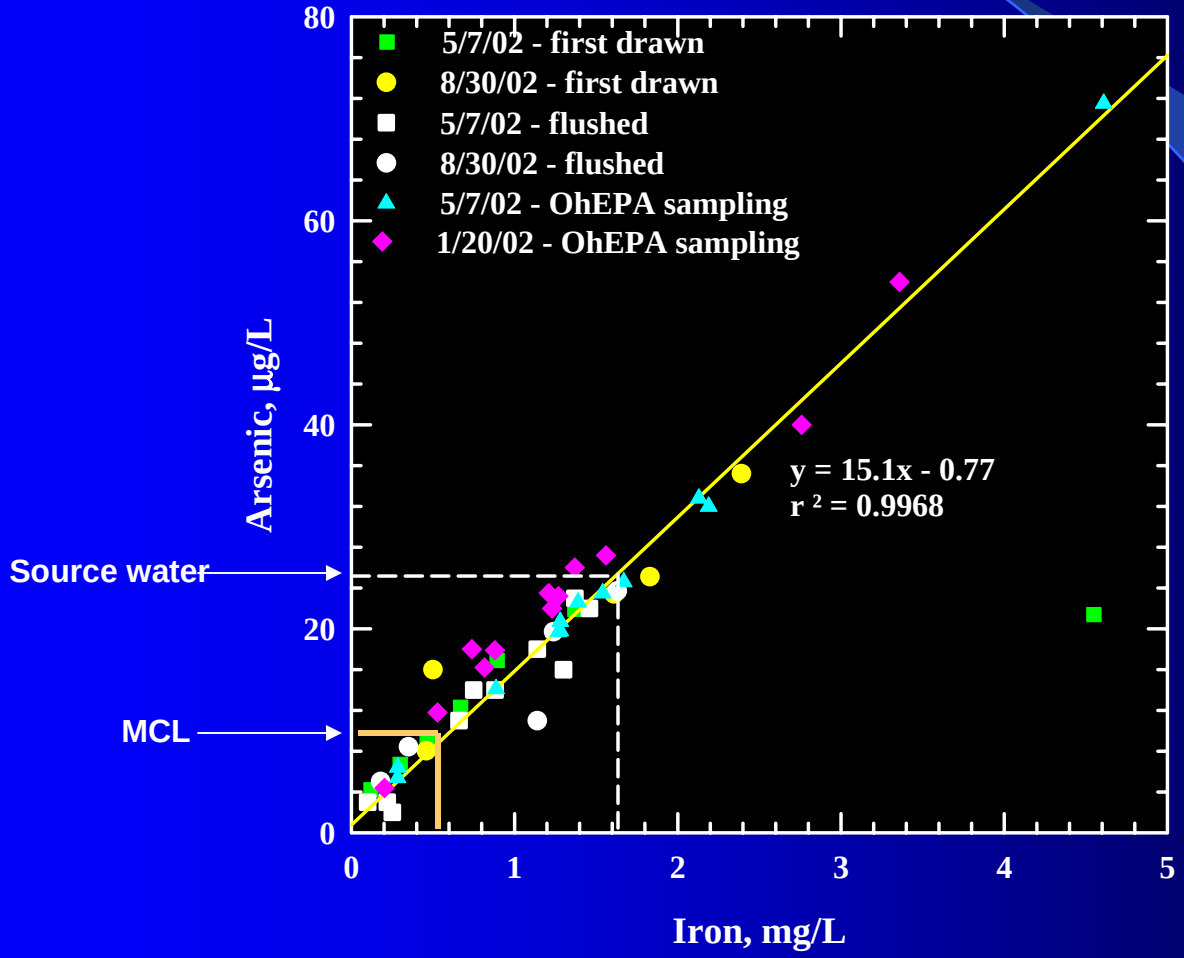
Case Study: Arsenic in Distribution Systems

Ohio Utility

- 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 □g As/L, 1.6 mg Fe/L
- chlorination

Relationship Between Arsenic and Iron in Distribution System Samples

Ohio System

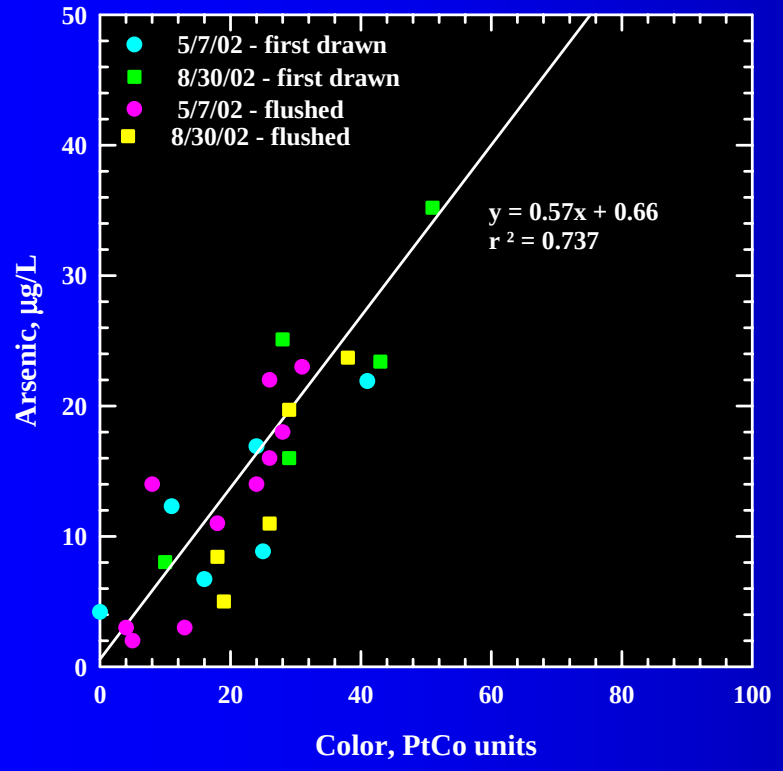


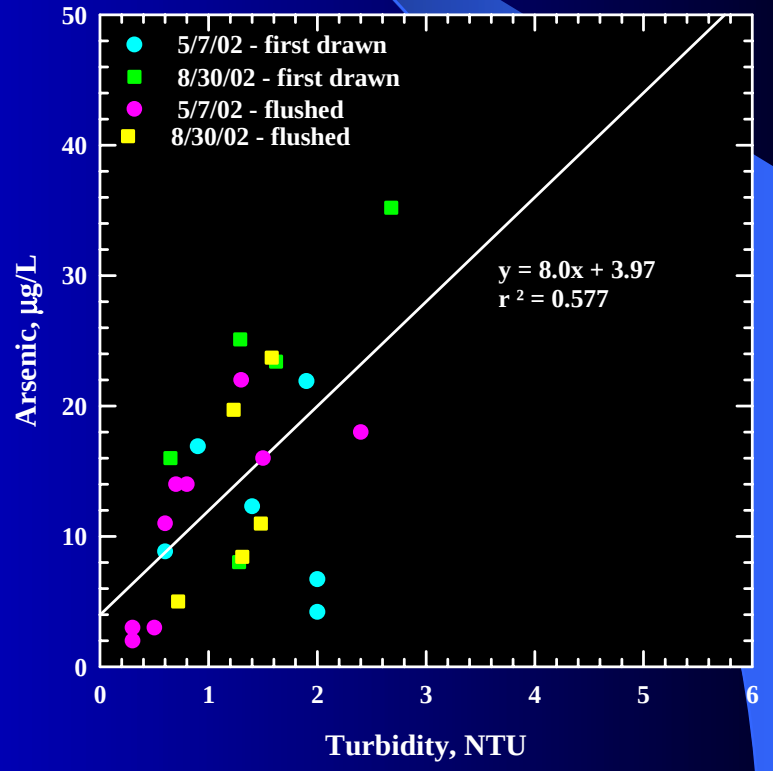
Case Study: Arsenic in Distribution Systems

Ohio Utility

Relationship Between Arsenic and Color/Turbidity in Distribution System Samples

Ohio System





What Does this Mean?

- Arsenic does concentrate in DW DS
- Suggests that disturbances to DS may release arsenic
  - Particle destabilization
  - Desorption
  - Competitive desorption
  - Redox chemistry changes
  - Microorganisms
- Health effects??
- Need for future investigation

What do we do about it?

- Remove arsenic from source
- POU devices
- Distribution system maintenance
  - Corrosion control
  - Flushing
- Awareness of indicators
- Research- better understanding of factors that impact As release

Conclusions

- Arsenic does concentrate in DW DS
- Amount of arsenic was independent of variables considered in this study
- Turbidity and color are indicators of arsenic release when particulate iron was involved
- More research is needed