Complying with the New Arsenic MCL: Co-occurring contaminants and treatment options

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Overview

- Describe regulatory policy work on multi-contaminant regulation from 2001
- Update on current situation with respect to arsenic

Contaminant-by-contaminant regulation

- EPA sequentially sets Maximum Contaminant Levels (MCLs)
- The list grows ever longer

What about the big picture?

- Does regulating one contaminant decrease or increase exposure to other contaminants?

Project Goal

- Build integrated model of occurrence and regulation of multiple contaminants in drinking water
  - Use statistical simulation approach
  - Gurian, P.L, M.J. Small, J.R. Lockwood III and M.J. Schervish. 2004. Assessing nationwide cost-benefit implications of multi-contaminant drinking water standards. *Journal of the American Water Works Association*, March 2004

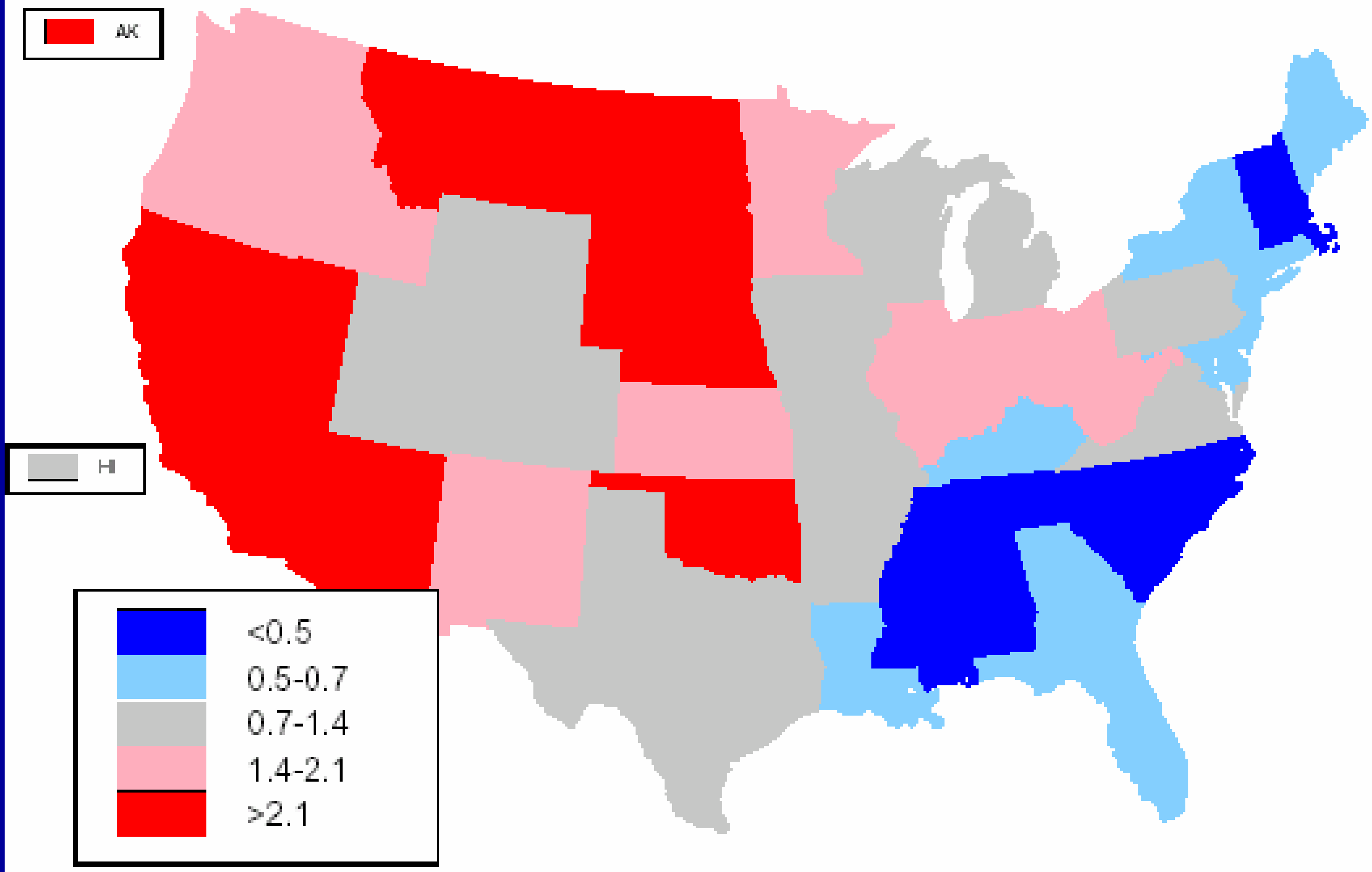
Model application

- 3 regulated anionic contaminants:
  - Arsenic (10 μg/l)
  - Uranium (30 μg/l)
  - Nitrate (10 mg/l)
- Secondary contaminants
  - Sulfate: interferes with anion exchange
  - Manganese: plants with existing manganese removal will also remove arsenic
  - Ca and Mg: plants with existing softening will also remove arsenic

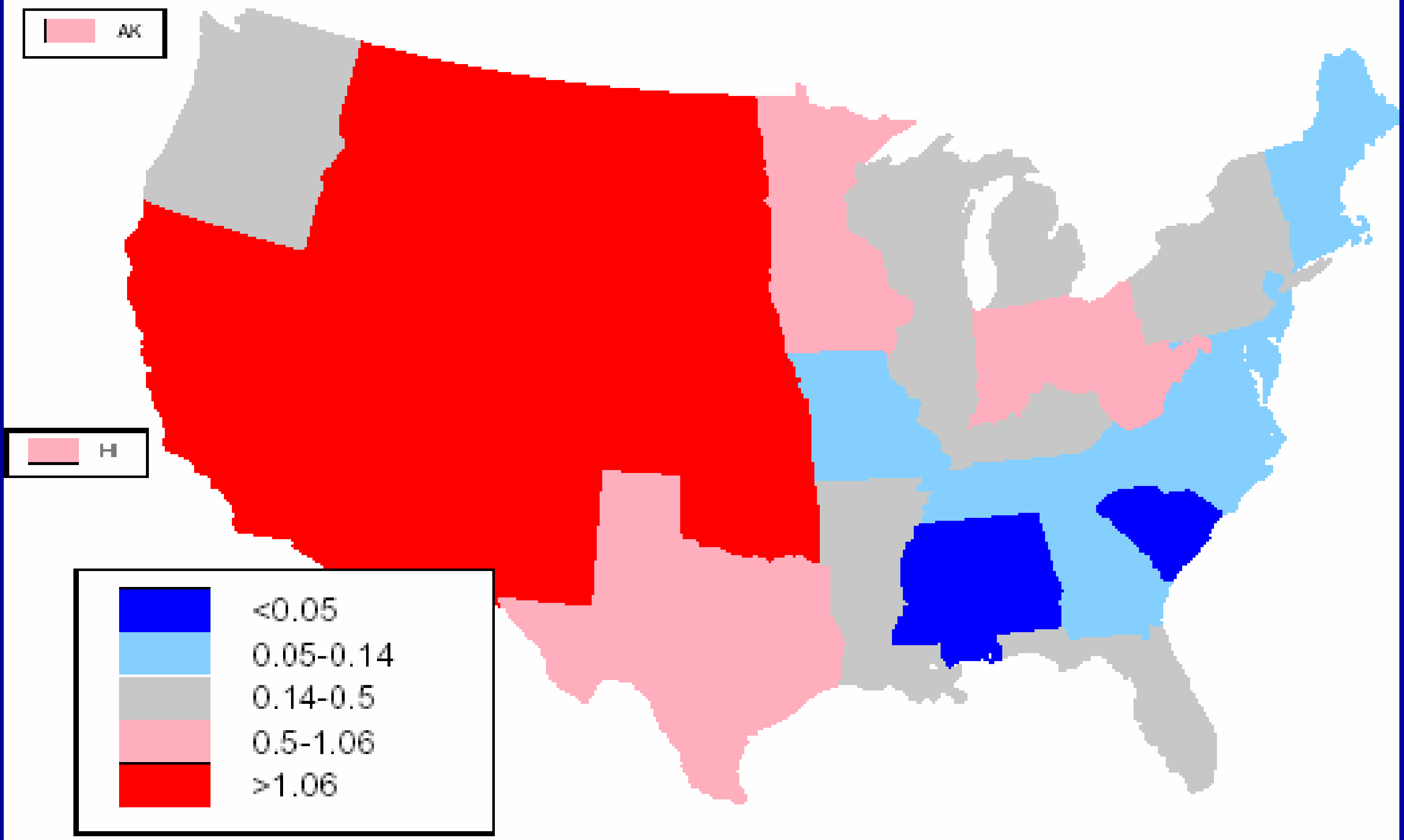
Occurrence correlations

- As and U correlated in raw water
  - Both trace contaminants mobilized through geochemical processes
- Little correlation between arsenic (naturally occurring) and nitrate (agricultural contaminant)

Arsenic (ground)



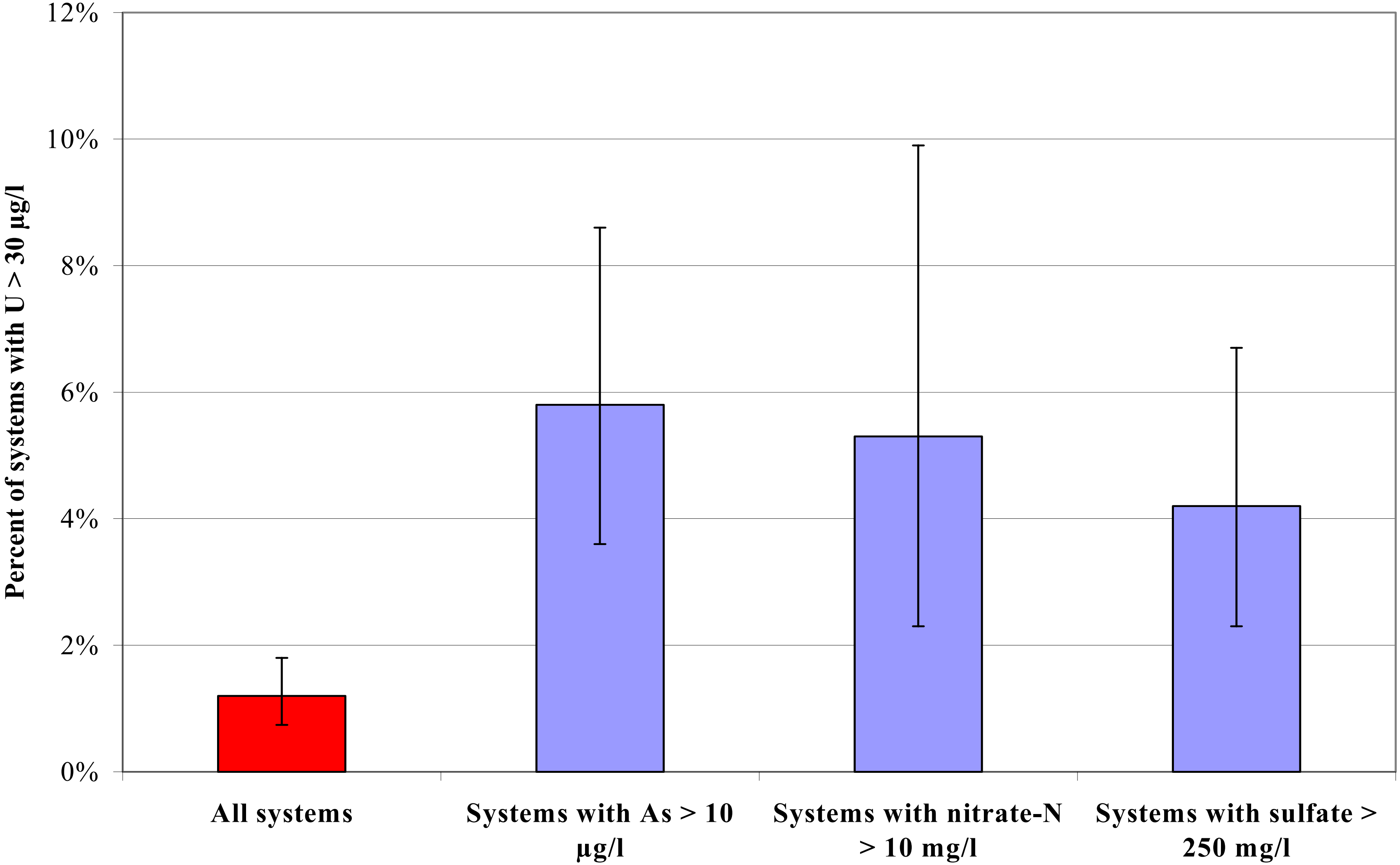
Uranium (ground)



Finished water

- As and U also correlated in finished water
- Likelihood of exceeding U MCL is much higher if you exceed the As MCL

Contaminant Co-occurrence (90% CI)



Benefits of Co-occurrence

- Both As and U adsorb to iron and can be removed by anion exchange
  - Sorg 1988, Lee and Bondietti 1983, Zhang and Clifford 1994, Clifford and Zhang 1994, Vaarmaa et al. 2000, Raff and Wilken 1999
- This is an expected result given how contaminants were selected for model
- *In this case* overall impacts on costs and benefits were modest

Concerns due to co-occurrence

- Estimated 5% of water supplies exceed 250 mg/l sulfate
- 12% of supplies exceeding arsenic MCL
- 19% of supplies exceeding uranium MCL
- Anion exchange may not be an option for these suppliers
- May be similar issues with silica and pH for metal hydroxide media

Do we have the right regulatory approach?

- Gurian, P.L., "Regulating Drinking Water Quality Incrementally: Better than Benefit-cost Analysis?" *Utility Manager, 8*(2) (2005).
- Gurian, P.L., "Making Sense of the Benefit-cost Provisions of the Safe Drinking Water Act" *Proceedings of the AWWA Annual Conference and Exposition*, Orlando, FL (2004).

Two-tiered Arsenic MCL

- Arsenic MCL of 10 µg/l
- Exempt systems in the 10-20 µg/l range with compliance costs exceeding $500/household
- Reduce costs by 11%
- Reduce benefits by 0.2%
- Full compliance with MCL of 10 µg/l comes at a cost of $110 million/life saved

Where are we now?

- The decision was made
- How will utilities comply with the new MCL?

Conventional Wisdom

- Larger systems: coagulation/filtration
  - Cost-effective and feasible for large systems
- Smaller systems: column treatment with an iron-based sorbent
  - Avoid continuous feed, filter backwashing, etc.

Waiting in the wings?

- Zero-valent iron
- Iron-coated substrates

Method	**Reference**	**As/Fe density mg/g, As=20µg/l**	***Material cost*** **$/g As removed at influent As=20µg/l**
Zero-valent iron	Su et al. 2003	0.4	1
Iron oxide coated sand	Thirunavukkarasu et al. 2003	0.03	3
Iron-based sorbents	CH2M Hill 2004	2-6	2-4

- Zero valent iron: how to control corrosion rate, do not want ferrous iron leaching into water
- Coated sand: bulky, short bed life

Other options

- Very small systems: point-of-use
  - It may not be pretty: Will 100% of households be in compliance 100% of the time? (Gurian and Small JAWWA March 2002)
- Anion exchange
  - Used for nitrate, cost feasible
  - Work by Mark Benjamin's lab: keep As out of routine regeneration brine
  - Can receiving waters take all the salt?

Consider the basic chemistry

- Arsenic adsorption on iron is dependent on surface area
- Coagulation/filtration produces small, high surface area particles

Comparing iron-based adsorbents and ferric chloride coagulation

Method	**Reference**	**As/Fe density mg/g, Influent As=20µg/l**	***Material* cost $/g As removed, influent As=20µg/l**
Coagulation /precipitation	Edwards 1994	4.6	0.09
Iron-based sorbents	CH2M Hill 2004	2-6	2-4

Don’t confuse this with useful advice

- Continuous feed processes are a bear
- So is filter backwashing
- I am not advocating coagulation/filtration for small systems
- Won’t clever process engineers work out the bugs someday?

Summary

- We can get away from contaminant by contaminant approach
  - Co-occurrence can generate local problems where utilities have limited options for treatment
- Rapid technological innovation in arsenic treatment options
  - Several options are competitive and different niches will be filled by different technologies