
Emerging Technologies for Arsenic Treatment for Small Communities

Bruce Thomson - University of New Mexico

Pat Brady - Sandia National Labs

Joe Chwirka - CH2M-Hill

Introduction & Objectives

- What's available, what's new, and what's needed
- Focus on small communities without treatment plants (i.e. ground water as source). Technologies relevant to big plants too.
- Topics covered
 - As oxidation
 - As removal (adsorption, IX, precipitation, membranes)
 - Residuals issues
 - Analytical methods & process control
- Identify needs in each area

Google Search

Arsenic AND Treatment AND Water

- 127,000 hits, (0.33 sec). Results of first 100 hits
 - Academic sites – 16
 - Treatment technologies – 13
 - Analytical technologies – 3
 - Consulting firms – 12
 - Federal, State & Local Govt. – 35
 - Other – 21

Identification of BATs

Technology	Federal Register (6/22/00)	EPA Guidance (815-R-00-013)	EPA Proven Technologies (EPA-542-S-02-002)
Softening	Modified lime softennng		
Precipitation	Coagulation/Filtration	Coagulation/Filtration	Precipitation/Coagulation
Membranes	RO, EDR	RO, EDR	RO, Nano-, Ultra-Filtration
IX	IX	IX	IX
Adsorption	Act. Alumina	Act. Alumina	Act. Alumina, GAC, Cu-Zn, FeOx, Mn

EPA R&D Program

(<http://www.epa.gov/ORD/NRMRL/arsenic/research.htm#round1>)

- Demonstration of treatment technology at ~20 sites
- EPA 73 proposals
 - 19 companies submitted proposal
 - Proposed technologies
 - Adsorption - 25
 - Coagulation/Precipitation/Filtration - 39
 - IX - 2
 - In-Situ - 2
 - Other - 3
- 12 sites selected for technology demonstration

EPA SBIR Program

- 8 awards
- Technologies
 - Adsorption - 7
 - In-situ - 1

AwwaRF As Research

(www.awwarf.com)

- AwwaRF Projects
 - 17 on treatment technologies, oxidation or residuals management
 - 6 on analytical methods including speciation
 - 6 on health effects

NSF International

(<http://www.nsf.org>)

- Environmental Technology Verification Drinking Water Systems Center - 4 technologies:
 - 2 membrane technologies (RO)
 - 2 coagulation filtration technologies

Review of Technologies

- As(III) Oxidation
- Drinking water treatment technologies for As
- Residuals
- Analytical methods

Pretreatment - As(III) Oxidation

- Effective oxidants – Cl_2 & derivatives, O_3
- Less effective – ClO_2 , choramines
- Emerging oxidants – UV/ O_2 , solid oxidants (Mn, Ru, etc.)
- Difficult to oxidize organic-As (?)

Oxidation Technology Needs

- Limited need for additional technology

Drinking Water Treatment Technologies

- Coagulation/Precipitation/Filtration
- IX
- Adsorption
- Membrane Process
- POU
- In-situ technologies
- Other

Coagulation/Precipitation/Filtration

- Good understanding of technology based on work by Edwards, Hering & others to correlate As removal to removal of Al, Fe.
 - Other coagulants – La
- Alternatives for floc removal
 - Granular Media Filtration
 - Membranes
- Variations of technology are commercially available

Challenges with Coagulation/Precipitation/Filtration

- Capital cost
- Complexity
 - Requires high level of technical expertise
- Effects of water chemistry on performance
 - pH
 - Competing ions

Technology Needs for Coagulation/Precipitation/Filtration

- Demonstrate performance of small plants ($<10^5$ gal/d)
 - Granular media filtration
 - Membrane filtration
- Develop process automation & control appropriate for small communities

Ion Exchange

- Good understanding of technology based on work by Clifford, Lowry, and others
- Mature technology
- Commercially available

Ion Exchange Challenges

- Process control, especially when to regenerate
- High salt use
- Complexity
 - Requires high level of technical competence
- Brine management & disposal
 - Hazardous waste?

Technology Needs for Ion Exchange

- Develop media with improved selectivity for As

Adsorption

- Current adsorbents – Activated Alumina, Fe media
- Evolving understanding of technology (EPA/600/R-03/019)
 - Especially effect of water chemistry on performance
- New adsorbents: ZVI, Mn, modified zeolites (Fe & surfactants), Zr, La, Ru, low cost-low capacity natural materials (limestone), etc.
 - Difficult to evaluate performance of new media
- Single use (i.e. throw-away) vs. regenerable media

Some As Adsorbents

Media	Company	Web Site or Reference
Media G2®	ADI Group	http://www.adi.ca/
Aqua-Bind™	Apyron Technologies, Inc.	http://www.apyron.com/
Arsenic Remed. Technol.	University of Connecticut	http://www.eng2.uconn.edu/~nikos/asrt-brochure.html
Metall:X™	SolmeteX Products	http://www.solmetex.com/metallx.htm
KDF® Drinking Water Filters	KDF Fluid Treatment, Inc.	http://www.software-exchange.com/what_s_kdf.html
WHOLLY Water®	Life Streams International Mfg. Co.	http://www.wholly-water.com/
Granular Ferric Hydroxide	US Filter	http://www.USFilter.com
Bayoxide, E-33	Severn-Trent	www.severntrentservices.com
AA-FS50 Activated Alum.	Alcan Chemicals Ltd.	http://www.chemicals.alcan.com/
CPN Activated Alum.	Alcoa	http://www.alcoa.com

Adsorption Challenges

- New adsorbents – developing & evaluating
- Effects of water chemistry on performance
 - pH, PO_4^{3-} , H_4SiO_4 , others
- Process control
- Residuals management

Technology Needs for Adsorption Processes

- Develop media with improved selectivity & As capacity at pH > 7.0
- Develop better understanding of effects of pH & competing ions on media performance
 - Quantitative performance model
- Develop procedures for rapid evaluation of media performance
- Need for lower cost media

Membrane Processes

- RO is effective for As(V), less effective for As(III)
- Nano- & Ultra-filtration effective for As(V)
 - Limited field experience with As treatment
- Costly
- High water use
- Microfiltration used with coagulation

Membrane Process Challenges

- Complexity
- Cost
- Water use
- Scaling & fouling
 - Sea water desalination vs. As removal from ground water
- Residuals management

Technology Needs for Membrane Processes

- Demonstrate performance of nano- & ultra-filtration
- Reduce cost & complexity
- Reduce water consumption

POU Systems

- Under-the-Sink Technologies
 - RO processes
 - Adsorption processes
- Implementation uncertainty (EPA Implementation Guidance for the Arsenic Rule - EPA-816-K-02-018)
- Very low capital cost is attractive to small communities
 - However, there are many hidden complications & costs
 - Very difficult O&M procedures

POU Challenges

- Servicing and sampling in the home is enormous challenge
- Implementation uncertainty
 - What constitutes compliance?
- Process monitoring
- Greater capacity media

- New paradigm in U.S. drinking water supply - The water in the distribution system may no longer be safe to drink

In-Situ Technologies

- Very early stage of development
 - Subsurface Treatment for Arsenic Removal (STAR) technology (DBS&A)
 - Phase I SBIR grant from EPA
 - Permeable reactive barriers for shallow ground water remediation (DOE/EPA)

Other Treatment Technologies

- Electrochemical reduction

Residuals Concerns

- Potential hazardous characteristics
 - TCLP, CalWET
 - Total As concentration
 - Handling issues
- Volume of waste
 - Water consumption
- Potential for As release
 - Anaerobic environment in landfill
 - Effects of stuck pH controller on loaded media

Technology Needs for Residuals Management

- Develop methods to reduce residuals volume
 - Need appropriate technology for dewatering
- Improved understanding of long term stability of As residuals

Analytical Methods

- Three types of analytical applications
 - Research
 - Compliance monitoring
 - Process control
- Current technologies
 - Optical Spectroscopy – GFAA, HGAA, ICP-OES
 - Mass spectroscopy – ICP-MS
 - Colorimetric (including test strips)
 - Electrochemical
 - Other
- Speciation

Analytical Challenges

- Method for process analysis
 - Reliable
 - Simple
 - Cheap

Emerging Technologies - 1

- As(III) Oxidation
 - Cl_2 & O_3 are effective, cheap & familiar
 - Perhaps some value in solid phase oxidant/adsorbent
- Treatment Technologies
 - Coagulation/Precipitation/Filtration
 - Al & Fe coagulants are effective, cheap & familiar
 - Value in simplifying & automating the processes for smaller applications
 - Membrane filters appear promising

Emerging Technologies - 2

- Treatment continued
 - IX
 - Opportunities to reduce water & brine use
 - Adsorption
 - Many new adsorbents on horizon (how to evaluate?)
 - Improved understanding of process & effects of water chemistry
 - Improvements in process monitoring
 - Concerns about residuals & costs

Emerging Technologies - 3

- Treatment continued
 - Membrane processes
 - Considerable promise in nano- & ultra-filtration
 - POU systems
 - Simplifications of systems for home application
- Residuals
 - Looming complications associated with disposal
 - Small scale dewatering of $\text{Fe}(\text{OH})_3$ sludges

Emerging Technologies - 4

- Analytical methods
 - Developments in process monitoring
 - Improved understanding of adsorption process

Summary

- Is there a silver bullet for As treatment?