Meeting the New Drinking Water Standard for Arsenic

Arsenic Water Treatment Technology Forum

New Mexico Environmental Health Conference

Albuquerque, NM

November 2, 2005

Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

NNSA National Nuclear Security Administration

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Technical Theme Session Agenda (I)

8:00 Introduction to Session

8:10 The Arsenic Water Technology Partnership

8:30 Arsenic Removal Research Sponsored by Awwa Research Foundation

8:55 Pilot Demonstrations of Arsenic Removal Technologies in New Mexico

9:20 Use of CoAsT (Comprehensive Arsenic Tool) for Small Water Systems Affected by the Upcoming Arsenic Rule

9:45 Current Status of Sandia's Rural Arsenic Outreach Program

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Technical Theme Session Agenda (II)

10:00 Break

10:15 Applications for Laboratory Column Tests in Evaluating Arsenic Adsorption Media

10:40 Complying with a Lower Arsenic MCL: Co-occurring contaminants and treatment options

11:05 Water Quality Variation and Its Effects on Arsenic Removal

Arsenic Water Treatment Technology Forum

- Presentations by vendors - November 2
  - 1:30 – 6:15 PM
  - Open session
  - 11 vendors x 20 minute presentations and Q&A
- Technical Evaluation Team meeting with vendors
  - November 3
  - 8:00 AM – 4:10 PM with break for lunch
  - Closed session
  - Screening of technologies for 2006 pilot studies
  - Results posted on AWTP website

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Arsenic Water Technology Partnership
Status – November 2005

Malcolm Siegel, Albert Ilges, Abbas Ghassemi

Arsenic Water Treatment Technology Forum

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The New Standard for Arsenic

- Reduction of drinking water Maximum Concentration Level (MCL) for arsenic from 50 ppb to 10 ppb was intended to reduce incidence of bladder cancer and other cancers in US.
- Southwestern United States is characterized by high and variable background levels for arsenic
- New MCL is controversial due to high costs and uncertain health benefits.
- Estimated national annual costs of implementing 10 ppb MCL range from $165M to $605M to save 7 – 33 lives.
  - $5M – $23.9M /life saved
  - $1.3M – $6.6M/ year of life saved
    - About 1 life/500,000 exposed persons per year

Can advances in water treatment technology significantly reduce costs?

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Arsenic Water Technology Partnership Background

- Congressional Appropriation - $10M
- DOE- funded peer-reviewed, cost-shared research program to develop and demonstrate innovative technologies for removal and disposal of arsenic from drinking water

- Nominal Partner Roles
  - Bench-Scale Studies (AwwaRF)
  - Demonstration Studies (Sandia)
  - Economic Analysis/Outreach (WERC)
- Focus on small systems
  - 40% of resources directed to rural and Native American utility needs
  - Minimize costs - capital, operating, maintenance
  - Minimize residual quantities & disposal costs

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Outline

- Technology Development and Screening
  - AwwaRF, Sandia, WERC
- Technology Evaluation in Pilot studies
  - Site selection, pilot test designs
- Technology Transfer
  - Economic models and outreach
- Summary

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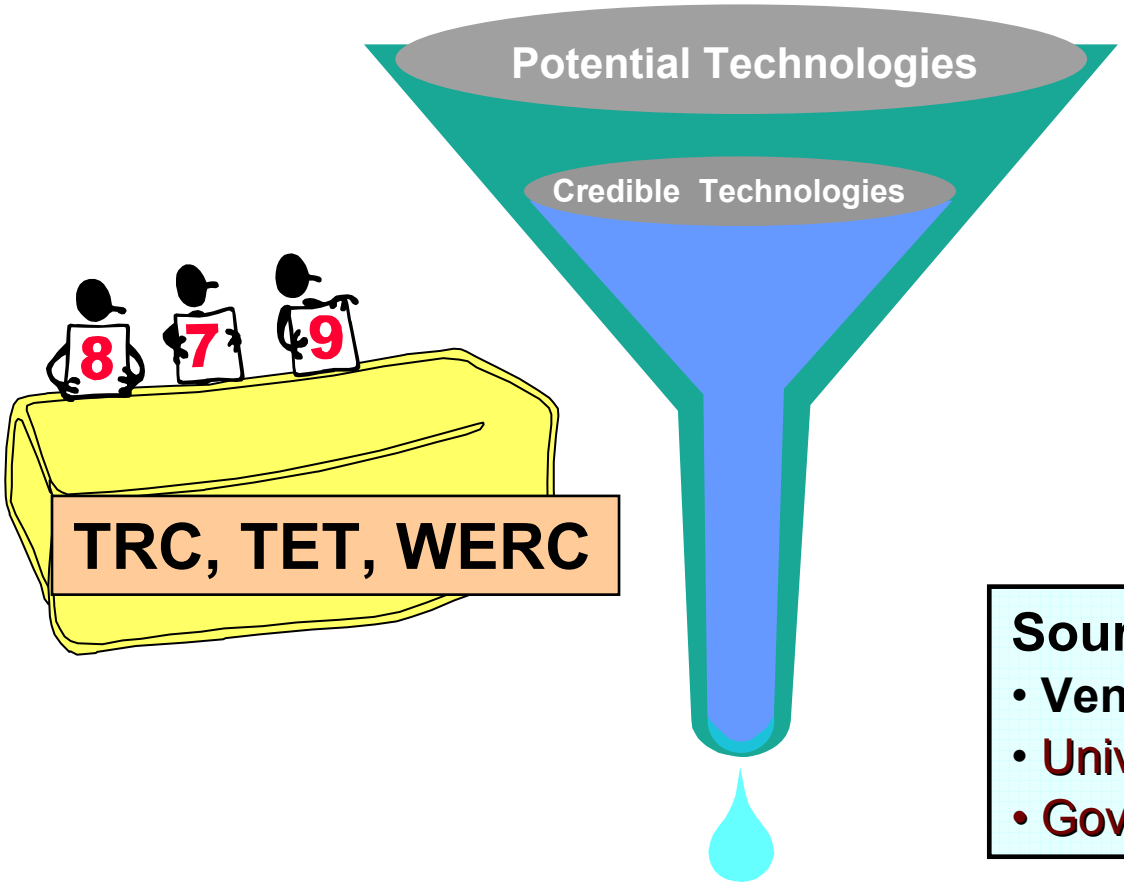
Conventional Arsenic Treatment

- Sorption treatment processes
  - Ion exchange
  - Activated alumina
  - Iron-based sorbents
- Membrane treatment processes
  - Reverse-osmosis
  - Precipitation/filtration processes
    - Conventional gravity coagulation/filtration
    - Coagulation-assisted microfiltration
    - Enhanced lime softening
    - Oxidation/filtration

AWTP Technology Screening Process



- Performance
- Cost
- Complexity
- Maturity

Sources of new technologies
- Vendors
- Universities
- Government labs

Suggested Pilot Technologies

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General Treatment Innovations

- **Sorption treatment processes**
  - Regenerable, higher capacity and selectivity
  - More stable residuals
  - 'Tougher' sorbents
  - Coatings on inexpensive materials (industrial waste, natural materials)
- **Precipitation/filtration processes**
  - Enhanced coagulation with Fe compounds or polyelectrolytes
  - Improved filtration with nanocomposite materials
  - Recycle systems to minimize chemical addition

2003 and 2004 Vendor Forums led to recommendation of 10 innovative technologies for initial pilots and 6 for bench-scale studies

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Current Sorption Treatment Innovations

- **Fe, Ti, Cu, Zr or mixed metal oxides** in granules formed by chemical precipitation or nanoparticle agglomeration. (e.g. AdEdge, Kemiron, Argonide, Graver)
- **Coating granular activated carbon (GAC),** strong base anion exchangers resin or polymeric ligand exchangers with nanoparticulate metal oxides. (e.g. Purolite, Resintech, Auburn University)
- **Coating inexpensive natural media** or waste products with metal oxides or other functional groups. (e.g. ADA, Virotec, Arizona State)
- **Increased surface area** and chemical selectivity based on fibrous or gel substrates coated by metal oxides or materials with sulfhydryl functional groups. (e.g. NMSU, Weber State, Drexel University)

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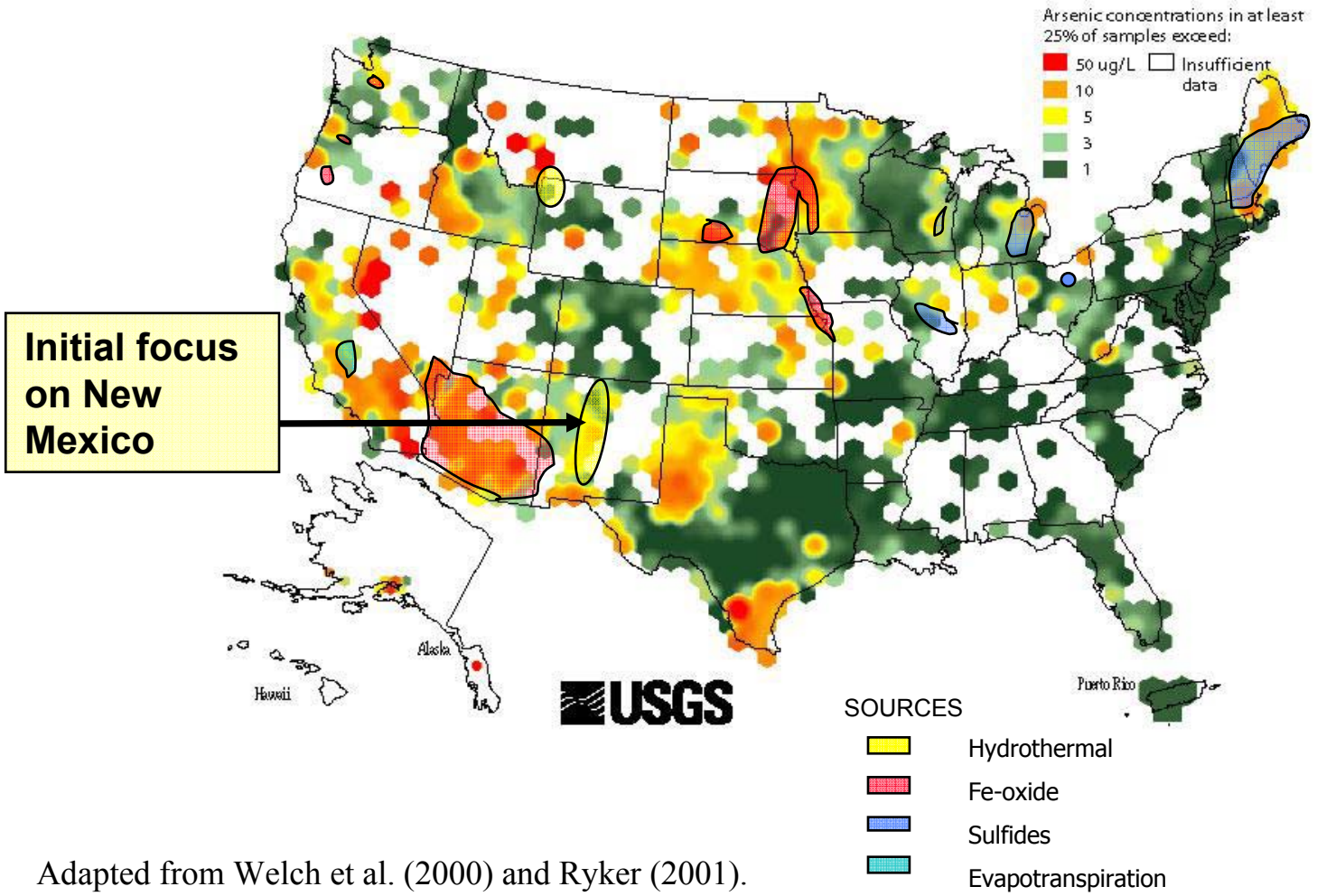
Things we look for in a pilot site

- As concentration (>10 ppb)
- Example ground water composition that will help other communities
  - pH, TDS, foulants such as Fe, Mn, silica, and organics
  - As(III)/As(V)
  - Competing ions (V, SO_4, etc.)
  - Other contaminants of concern/benefit (e.g, Ra, U, ClO_4, F)
- Small size of system to be treated (< 10,000 users)
- Community support facilitates rapid deployment
  - Water utility
  - Municipal government
- Ability to deal with residuals/treated effluent
- Rural and Native American communities that would benefit from assistance

National Scope of Program: Consider all Arsenic levels and source types



Adapted from Welch et al. (2000) and Ryker (2001).

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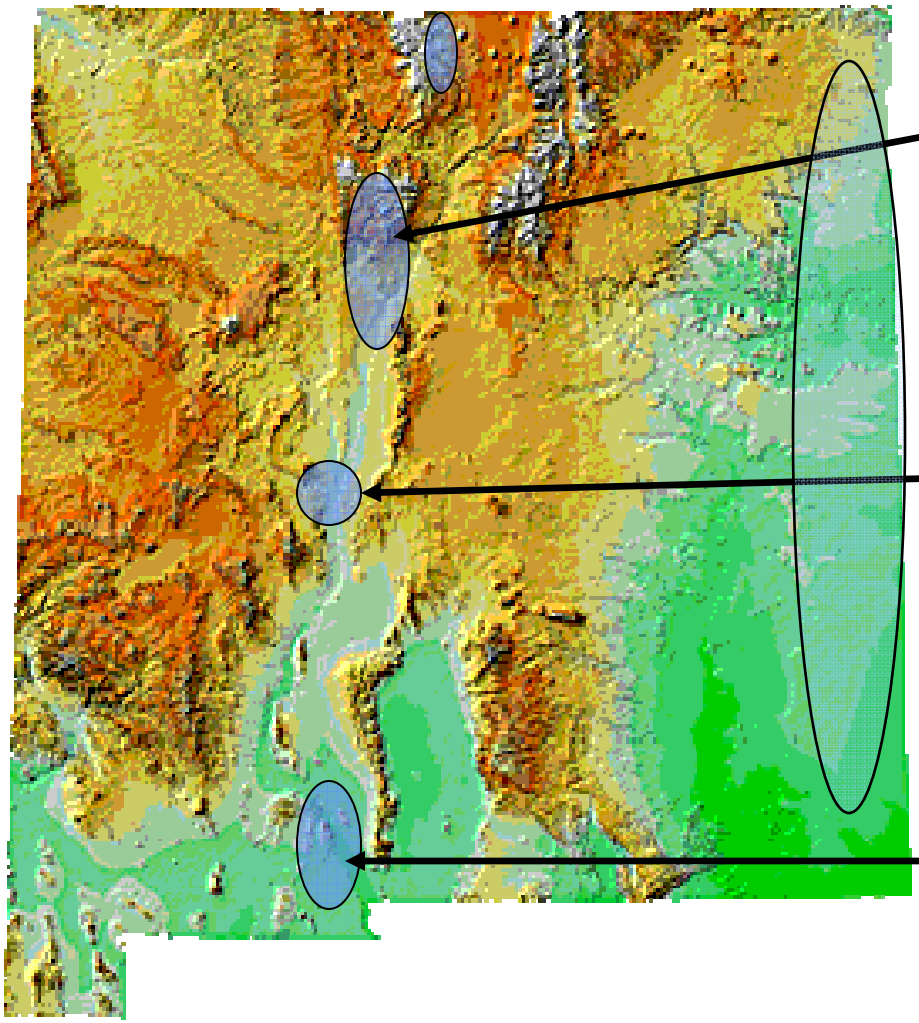
High Arsenic in New Mexico's Waters



- **Abundant in silicic volcanics**
  - **derived volcaniclastic sediments and associated hydrothermal systems**
- **Arsenic enrichment by Potassium Metasomatism**
  - **low temperature alteration common in closed hydrographic basins in arid climates**
- **Mixing of deep geothermal waters and shallower surface influenced waters**

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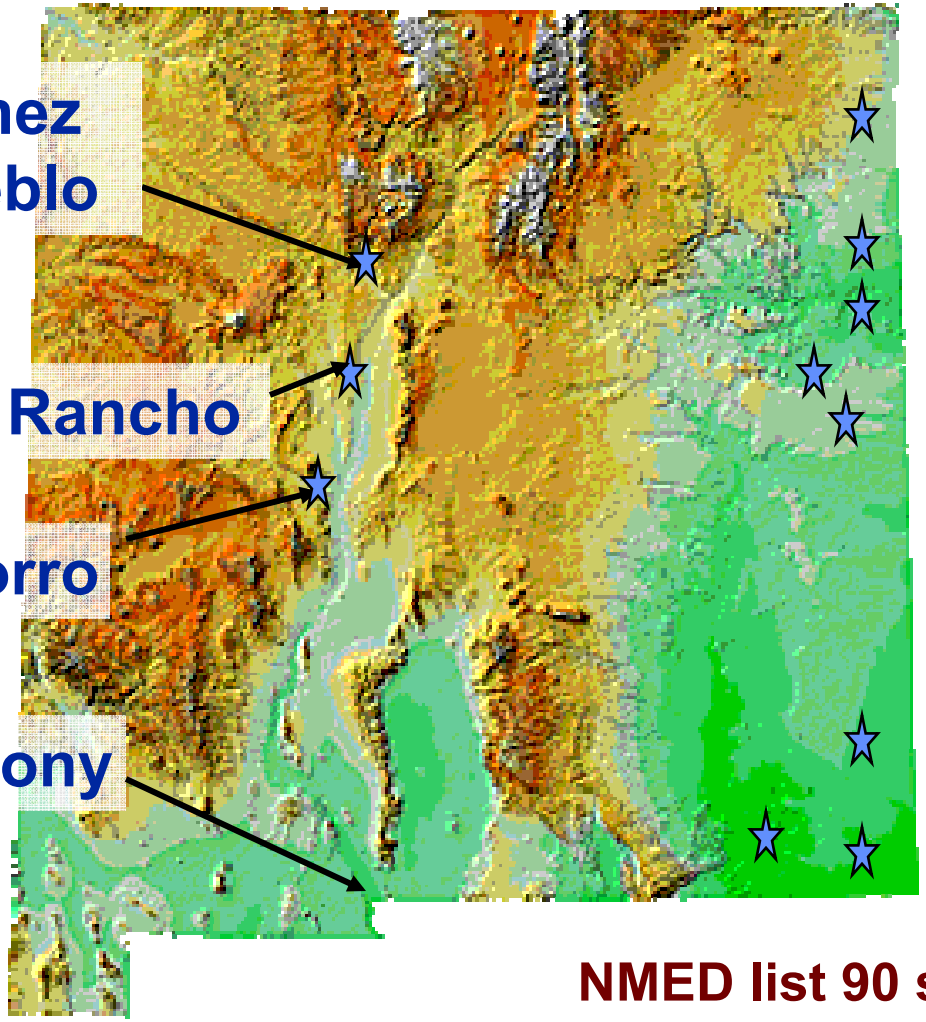
Current Sites in New Mexico



NMED list 90 sites >10 ppb in state

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Sandia Pilot Test Concepts

- **Side-by-side demonstrations of technologies tested by AwwaRF bench-scale program, WERC design contest, or commercial technologies vetted through Vendor Forums**
  - **Test duration: 3 – 9 months**
  - **Test size: 0.3 – 10 gpm**
  - **Different technology classes: adsorptive media, Coagulation/Filtration, membranes, electrochemical**
- **Cooperative effort between Sandia, Technology Owner and Site Owner**
- **Test Protocols developed with help from NSF International , academia, industry during 2004-2005**
- **Phase I Tests: Fixed bed adsorbents designed with vendor data**
  - **Particle size, desired hydraulic loading rate**
  - **Optimum Empty Bed Contact Times**
- Phase II: evaluate newer media, pH changes, corrosivity, other effects.

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Pilot Test Configurations

- Pump house
- Skid Mount or container
- Mobile unit

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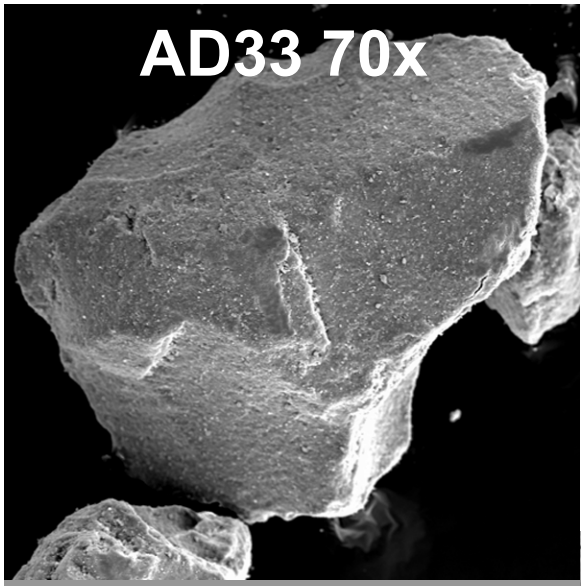
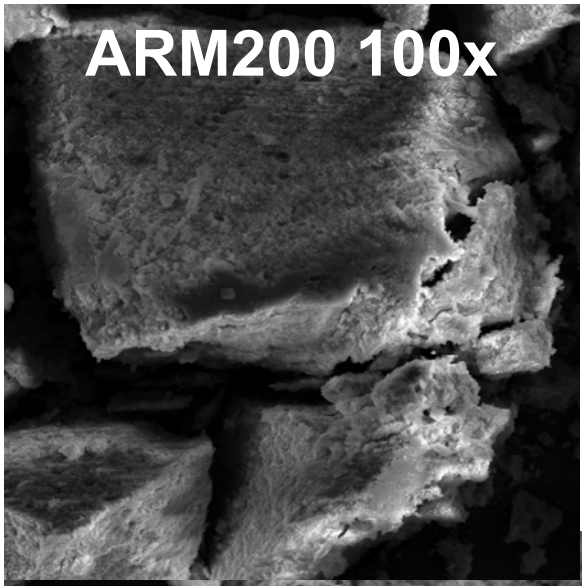
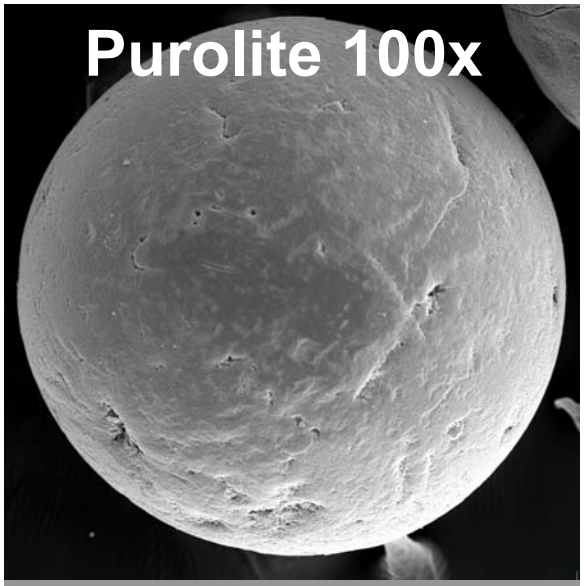
Supporting Laboratory Studies

- **Objective:** Compare performance predictions from different kinds of tests
- **Materials characterization**
  - Pre-test and post studies
  - Surface area (BET), pore size distribution
  - Particle morphology and surface chemistry
  - Attrition loss
- **Batch sorption studies**
  - Isotherms
  - Kinetic
- **Rapid small scale column tests (RSSCTS)**

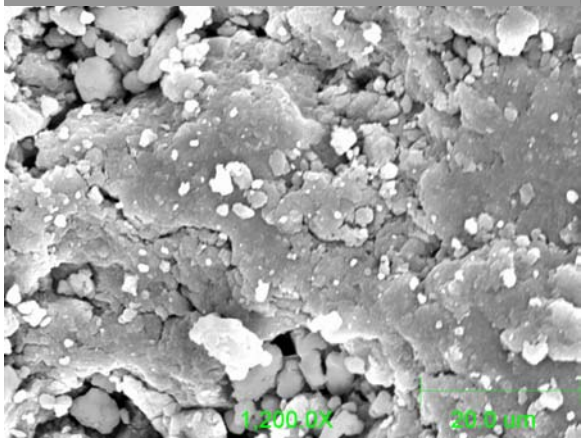
SEM Photos of Adsorption Media



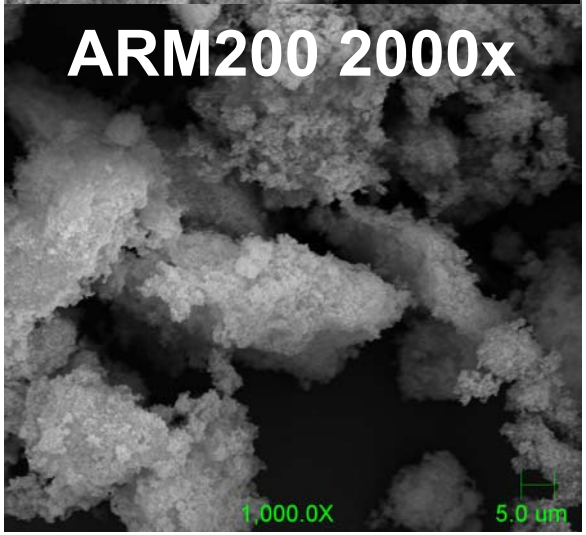




AD33 1200x



ARM200 2000x



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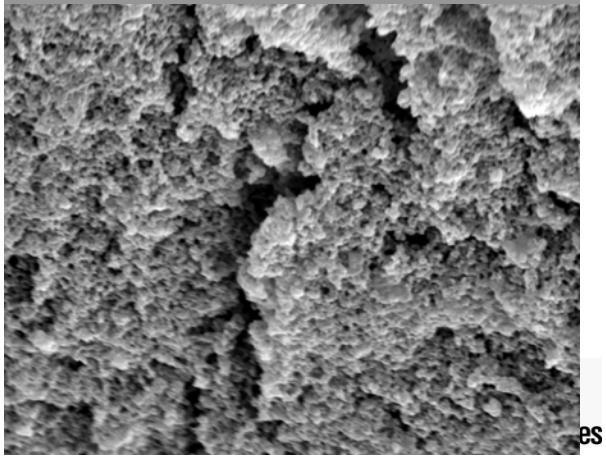
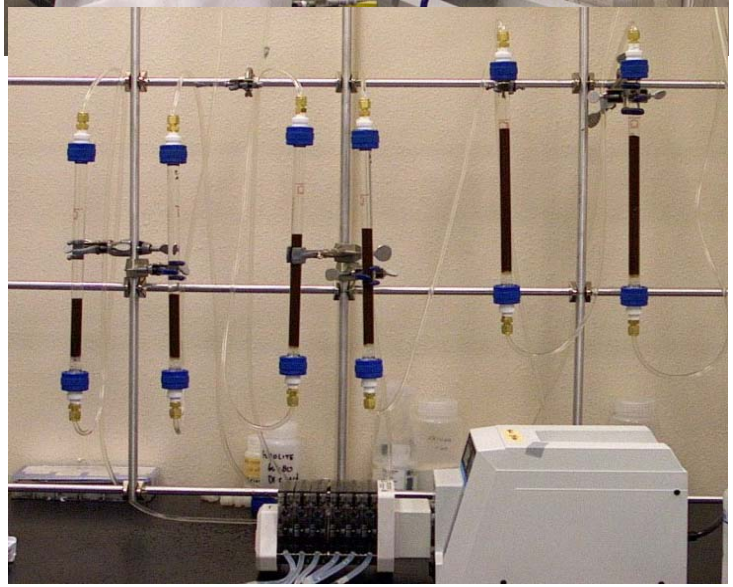
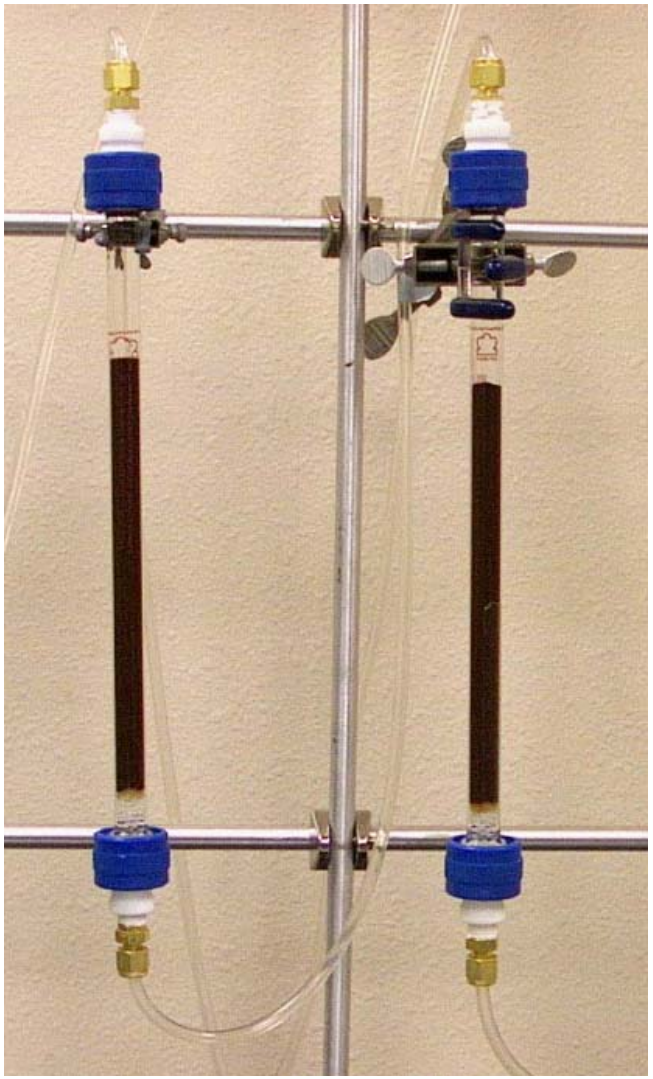


Objective of RSSCTs

- Apply RSSCTs to site specific waters to aid in the design of pilot studies and full-scale treatment systems
- Significantly reduce time and costs associated with pilot studies
- Two RSSCT designs:
  - Proportional Diffusivity: duration 2-5 weeks
  - Constant Diffusivity: duration 2-10 days
- Breakthrough curves from PD and CD RSSCTs should bracket breakthrough curves from pilot columns

RSSCT Columns





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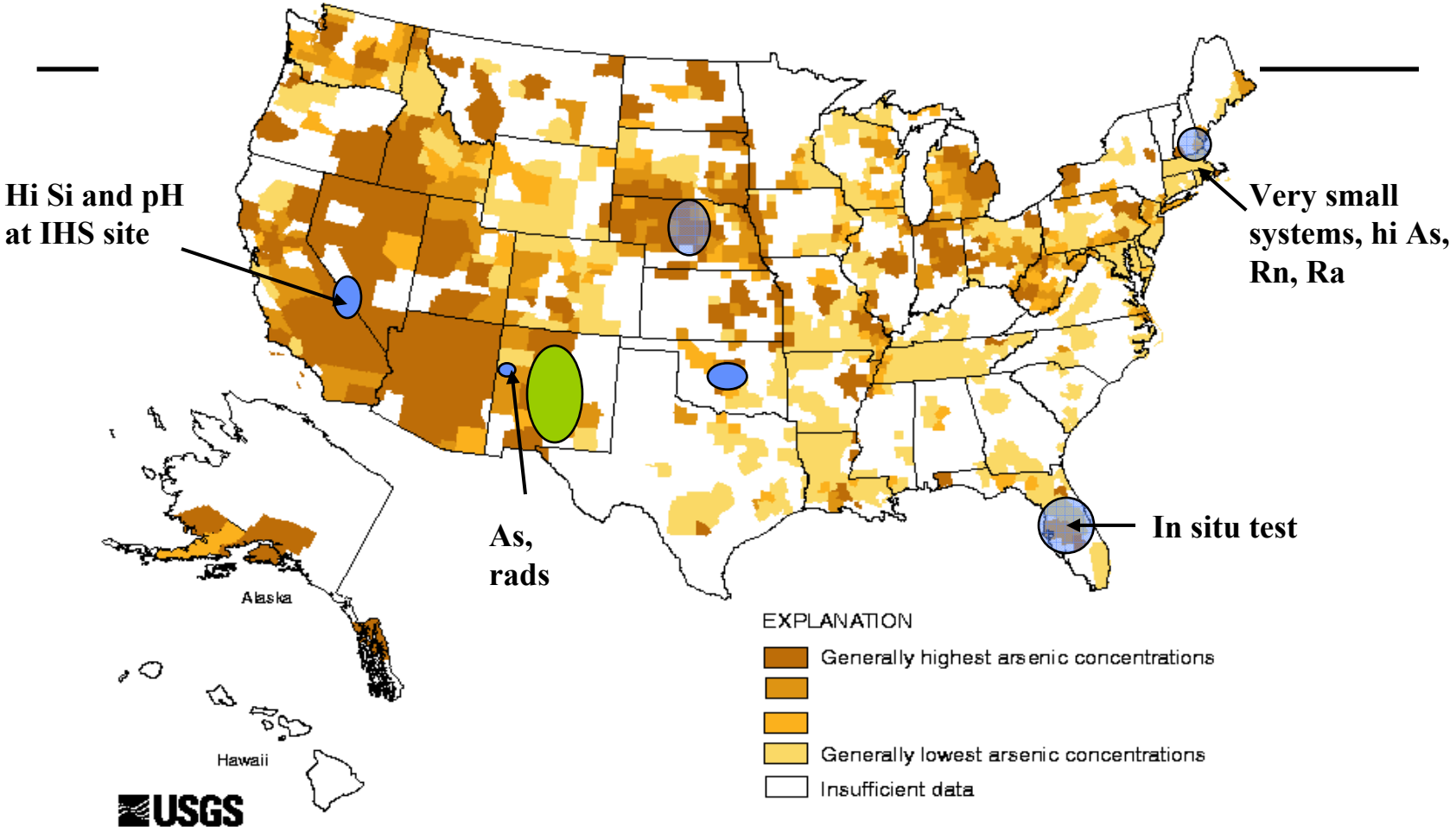
Future Pilot Studies Under Consideration



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Tech transfer

- **Cost model development - WERC**
  - Review/modify EPA and AwwaRF cost models
  - Interactive web based decision tool
  - Audience: consultants, regulators, utilities
- **Community outreach**
  - Regional training workshops - WERC
  - Site-specific help in technology selection, applications for exemptions and loans – Sandia

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Summary

- **Arsenic Partnership Objectives**
  - Generate cost/performance data for innovative technologies for small communities
  - Community outreach to aid in technology selection and implementation
- **Technology Selection**
  - Initial technologies chosen from participants in Vendors Forum
  - Later stages include technologies from universities, national labs and industry
- **Site Selection**
  - Four initial sites in New Mexico
  - Subsequent sites chosen through Congressional, State and Tribal contacts
- **Initial Pilot Studies**
  - Socorro, NM – February 2005 start
  - Desert Sands, NM – Fall 2005 start
  - Rio Rancho, NM – Fall 2005 start
  - Jemez Pueblo – Spring 2006 start

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Thanks to the AWTP Team Members

- Tom Hinkebein, Malynda Aragon, Alicia Aragon, Brian Dwyer, Randy Everett, William Holub Jr., Carolyn Kirby, Linnah Neidel, Justin Marbury, Paul McConnell, Michelle Shedd, Emily Wright, Jerome Wright, Hong-Ting Zhao (Sandia National Laboratories)
- Frederick Partey (NMT), Pedro Gutierrez (UTEP), Nik Rael, David Stromberg, Andres Sanchez (UNM)
- Hsaio-wen Chen (AwwaRF)
- Fernando Cadena, Rose Thompson, Peter Nathanson (WERC/NMSU).

- Websites: http://www arsenicpartners.org
  http://www.sandia.gov/water/arsenic.htm

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Initial Activities (FY2003 – 2004)

- Initial technology deployment at Kirtland AFB
- AwwaRF funded Research
  - New Ion Exchangers, Zirconium & Titanium-Based Nanoparticle Media, Aerogel & Iron-Oxide Impregnated GAC
- Sponsored activities at New Mexico Environ. Health Conference (October 2003)
  - Theme session to introduce program
  - Vendors Forum to evaluate commercial technologies
  - Website: http://www.sandia.gov/water/arsenic.htm
- 2004 WERC design contest included As challenge
- Initial development of cost model by WERC

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Activities in FY2005

- Second round of RFPs issued by AwwaRF
  - Chemical modeling, secondary impacts, small systems
- 2nd Vendors Forum at 9th New Mexico Environmental Health Conference (Oct. 19 - 20)
- Start pilot test deployment at Socorro, NM, Jemez Pueblo, and Desert Sands, NM
- 2005 WERC design contest includes As + NO_3 challenge
- Develop plans for pilots at 4-5 sites chosen from candidates in Michigan, Navajo Nation, New England, Arizona, North Carolina, New Jersey and additional sites in New Mexico
- Additional development of cost model

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RSSCT Theory – Mass Transfer Models

- **HSDM – Homogeneous Surface Diffusion Model**
  - Advective flow
  - Liquid phase mass transfer resistance
  - Local adsorption equilibrium at exterior surface
  - Surface diffusion
  - Used in determination of intraparticle mass transport
- **DFPSDM – Dispersed Flow Pore Surface Diffusion Model**
  - Advective flow
  - Liquid phase (film) mass transfer resistance
  - Local adsorption equilibrium at exterior surface
  - Surface AND pore diffusion
  - Dispersive axial transport
  - Competitive adsorption of multiple solutes
  - Used in determining scaling relationships