SAND2005-7506C

Sandia National Laboratories Arsenic Treatment Technology Demonstration Program

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January 31, 2006

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.

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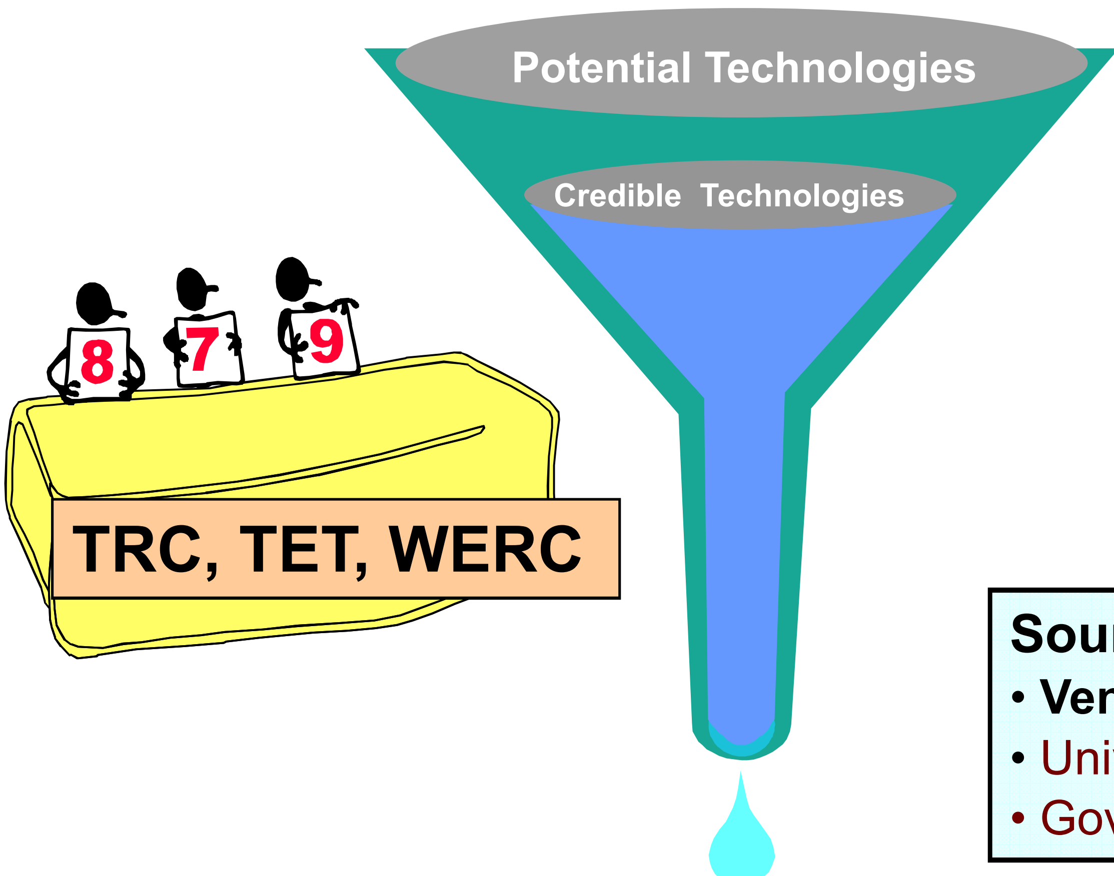
Arsenic Water Technology Partnership Background

- Congressional Appropriation - $10M FY03 – FY05
- DOE- funded peer-reviewed, cost-shared research program to develop and demonstrate innovative technologies for removal and disposal of arsenic from drinking water
- 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

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: Innovative technologies designed with vendor input**
  - **Fixed bed adsorbent media: Particle size, hydraulic loading rate, Empty Bed Contact Time**
  - **Batch systems (e.g. C/F) with vendor equipment**
- **Phase II**: evaluate newer media, pH changes, corrosivity, other effects**.**

AWTP Technology Screening Process



Suggested Pilot Technologies

- Performance
- Cost
- Complexity
- Maturity

Sources of new technologies
- **Vendors**
- Universities
- Government labs

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, 2004, 2005 Vendor Forums led to recommendation of innovative technologies for initial pilots and others for additional 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

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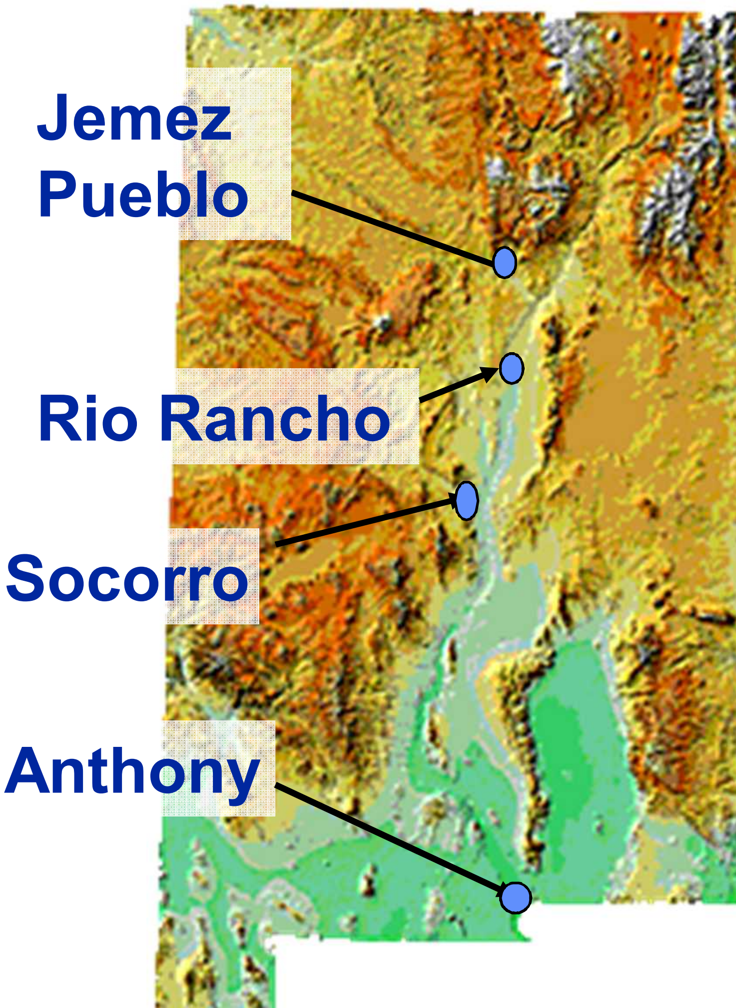
Sites in New Mexico



New Mexico Pilot Sites – Water Quality

Site	Total As/As(III)	V (ppb)	SO_4 (ppm)	Fe (ppm)	pH
Socorro	*42 ppb / 0 ppb*	*11*	*29*	*0.4*	*8.0*
Anthony	20 ppb / 18 ppb	2	180	0.15	7.7
Rio Rancho	19 ppb / < 1 ppb	15	100	<0.10	7.7
Jemez Pueblo	20 ppb / 19 ppb	<1	24	1.2	7.5

Site	Cond. (μS/cm)	TOC (ppm)	Ca Hard (ppm $CaCO_3$)	Alkalinity (ppm $CaCO_3$)	SiO_2 (ppm)
Socorro	*360*	*0.5*	*44*	*120*	*25*
Anthony	1380	0.8	66	180	37
Rio Rancho	630	ND	62.5	184	22
Jemez Pueblo	770	2.0	155	290	50

First Community Pilot: Socorro, NM

- 100% groundwater source for drinking water
- 2 warm springs (90^{o}F) provide 500 gpm, 35 – 55 ppb As(V) by gravity flow.
- Formerly site of tap for bottled water company;
- Optimal F for oral health
- Phase 1: Feb-Oct 2005
  - Tested
    - Fe oxides: AD33, ARM200
    - Resin - AsX^{np}
    - Ti-oxide - Metsorb
    - Zr-oxide - Isolux
  - EBCT study of AD33
    - 3,4,5 min

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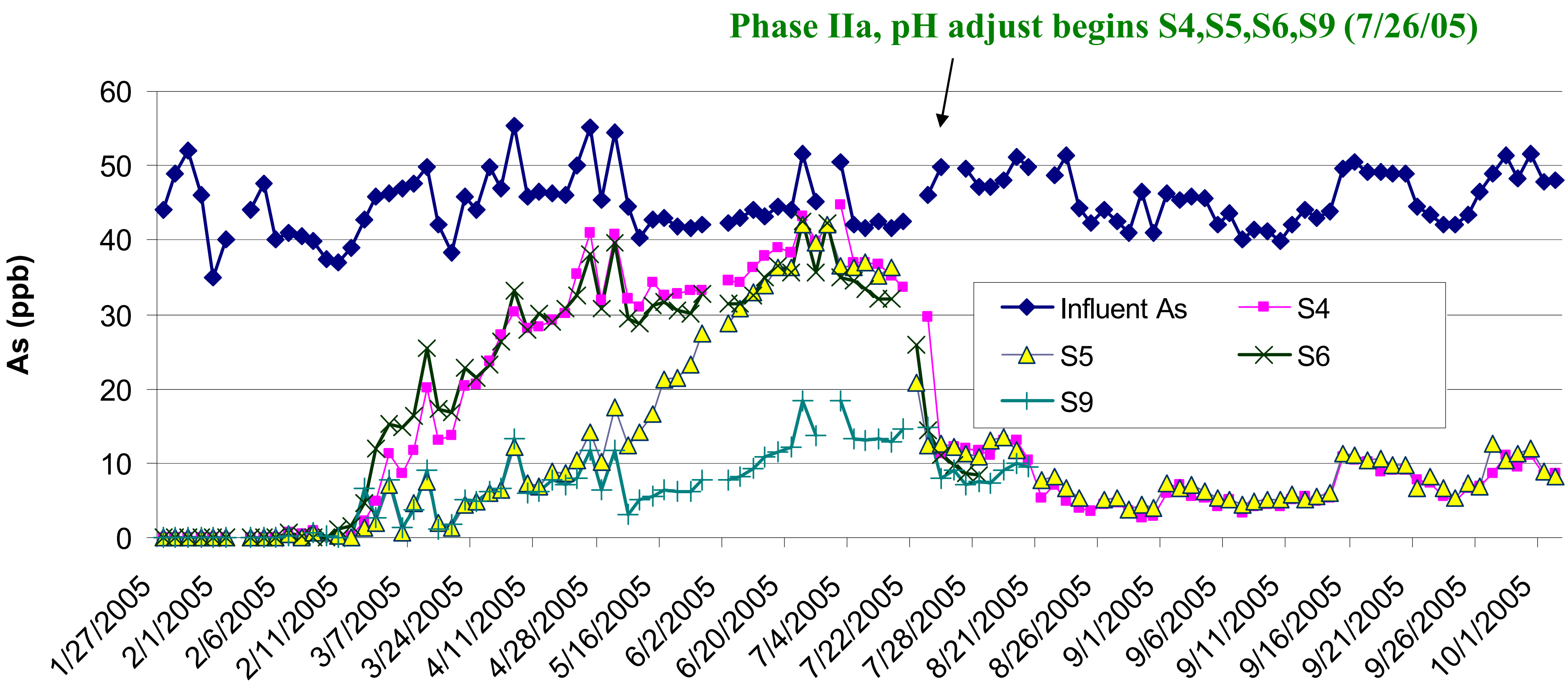
Socorro Pilot Phase I and IIa Events

S4 = ARM200 (FeOx); S5 = AsXnp (resin); S6 = Metsorb (TiOx); S7 = Isolux (ZrOx); S9 = AD33 (FeOx)



Not a linear scale!

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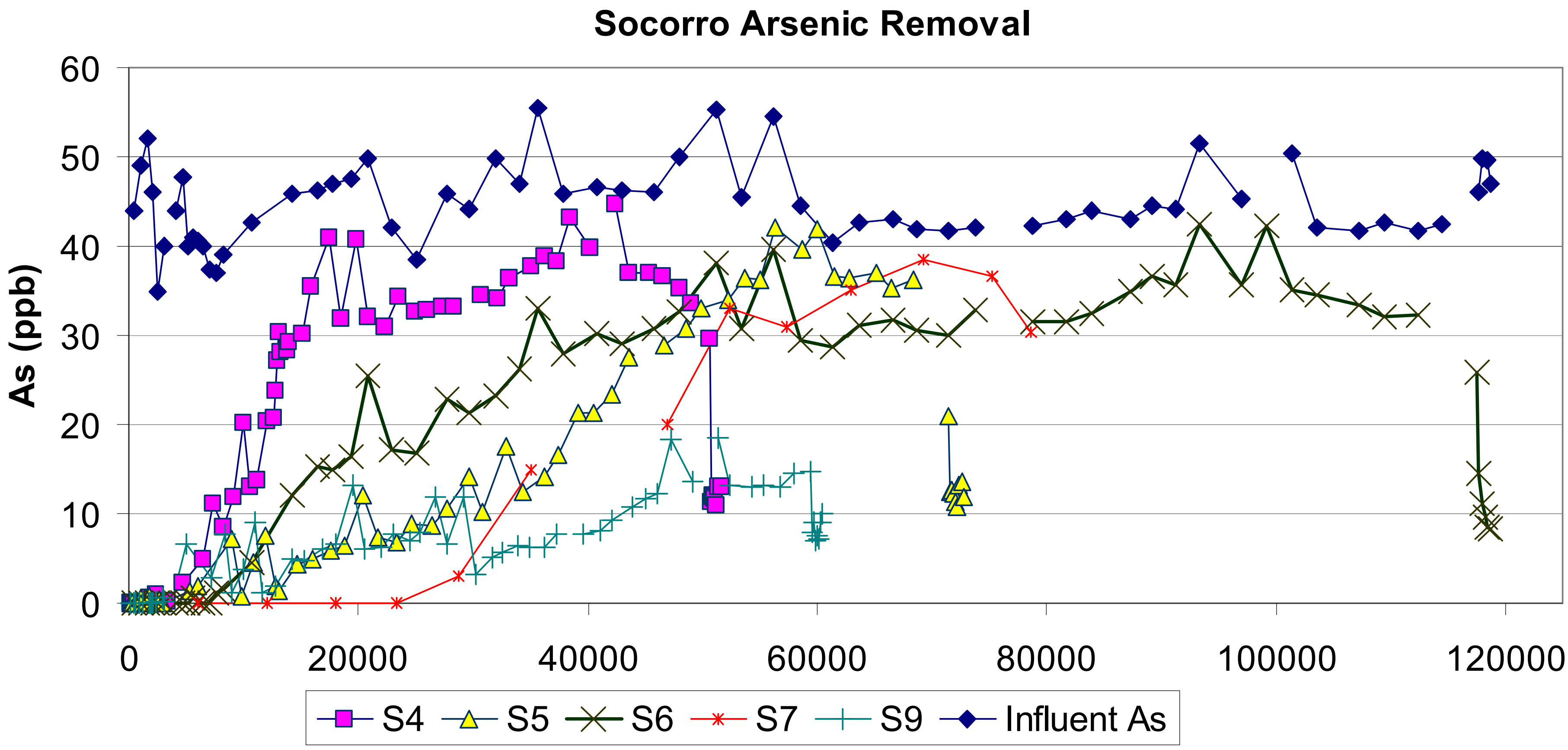
Media Performance Socorro, NM

S4 = ARM200 (FeOx); S5 = AsXnp (resin); S6 = Metsorb (TiOx); S7 = Isolux (ZrOx); S9 = AD33 (FeOx)



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Media Performance in Socorro, NM

- **Arsenic Removal Capacity**

Parameter	ARM200 FeOx	Metsorb - TiOx	*AsX^np	Isolux ZrOx	AD33 (FeOx)
BV to 10 ppb	8,600	13,000	27,000	32,000	43,000
Capacity at 10 ppb, mg/g	0.60	0.70	1.38	1.67	3.56
Capacity at 35K BV, mg/g	1.17	1.39	1.75	1.67	3.01
Depletion - C/Co at 35K BV	0.88	0.60	0.35	0.38	0.15
BV at C/Co = 0.8	33,000	87,000	53,000	63,000	>270,000
Capacity at C/Co = 0.8	1.15	2.26	2.10	2.23	> 4.62

*AsX^{np} batch was defective

Parametric Study: Socorro, NM

- **Effect of EBCT on Arsenic Removal Capacity**

Parameter	AD33		
	2 min	4 min	5 min
BV to 10 ppb	24,000	43,000	42,000
Capacity at 10 ppb, mg/g	1.95	3.56	3.47
Capacity at 35K BV, mg/g	2.59	3.01	2.92
Depletion - C/Co at 35K BV	0.50	0.15	0.12
BV at C/Co = 0.8	84,000	>270,000	>235,000
Capacity at C/Co = 0.8	4.03	> 4.62	>3.47

Hydraulic Test Results: Socorro, NM

Results: Physical Observations

- Sieve Analysis: 0.8-29% media loss
- Particle Size Uniformity: All media had C_u < 5, most <2.5 (fairly uniform)
- Surface Area: Doesn't seem to control As removal – the media with the smallest surface area had the highest capacity
- Each column reacted differently to operating conditions
  - Media was lost due to backwashing
  - Media compacted throughout pilot experiment

Phase II Studies in Socorro

- **Capacity extension tests of spent media**
  - pH adjustment by CO_2 gas
  - Interrupted flow
- **Evaluate inadvertent effects of treatment**
  - Loss of pH control and arsenic spike
- **Side-by side comparisons of 5 media at 2 pH**

  pH = (8: ambient and 6.8:CO_2 gas)
  - AsX^{np} – QC'd batches
  - Isolux – larger cartridge for more 'reliable' BV
  - Kemiron – FeOx media
  - SANS – Sandia proprietary media
  - Metsorb – TiOx media

Second Community Pilot: Anthony, NM

- **100% groundwater source for drinking water**
- **Warm springs (~85°F) provide 240-270 gpm, 20 ppb As - mainly As(III).**
- **High sulfates, TDS**
- **Intermittent Flow Operation**
- **Phase 1: August 2005**
  - **3 FeOx, 1 ZrOx, 2 TiOx, resin**
- **Phase 2: Coated media December 2005**
  - **La-coated diatomaceous earth**
  - **Oxide-Coated GAC**
  - **Fe-coated silicate**
  - **Fe-coated SBA resin**

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Third Community Pilot: Rio Rancho, NM

- **100% groundwater source for drinking water**
- **Deep well (800 ft) provides 2000 gpm, 20 ppb As (mainly As V).**
- **High sulfates, Vanadium, TDS**
- **Phase 1: September 2005 Start**
  - **Tested 2 FeOx, 1 ZrOx, 1 TiOx, 2 resins, 2 under-the sink RO units**
- **Continuous Flow Operation**
- **Pre-sieved media prior to loading & initial backwash (> 60 mesh)**

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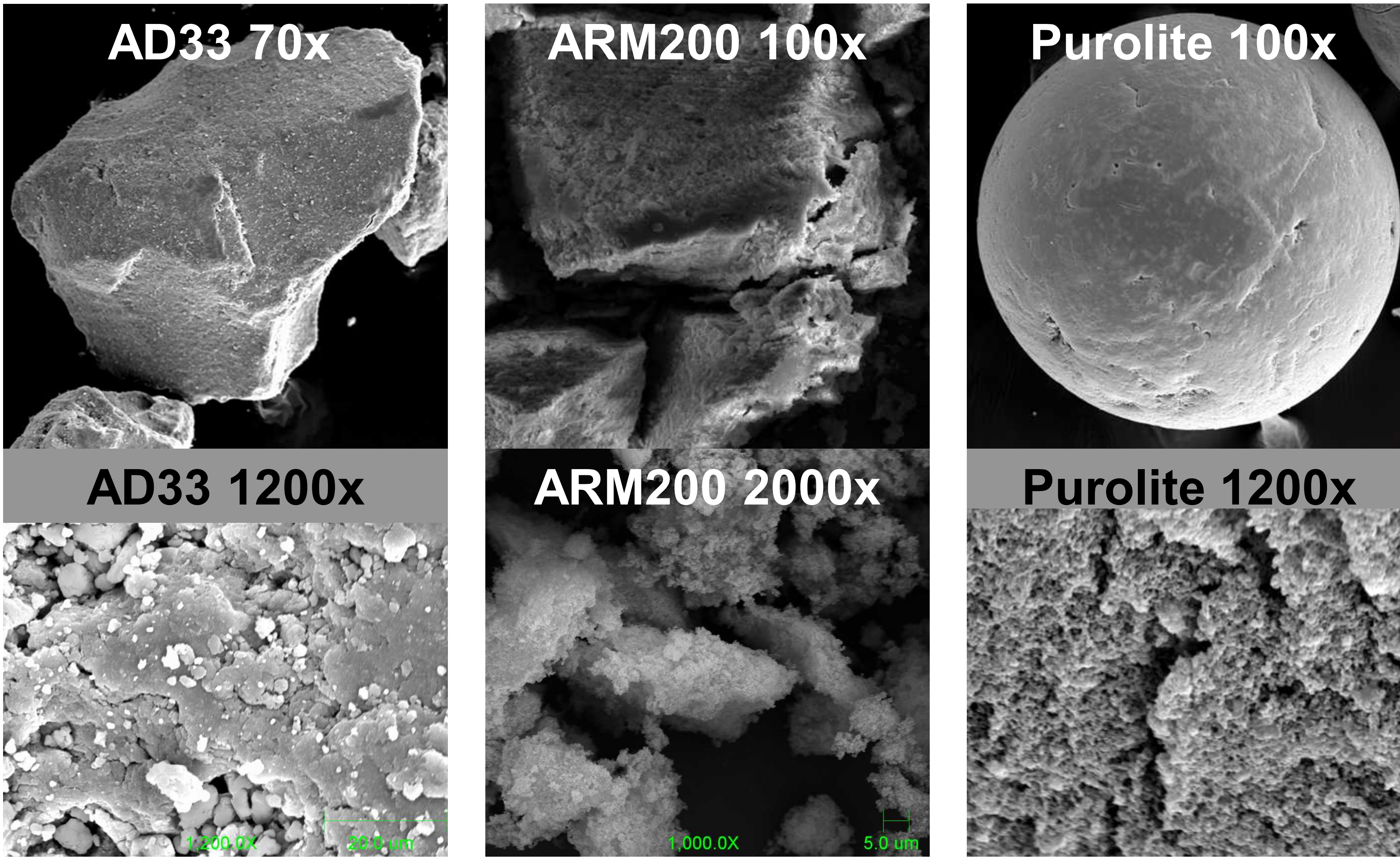
Supporting Laboratory Studies

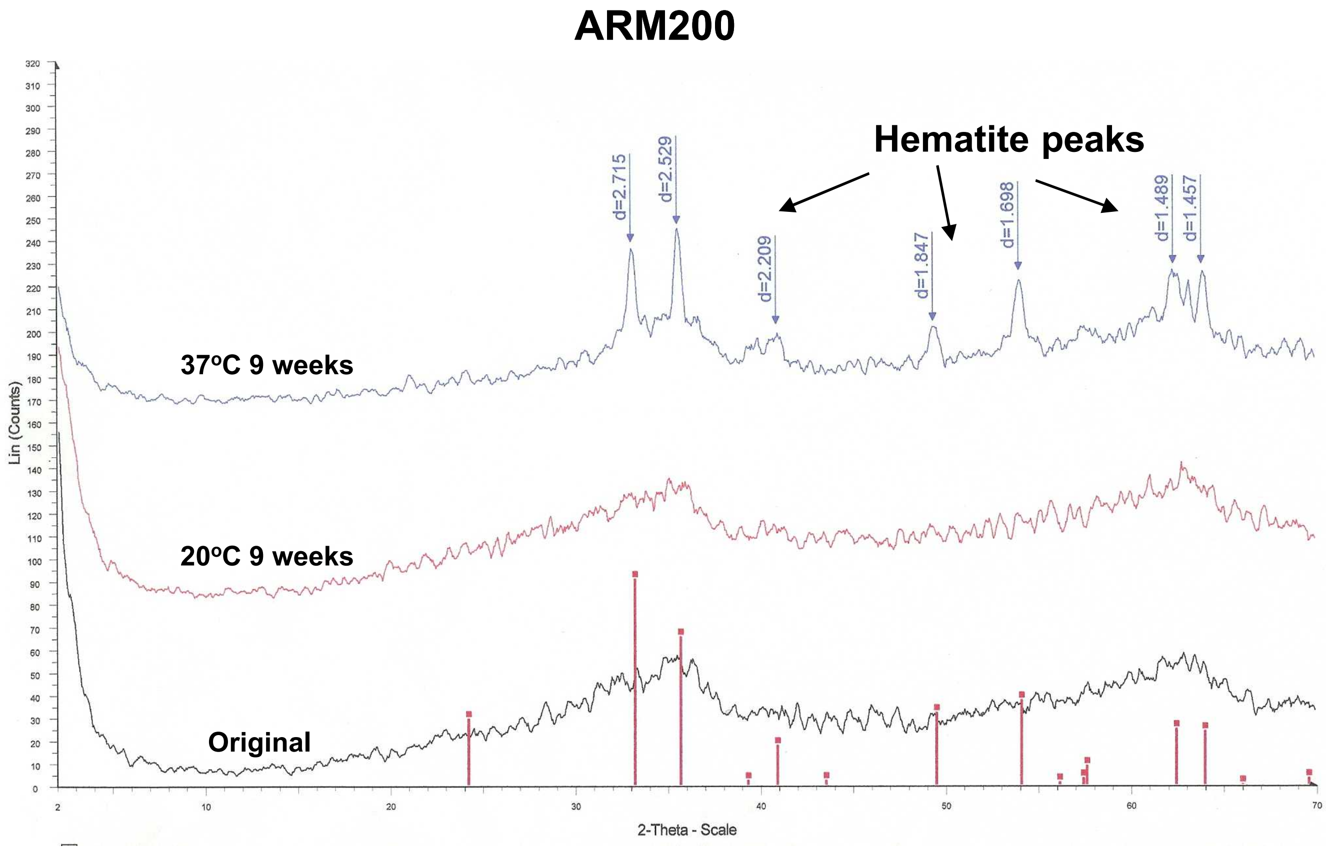
Objective: Compare predictions of media performance obtained from different kinds of tests

- **Materials characterization**
  - Pre-test and post studies, temperature-ageing studies
  - XRD, Surface area (BET), pore size distribution
  - Particle morphology and surface chemistry
  - Attrition loss
  - Post-mortem pore fluids and solids
- **Batch sorption studies**
  - Isotherms (linear, Freundlich, Langmuir)
  - Kinetic (15^{o}C and 40^{o}C)
- **Rapid small scale column tests (RSSCTS)**
  - Proportional and Constant Diffusivity

SEM Photos of Adsorption Media



XRD Studies Used to Evaluate Potential Changes in Mineralogy of Media



Recrystallization may impact performance.

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 but so far results are not consistent.

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Estimates of Arsenic Sorption Capacity from different tests

	AD33	ARM200	Metsorb
BV to 10ppb (pilot)	43,000	8,600	13,000
As at 10ppb (pilot)	3.56 mg/g	0.6 mg/g	0.7 mg/g
BV to 10ppb (RSSCT)	43,000 (PD)	6000 (CD)	12,800 (PD)
As at 10 ppb (RSSCT)	3.39 mg/g (PD)	0.42 mg/g (CD)	0.69 mg/g (PD)
As at 10 ppb (Freundlich)	4.97 mg/g	3.57 mg/g	1.78 mg/g

BV = bed volumes, PD = proportional diffusivity, CD = constant diffusivity

Summary

- **Pilot Test Demonstration Objectives**
  - Generate cost/performance data for innovative technologies for small communities
- **Technology Selection**
  - Initial technologies chosen from participants in Vendors Forum
- **Site Selection**
  - Initial sites in New Mexico
  - Subsequent sites chosen through State and Tribal contacts and Web site applications
- **Initial Pilot Studies**
  - Socorro, NM – February 2005 start
  - Desert Sands, NM – Fall 2005 start
  - Rio Rancho, NM – Fall 2005 start

Summary (II)

- The new arsenic MCL will result in modification of many rural water systems that otherwise would not be evaluated.
- Because of its high profile, the new MCL is spawning a new water treatment industry and infrastructure that has the potential to affect many communities.
- The Arsenic Water Technology Partnership will complement other programs carried out by the EPA and private industry by evaluating the use of innovative technologies in the removal of arsenic and other improvements to community water systems.
- Opportunities for improvement of water quality in systems that currently do not comply with other standards would be an added benefit from the new arsenic MCL that has both economic and public health value.