SAND2007-2281C

Removal of Arsenic and Radium
Pine Hill School
Ramah Navajo Reservation

Malcolm Siegel, Ph.D., MPH; Kathleen Holt; Sandia National Laboratories, Albuquerque, NM.
S. Deb Misra, P.E., Navajo Nation EPA, Window Rock, AZ.
Ward Hunter, Facility Management, Pine Hill School, Pine Hill, NM.

2007 NGWA Conference Naturally Occurring Contaminants
March 23, 2007

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.

Acknowledgements

- Ramah Navajo School Board
- Ron Francis, Dominic Maria, Steve Garcia (Pine Hill field)
- Dariel Yazzie, Yolanda Barney (NNEPA)
- Malynda Aragon, Randy Everett, William Holub Jr. (SNL Field and design))
- Carolyn Kirby, Michelle Shedd, Andres Sanchez, Rose Preston, Joe Zigmond, Jen Ashley, Pam Puissant, (SNL lab)
- Pat Brady, Richard Kottenstette (SNL PM)
- Arsenic Water Technology Partnership (SNL, AwwaRF, WERC)

Sandia National Laboratories

Outline

- **Background:**
  - **Occurrence and significance of arsenic and radium in drinking water sources in Southwest**
- **Description of Pine Hill School site**
- **Pilot Test**
  - **Objectives**
  - **Treatment technologies**
  - **Results**
- **Proposed Engineers Without Borders Project on Technologies for non-PWS users**

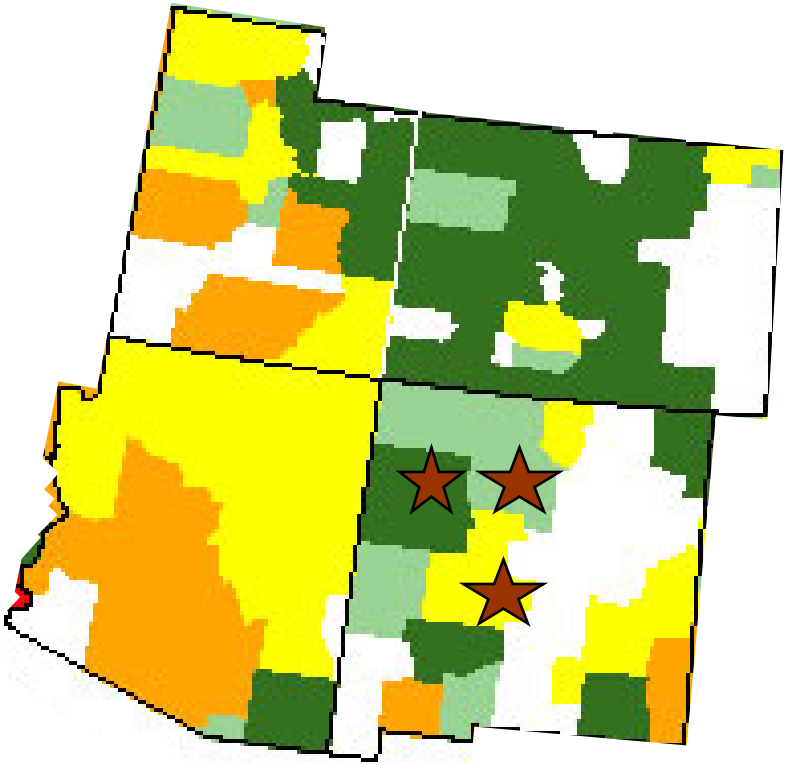
Sandia National Laboratories

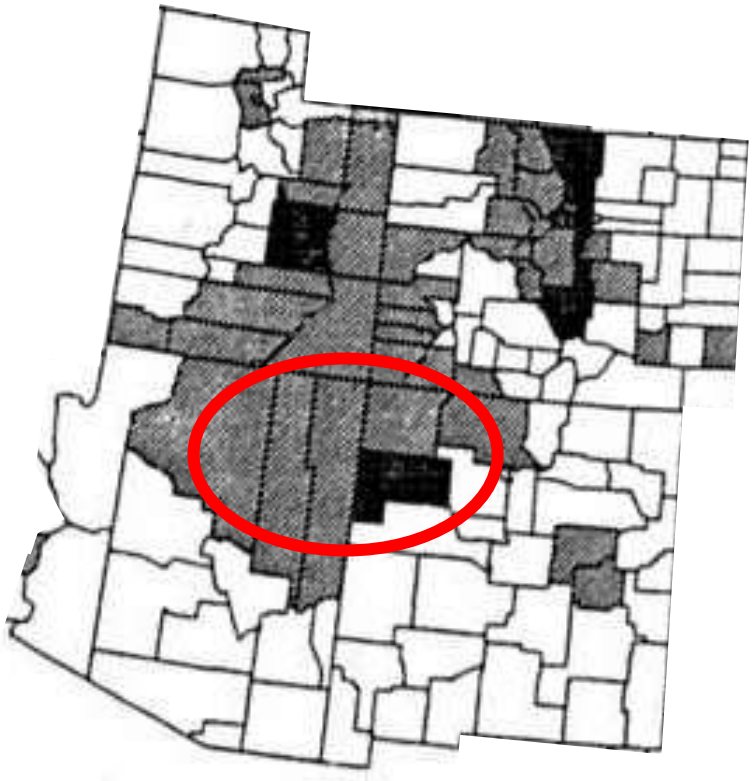
Arsenic and radionuclides in drinking water

- Southwestern United States is characterized by high and variable background levels for arsenic.
- Uranium and its radioactive daughters (radium and radon) are also high and variable in Southwest drinking water
- Health effects of concern:
  - As: bladder and lung cancer
  - Ra: bone sarcoma and head carcinoma
- Controversial standards due to uncertainty and high costs
- Systems that can remove several contaminants (e.g. arsenic and radium) will be most cost-effective for communities and should be considered when selecting technology for water treatment.

Sandia National Laboratories

Arsenic and radium in the Southwest





25% As

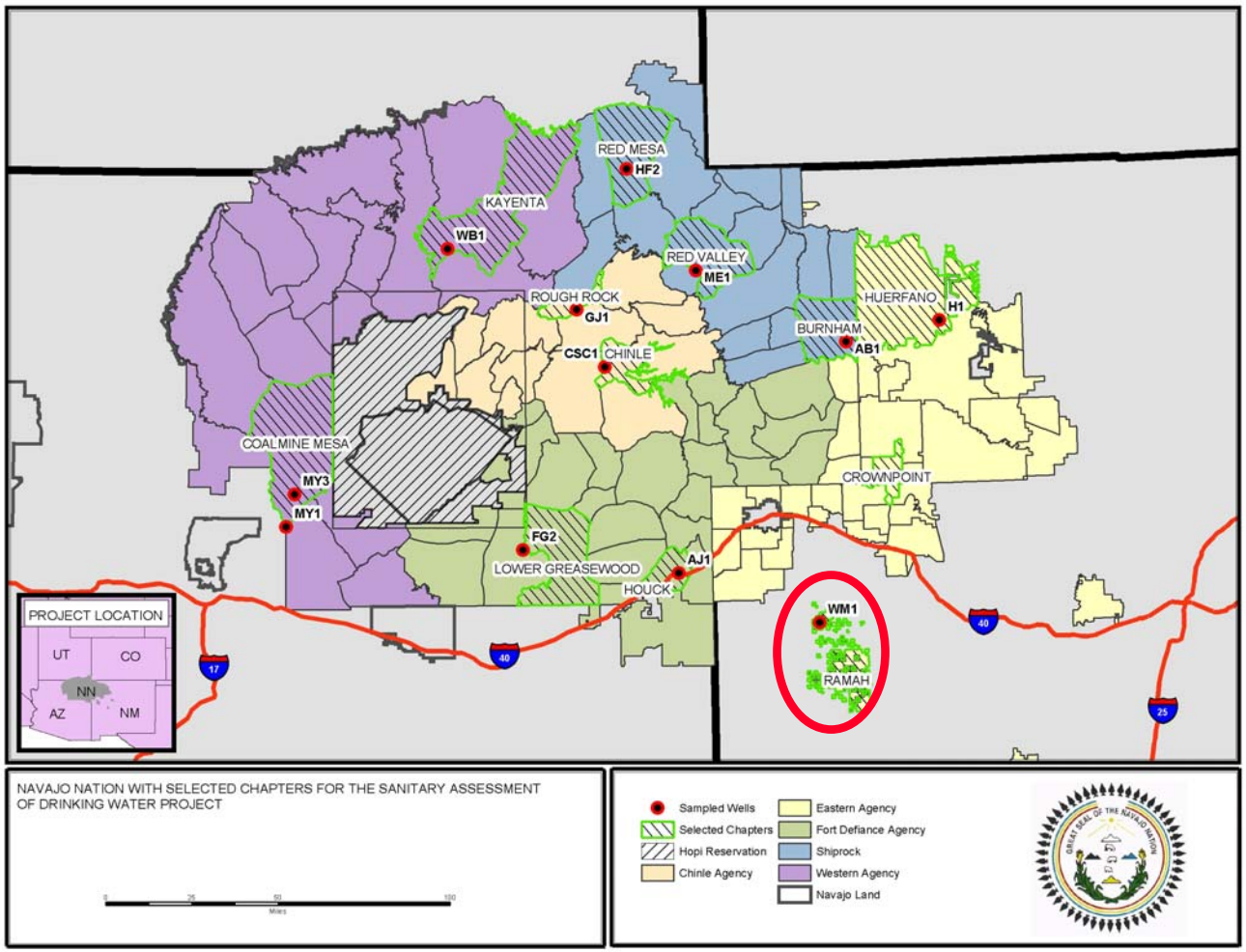
- 10 µg/L
- 5 µg/L
- 3 µg/L
- 1 µg/L

Ave. Ra

- >5 pCi/L
- 1-5 pCi/L
- <1 pCi/L

Sandia National Laboratories

Collaboration with Navajo Nation EPA



AWTP goal: "40% of resources directed to rural and Native American utility needs"

Sandia National Laboratories

Arsenic Occurrence in Drinking Water Sources on the Navajo Nation

- **Public Water Systems Supervision Program under Navajo Nation EPA regulates approx. 166 public water systems (PWSs)**
- **Water sources of approx. 22 PWSs (13%) exceed Arsenic MCL of 10 ppb; some are Community Water Systems (CWSs) others are Non-Transient Non-Community Water Systems (NTNCWSs)**
- **Over 30% of Navajo residents are not connected to PWSs. Most of them haul water from unregulated water sources which contain contaminants such as arsenic, uranium, coliform and pesticides**

Sandia National Laboratories

Outline

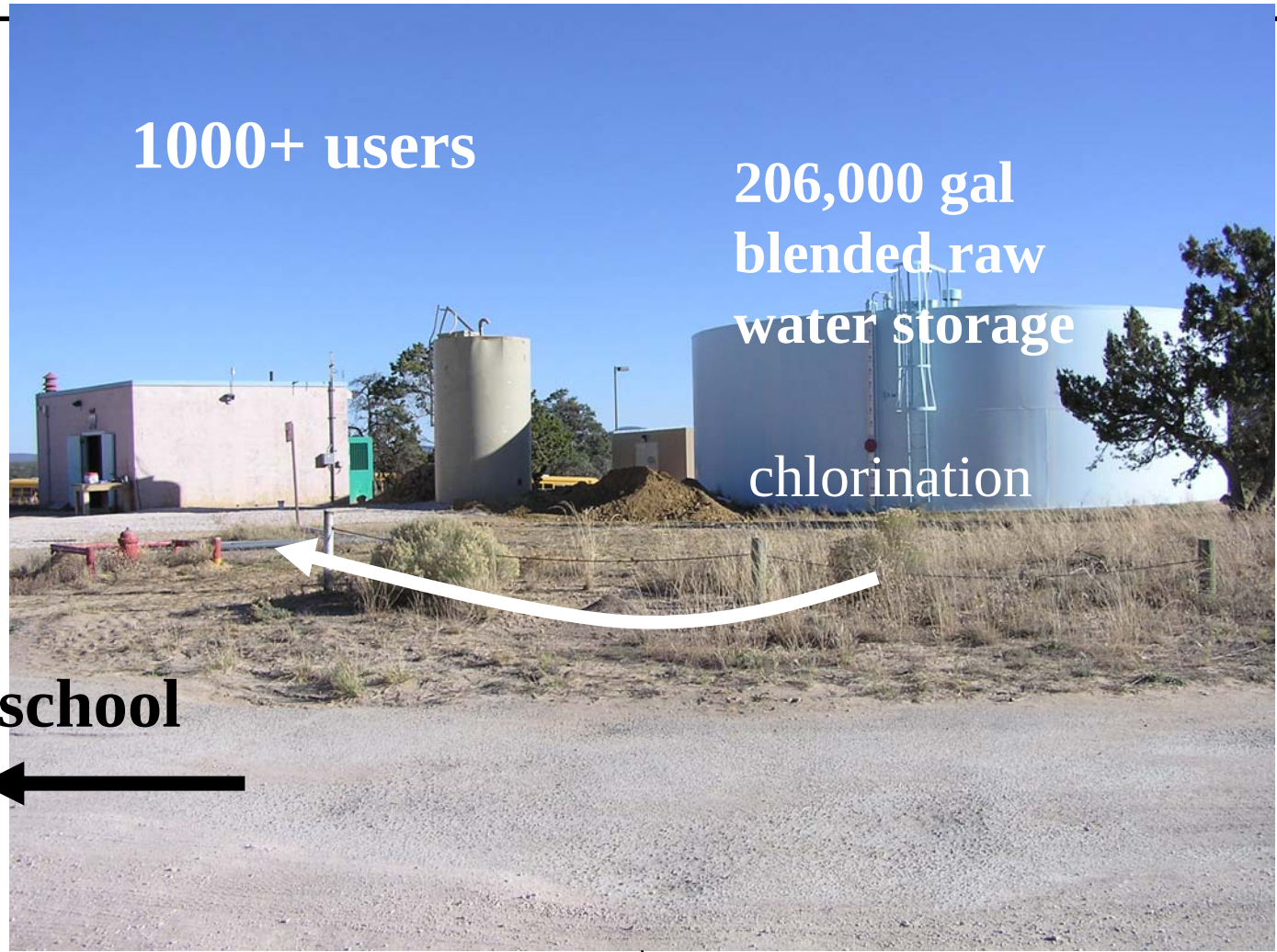
- Background:
  - Significance of multiple naturally-occurring contaminants in drinking water sources
- **Description of Pine Hill School site**
- Pilot Test
  - Objectives
  - Treatment technologies
  - Results
- Proposed Engineers Without Borders Project on Technologies for non-PWS users

Sandia National Laboratories

Pine Hill School, Ramah Navajo Reservation

Sandia National Laboratories

Pine Hill Water Treatment Plant



Sandia National Laboratories

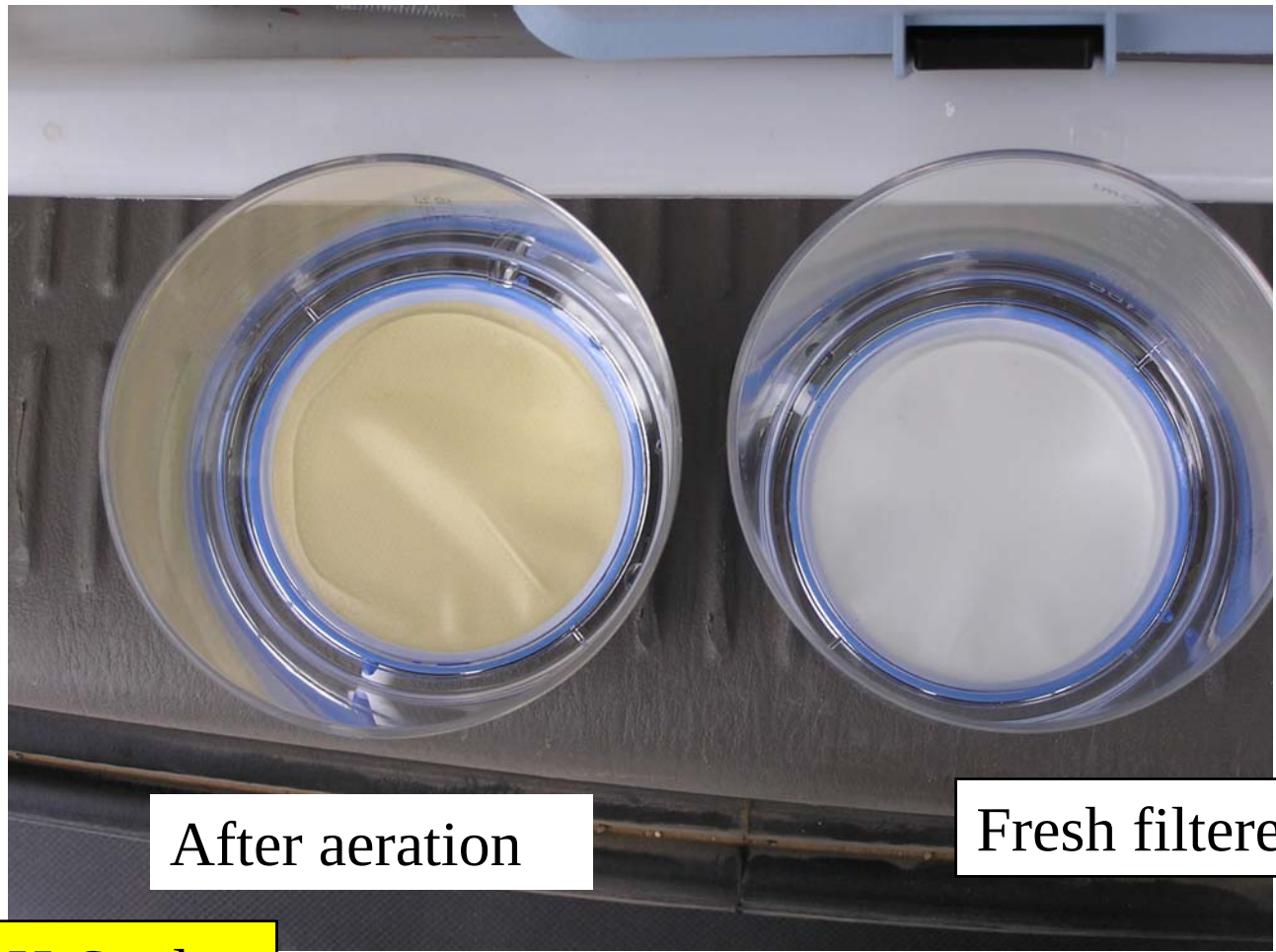
Pine Hill Water Quality

Red values exceed standards; (max) values shown

	Well #2	Standard
As (ppb)- about 85% as As(III)	30 (69)	10
Fe (ppm)	1.5	0.3
pH	7.8	NA
Gross alpha (^{230}Th pCi/L)	44.2 (103)	15
Gross beta (^{90}Sr pCi/L)	23.5	4 rem
Ra-226 (pCi/L)	12.0 (95)	Total = 5
Ra-228 (pCi/L)	2.3	
U (ppb)	2.9	30
SO_4^{2-}	302	250
Hardness as $CaCO_3$ ppm	146	NA

Sandia National Laboratories

Source water is unstable



Strong H_2S odor

Sandia National Laboratories

Current system: iron removal

disinfection/fluoridation

Ra > MCL

Softening removes Ra

← iron removal

Sandia National Laboratories

Outline

- Background:
  - Significance of multiple naturally-occurring contaminants in drinking water sources
- Description of Pine Hill School site
- Pilot Test
  - Objectives
  - Treatment technologies
  - Results
- Proposed Engineers Without Borders Project on Technologies for non-PWS users

Sandia National Laboratories

Objectives of Test

- **Naturally-occurring radium in treated Pine Hill water supply above regulatory standards causes shut down of Well #2.**
  - **Arsenic in well exceeds new MCL**
  - **Community wanted to treat unblended water from the well for future growth and backup.**
- **Sandia National Labs (SNL) proposed to test innovative treatment technologies to augment or replace the current system at Pine Hill.**
  - **Results of test will help community choose new treatment system.**

Sandia National Laboratories

Additional Test Objectives

- Challenge adsorptive media with As(III)
- Compare adsorptive media to Coag/filtration
- Evaluate rapid low-cost analytical techniques for analysis of radionuclides at low levels relevant to regulations
  - 3M Empore disks for radium analysis
  - Compare results to EPA-certified lab (GEL)
- Identify potential technologies of Point-of-Use systems for population not on PWS in Pine Hill (36%) and remote parts of reservation (30%)

Sandia National Laboratories

Selected Technologies

- **McPhee/Purolite**
  - **Two ion exchange resins for separate removal of arsenic and radium**
- **Calgon Carbon**
  - **CalMedia ™ GSR Plus synthetic granular manganese dioxide coated filter media**
    - **Addition of iron and manganese to assist in removal**
    - **Filter removes Fe, Mn, As, Ra and U**
    - **Backwash to sewer**
- **None of the treated water is returned to the distribution system from the pilot**

Sandia National Laboratories

NSF/ANSI 61 Certified Material Used in Tests

Calgon CalMedia GSR Plus

ArsenX^{np}

As sorption onto Fe-oxide floc; Ra sorption onto Mn oxide floc

As sorption by nano-Fe-oxide in resin

3 resins for Ra

Sandia National Laboratories

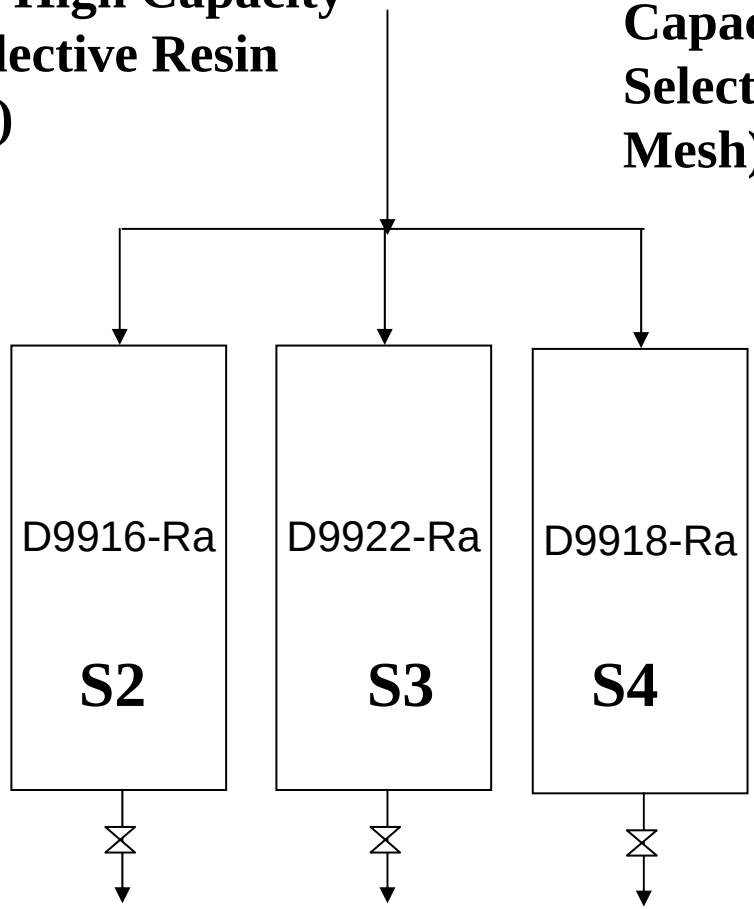
Pilot Treatment Shed and Storage Tank Supplied by Pine Hill School Facilities

Sandia National Laboratories

Test of Three Resins for Radium Removal

D9916 RS - High Capacity Radium Selective Resin (Single Use)

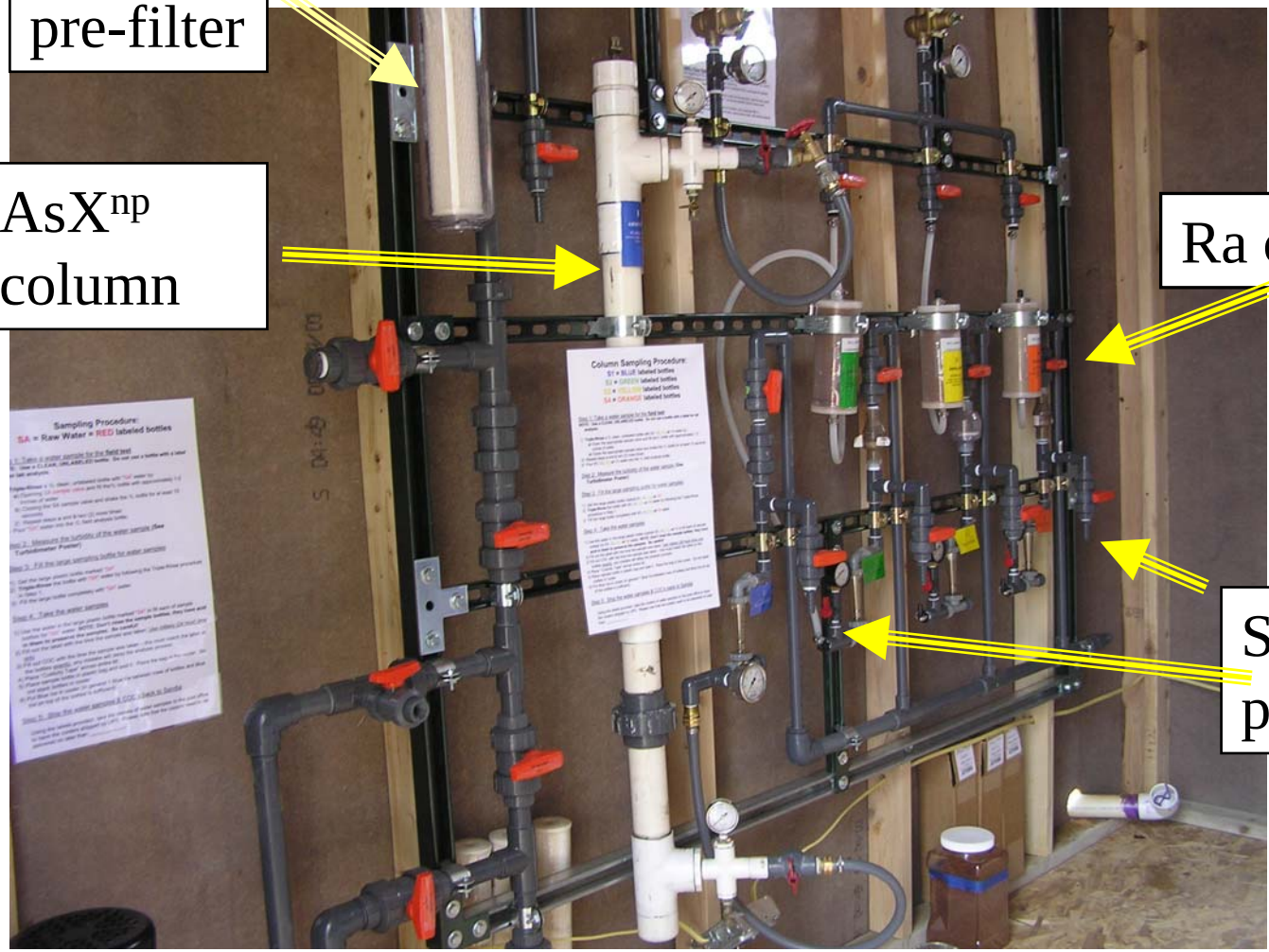
D9922 FM - High Capacity Radium Selective Resin (Fine Mesh) (Regenerable)



D9918-Ra - Shell-Core Resin - Radium/Hardness Removal (regenerable)- "Control"

Sandia National Laboratories

SNL Adsorptive media skid



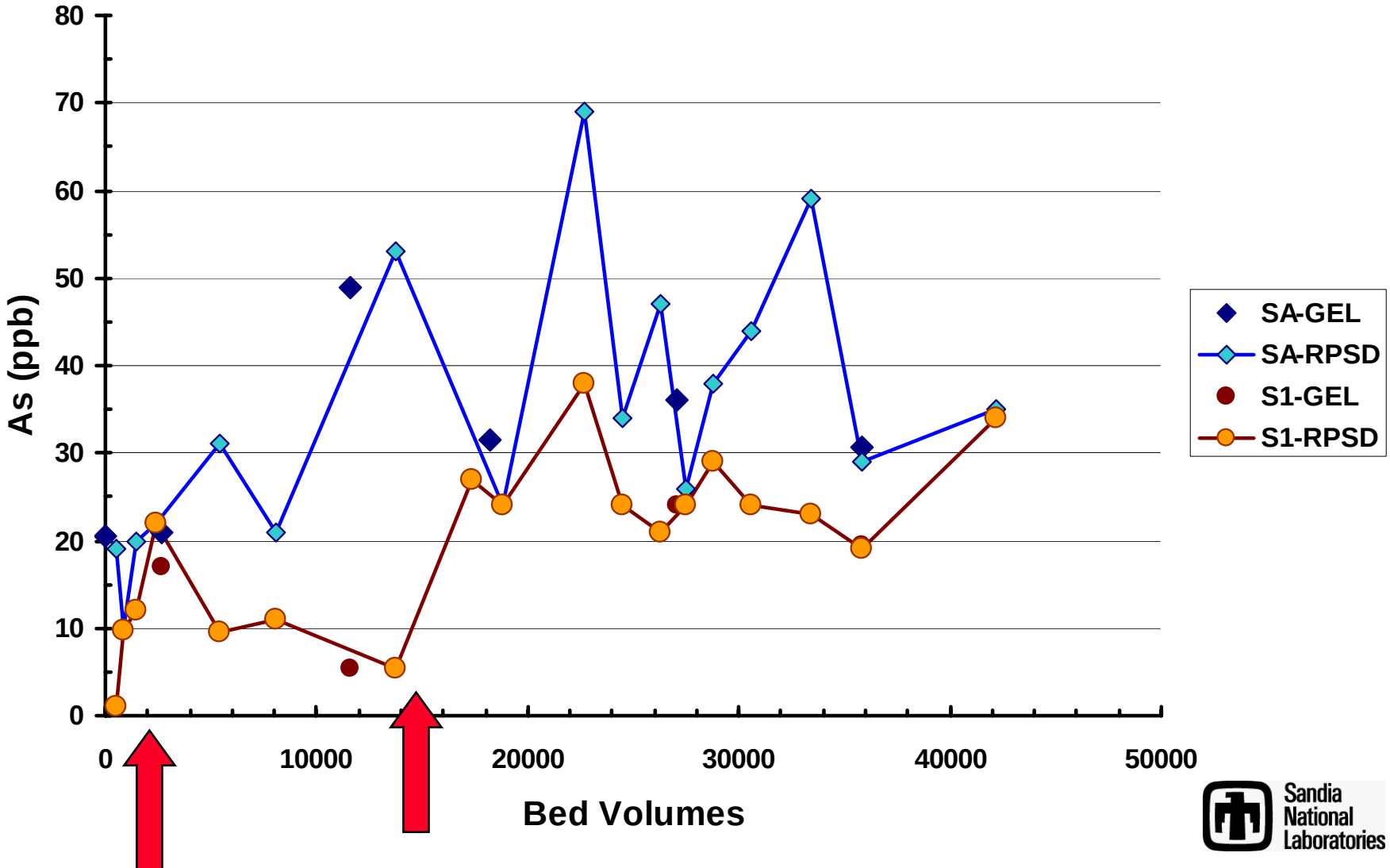
Sandia National Laboratories

Outline

- Background:
  - Significance of multiple naturally-occurring contaminants in drinking water sources
- Description of Pine Hill School site
- Pilot Test
  - Objectives
  - Treatment technologies
  - **Results**
- Proposed Engineers Without Borders Project on Technologies for non-PWS users

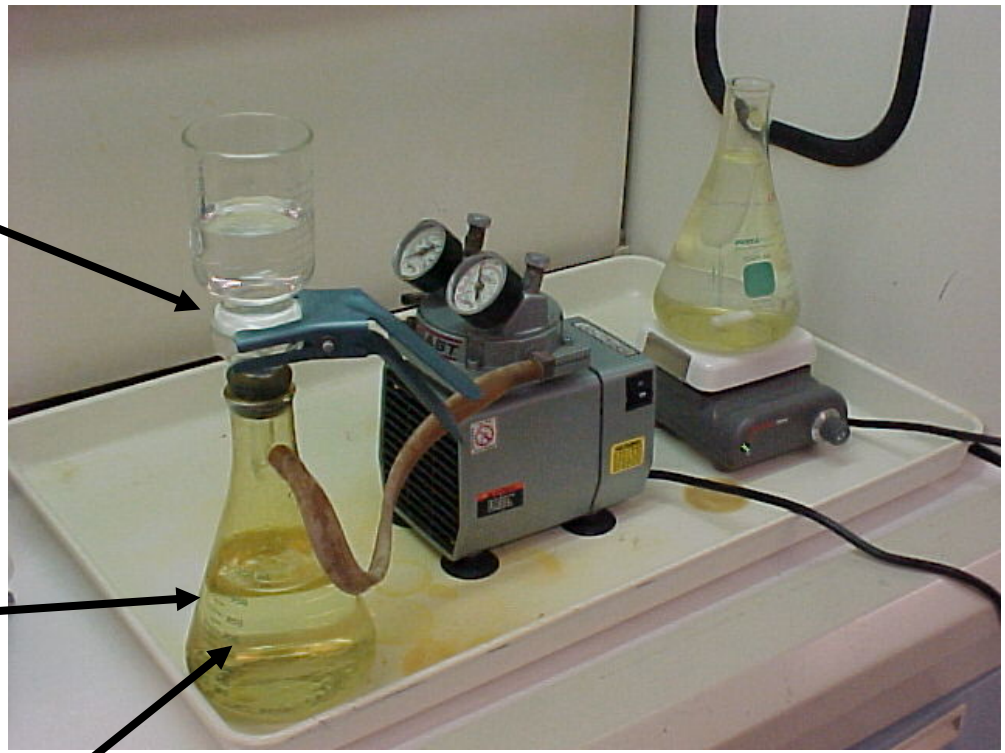
Sandia National Laboratories

Removal of Arsenic by AsX^{np}



Sandia National Laboratories

Semi-quantitative Radium Analysis (RPSD)



3M Empore Radium Rad Disk

1L sample, 2M HNO3

1L sample + ^{226}Ra standard

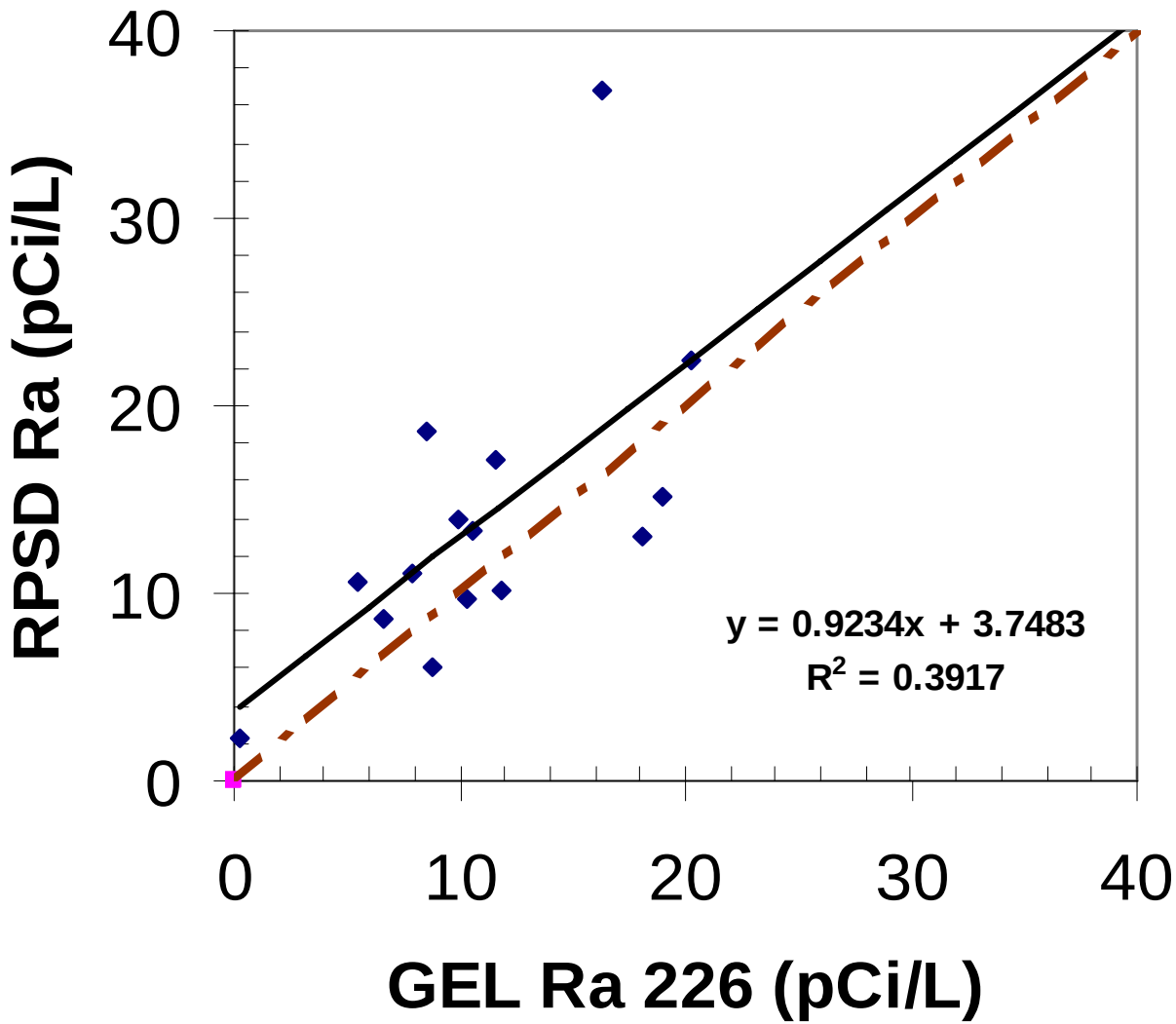
Place filter on planchet and dry in oven

Count samples for 100 minutes in GPC

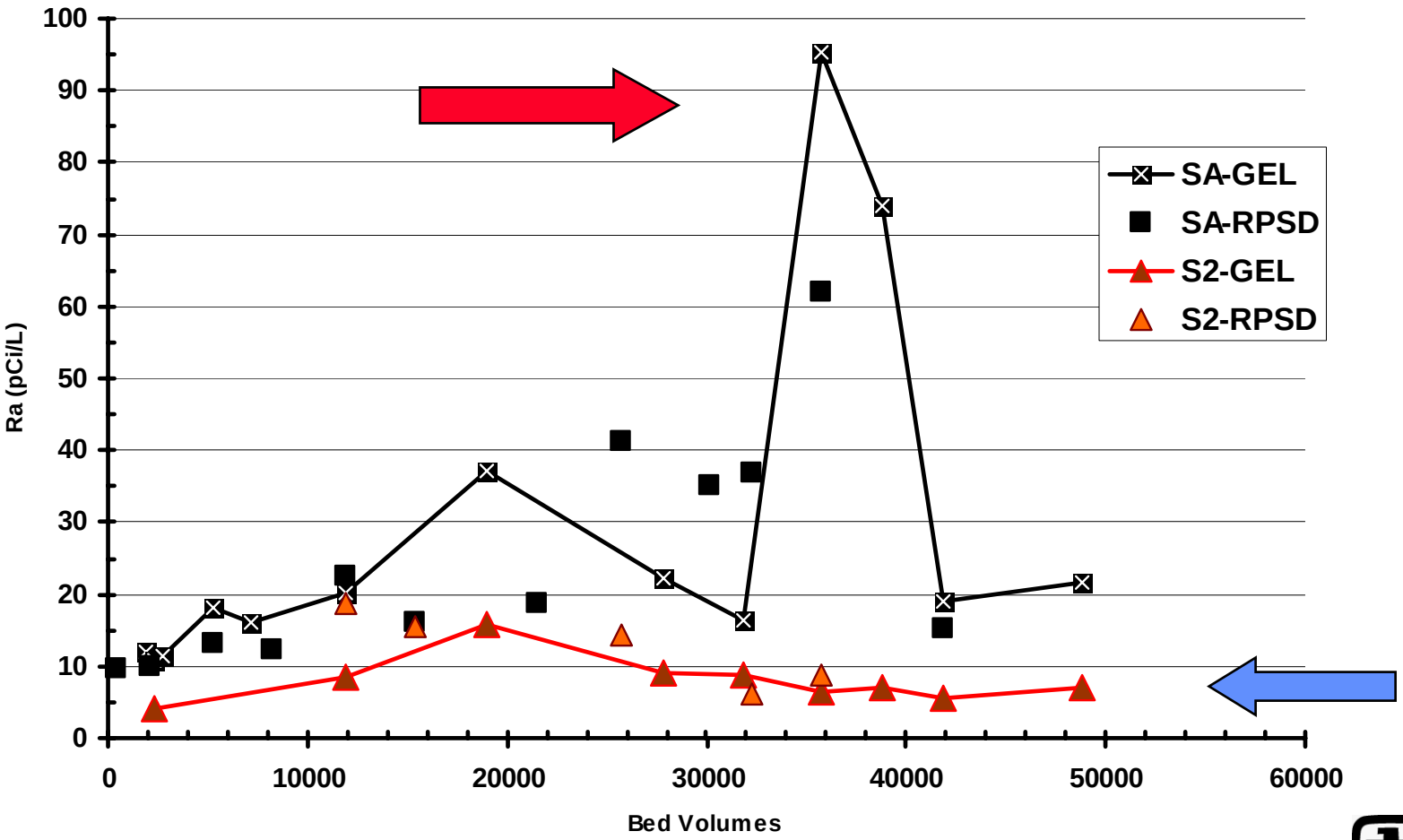
Correct for % recovery and elapsed time

Sandia National Laboratories

Correlation Between GEL Ra-226 and 3M Ra-226

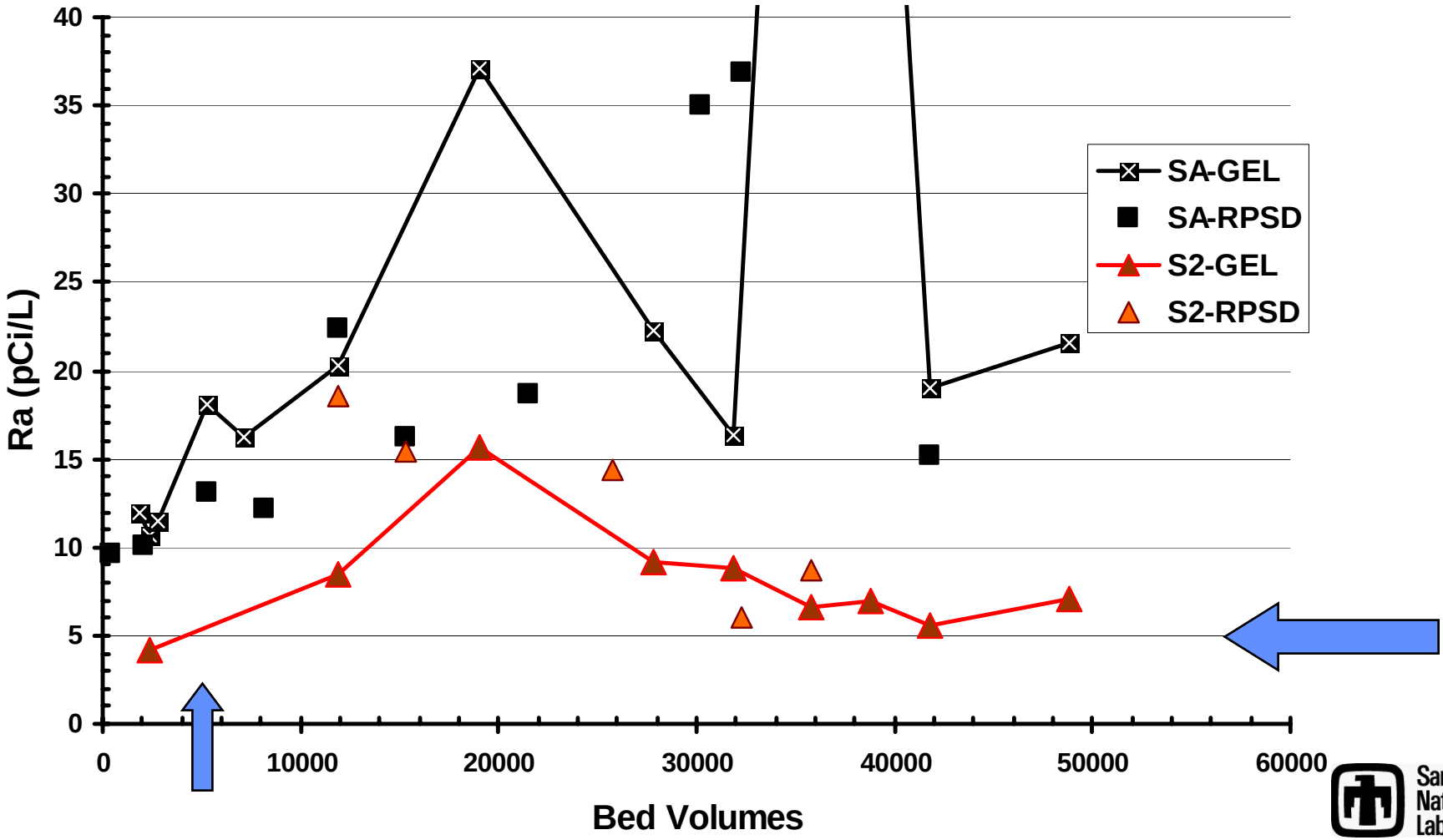


Ra-226 removal with D9916-Ra high-capacity single-use resin



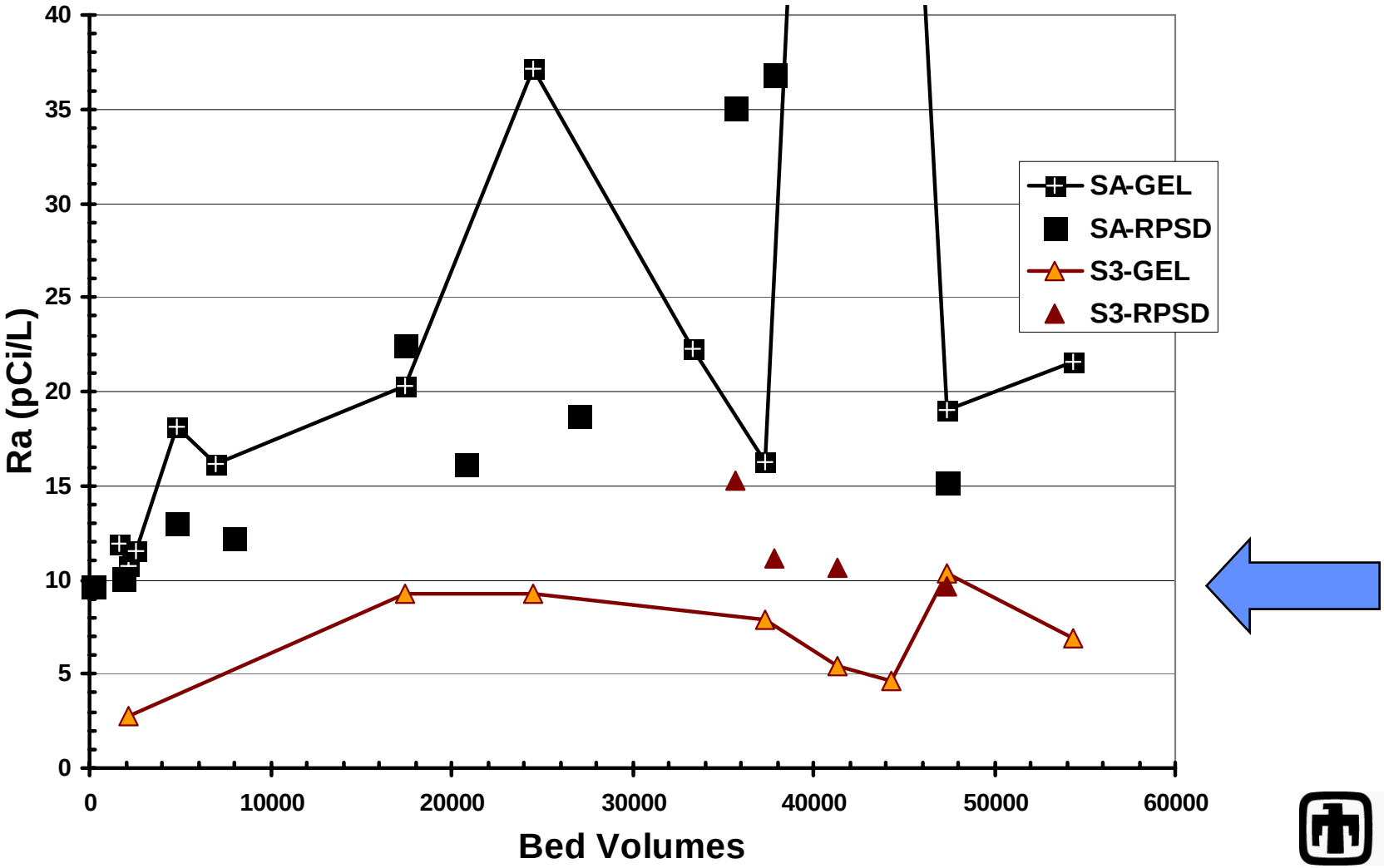
Sandia National Laboratories

D9916-Ra high-capacity single-use resin (detail)



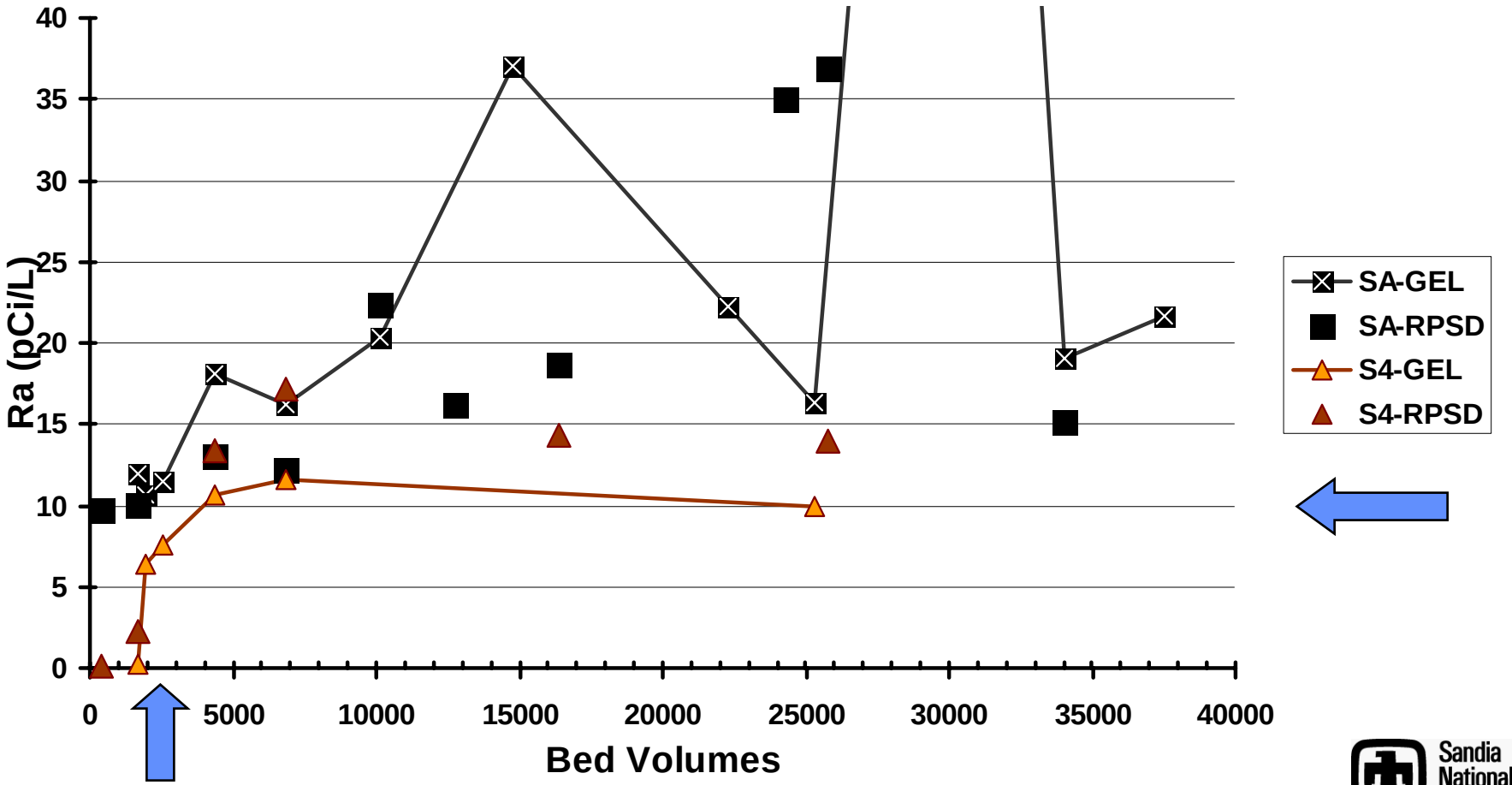
Sandia National Laboratories

Ra-226 removal with D9922-Ra high-capacity regenerable resin



Sandia National Laboratories

Ra-226 removal with D9918-Ra shell-core hardness resin (control)



Sandia National Laboratories

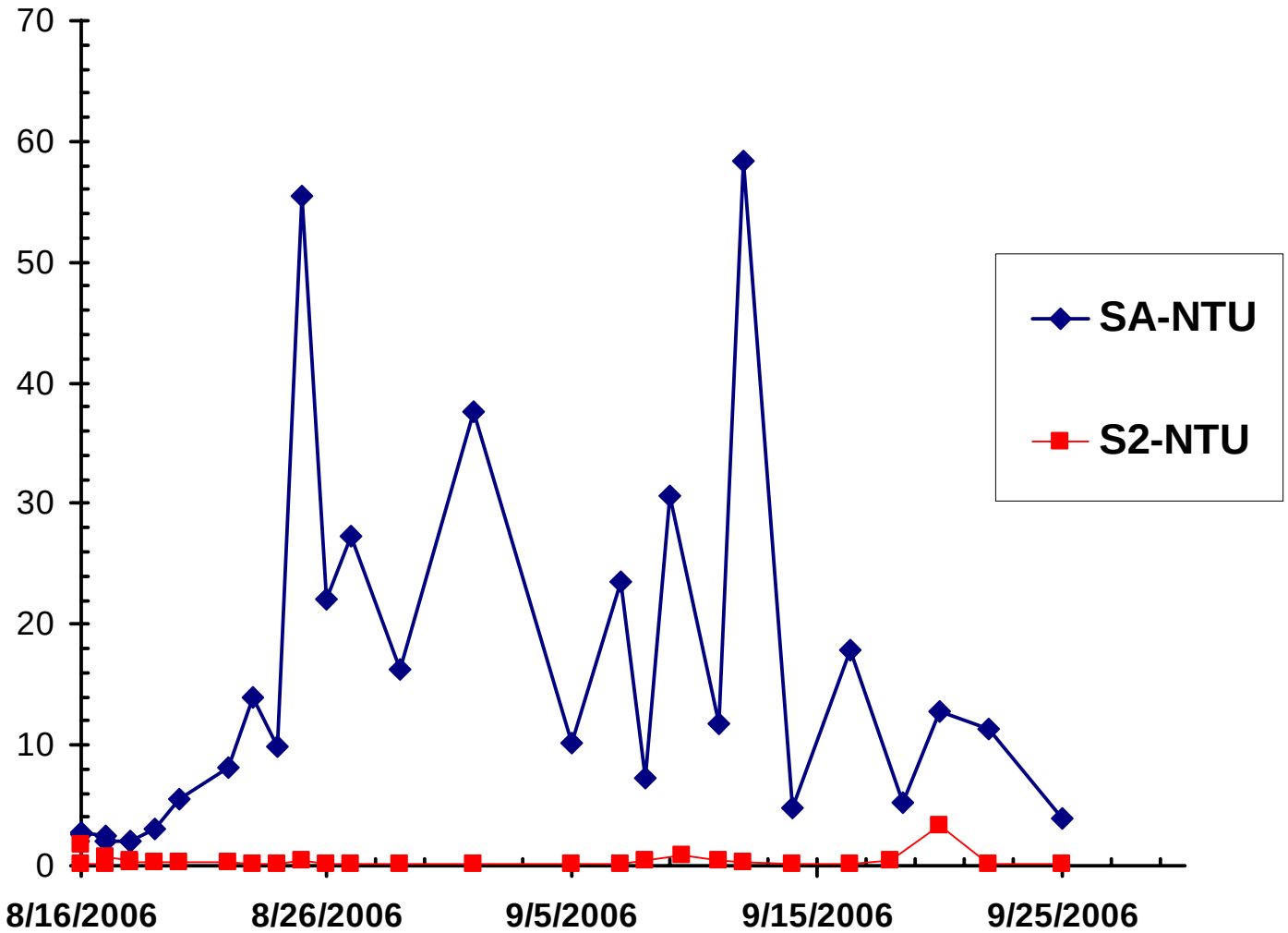
Summary of Performance of Media: BV to breakthrough

Treatment Column

COC	MCL	AsX^{np}	9916	9922	9918
As	10 μg/L	<19000	NA	NA	NA
Note	AsX^{np} needed 8K BV break-in period for arsenic.				
^{226}Ra	5 pCi/L	NA	<12000	<18000	<3000
Note	High capacity resins Ra-226 removed to below 10 pCi/L for > 50KBV.				

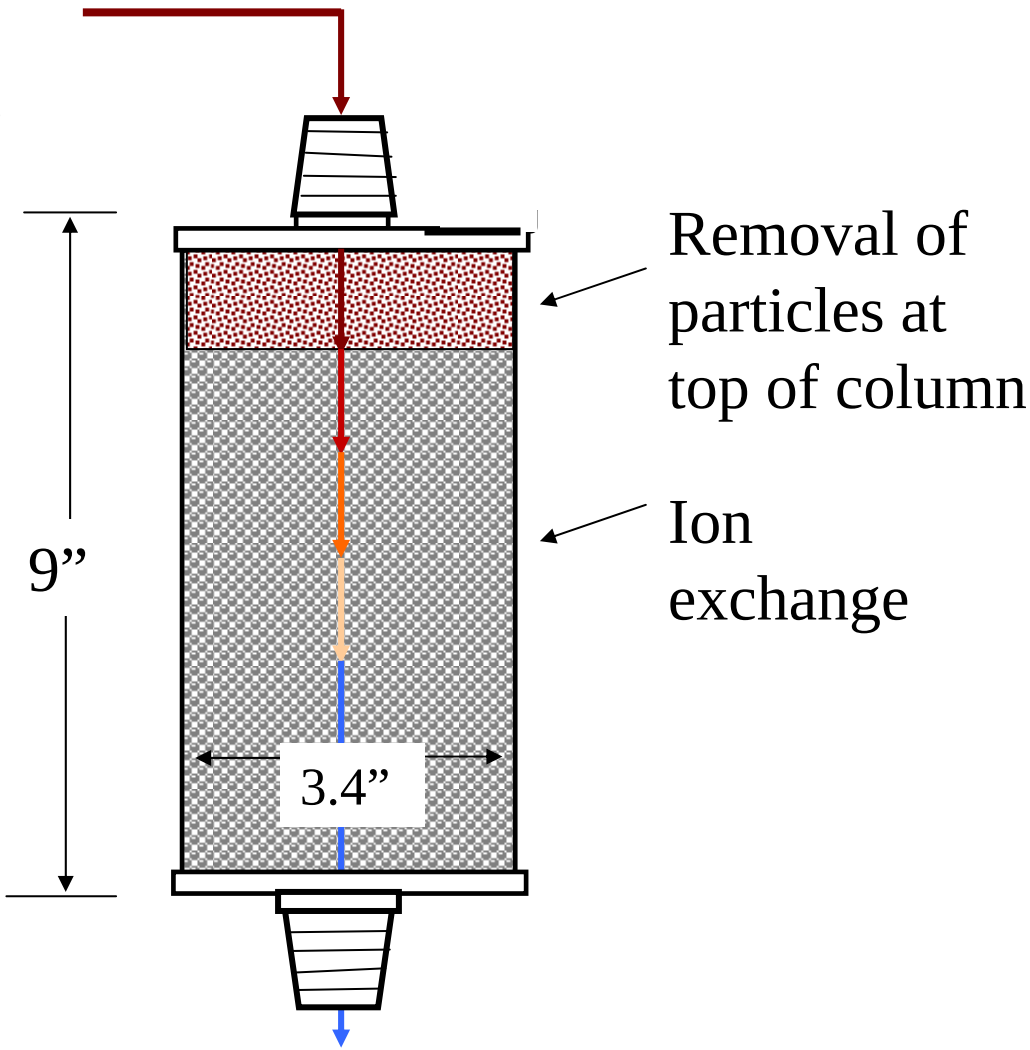
Sandia National Laboratories

Turbidities of influent and treated waters



Sandia National Laboratories

Removal of Contaminants by Filtration and Sorption



Radium columns

Sandia National Laboratories

Outline

- Background:
  - Significance of multiple naturally-occurring contaminants in drinking water sources
- Description of Pine Hill School site
- Pilot Test
  - Objectives
  - Treatment technologies - Calgon
  - Results
- Proposed Engineers Without Borders Project on Technologies for non-PWS users

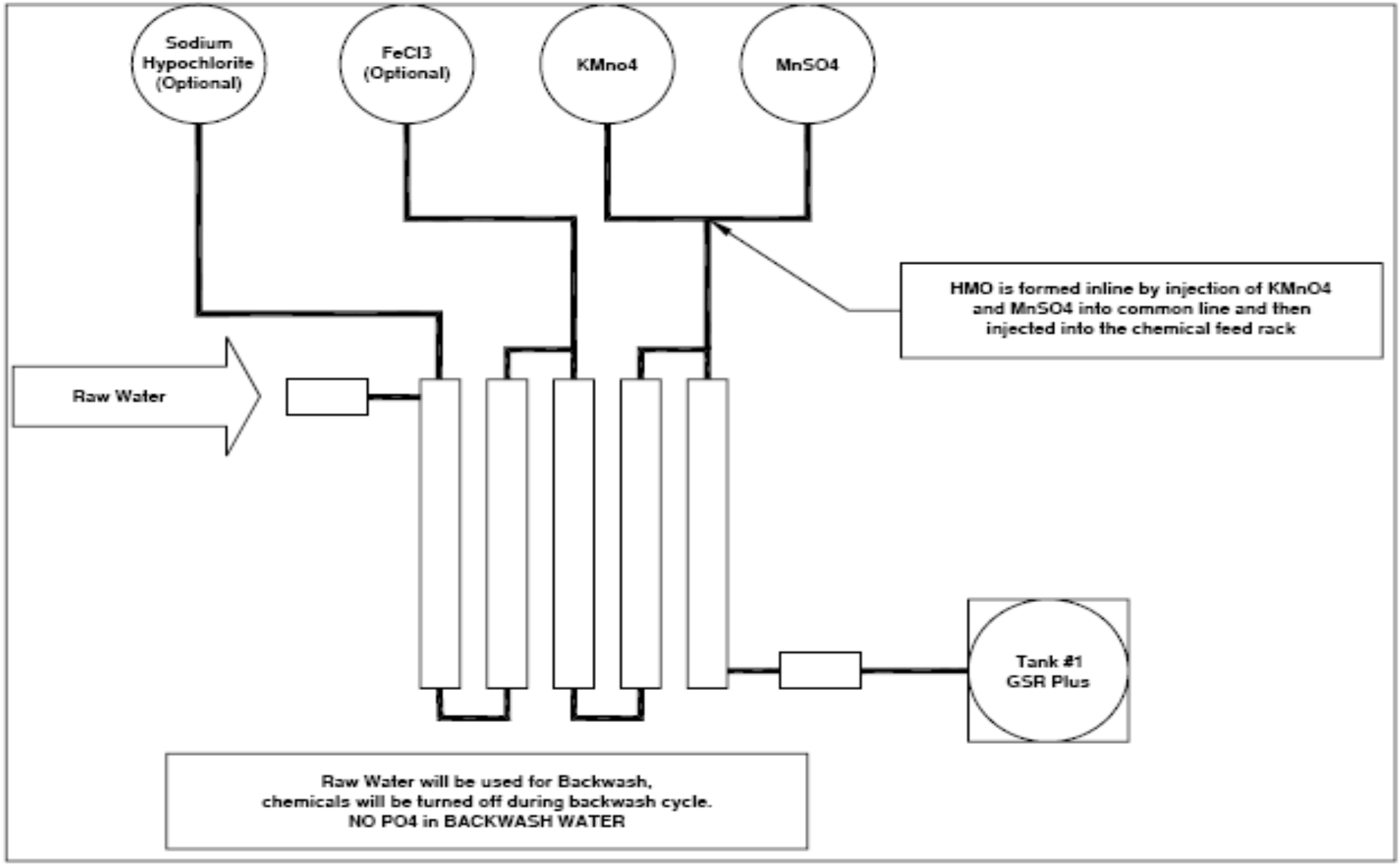
Sandia National Laboratories

Calgon Carbon Pilot System

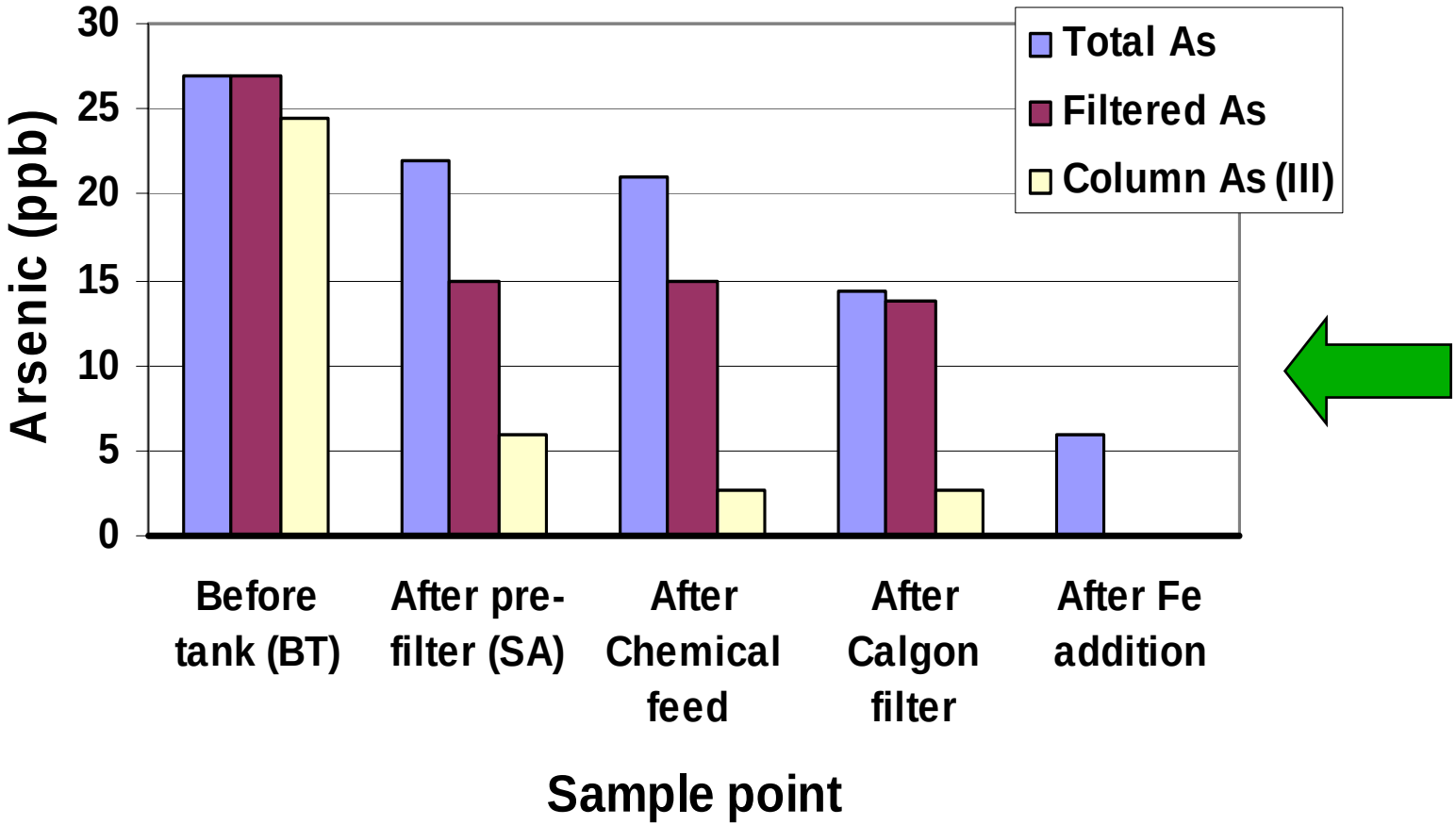
Oxidation/filtration system

Sandia National Laboratories

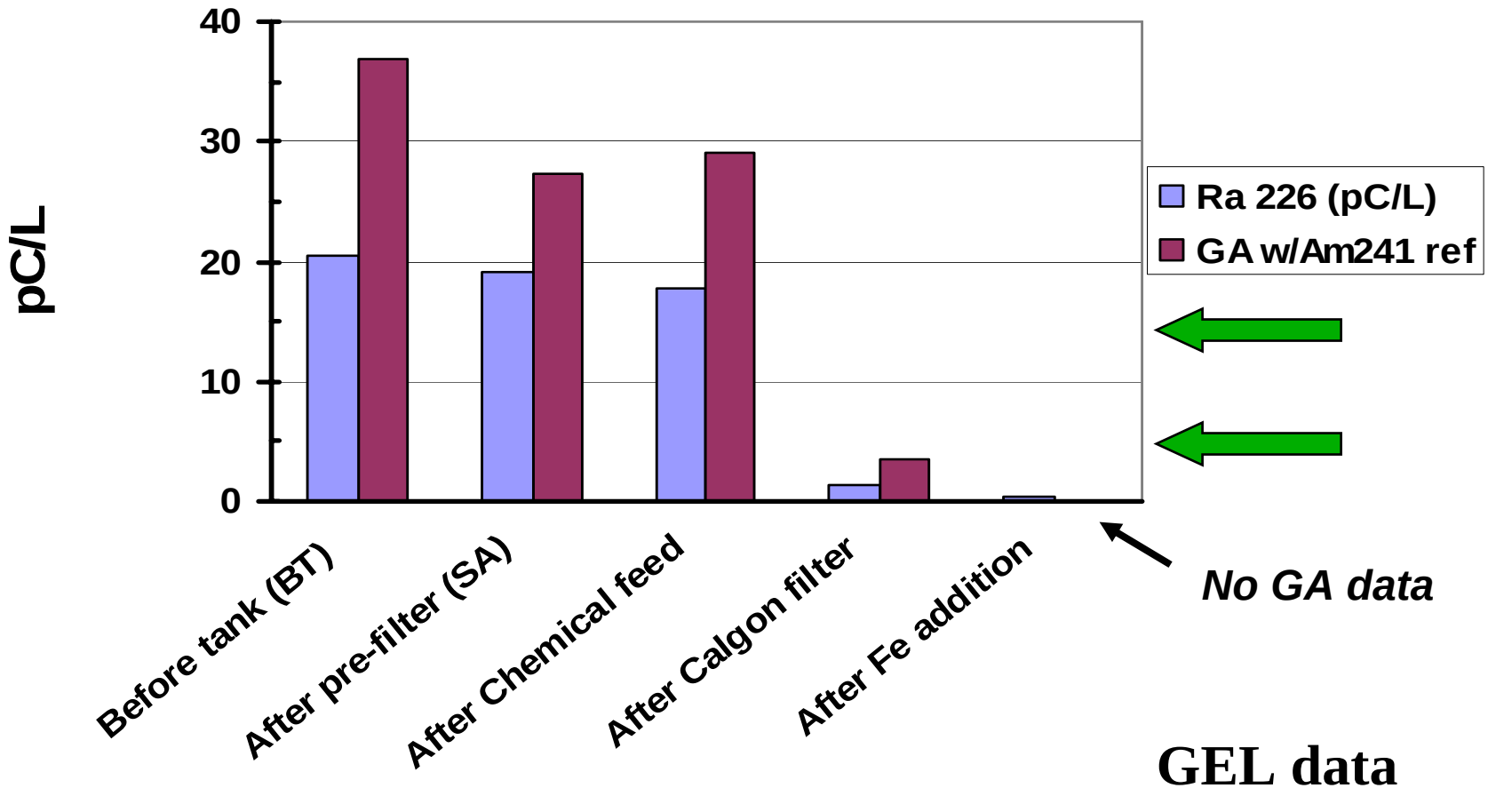
Calgon Carbon System



Removal of arsenic by Calgon Process

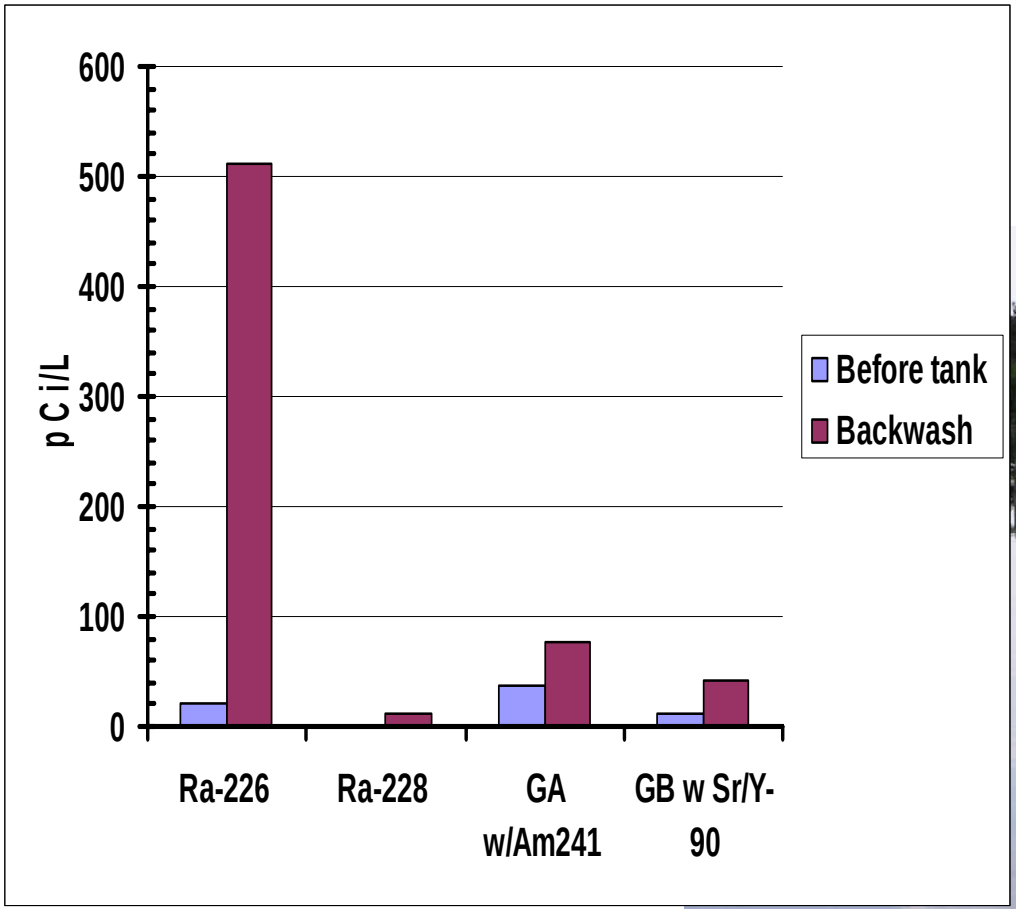


Removal of radionuclides by Calgon Process



GEL data

Backwash analysis



Pine Hill Sewage Lagoon

Tribal concerns about disposal

Summary of Test Results

- **Composition of influent water variable and dominates column performance**
  - **May reflect changes in source water during intermittent pumping cycle**
  - **May reflect changes in storage tank**
- **Resins were not effective for As and Ra removal in “low-tech” mode**
  - **No pre-chlorination**
  - **No-prefilter**
  - **Columns may need breaking in period.**

Sandia National Laboratories

Summary of Test Results (II)

- Low-cost radium analysis method good for screening.
- Coagulation-filtration system was successful
  - More complex, suitable for trained water system operators
  - Concerns about disposal of backwash
- Vendor of Reverse Osmosis systems has carried out short term test with NMRWA.
- Additional companies have expressed interest in pilot testing simple adsorption systems

Sandia National Laboratories

Outline

- **Background:**
  - **Significance of multiple naturally-occurring contaminants in drinking water sources**
- **Description of Pine Hill School site**
- **Pilot Test**
  - **Objectives**
  - **Treatment technologies**
  - **Results**
- **Proposed Engineers Without Borders Project on Technologies for non-PWS users**

Sandia National Laboratories

POU Technologies for Water Haulers

- **Nationwide, more than 36,000 tribal homes lack access to safe drinking water.**
  - **Over 30% of Navajo residents are not connected to PWSs, and many haul water from unregulated water sources.**
    - **arsenic, uranium, coliform and pesticides**
  - **New 10 ppb MCL for arsenic led to increase in systems out of compliance with SDWA.**
- **Water hauling imposes large financial burden on affected families.**
  - **5% of average household income ($1000)**
  - **NM Region 6 estimate: “up to $22,500/yr”.**
- **Can innovative point-of-use technologies be applied in areas not served by PWS on Tribal Lands?**

Sandia National Laboratories

Unregulated Water Sources on Navajo Reservation

Need is well-recognized; but no funds to address it!

Box Spring

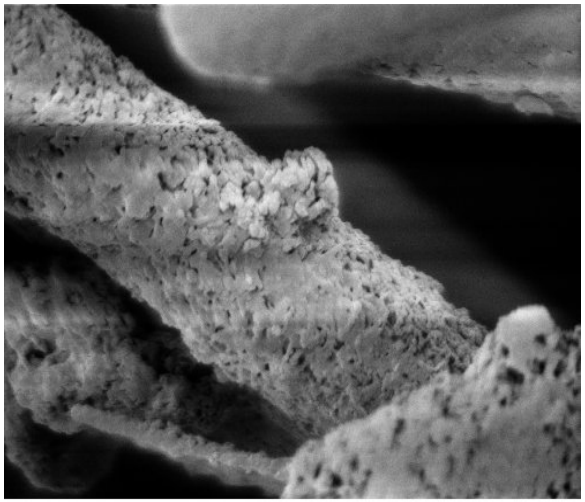
Proposals for Engineers (EWB) Without Borders Projects

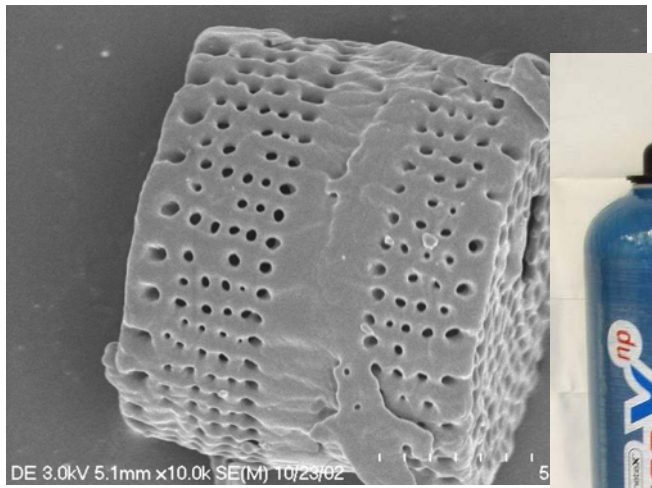
- **Expand existing water treatment project on Ramah Navajo Reservation**
  - **Pilot test additional technologies at experimental facility**
  - **Education program at Pine Hill School**
- **Point- of-Use Treatment Technologies for Water Haulers**
  - **Sample water sources to identify treatable sources**
  - **Workshop involving agencies and vendors**
  - **Demonstrate Low-tech and nano- technologies**

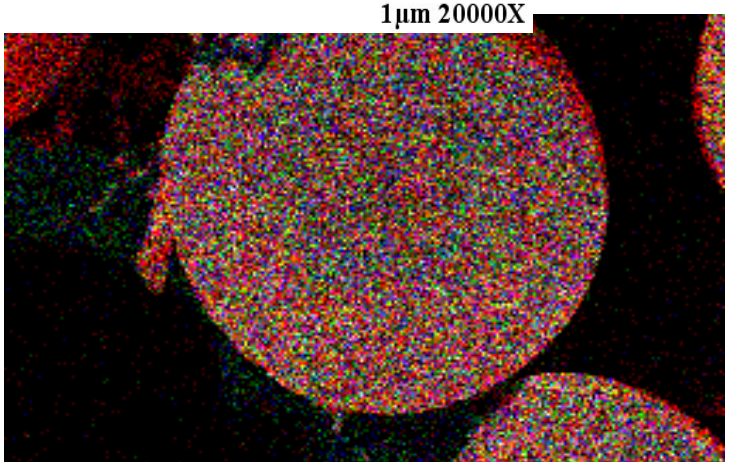
EWB looking for corporate sponsors for projects.

Sandia National Laboratories

Treatment Using Engineered Nanotech Materials

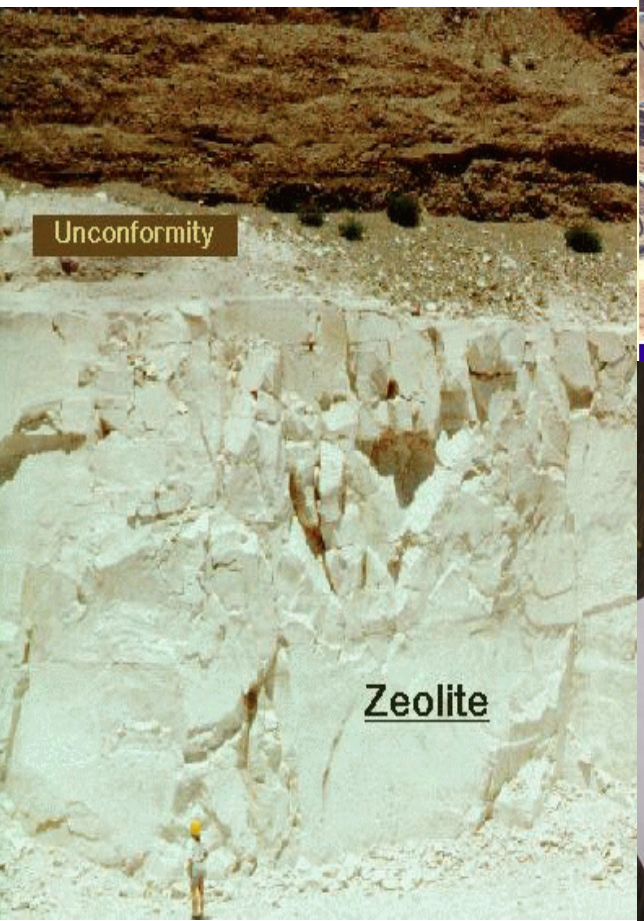






Sandia National Laboratories

Treatment using low-cost materials



Sandia National Laboratories

Summary

- **Pine Hill water presents challenges to conventional treatment technologies:**
  - **Hardness, radioactivity, As(III), hi Fe(II)**
  - **Arsenic, radium and sulfate levels are above regulatory standards.**
- **Collaboration between Sandia National Labs, Pine Hill Facilities and NNEPA provides basis for testing innovative treatment technologies to augment the current system.**
  - **Test designed to identify best commercially available technologies.**
- **Results may be applicable to other water systems with multiple contaminants**
  - **Desire to find technologies that can be used in POU applications in non-PWS in Navajo Nation.**
  - **EWB looking for corporate sponsors to work on Reservation**

Sandia National Laboratories

- **Thank you for your interest.**
- **Project website**

http://www.sandia.gov/water/arsenic.htm

- **Questions?**

Sandia National Laboratories