



# **Removal of Arsenic and Radium Pine Hill School Ramah Navajo Reservation**

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# Acknowledgements

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- **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 Zigmund, Jen Ashley, Pam Puissant, (SNL lab)**
- **Pat Brady, Richard Kottenstette (SNL PM)**
- **Arsenic Water Technology Partnership (SNL, AwwaRF, WERC)**



# Outline

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- **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**

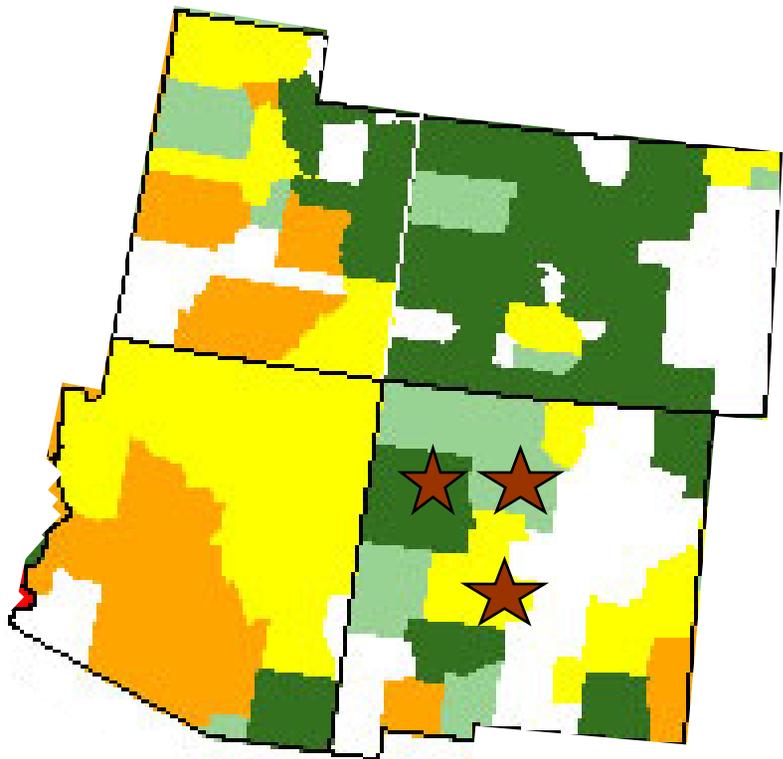


# **Arsenic and radionuclides in drinking water**

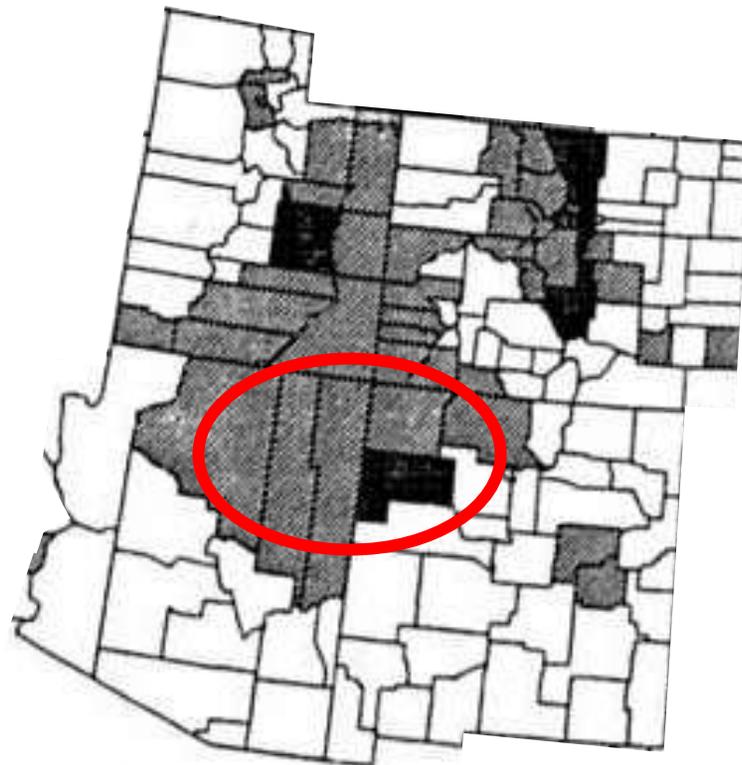
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- **Southwestern United States is characterized by high and variable background levels for arsenic.**
- **Uranium and its radioactive daughters (radium and radon) are also high and variable in Southwest drinking water**
- **Health effects of concern:**
  - **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.**

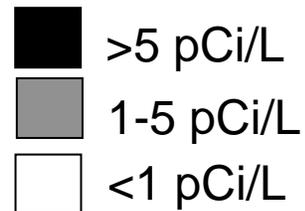
# Arsenic and radium in the Southwest



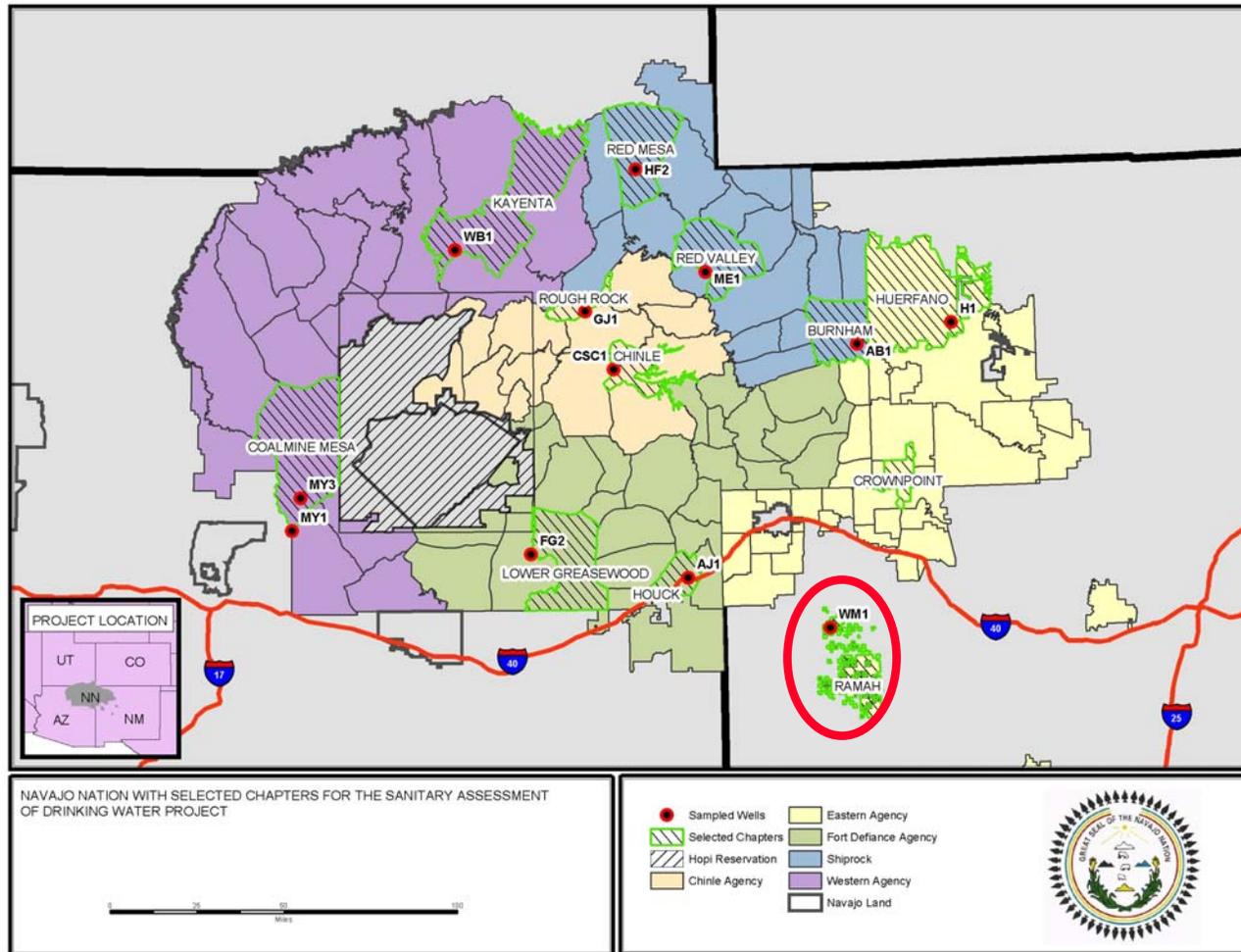
25% As



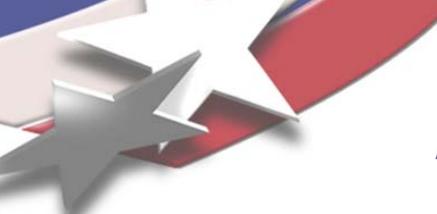
Ave. Ra



# Collaboration with Navajo Nation EPA



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



# Arsenic Occurrence in Drinking Water Sources on the Navajo Nation

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- **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**

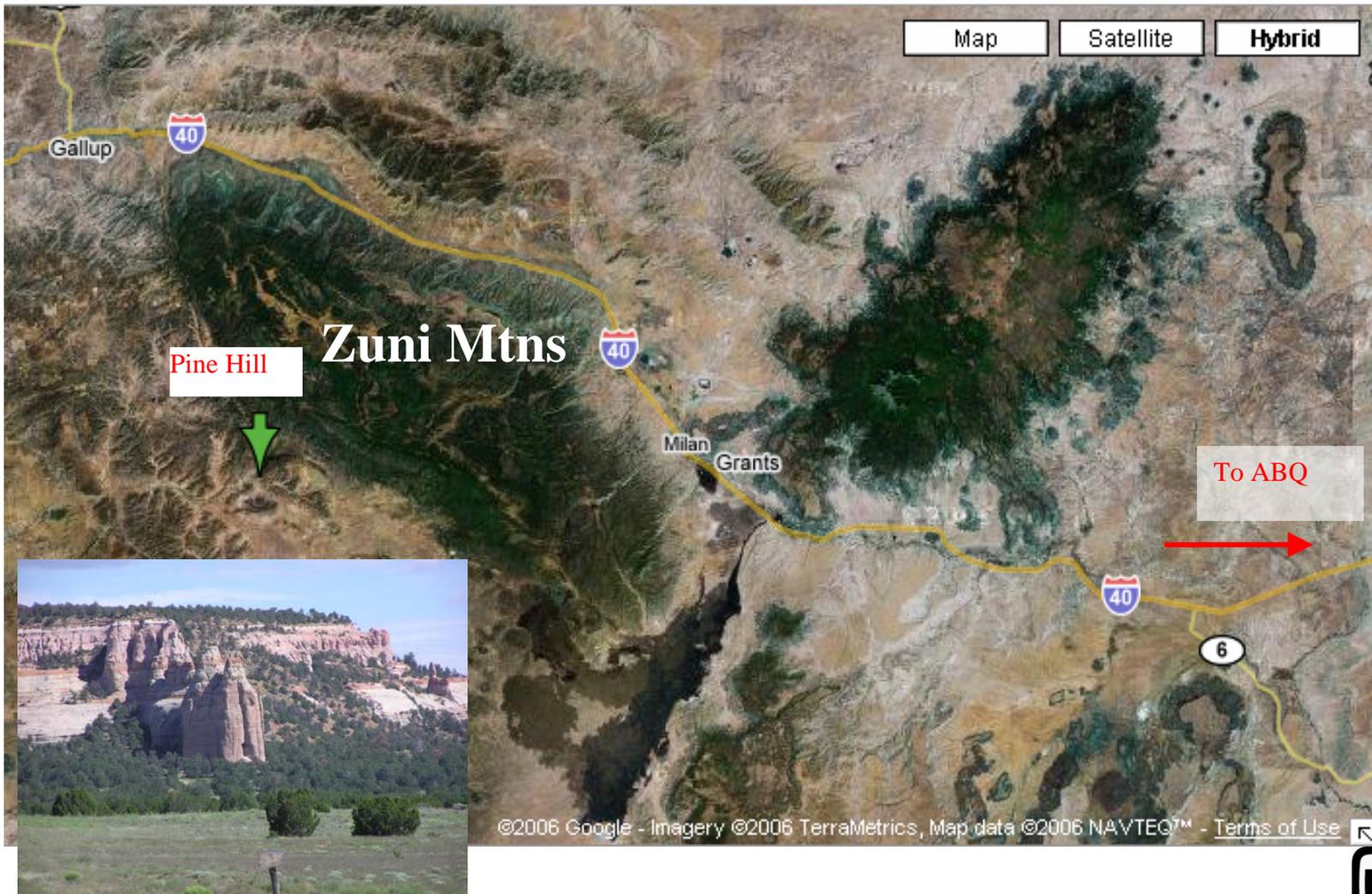


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  - Significance of multiple naturally-occurring contaminants in drinking water sources
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# Pine Hill School, Ramah Navajo Reservation



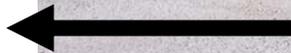
# Pine Hill Water Treatment Plant

1000+ users

206,000 gal  
blended raw  
water storage

chlorination

school



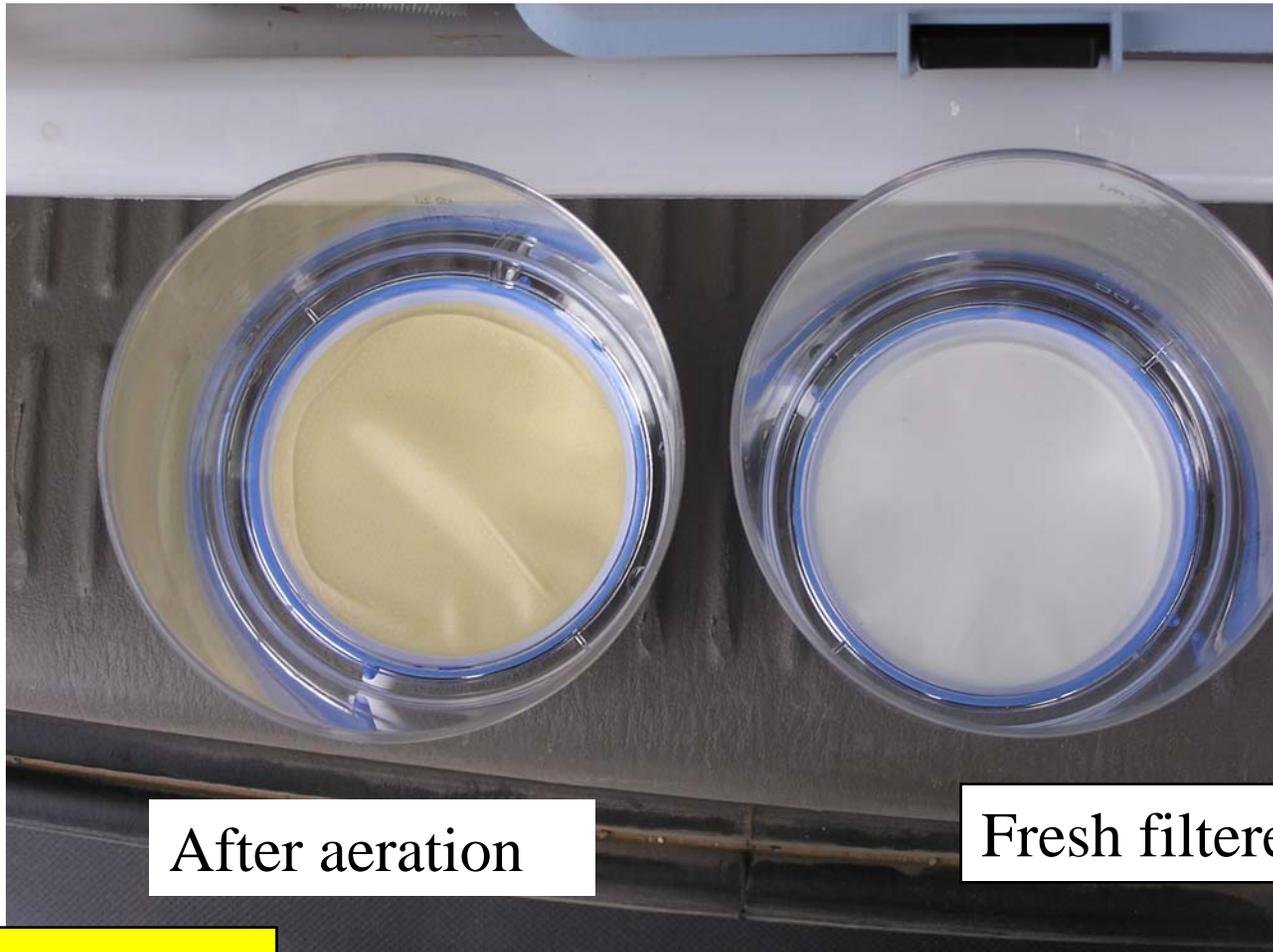


# Pine Hill Water Quality

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 ( $^{230}\text{Th}$ pCi/L)	44.2 (103)	15
Gross beta ( $^{90}\text{Sr}$ 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
$\text{SO}_4^{2-}$	302	250
Hardness as $\text{CaCO}_3$ ppm	146	NA

# Source water is unstable



After aeration

Fresh filtered

Strong H<sub>2</sub>S odor

# Current system: iron removal



**disinfection/fluoridation**

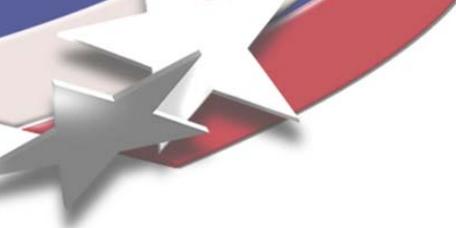


**Ra > MCL**

**Softening  
removes Ra**



**← iron removal**



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# Objectives of Test

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- **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.**



# Additional Test Objectives

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- **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%)**



# Selected Technologies

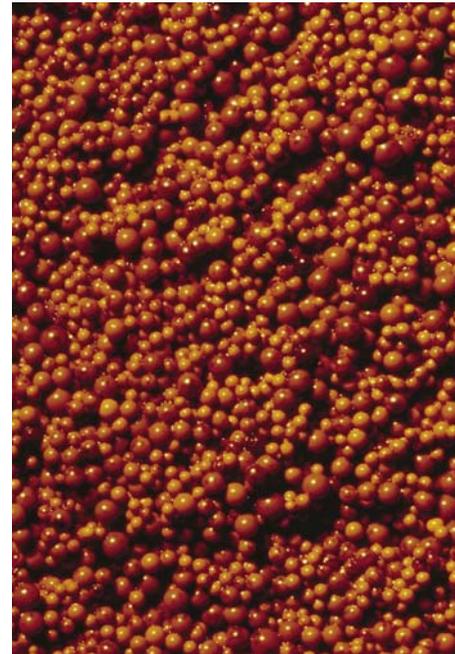
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- **McPhee/Purolite**
  - Two ion exchange resins for separate removal of arsenic and radium
- **Calgon Carbon**
  - **CalMedia™ GSR Plus synthetic granular manganese dioxide coated filter media**
    - Addition of iron and manganese to assist in removal
    - 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**

# NSF/ANSI 61 Certified Material Used in Tests



Calgon CalMedia GSR Plus



ArsenX<sup>np</sup>

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

As sorption by nano-Fe-oxide in resin

3 resins for Ra

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



Water flow

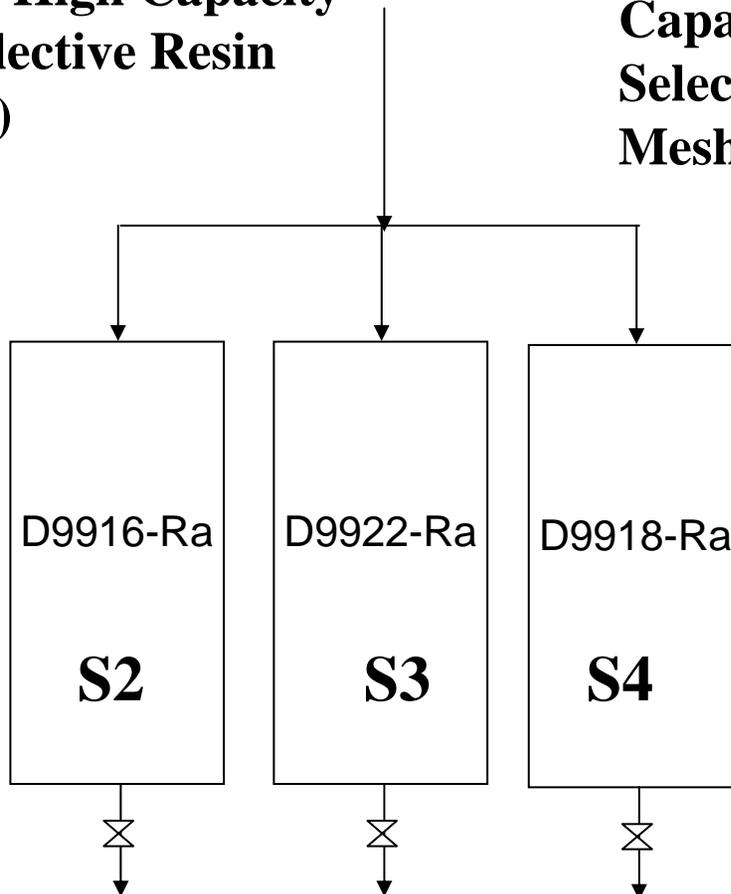


# Test of Three Resins for Radium Removal

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**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”**

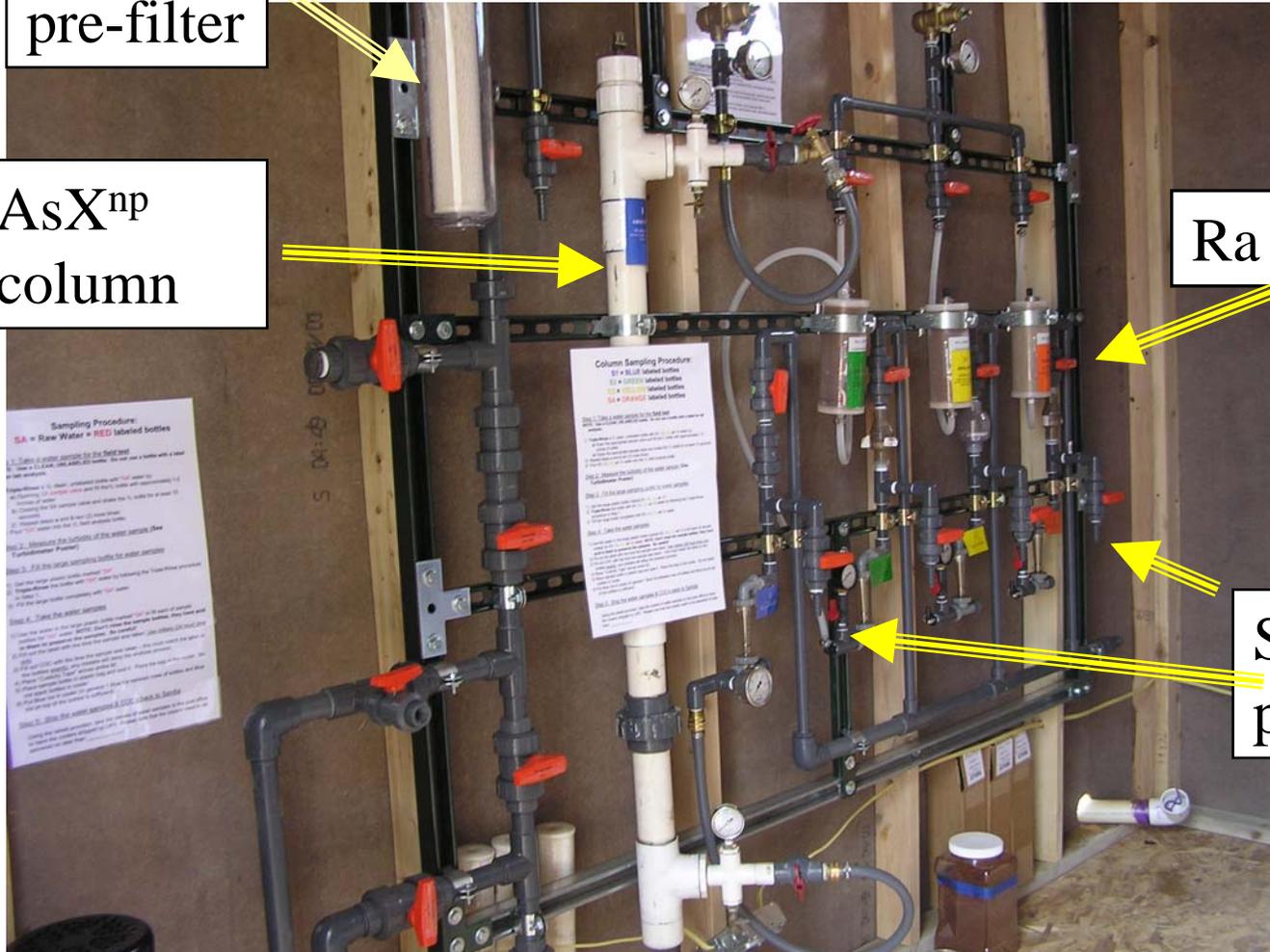
# SNL Adsorptive media skid

5-  $\mu\text{m}$   
pre-filter

AsX<sup>np</sup>  
column

Ra columns

Sample  
ports



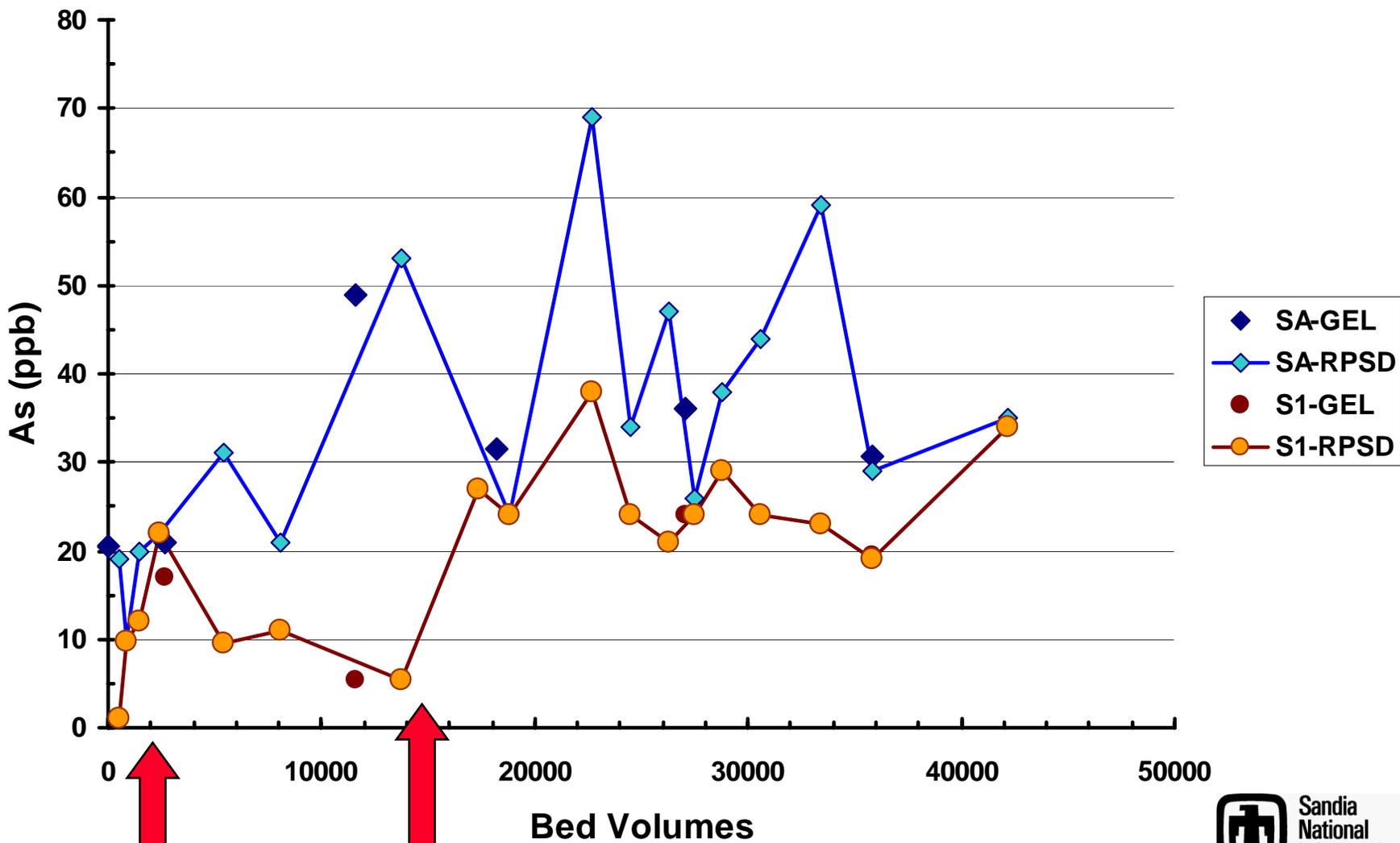


# Outline

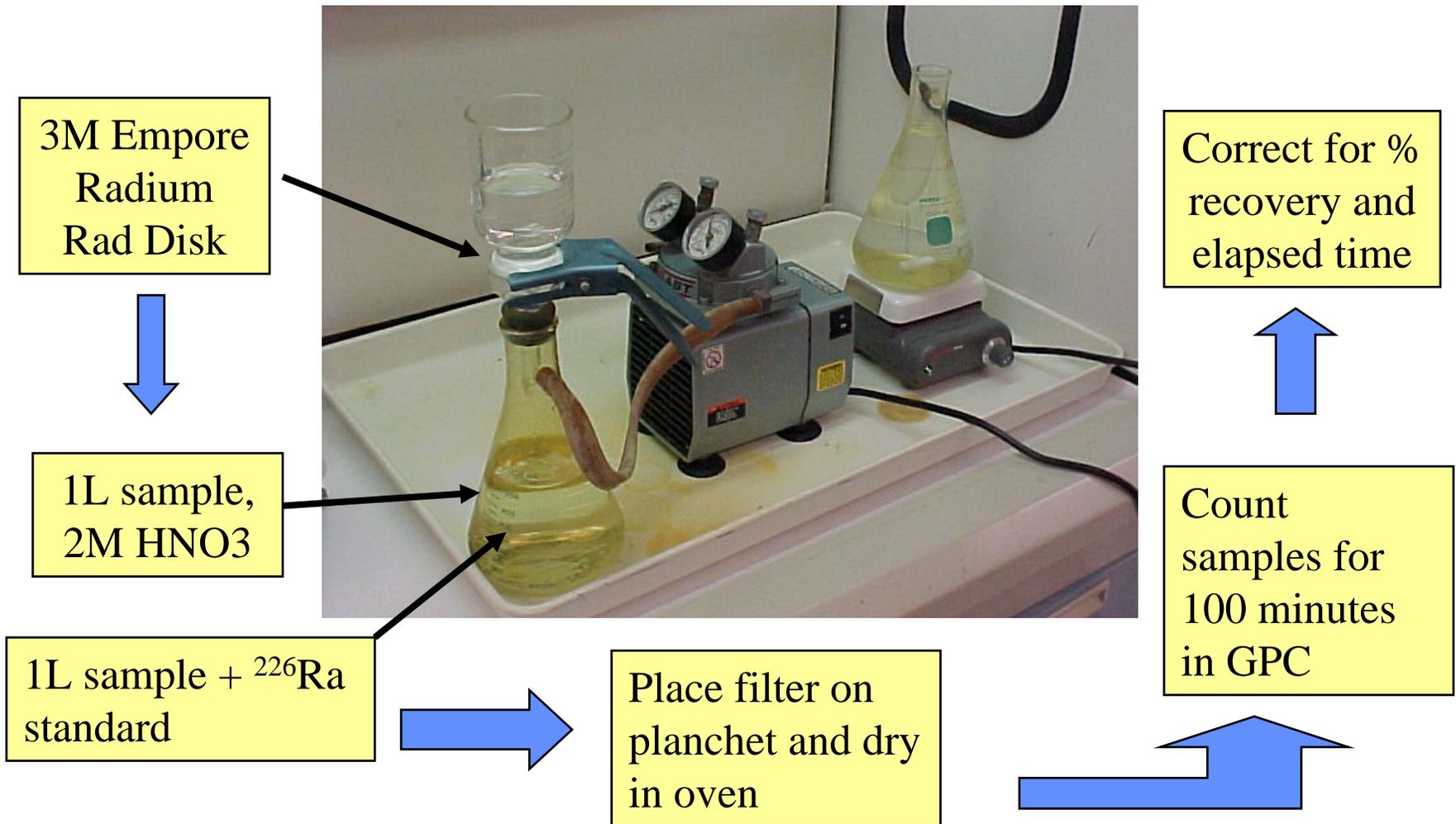
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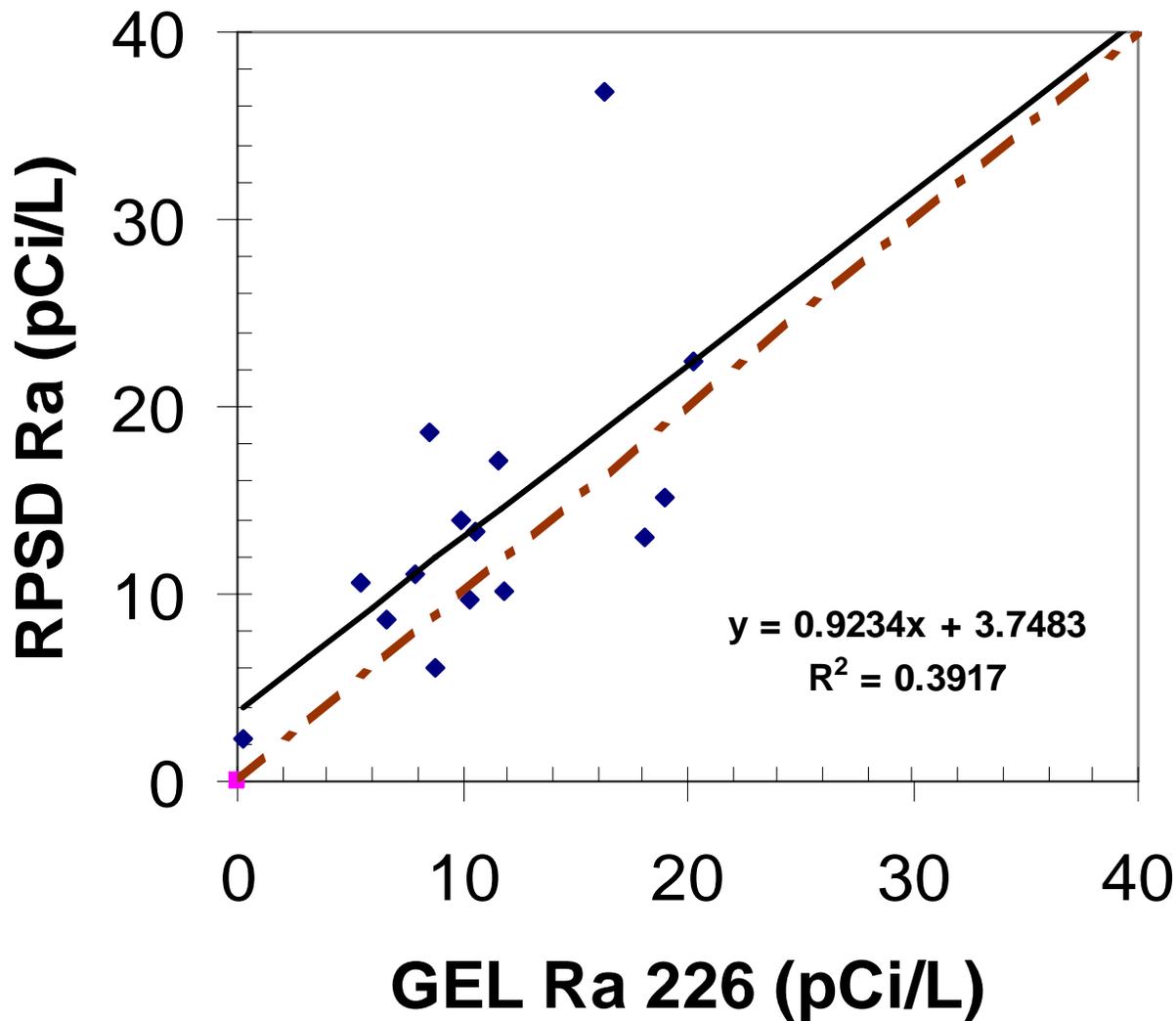
# Removal of Arsenic by AsX<sup>np</sup>



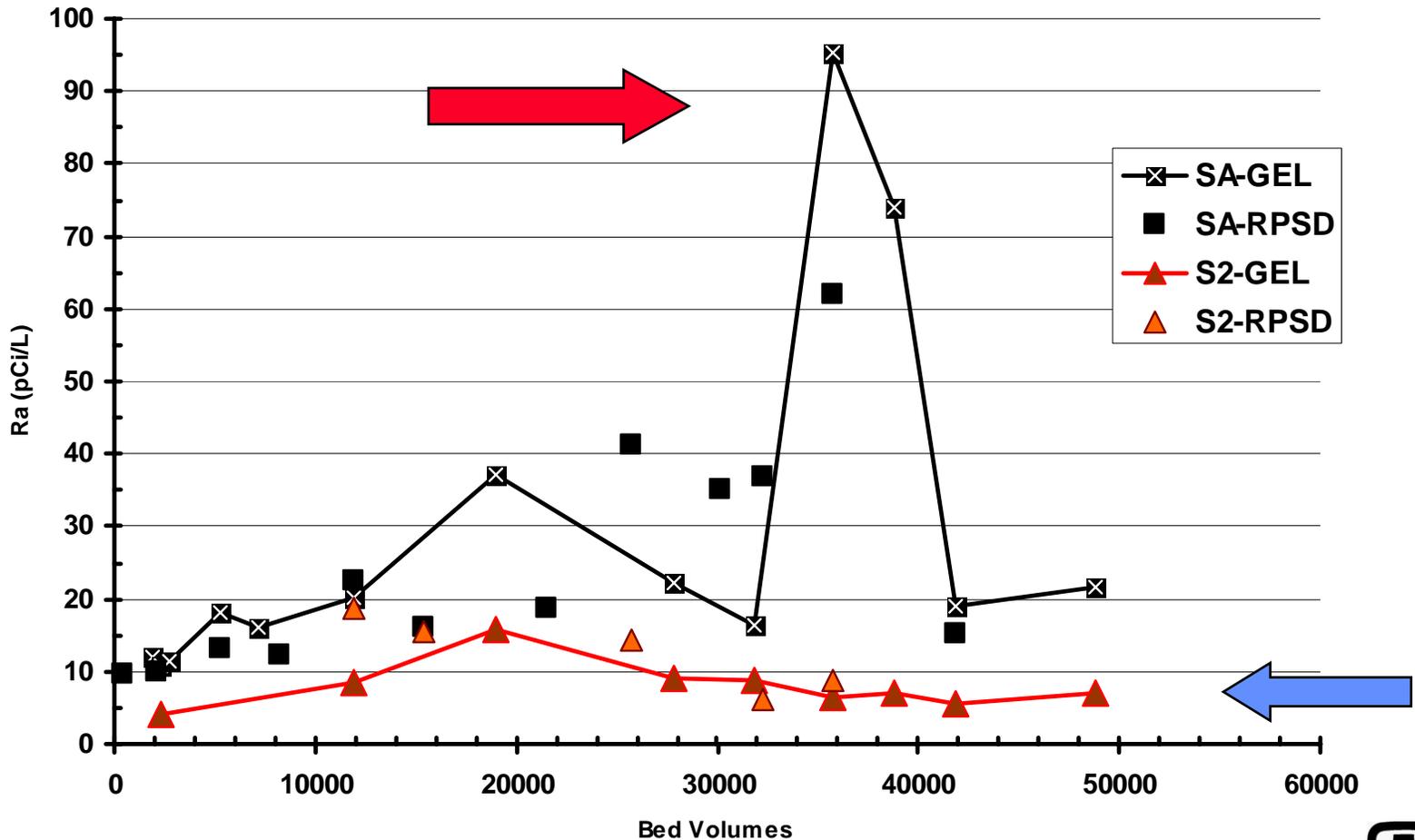
# Semi-quantitative Radium Analysis (RPSD)



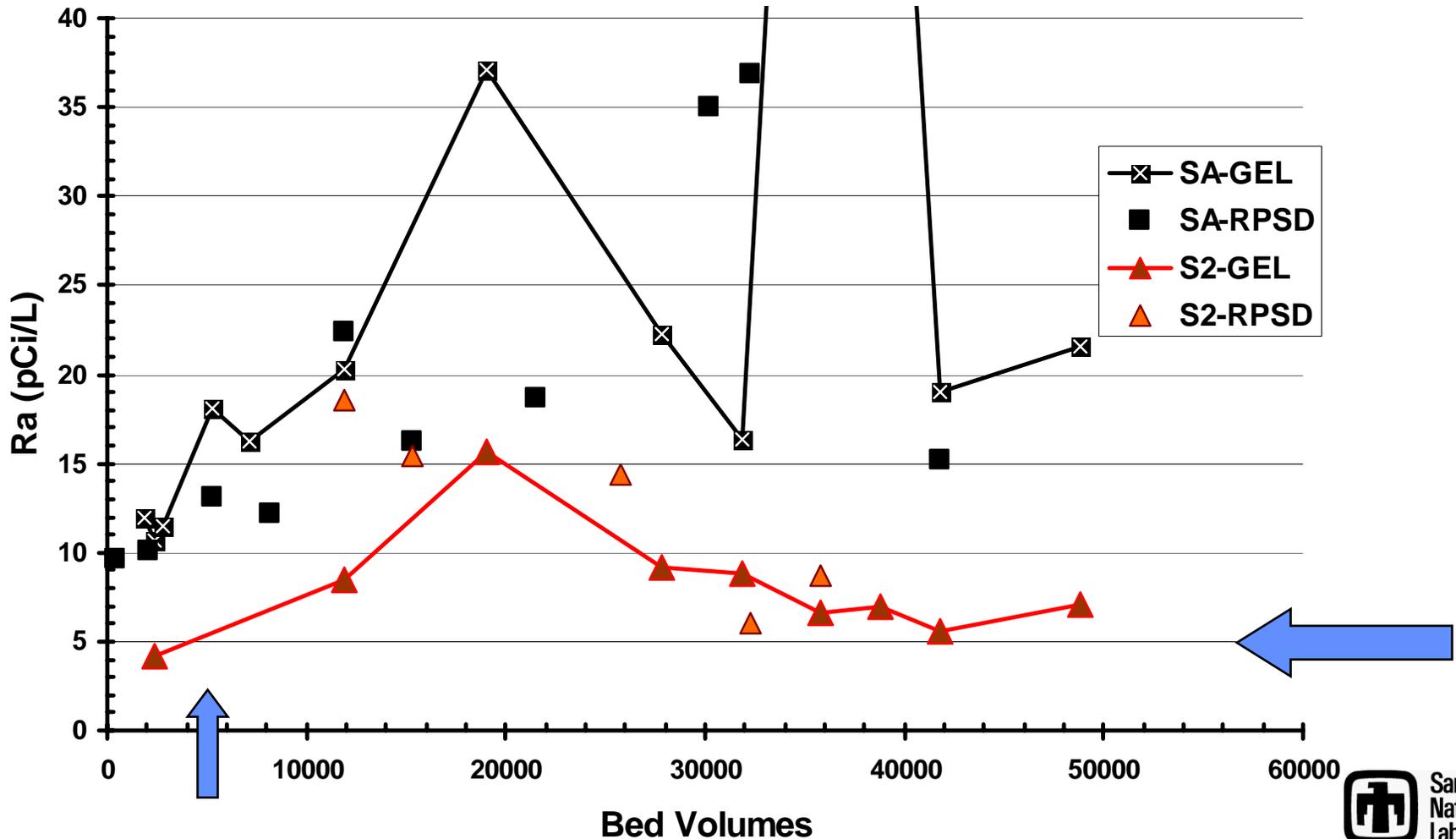
# Correlation Between GEL Ra-226 and 3M Ra-226



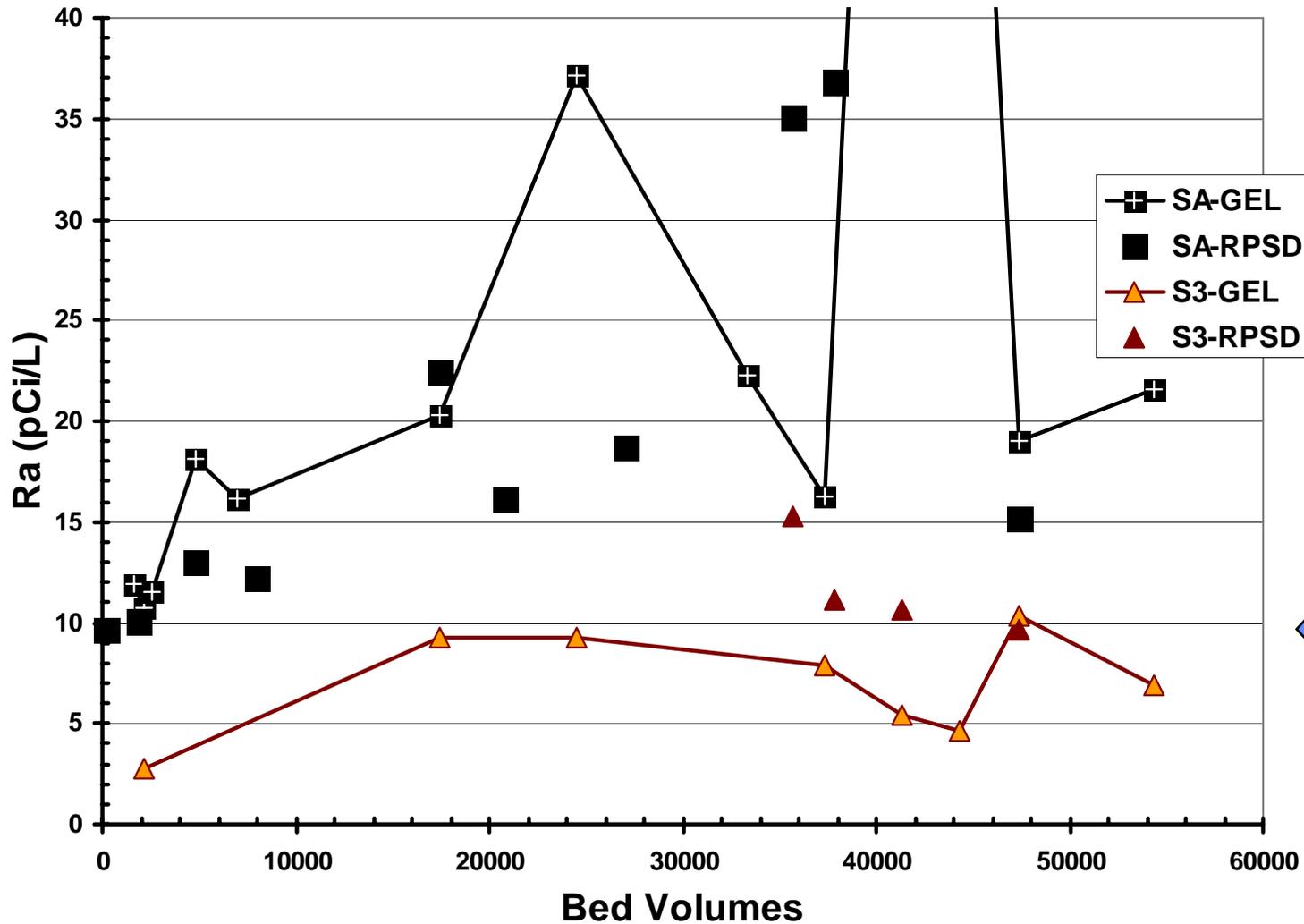
# Ra-226 removal with D9916-Ra high-capacity single-use resin



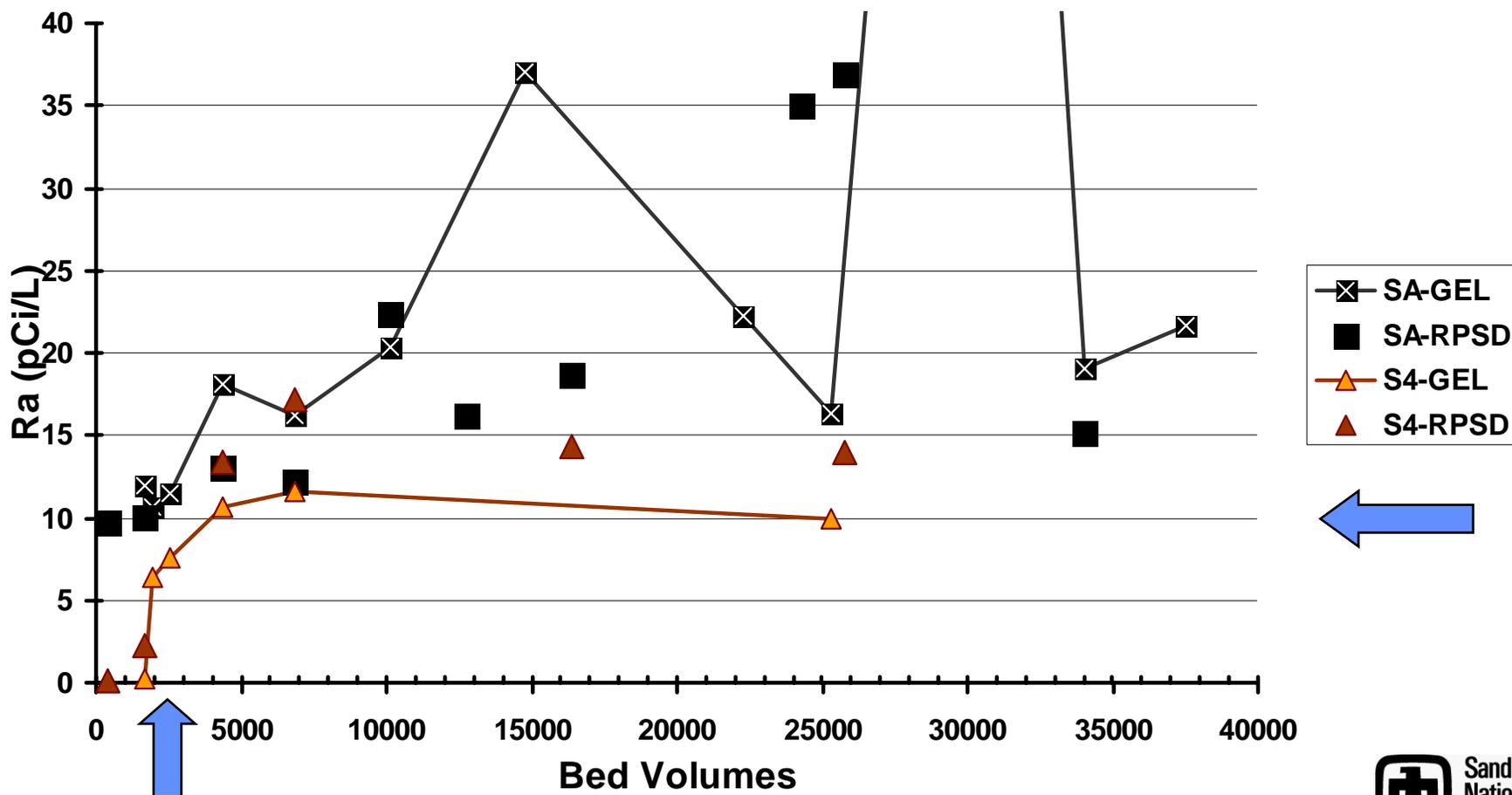
# D9916-Ra high-capacity single-use resin (detail)



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



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





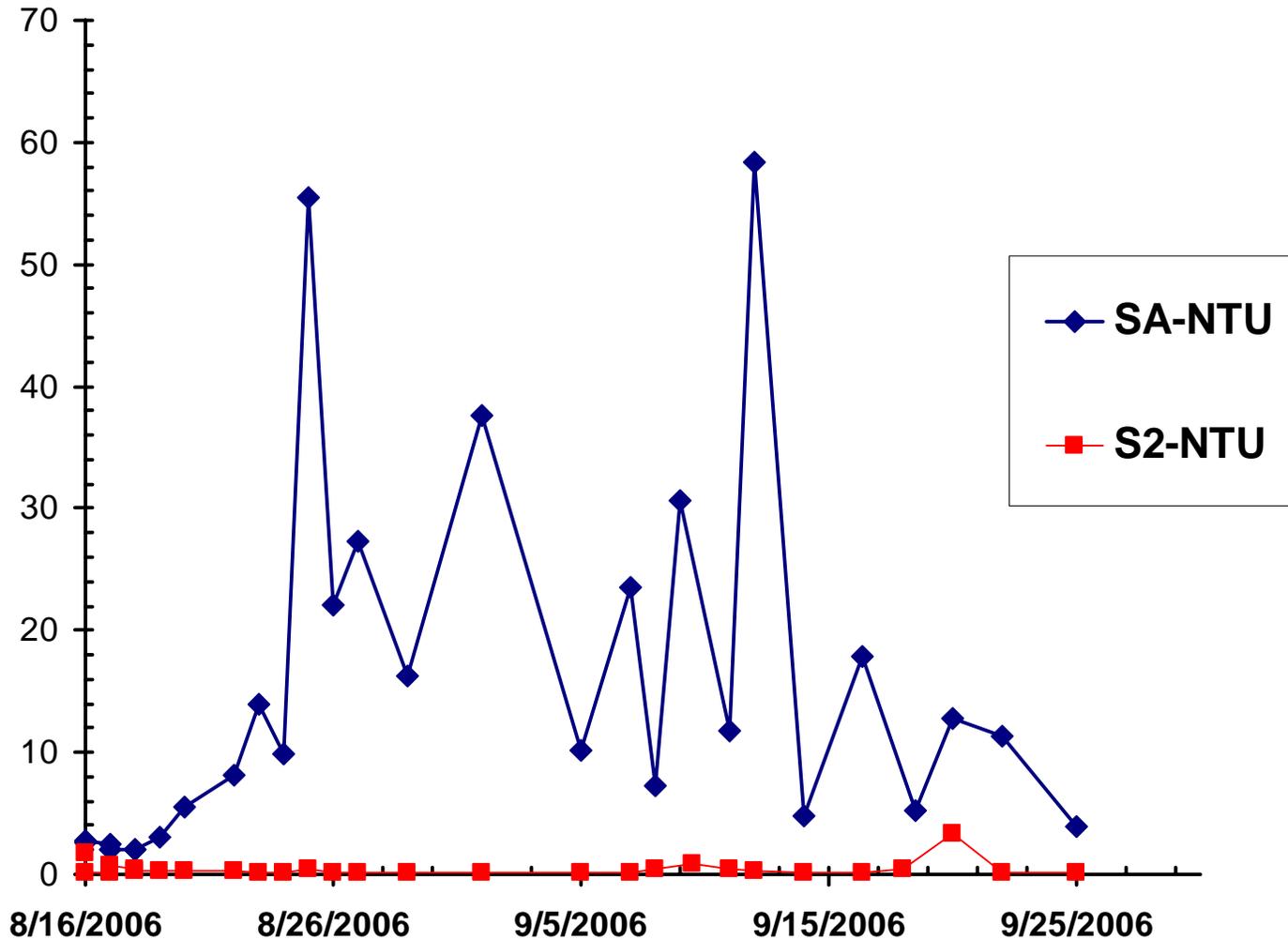
# Summary of Performance of Media: BV to breakthrough

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## Treatment Column

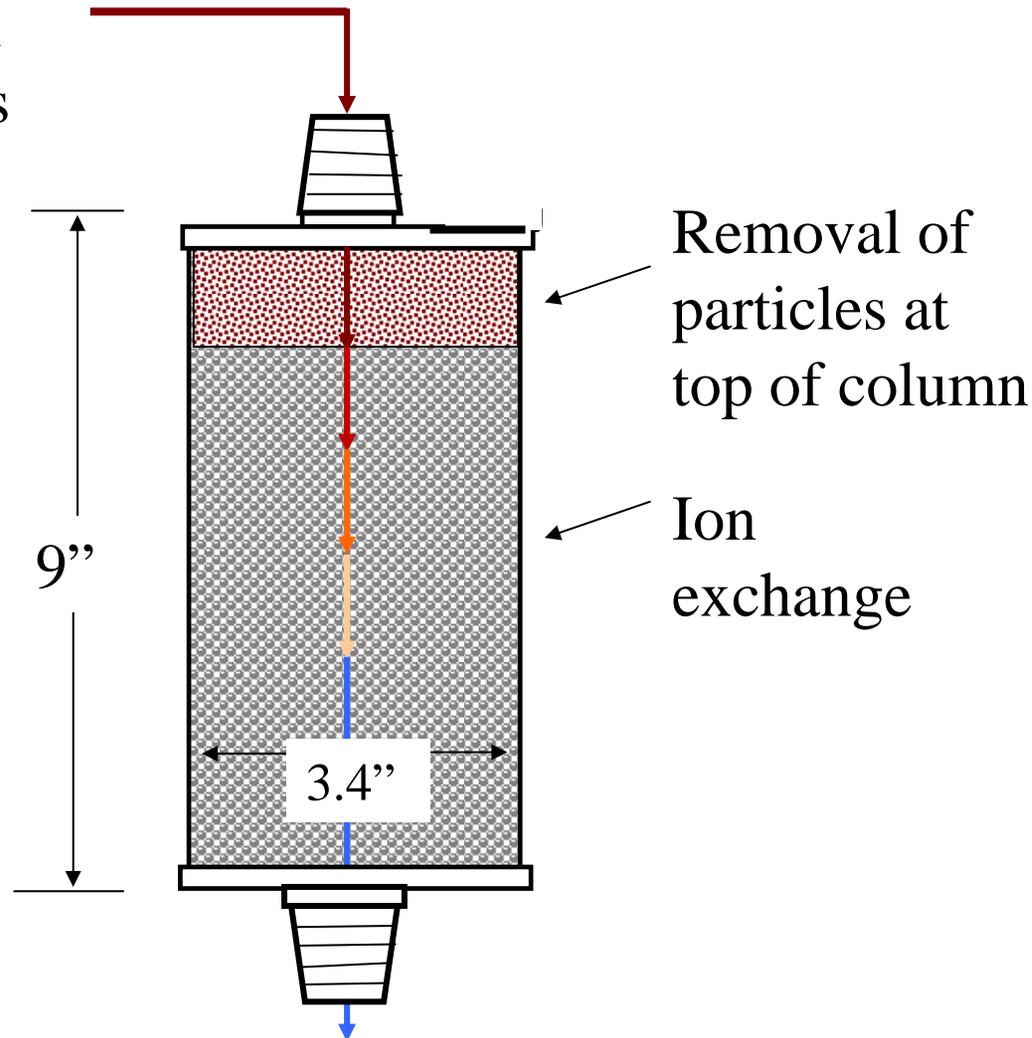
<b>COC</b>	<b>MCL</b>	<b>AsX<sup>np</sup></b>	<b>9916</b>	<b>9922</b>	<b>9918</b>
As	10 µg/L	<19000	NA	NA	NA
Note	AsX <sup>np</sup> needed 8K BV break-in period for arsenic.				
<sup>226</sup> Ra	5 pCi/L	NA	<12000	<18000	<3000
Note	High capacity resins Ra-226 removed to below 10 pCi/L for > 50KBV.				

# Turbidities of influent and treated waters



# Removal of Contaminants by Filtration and Sorption

Water with  
particulates



**Radium  
columns**



# Outline

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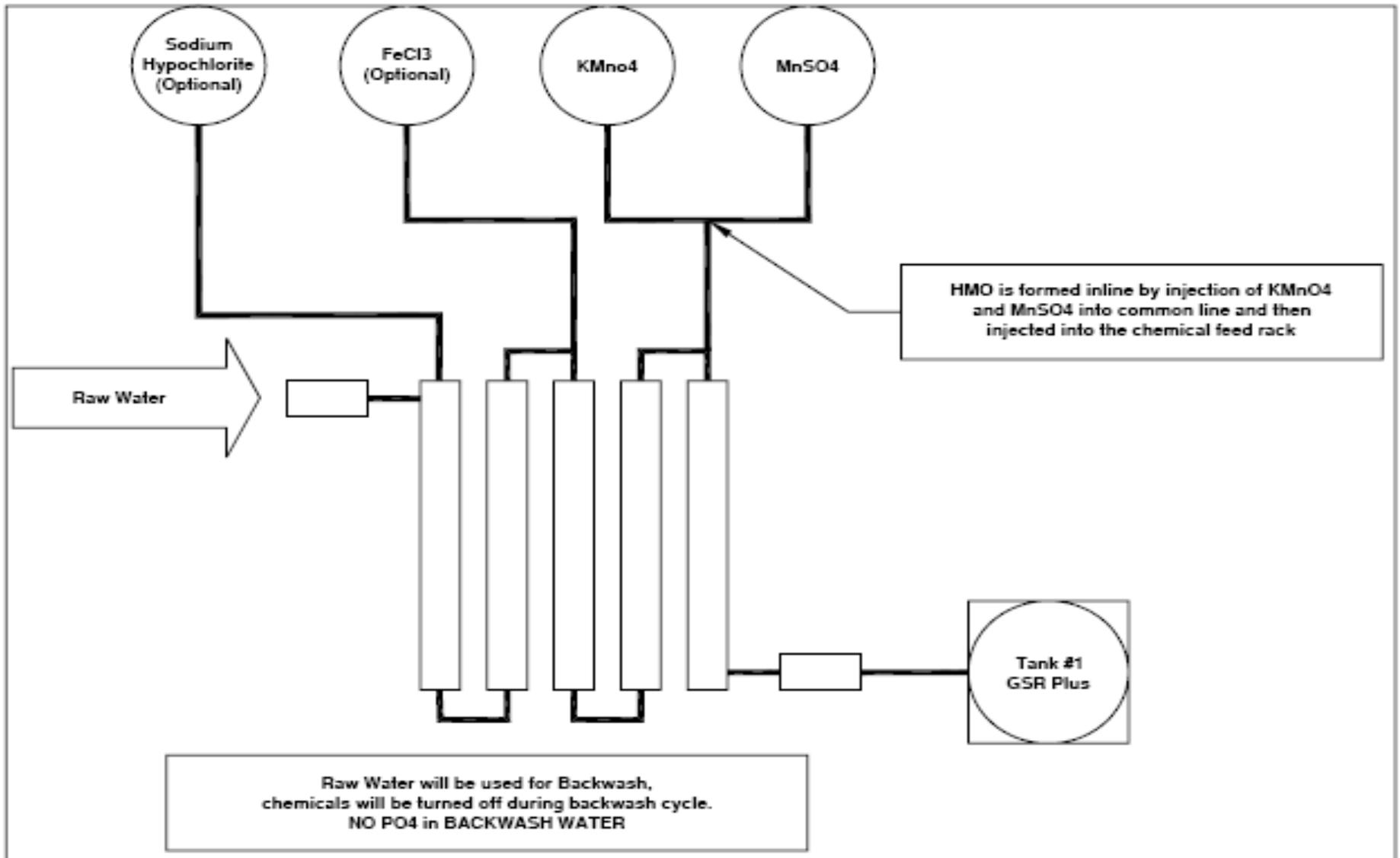
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# Calgon Carbon Pilot System

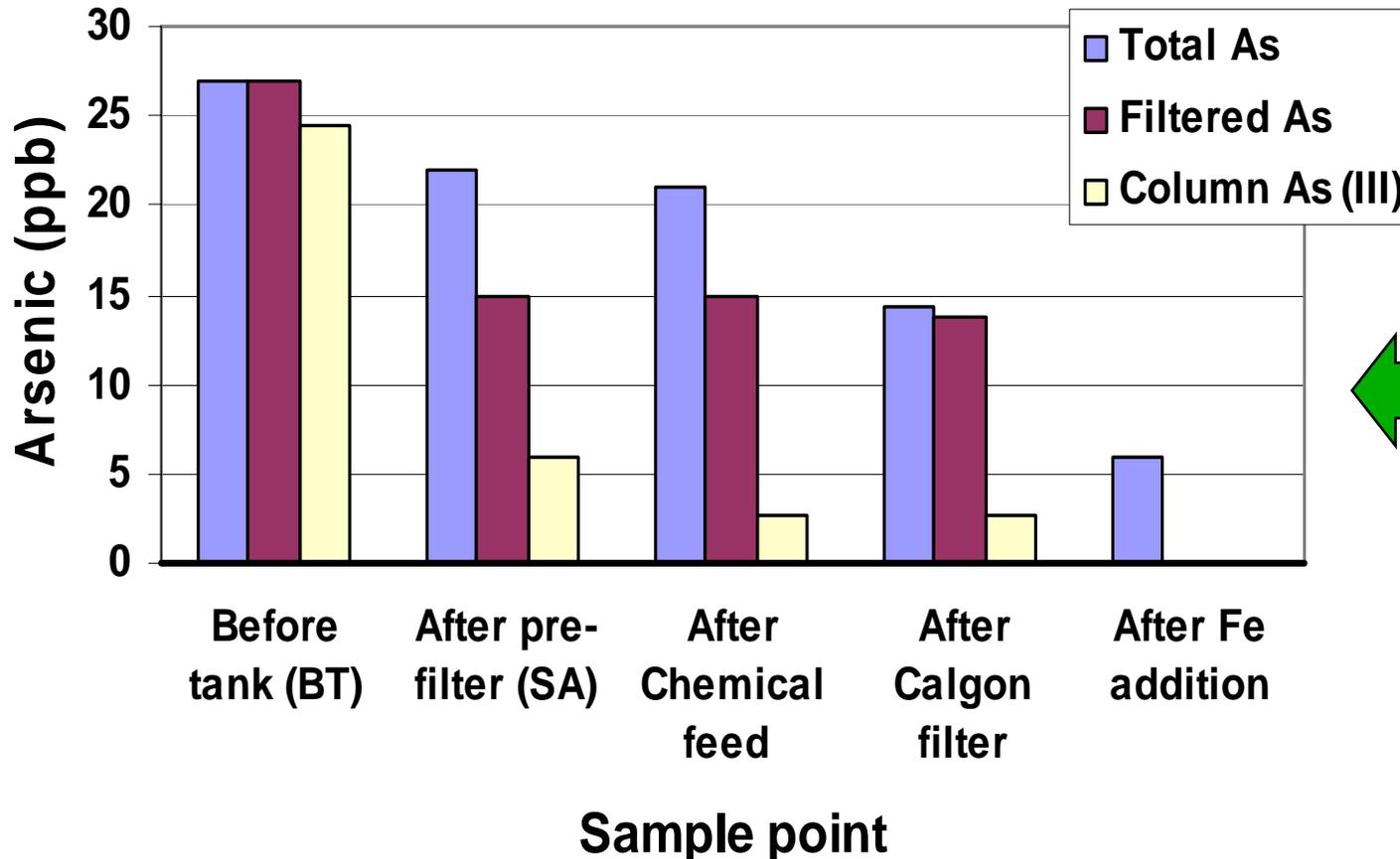
## Oxidation/filtration system



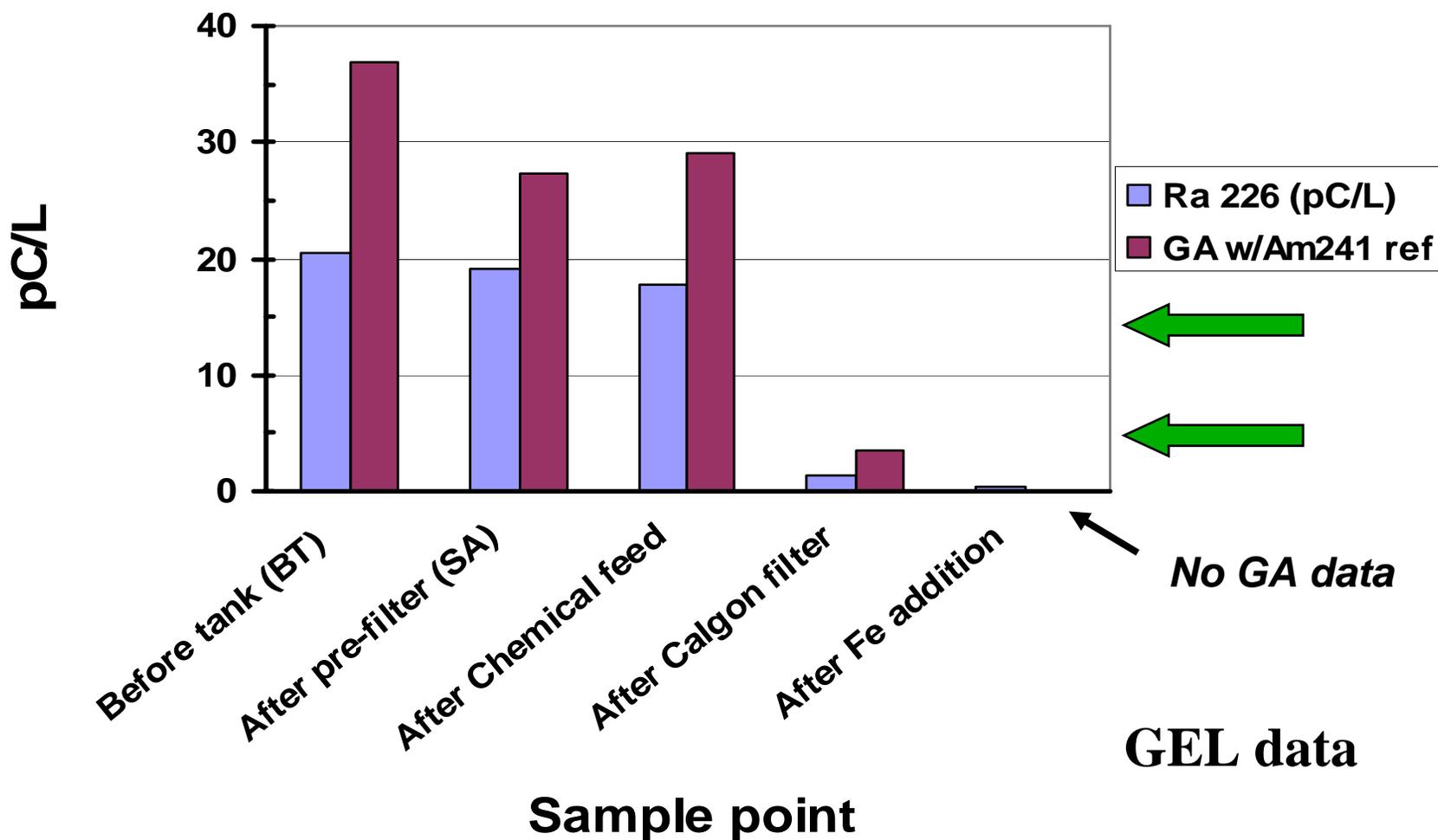
# Calgon Carbon System



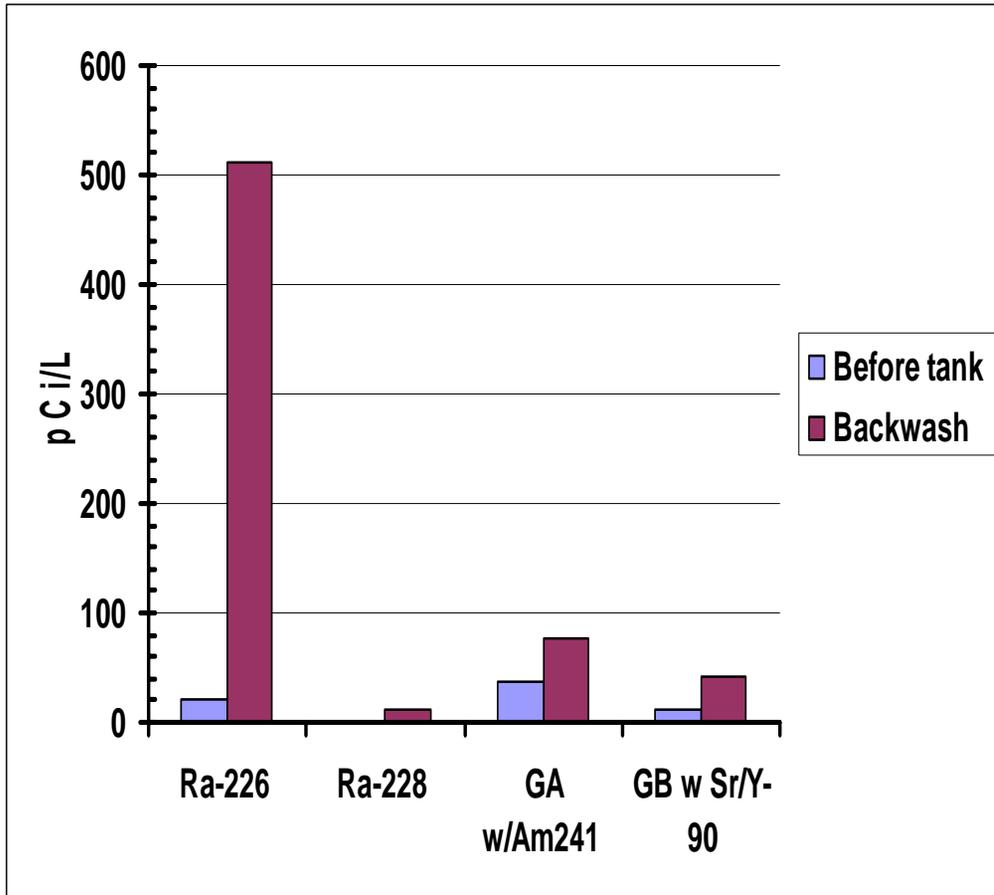
# Removal of arsenic by Calgon Process



# Removal of radionuclides by Calgon Process



# Backwash analysis



Pine Hill Sewage Lagoon



Tribal concerns  
about disposal



# Summary of Test Results

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- **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.



## Summary of Test Results (II)

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- **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**



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# POU Technologies for Water Haulers

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- **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?**

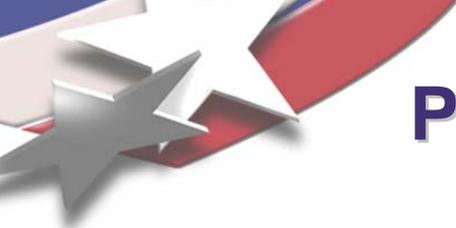
# Unregulated Water Sources on Navajo Reservation



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

**Box Spring**





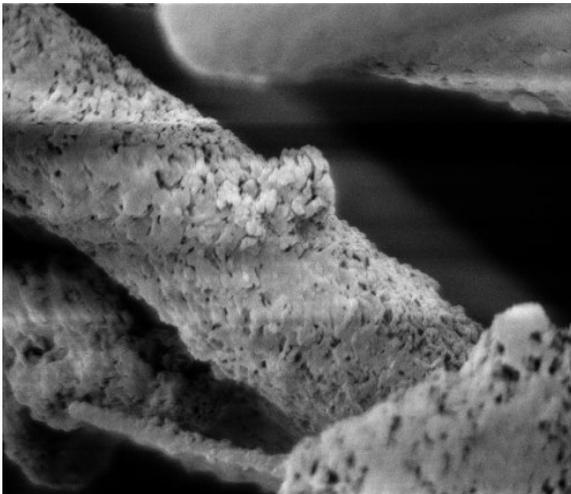
# Proposals for Engineers (EWB) Without Borders Projects

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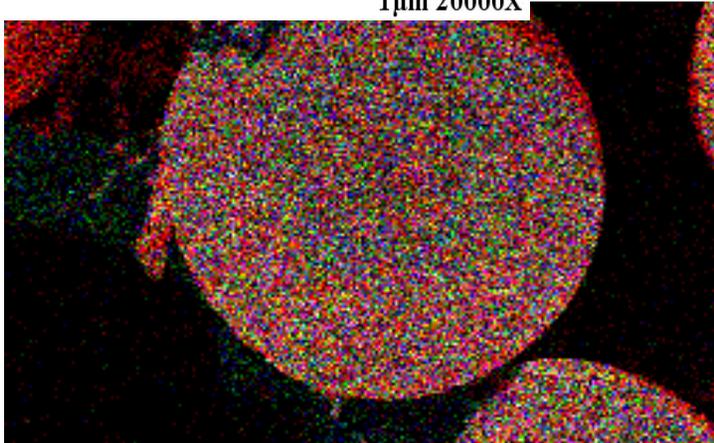
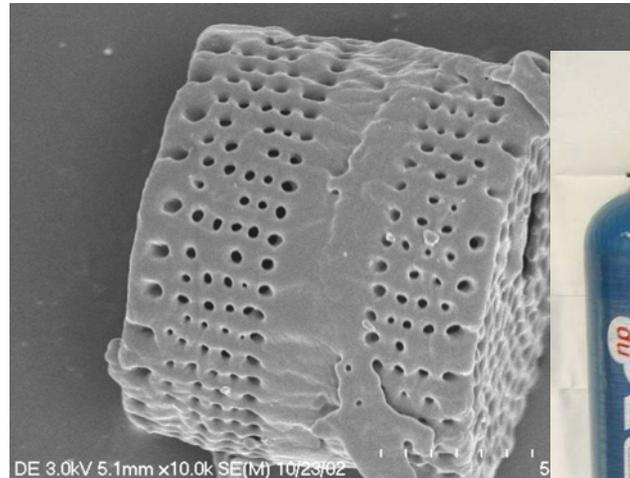
- **Expand existing water treatment project on Ramah Navajo Reservation**
  - Pilot test additional technologies at experimental facility
  - Education program at Pine Hill School
- **Point- of-Use Treatment Technologies for Water Haulers**
  - Sample water sources to identify treatable sources
  - Workshop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

**EWB looking for corporate sponsors for projects.**

# Treatment Using Engineered Nanotech Materials



1  $\mu\text{m}$  20000X



# Treatment using low-cost materials

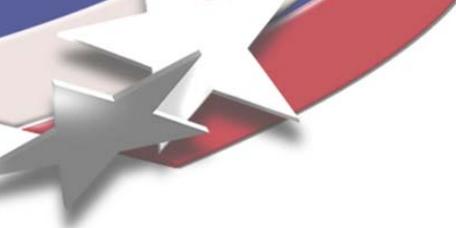




# Summary

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- **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



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- **Thank you for your interest.**

- **Project website**

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

- **Questions?**