REMOVING RADIOACTIVE CONTAMINATION FROM ION EXCHANGE RESINS USED IN DRINKING WATER TREATMENT

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James McMahon
Dr. M. R. Collins

Department of Civil Engineering - University of New Hampshire

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Presentation Outline

- Background
  - Chemistry/Radionuclides/Radium-226
- Radium-226 Treatment Processes
  - Ion Exchange Resins/Water Treatment
- Research Work Tasks
  - Resin Exhaustion Study
  - Resin Regeneration
    - Batch Studies
    - Column Study
    - Field Verification Study

Drinking Water Regulations for Radionuclides

- 1962 US Public Health Services DWS
  - 3 pCi/L Radium 226
- 1977 USEPA National Interim Prim. DWS
  - 5 pCi/L Combined Radium 226/228
- 2000 Radionuclide Rule USEPA

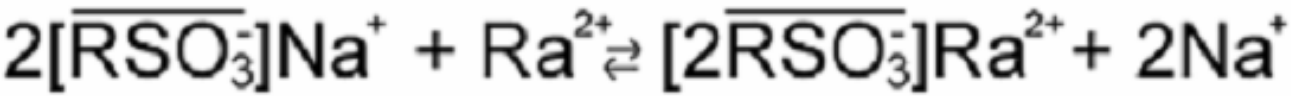
Regulated Contaminant	**MCL**	**MCLG**
Beta/photon emitters	4 mrem/year	0
Gross alpha particle	15 pCi/L	0
Combined Radium-226/228	5pCi/L	0
Uranium	30 ug/L	0

Treatment Options for Radium-226 in Drinking Water

- EPA Best Available Technologies (BAT)
  - Ion Exchange (IX)
  - Lime Softening
  - Reverse Osmosis
- Other Practices
  - Blending water sources to below standards
  - Find alternate well site

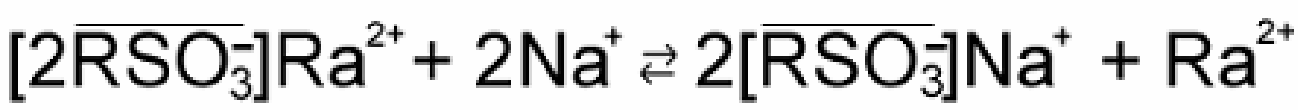
Radium-226 Treatment Using Ion Exchange Resin

- Raw water flows through treatment unit
- Exchanges Ion (Resin Exhaustion)



$$2[\overline{RSO_3^-}]Na^+ + Ra^{2+} \rightleftarrows [2\overline{RSO_3^-}]Ra^{2+} + 2Na^+$$

- Backwash Cycle (Resin Regeneration)

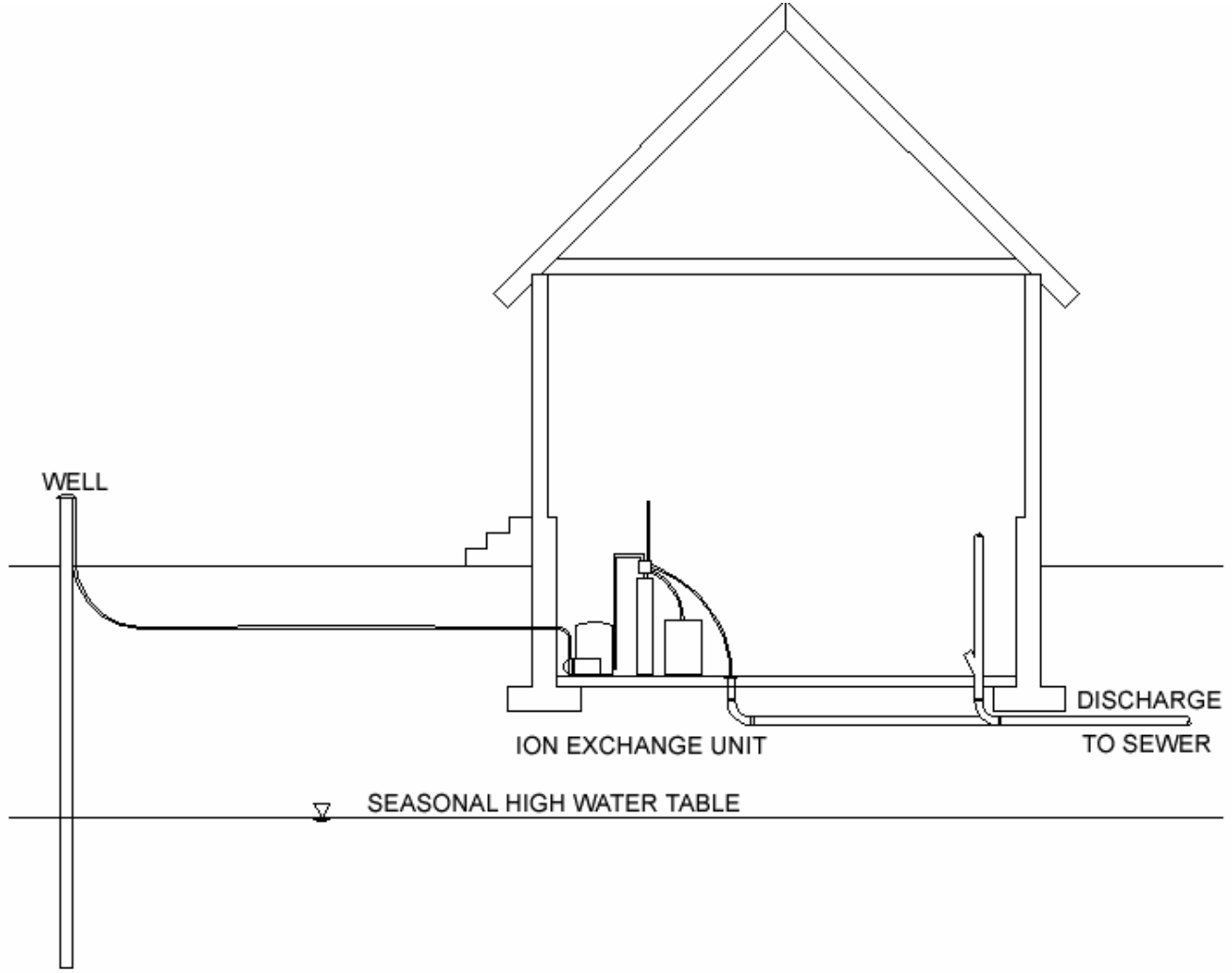


$$[2\overline{RSO_3^-}]Ra^{2+} + 2Na^+ \rightleftarrows 2[\overline{RSO_3^-}]Na^+ + Ra^{2+}$$

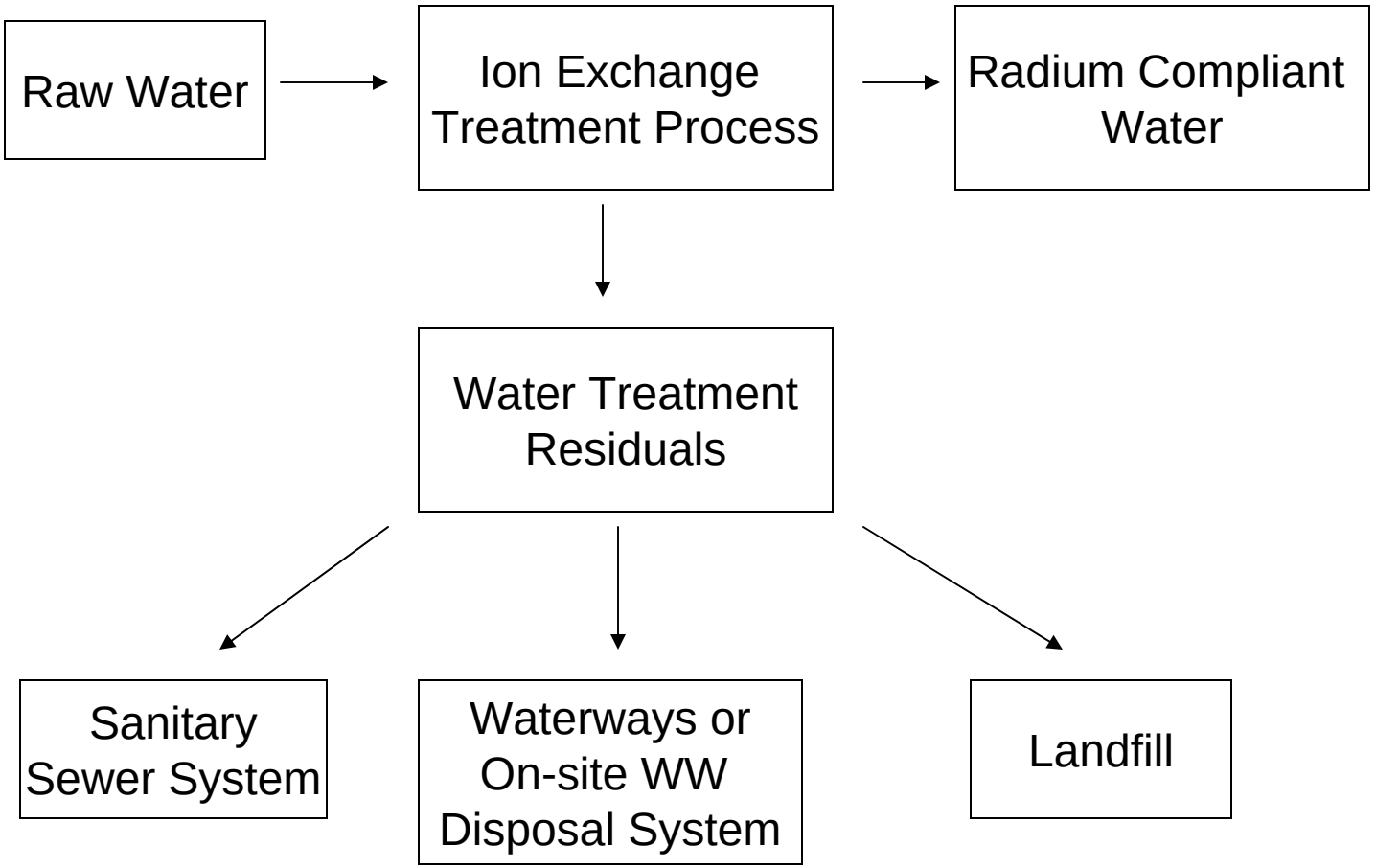
Cation Exchange Resin

- Effectiveness of IX Resin in Water Treatment based on:
  - Ion affinities
  - Ion concentrations
  - Abundance of oppositely charged sites on resin

Typical Home Ion Exchange Water Softening System Layout



Ion Exchange Waste Disposal Options Diagram



Project Specific Objectives

- Objective 1
  - Determine the extent of Radium-226 fouling on cation exchange resins
- Objective 2
  - Assess the amount of Radium-226 removal using various regenerate solutions and contact times
- Objective 3
  - Determine the Radium-226 ion-to-resin exposure time has on the Radium-226 removal process

Project Work Tasks Outline

- Objective 1
  - Resin Exhaustion Column Study
    - Treat water with high Ra-226 concentrations and accumulate Ra-226 on cation exchange resin for cleaning
- Objective 2
  - Resin Regeneration Batch Studies
    - Assess impact of cleaning variables on exhausted cation exchange resins
  - Resin Regeneration Column Study
    - Optimize most influential regeneration variables
- Objective 3
  - Field Assessment of Fouled Cation Exchange Resins
    - Compare optimized regeneration solution to resins which have been in operation for an extended period of time

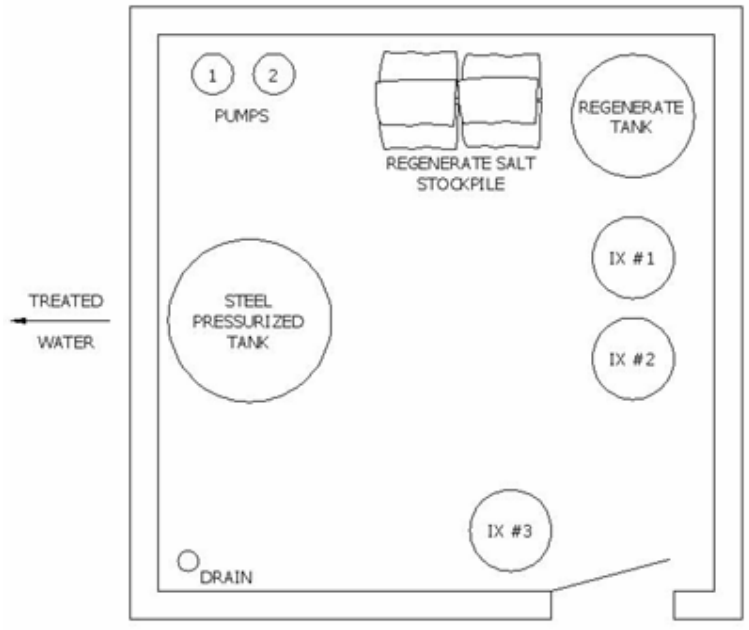
Objective 1 - Resin Exhaustion Study

Site Location & Layout

Water Treatment Building

For Apartment Complex

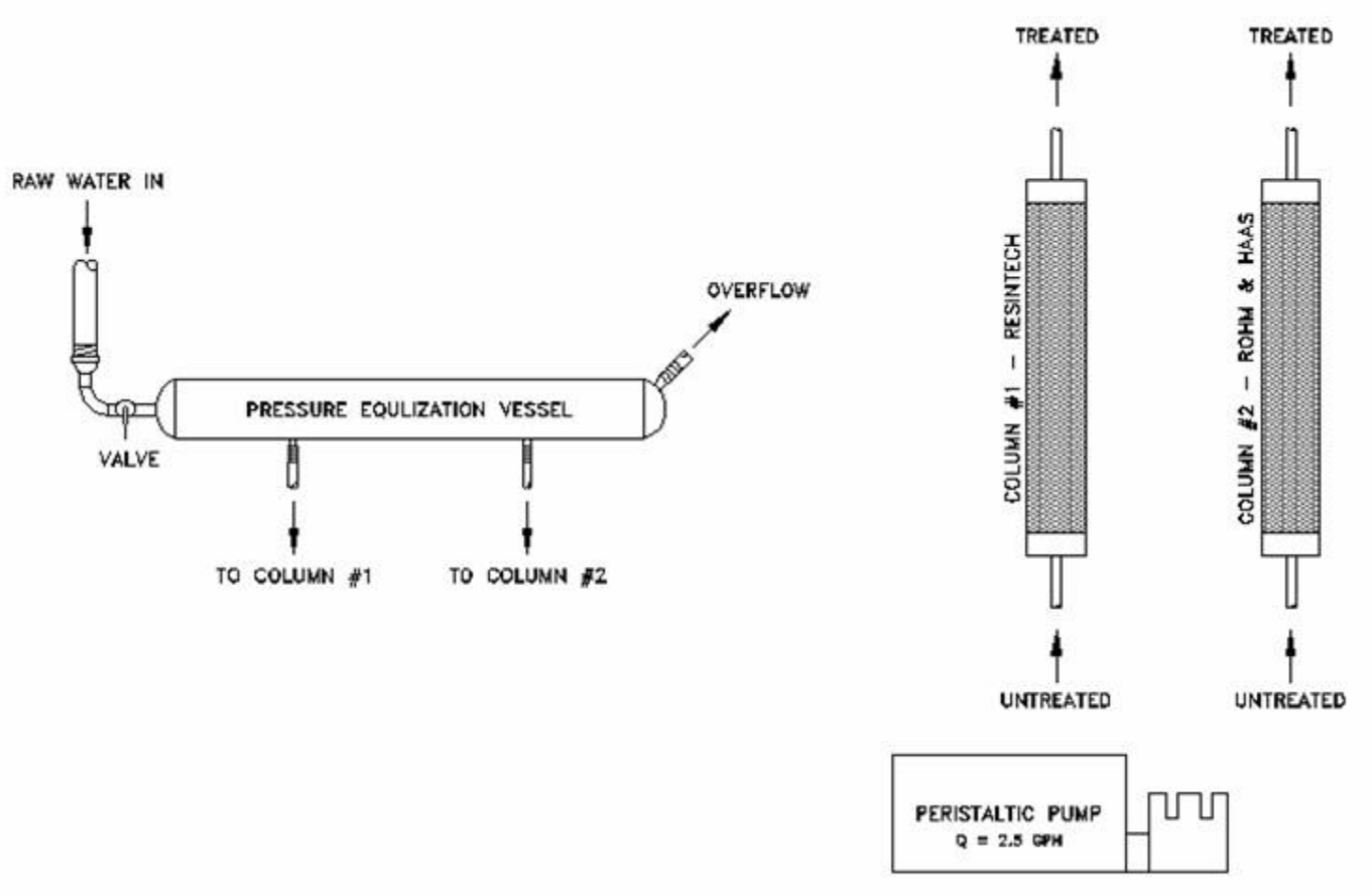
Pelham, NH



Treatment Building Layout

Objective 1 - Resin Exhaustion Study

Column Layout



Objective 1 - Resin Exhaustion Study
Sampling Event

Sample Volumes

2 L (Radium-226)

14 mL (Metals)

Raw Water Data

Radium-226 (10.8 pCi/L)

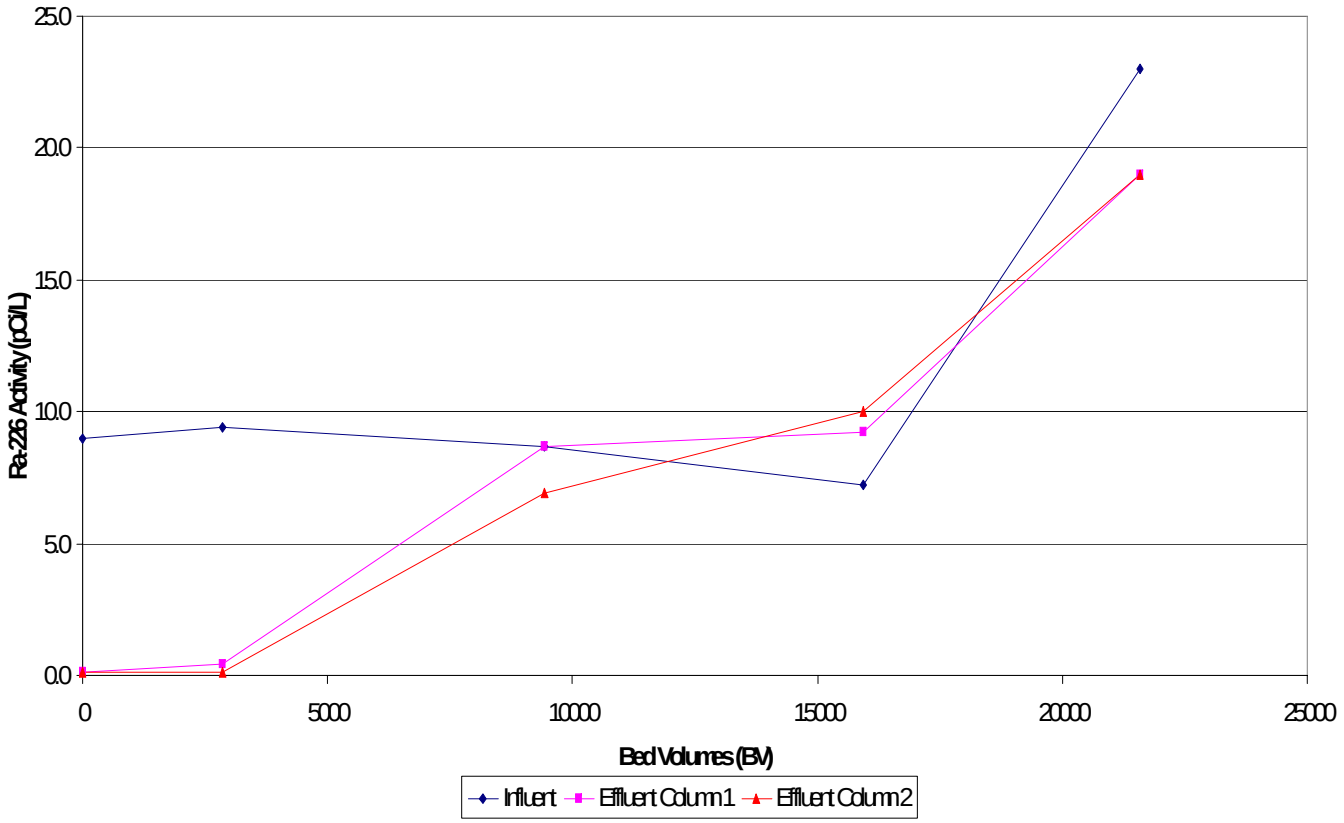
Calcium (150.3 mg/L)

Magnesium (25.1 mg/L)

Iron (2.2 mg/L)

Objective 1 - Resin Exhaustion Study

Radium-226 Breakthrough Curve



Objective 1 - Resin Exhaustion Study
Cation Accumulations on Resins

Summary Table - Column Setup 1 (40 Days)			
Item	**Units**	**Resintech**	**Rohm & Haas**
Radium-226	pCi/g	34.5	36.0
Calcium	mg/g	48.4	8.0
Magnesium	mg/g	3.0	1.1
Iron	mg/g	1.0	0.5

Summary Table - Column Setup 2 (28 Days)			
Item	**Units**	**Resintech**	**Rohm & Haas**
Radium-226	pCi/g	17.0	16.5
Calcium	mg/g	16.4	9.7
Magnesium	mg/g	1.7	1.4
Iron	mg/g	0.1	0.3

Note: All concentrations based on gram dry weight resin

Objective 2 - Resin Regeneration Batch Studies

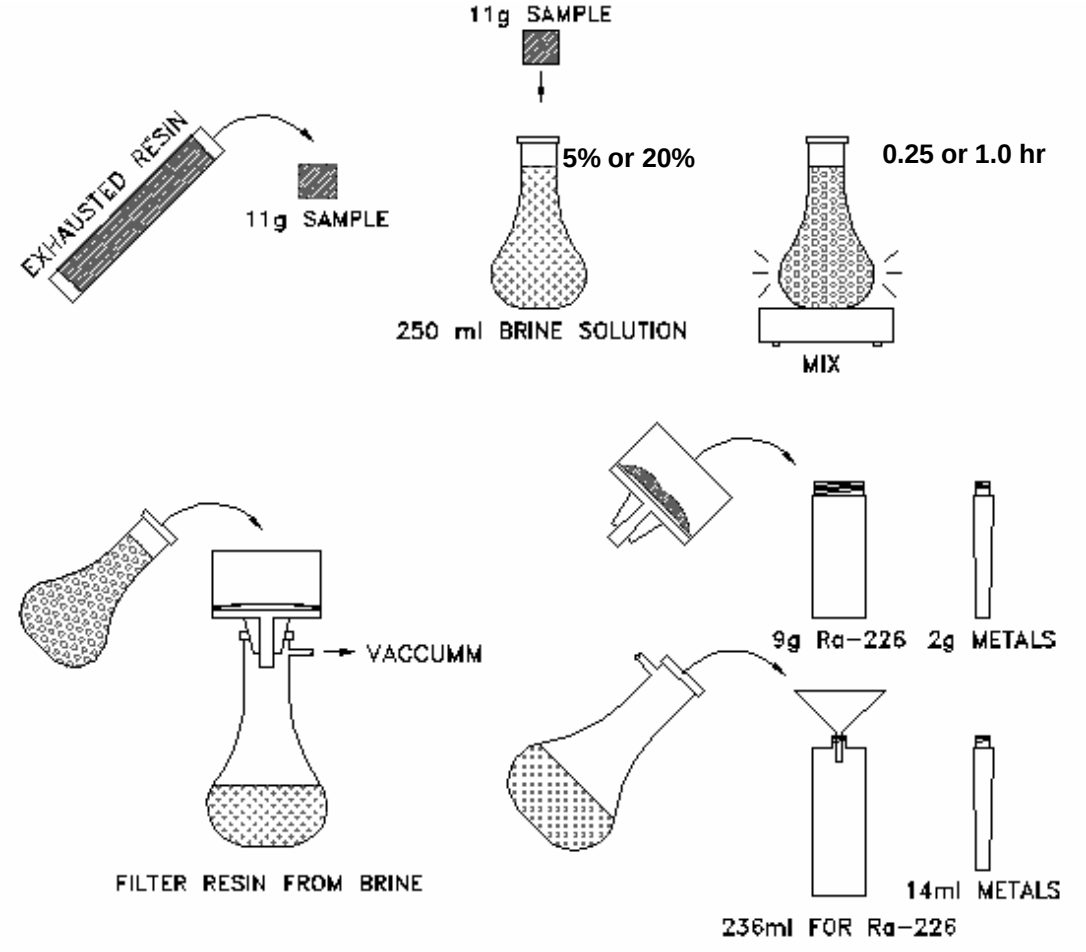
Experimental Approach

To assess various Regeneration Conditions

Sample	Brine Strength (% NaCl)	pH	Regenerate Contact Time (hr)	Ra-226 to Resin Exposure Time (days)
1	5	5.5	0.25	30 to 166
2			1.0	
3		8.5	0.25	
4			1.0	
5	20	5.5	0.25	
6			1.0	
7		8.5	0.25	
8			1.0	

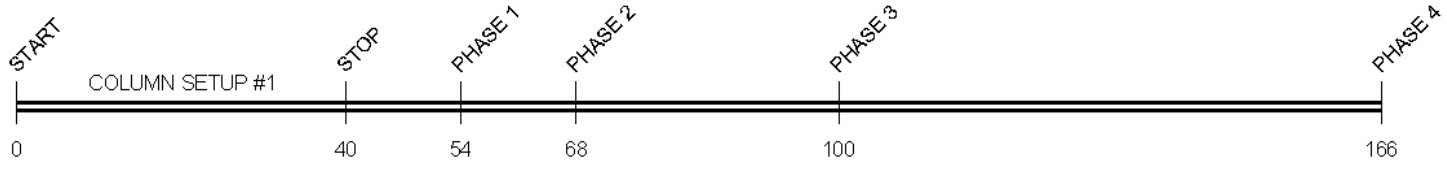
Objective 2 - Resin Regeneration Batch Studies

Experiment Procedure



Objective 2 - Resin Regeneration Batch Studies

Timeline



Phase 1

Sample	Brine Strength (% NaCl)	pH	Regenerate Contact Time (hr)	Exposure Time (days)
1	5	5.5	0.25	54
2			1	
3		8.5	0.25	
4			1	
5	20	5.5	0.25	
6			1	
7		8.5	0.25	
8			1	

Phase 2

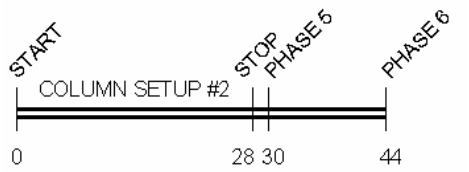
Sample	Brine Strength (% NaCl)	pH	Regenerate Contact Time (hr)	Exposure Time (days)
9	5	5.5	0.25	68
10			1	
11		8.5	0.25	
12			1	
13	20	5.5	0.25	
14			1	
15		8.5	0.25	
16			1	

Phase 3

Sample	Brine Strength (% NaCl)	pH	Regenerate Contact Time (hr)	Exposure Time (days)
17	5	5.5	0.25	100
18			1	
19		8.5	0.25	
20			1	
21	20	5.5	0.25	
22			1	
23		8.5	0.25	
24			1	

Phase 4

Sample	Brine Strength (% NaCl)	pH	Regenerate Contact Time (hr)	Exposure Time (days)
25	5	5.5	0.25	166
26			1	
27		8.5	0.25	
28			1	
29	20	5.5	0.25	
30			1	
31		8.5	0.25	
32			1	



Phase 5

Sample	Brine Strength (% NaCl)	pH	Regenerate Contact Time (hr)	Exposure Time (days)
33	5	5.5	0.25	30
34			1	
35		8.5	0.25	
36			1	
37	20	5.5	0.25	
38			1	
39		8.5	0.25	
40			1	

Phase 6

Sample	Brine Strength (% NaCl)	pH	Regenerate Contact Time (hr)	Exposure Time (days)
41	5	5.5	0.25	44
42			1	
43		8.5	0.25	
44			1	
45	20	5.5	0.25	
46			1	
47		8.5	0.25	
48			1	

Objective 2 - Resin Regeneration Batch Studies

Photo Summary 1

Brine Solution & pH meter

Brine and Resin Samples

Objective 2 - Resin Regeneration Batch Studies

Photo Summary 2

Samples on Mixing Table

Sample Containers
& Filter Setup

Objective 2 - Resin Regeneration Batch Studies

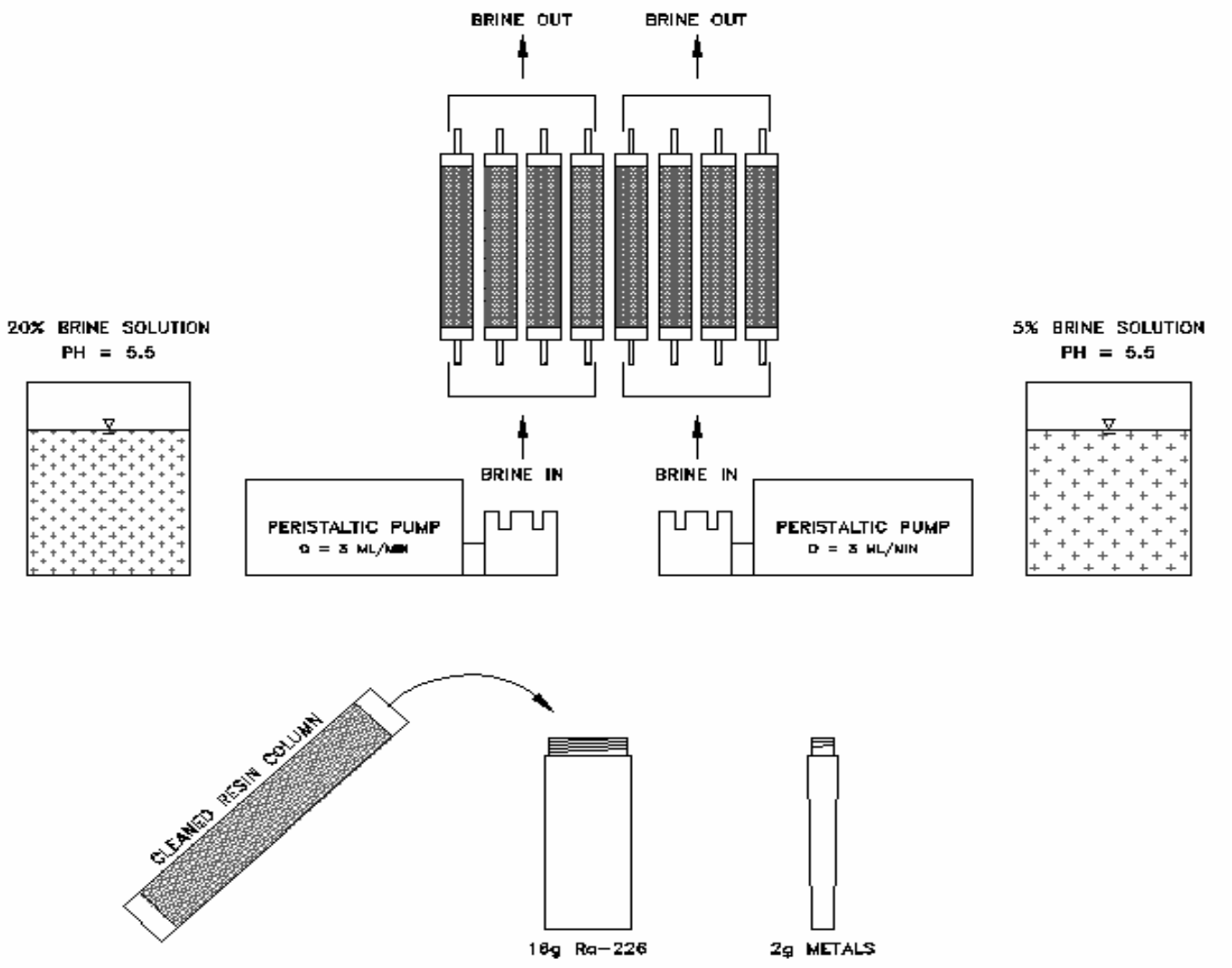
Analysis of Variance Results

Factors	Degrees of Freedom	Sum of Squares	F Ratio	% Contribution
Brine Strength	1	1.022	105.802**	**46.0%**
Resin Type	1	0.351	36.332 **	15.5%
Initial Radium-226 Resin Loading	1	0.239	24.751**	10.4%
Column Setups	1	0.183	18.980 **	7.9%
pH	1	0.075	7.817**	3.0%
Radium-226 Exposure Time	1	0.005	0.555**	N.S.
Brine Contact Time	1	0.000	0.01	N.S.
Error	64	0.618		**17.1%**

**Significant at 99% confidence interval
N.S. = Factor Not Significant

Objective 2 - Resin Regeneration Column Study

Experiment Procedure



Objective 2 - Resin Regeneration Column Study

Experimental Approach

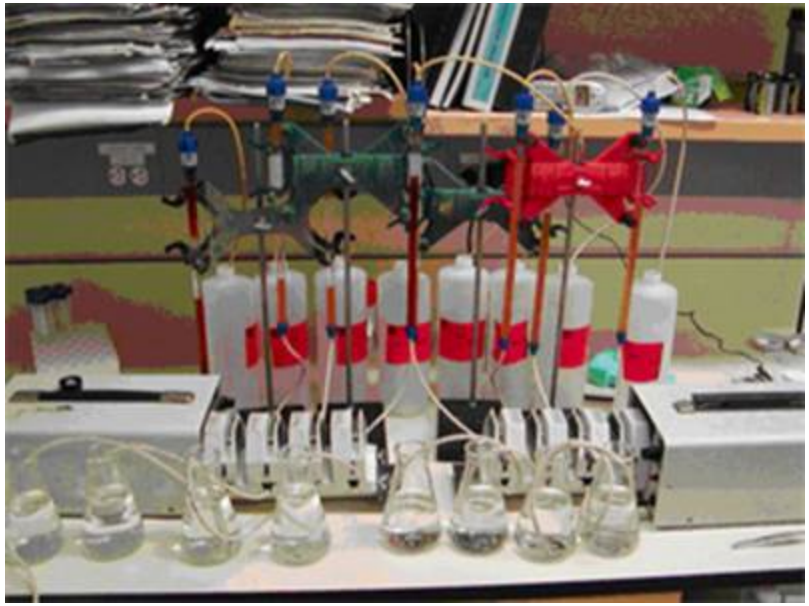
Using the most influential variables from Batch Studies

Column	Resin	Pump	pH	Brine Strength	Contact Time (hr)	Flow Rate (mL/min)
1	Rohm & Haas	1	5.5	5%	0.5	3 ml/min
2	Resintech				0.25	
3					0.5	
4					1	
5	Rohm & Haas	2		20%	0.5	
6	Resintech				0.25	
7					0.5	
8					1	

Objective 2 - Resin Regeneration Column Study

Photo Summary

Column Setup



Resin Sample

Objective 2 - Resin Regeneration Column Study

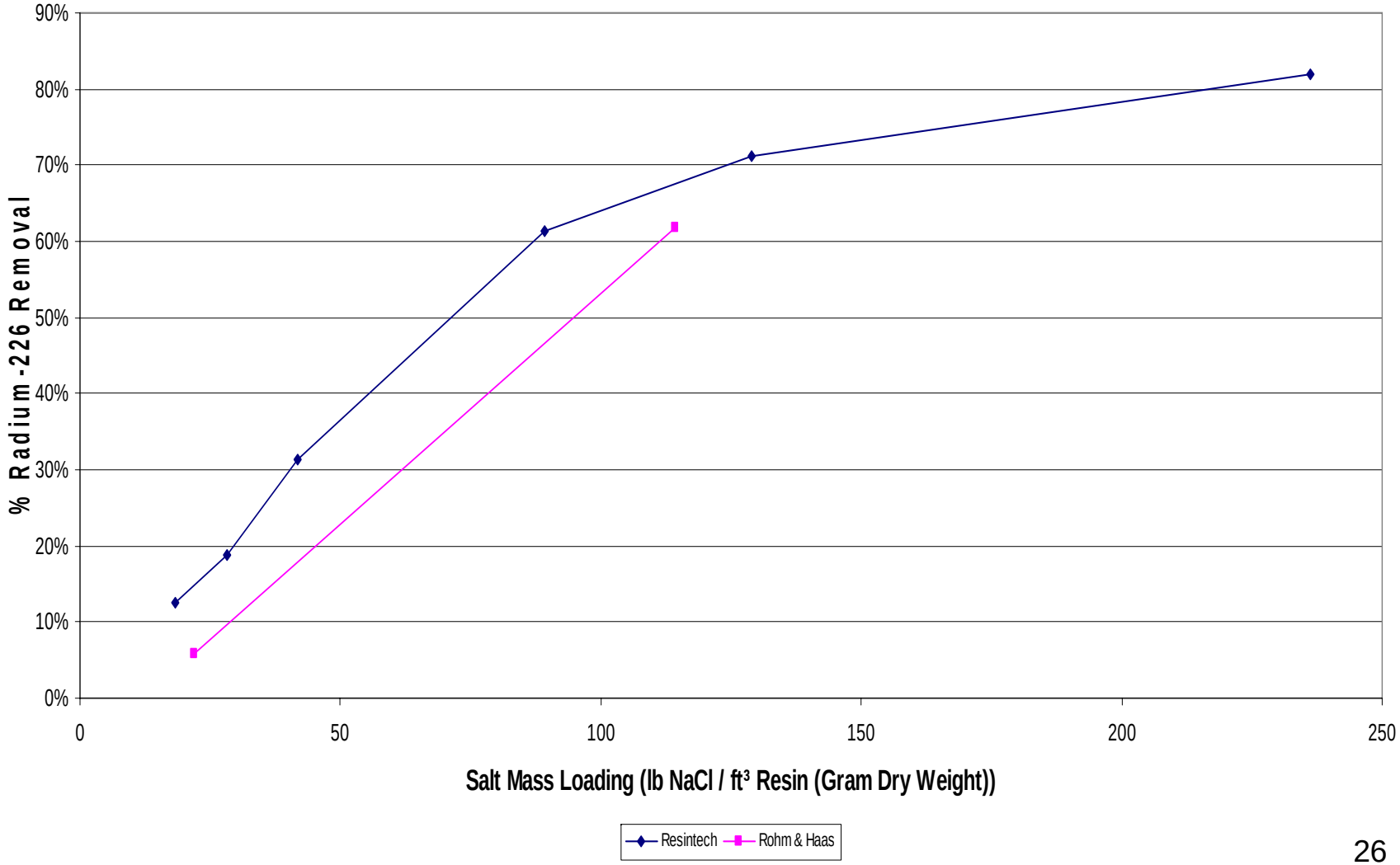
Analysis of Variance Results

Factors	Degrees of Freedom	Sum of Squares	F Ratio	% Contribution
Brine Strength	1	142.629	472.894**	**86.8%**
Resin Type	1	7.526	24.953*	4.4%
Brine Contact Time	1	0.208	0.689	N.S.
Brine Volume	1	0.001	0.002	N.S.
Error	3	0.905		**8.8%**

*Significant at 95% confidence interval
**Significant at 99% confidence interval
N.S. = Factor Not Significant

Objective 2 - Resin Regeneration Column Study

Salt Mass Loading vs. Ra-226 Removal



Objective 3 - Resin Regeneration Field Verification Study

Overview

- Sample cation exchange resins in service for greater than 1 year:
  - Pelham, NH
  - Windham, NH
- Sample resin before and after cleaning
- Clean dirty resin using optimized regenerate solution from previous work
- Compare existing cleaning practices with the results

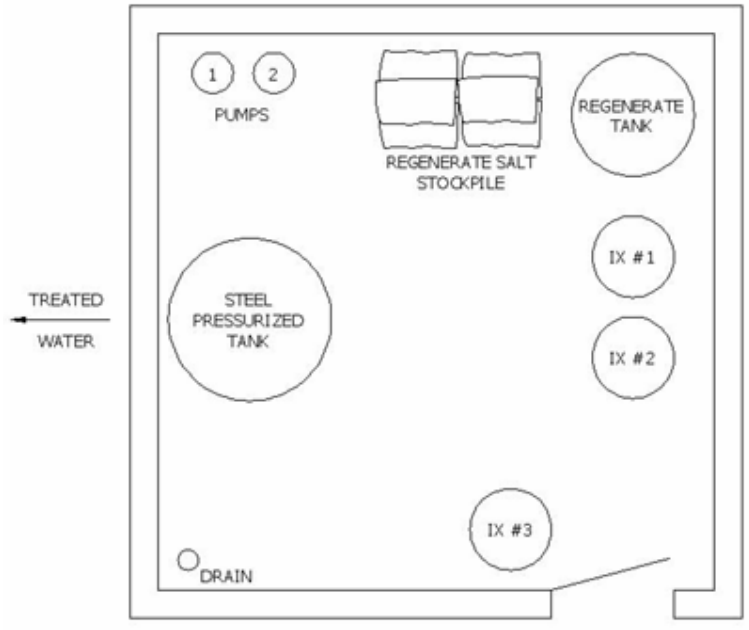
Objective 3 - Resin Regeneration Field Verification Study

Pelham Site Layout

Water Treatment Building

For Apartment Complex

Pelham, NH



Existing Treatment Building Layout

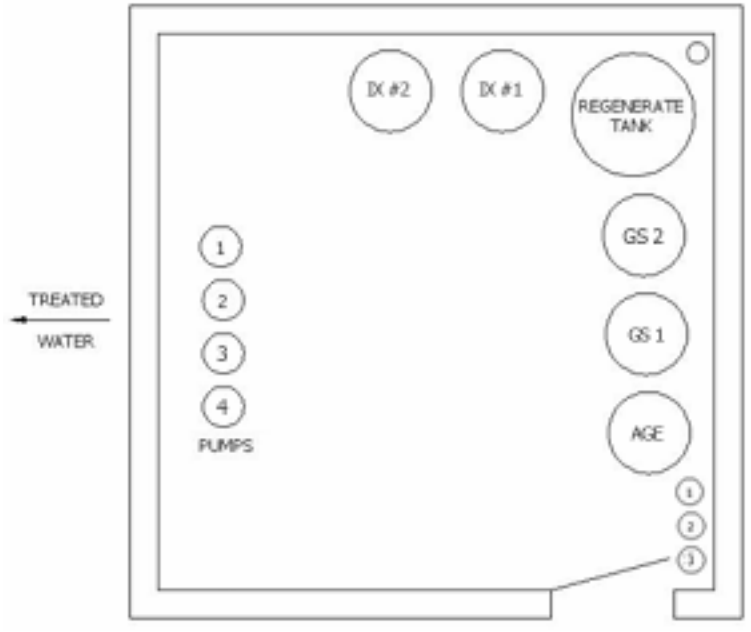
Objective 3 - Resin Regeneration Field Verification Study

Windham Site Layout

Water Treatment Building

For Windham Public Water

Windham, NH



Existing Treatment Building Layout

Objective 3 - Resin Regeneration Field Verification Study

Site Comparison

	Pelham, NH	**Windham, NH**
EPA ID	1852080	2542030
Date Installed	Jan-96	Nov-05
Treatment for	22 Apartments	Small Community (200 Connections)
Average Flow	2.4 gpm	80 gpm
Frequency of Backwash	2 days	1 day
Radium-226 (pCi/L)	10.4, 16	0.8 -4.4
Radium-228 (pCi/L)	0.1, 0.9	0.4
Gross Alpha (pCi/L)	0.6	4
Uranium (pCi/L)	27-81	30
Well Depth	575-625 ft	700-950 ft

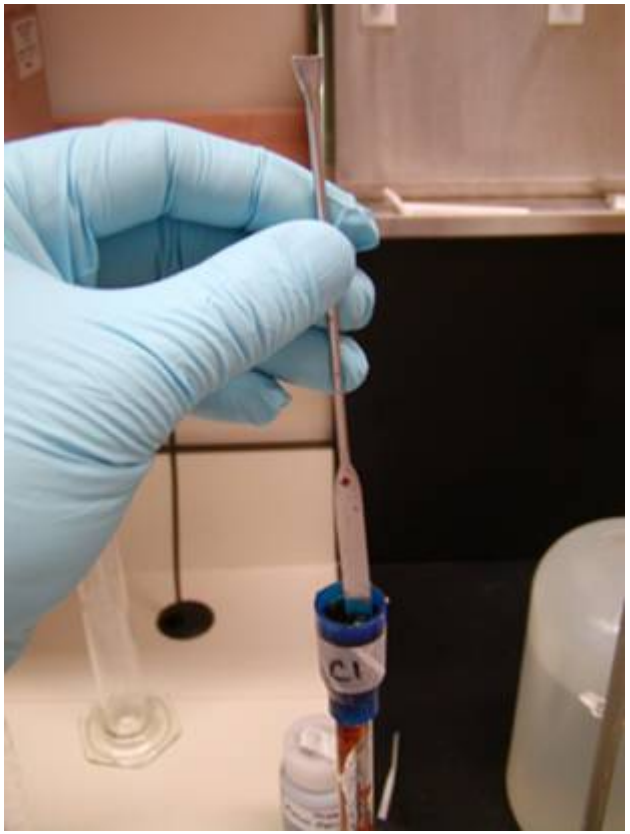
Objective 3 - Resin Regeneration Field Verification Study

Sample Locations

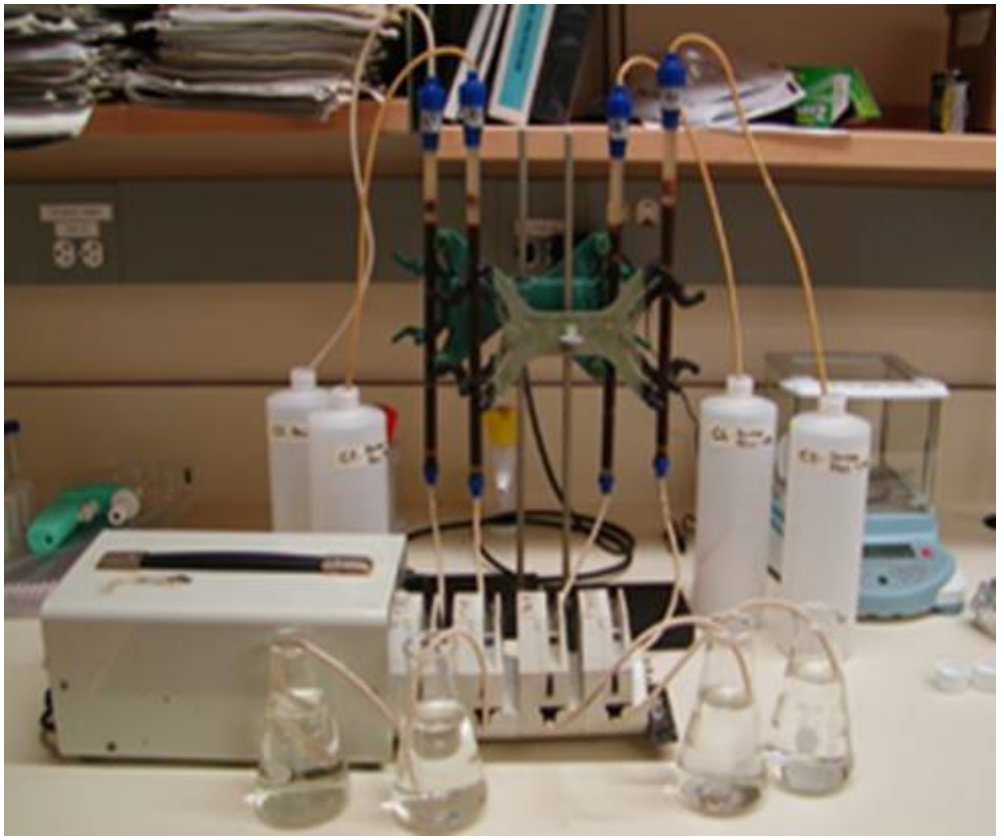
- Brine (500 mL)
  - Before Cleaning
  - After Cleaning
- Resin (200 g)
  - Before Cleaning
  - After Cleaning
- Raw Water (2L)
- Treated Water (2L)

Objective 3 - Resin Regeneration Field Verification Study

Procedure Photo Summary



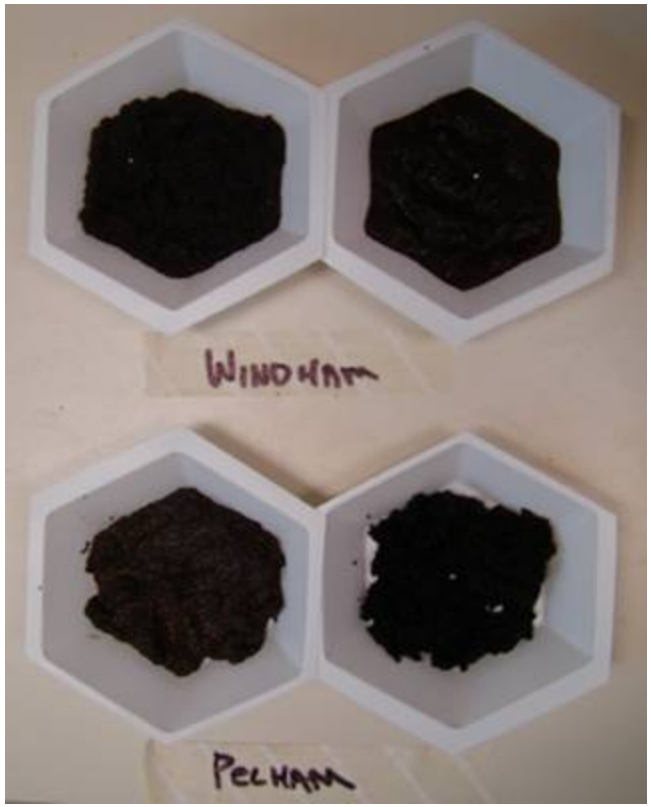
Adding Resin to Column



Column Setup

Objective 3 - Resin Regeneration Field Verification Study

Sample Photo Summary



Resin Samples

Brine Samples

Conclusions

- Objective 1
  - Resin Exhaustion Study
    - Ra-226 buildup is possible on cation exchange resins and occurs past hardness breakthrough
- Objective 2
  - Resin Regeneration Batch Studies
    - Brine strength or salt concentration is most influential cleaning factor
  - Resin Regeneration Column Study
    - Higher salt mass resin loadings (lb NaCl per ft^3 resin) will more effectively clean cation exchange resins
    - Higher salt mass loadings show diminishing removals (non-linear relationship)
    - No Radium-226 removals greater than 85%
- Objective 3
  - Resin Regeneration Field Verification Study
    - Treatment plants with regular maintenance and consistent salt crock levels can extend the life expectancy and effectiveness of the ion exchange resin in drinking water treatment (hypothesis)

Recommendations

- Treatment Operators
  - Maintain high salt mass loading on resin to optimize regeneration and Radium-226 removal from cation exchange resins
- Designers
  - Consider space requirements for ease of maintenance for operators when designing treatment system layout
- Developers
  - Pursue other drinking water sources if groundwater contains excessively high levels of radionuclides

Questions?