

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

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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

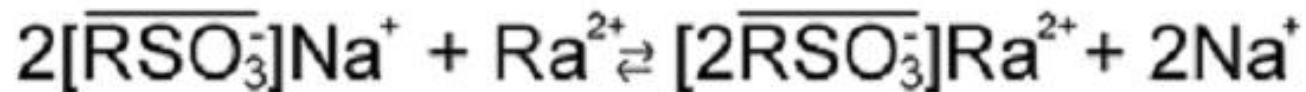
<u>Regulated Contaminant</u>	<u>MCL</u>	<u>MCLG</u>
Beta/photon emitters	4 mrem/year	0
Gross alpha particle	15 pCi/L	0
Combined Radium-226/228	5pCi/L	0
Uranium	30 ug/L	0

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)



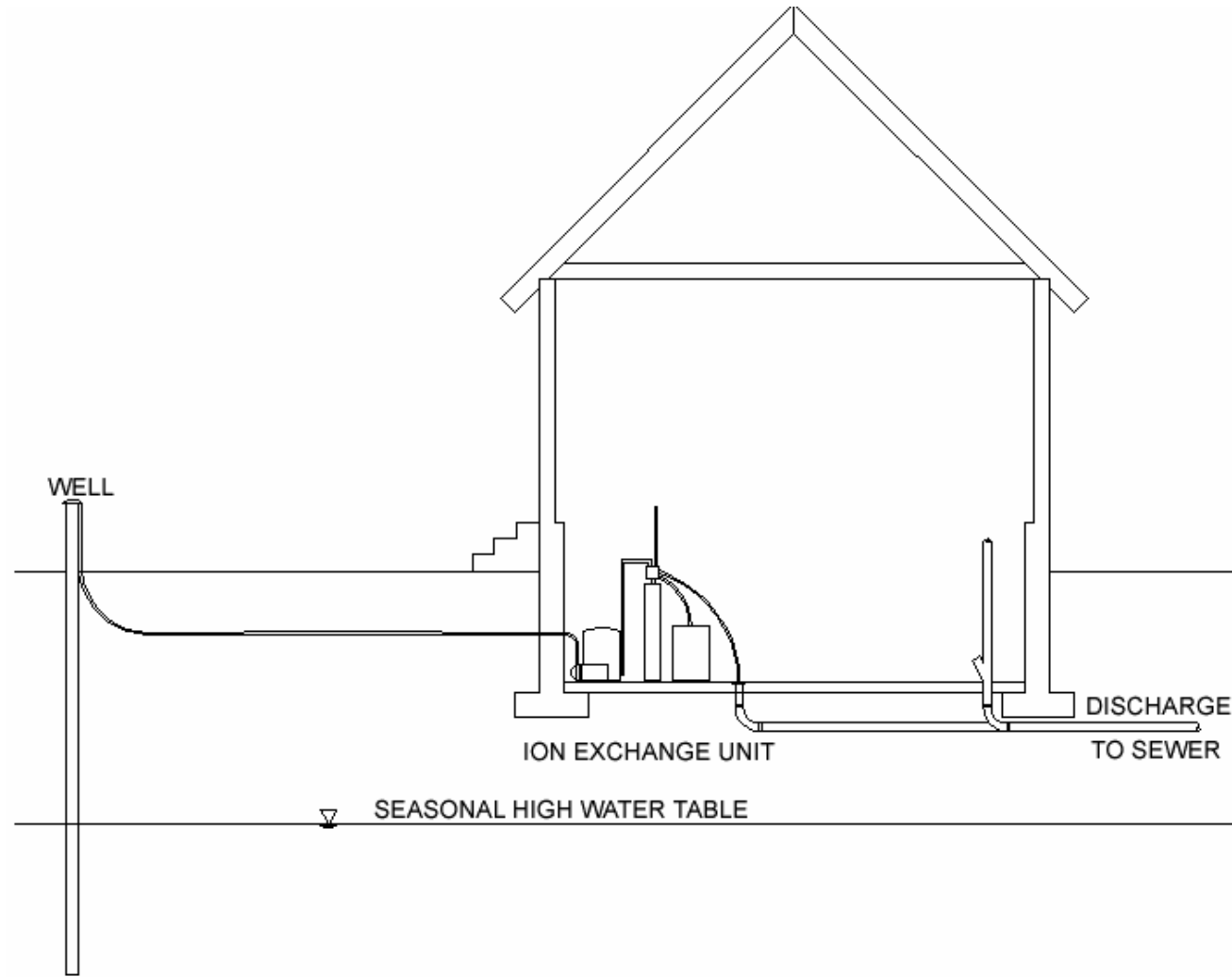
- Backwash Cycle (Resin Regeneration)



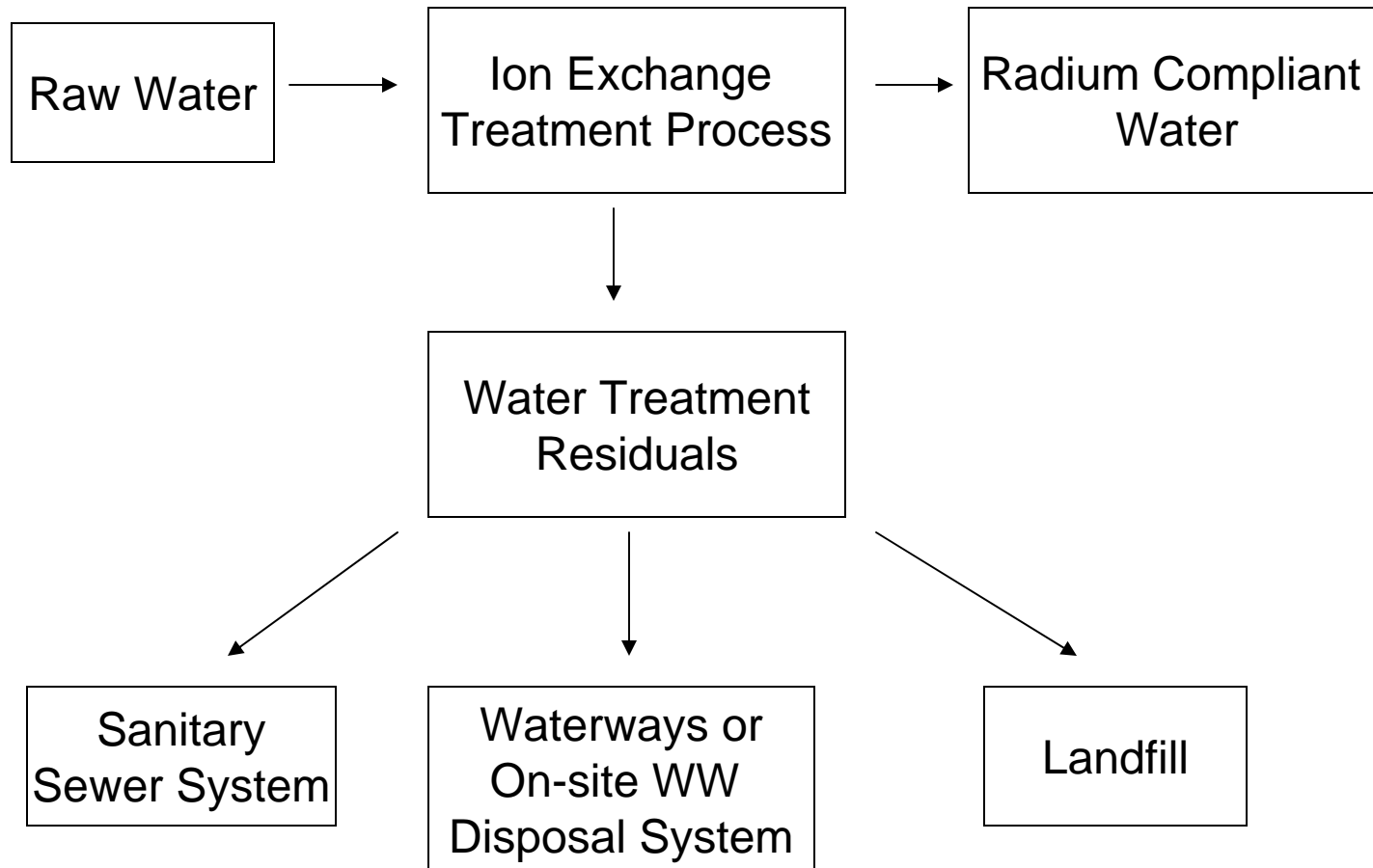
Cation Exchange Resin

- 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

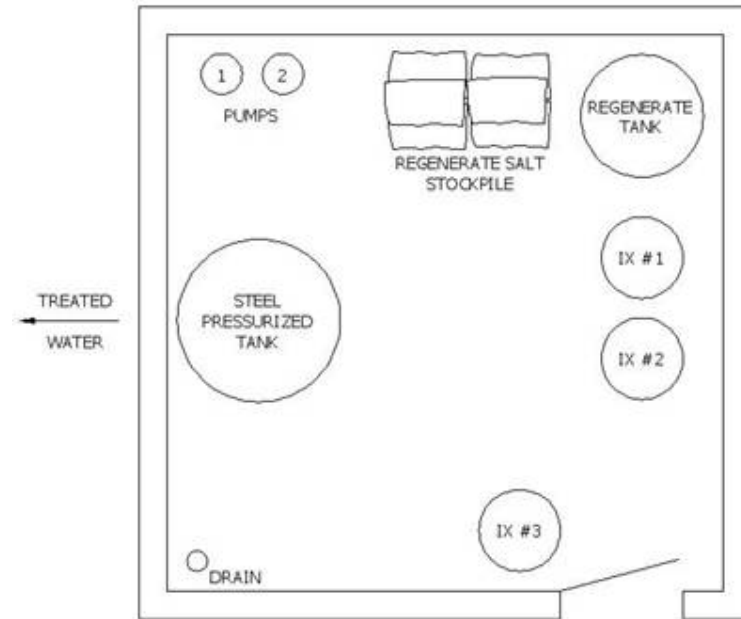
Project Work Tasks Outline

- 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



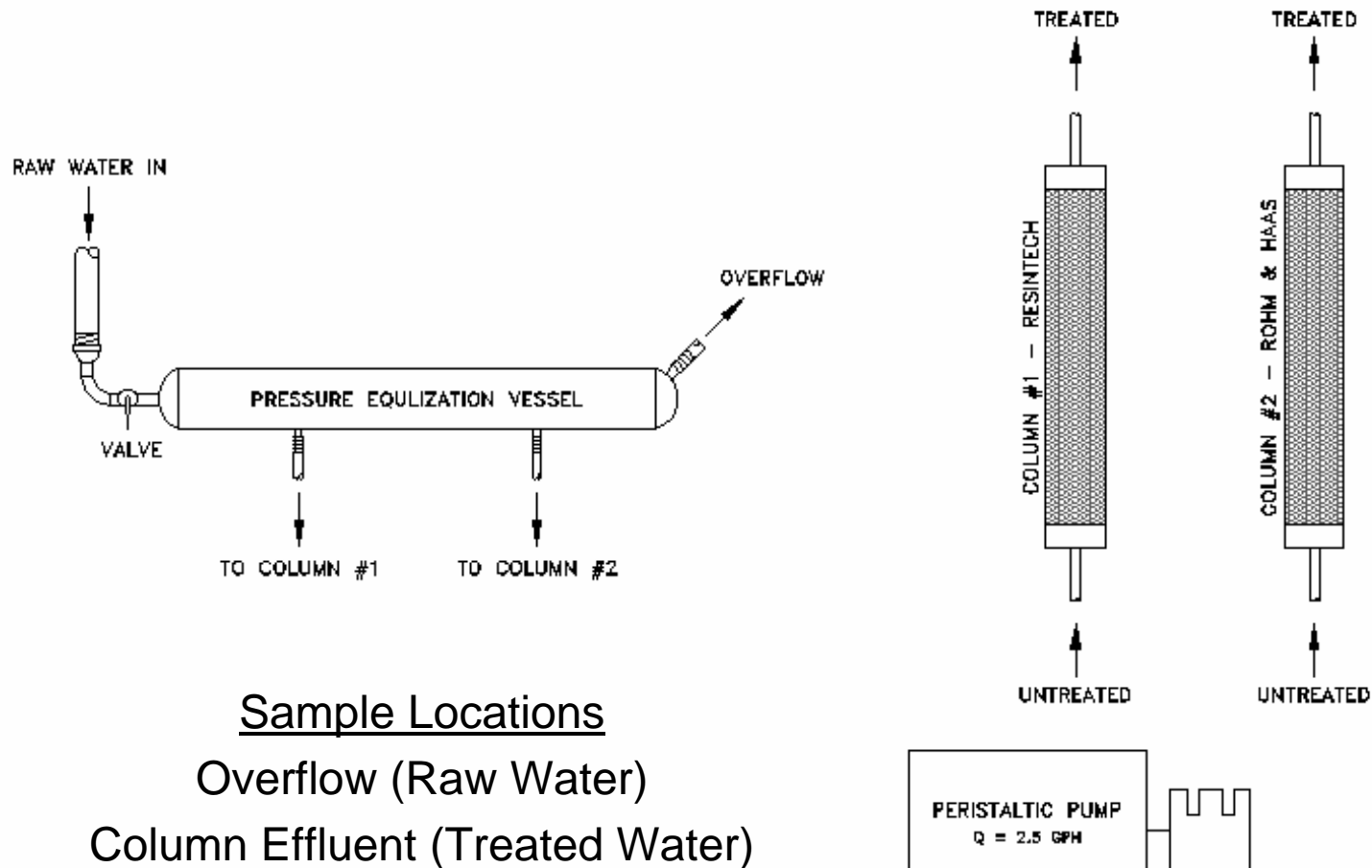
Water Treatment Building
For Apartment Complex
Pelham, NH



Treatment Building Layout

Objective 1 - Resin Exhaustion Study

Column Layout



Sample Locations

Overflow (Raw Water)

Column Effluent (Treated Water)

Objective 1 - Resin Exhaustion Study Sampling Event



Sample Volumes
2 L (Radium-226)
14 mL (Metals)

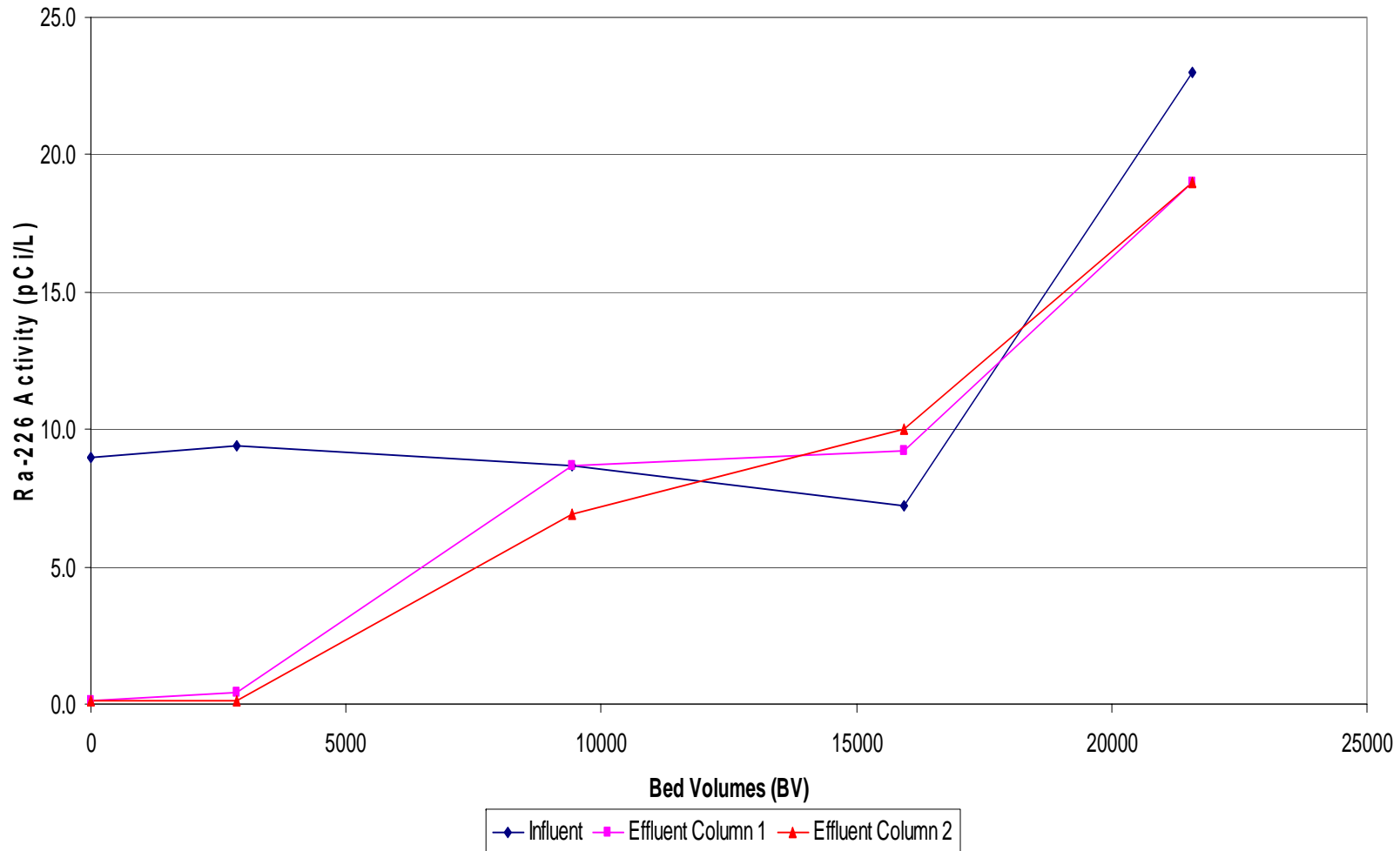


Raw Water Data

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

<u>Summary Table - Column Setup 1 (40 Days)</u>			
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

<u>Summary Table - Column Setup 2 (28 Days)</u>			
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

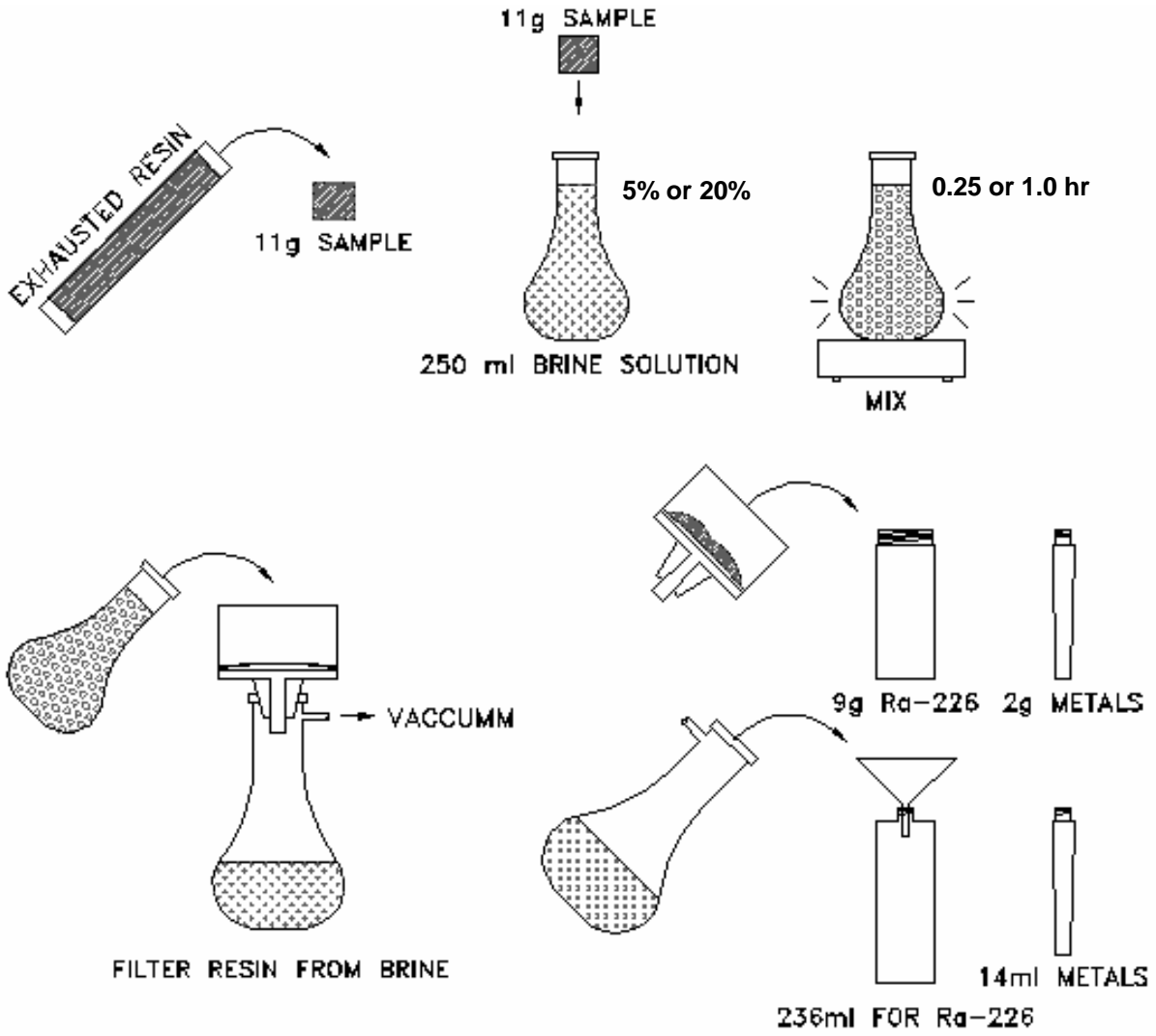
Experimental Approach

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	

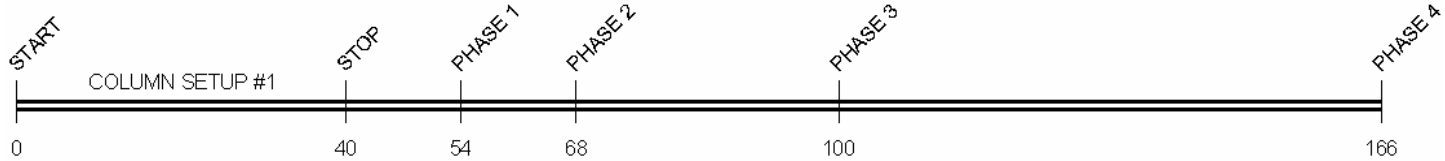
Objective 2 - Resin Regeneration Batch Studies

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			0.25	
4			1	
5	20	5.5	0.25	
6			1	
7			0.25	
8			1	

Phase 3

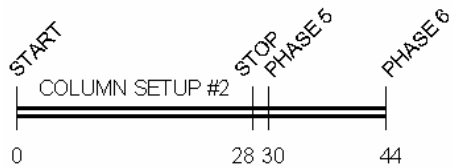
Sample	Brine Strength (% NaCl)	pH	Regenerate Contact Time (hr)	Exposure Time (days)
17	5	5.5	0.25	100
18			1	
19			0.25	
20			1	
21	20	5.5	0.25	
22			1	
23			0.25	
24			1	

Phase 2

Sample	Brine Strength (% NaCl)	pH	Regenerate Contact Time (hr)	Exposure Time (days)
9	5	5.5	0.25	68
10			1	
11			0.25	
12			1	
13	20	5.5	0.25	
14			1	
15			0.25	
16			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			0.25	
28			1	
29	20	5.5	0.25	
30			1	
31			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			0.25	
36			1	
37	20	5.5	0.25	
38			1	
39			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			0.25	
44			1	
45	20	5.5	0.25	
46			1	
47			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

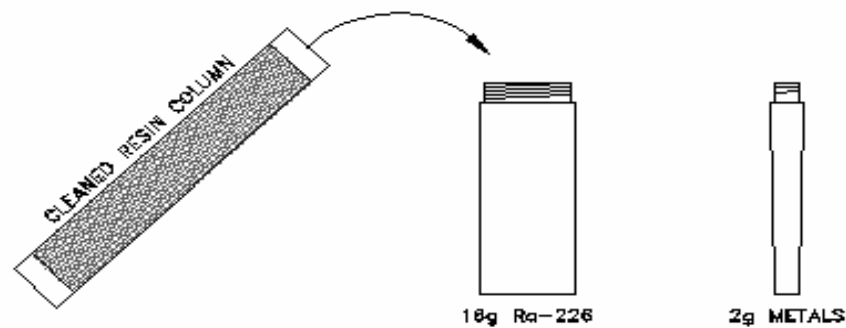
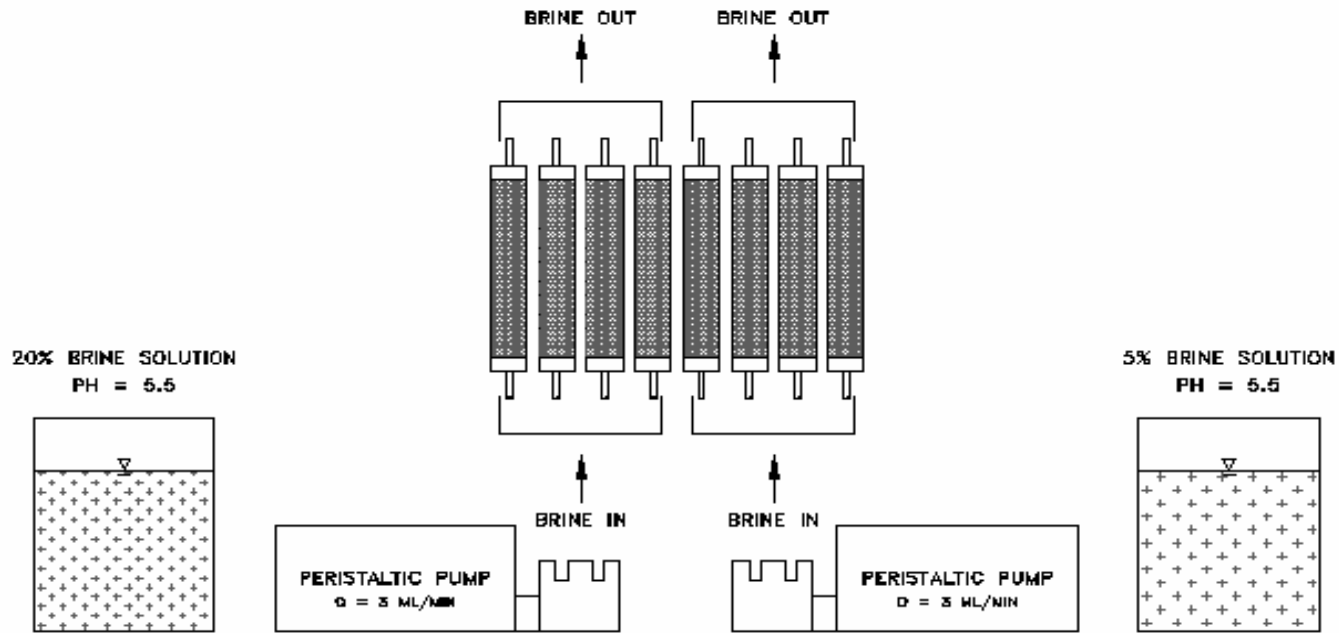
Factors	Degrees of Freedom	Sum of Squares	F Ratio	% Contribution
Brine Strength	1	1.022	105.802**	46.0%
Resin Type	1	0.351	36.332 **	15.5%
Initial Radium-226 Resin Loading	1	0.239	24.751**	10.4%
Column Setups	1	0.183	18.980 **	7.9%
pH	1	0.075	7.817**	3.0%
Radium-226 Exposure Time	1	0.005	0.555**	N.S.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



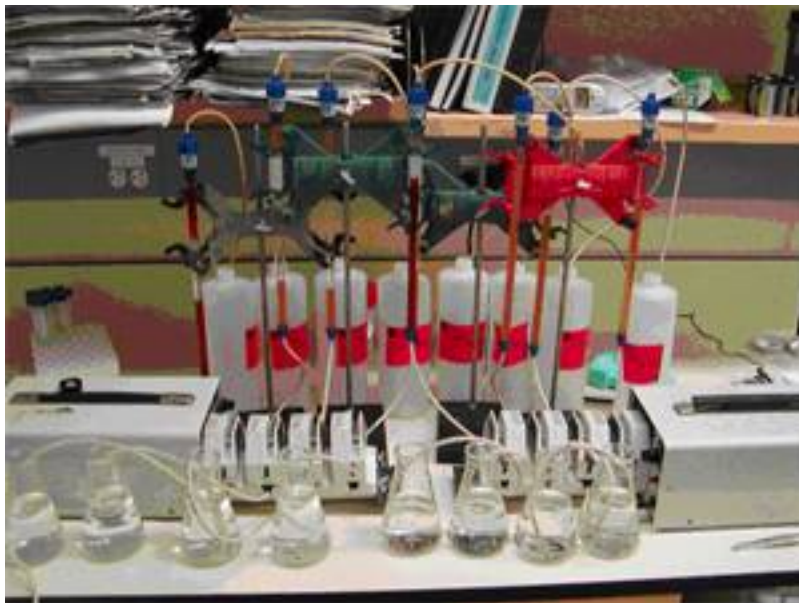
Objective 2 - Resin Regeneration Column Study

Experimental Approach

Using the most influential variables from Batch Studies

<u>Column</u>	<u>Resin</u>	<u>Pump</u>	<u>pH</u>	<u>Brine Strength</u>	<u>Contact Time (hr)</u>	<u>Flow Rate (mL/min)</u>
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%

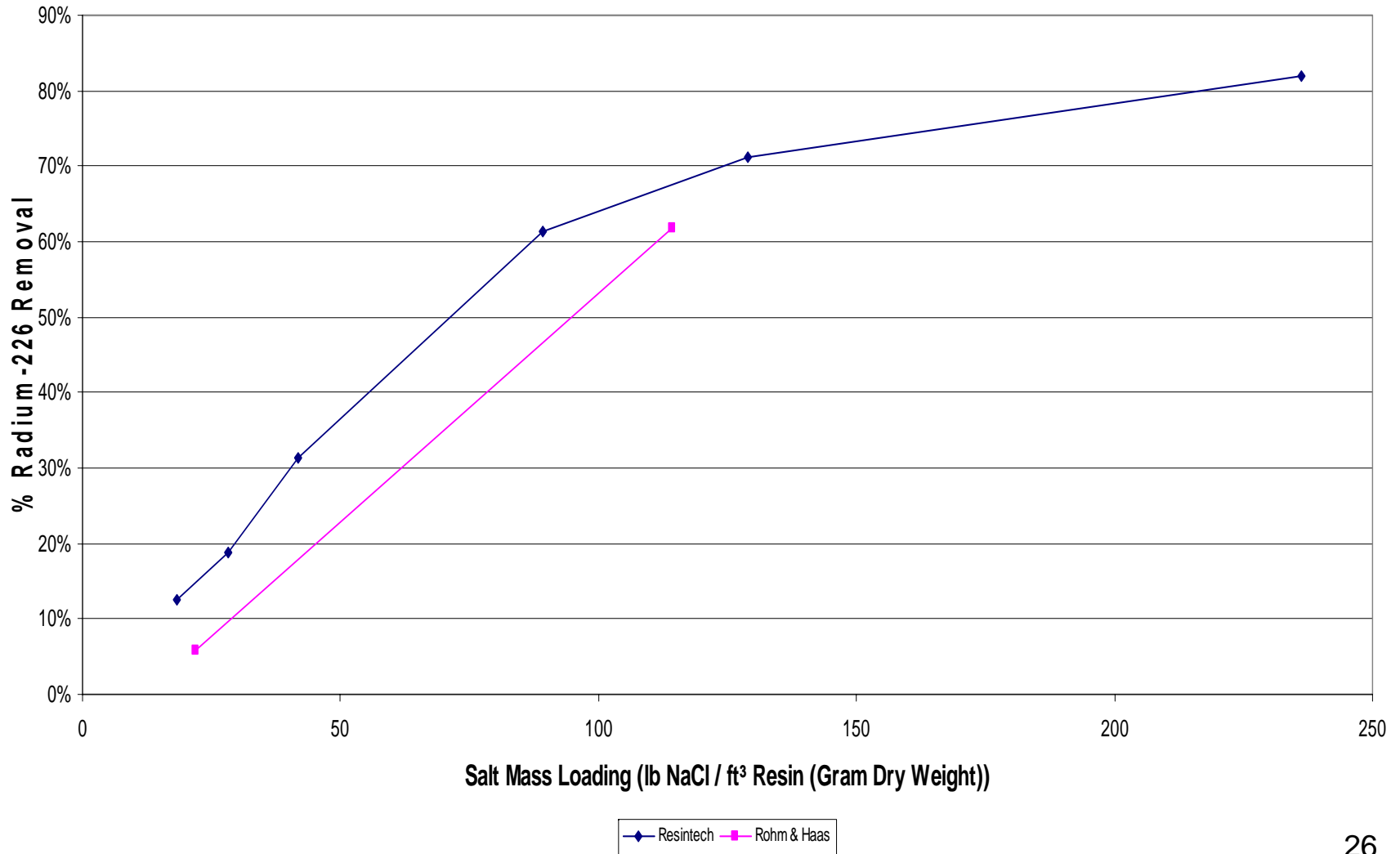
*Significant at 95% confidence interval

**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

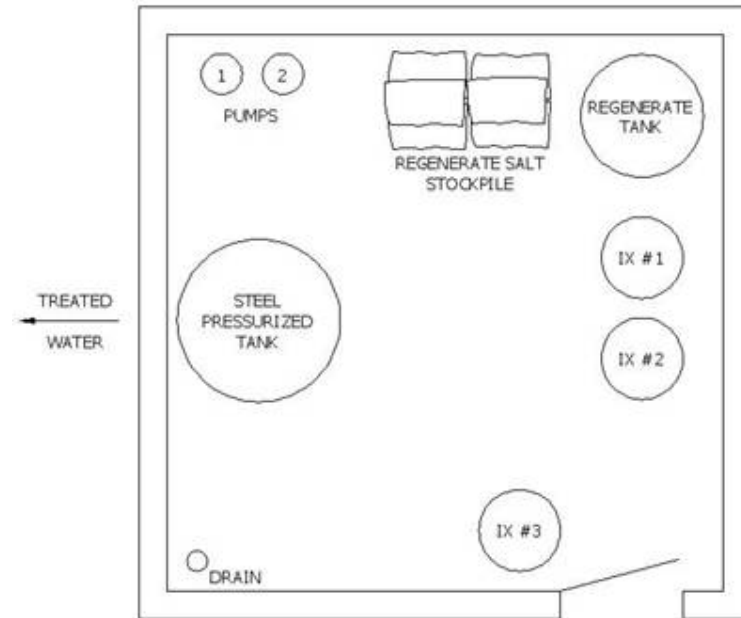
- Sample cation exchange resins in service for greater than 1 year:
 - Pelham, NH
 - Windham, NH
- Sample resin before and after cleaning
- Clean dirty resin using optimized regenerate solution from previous work
- Compare existing cleaning practices with the results

Objective 3 - Resin Regeneration Field Verification Study

Pelham Site Layout



Water Treatment Building
For Apartment Complex
Pelham, NH



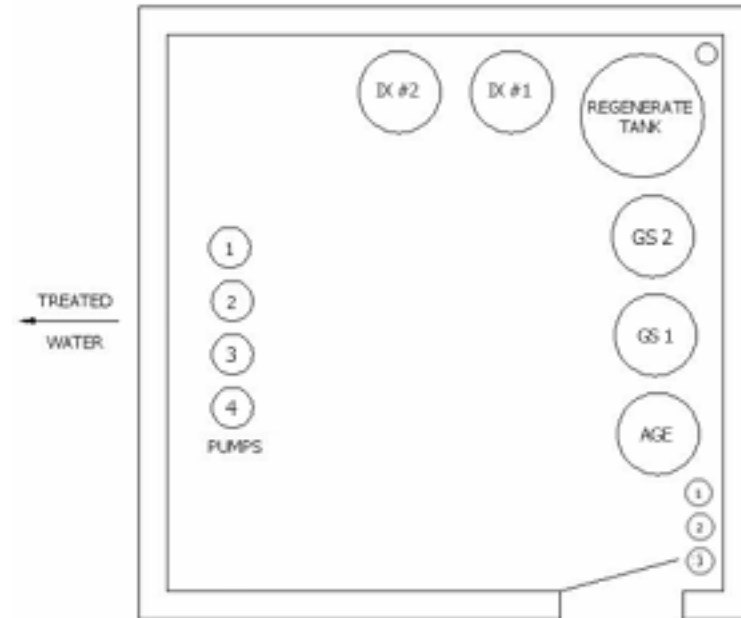
Existing Treatment Building Layout

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

	<u>Pelham, NH</u>	<u>Windham, NH</u>
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

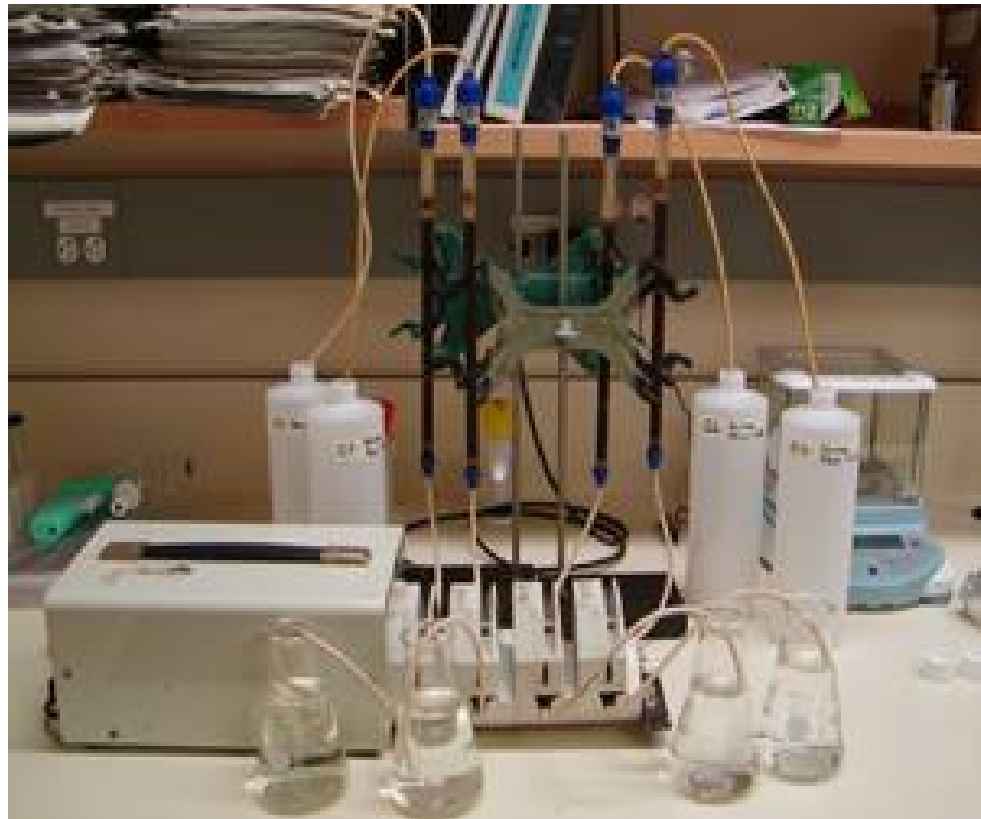


- Brine (500 mL)
 - Before Cleaning
 - After Cleaning
- Resin (200 g)
 - Before Cleaning
 - After Cleaning
- Raw Water (2L)
- Treated Water (2L)

Objective 3 - Resin Regeneration Field Verification Study Procedure Photo Summary



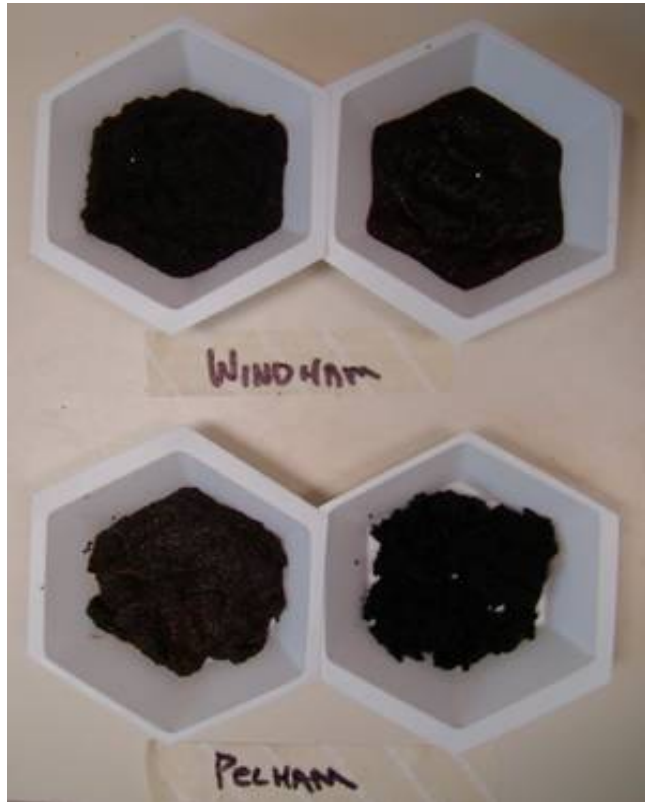
Adding Resin to Column



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 ft³ 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?