Pilot Study Report

for

Z-88™ Radium Treatment Process

conducted at the

Richland Special Utility District
Richland Springs, Texas

May 18, 2004

WATER REMEDIATION TECHNOLOGY, LLC
5460 Ward Road, Suite 100, Arvada, Colorado 80002 · 303-424-5355 · FAX 303-425-7497

Executive Summary

The Richland Special Utility District is located in Richland Springs, Texas. The pilot unit was located adjacent to the Utility's 100,000 gallon storage tank. Source water for the pilot was taken at the point where the water exits the storage tank. Discharge water from the pilot unit was released on the ground, on Richland SUD property, adjacent to the pilot unit location. Naturally occurring radionuclides in the Richland SUD's raw water source exceed current Maximum Contaminant Levels (MCL's) for Gross Alpha Emitters and Combined Radium.

The Richland SUD selected Water Remediation Technology's (WRT) Z-88™ Radium Removal Process as a possible cost effective solution for their radium problem. WRT provided a one GPM (gallons per minute) pilot plant, which was delivered and installed on December 3, 2003.

The purpose of this pilot study is to demonstrate the effectiveness of the treatment process on high radium and gross alpha water, establish design parameters for the full scale systems and meet regulatory piloting requirements.

As summarized in Table 1 below, the pilot unit successfully met gross alpha and radium compliance at all times during this 90 day study. It also performed successfully in all criteria that were predicated by the Texas Department of Environmental Quality (TCEQ). The pilot plant operated for over 90 days and throughout this period effectively reduced the level of radium (Figure 1) and gross alpha (Figure 2) to less than the MCL.

Table 1. Gross Alpha and Radium levels in feed and treated water.

	Feed (pCi/L)	Discharge @ Column 8 (pCi/L)
Gross Alpha MCL	**NA**	**15**
Average	37.7	1.8
Highest value	52.0	4.6
Lowest Value	29.2	0.5
Radium MCL	**NA**	**5**
Average	33.8	0.9
Highest value	44.7	1.4
Lowest Value	21.9	0.6

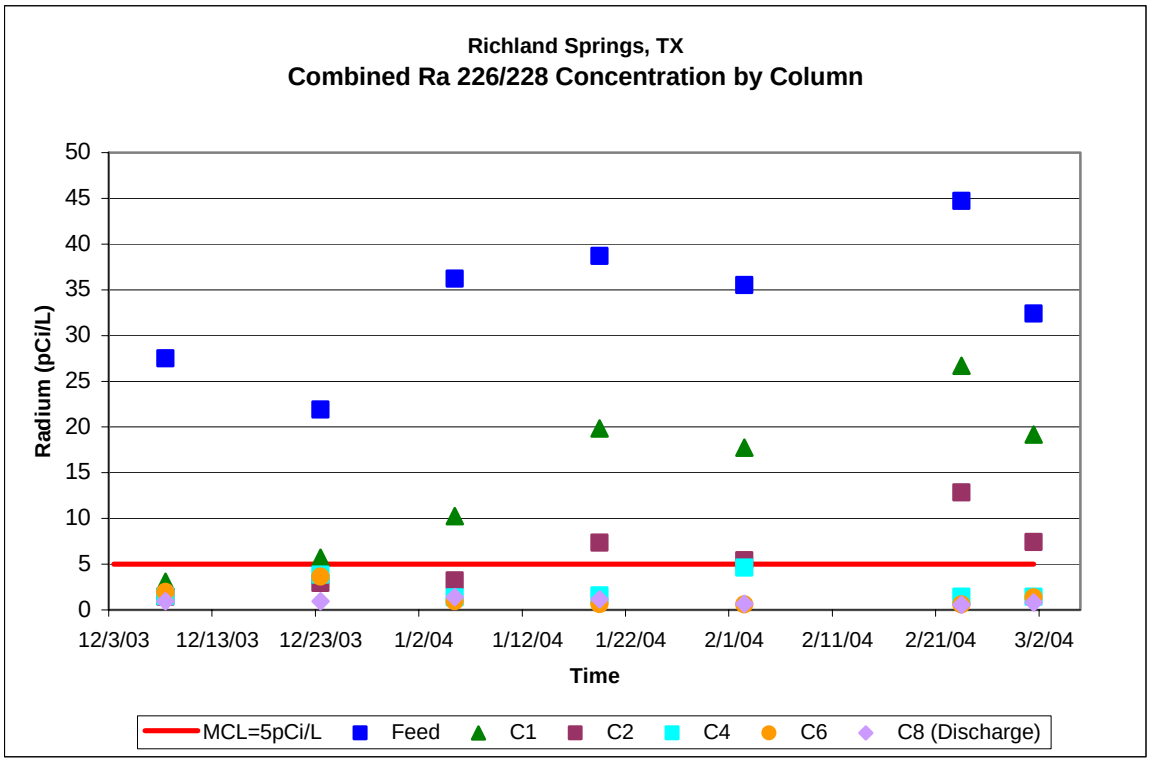

Figure 1

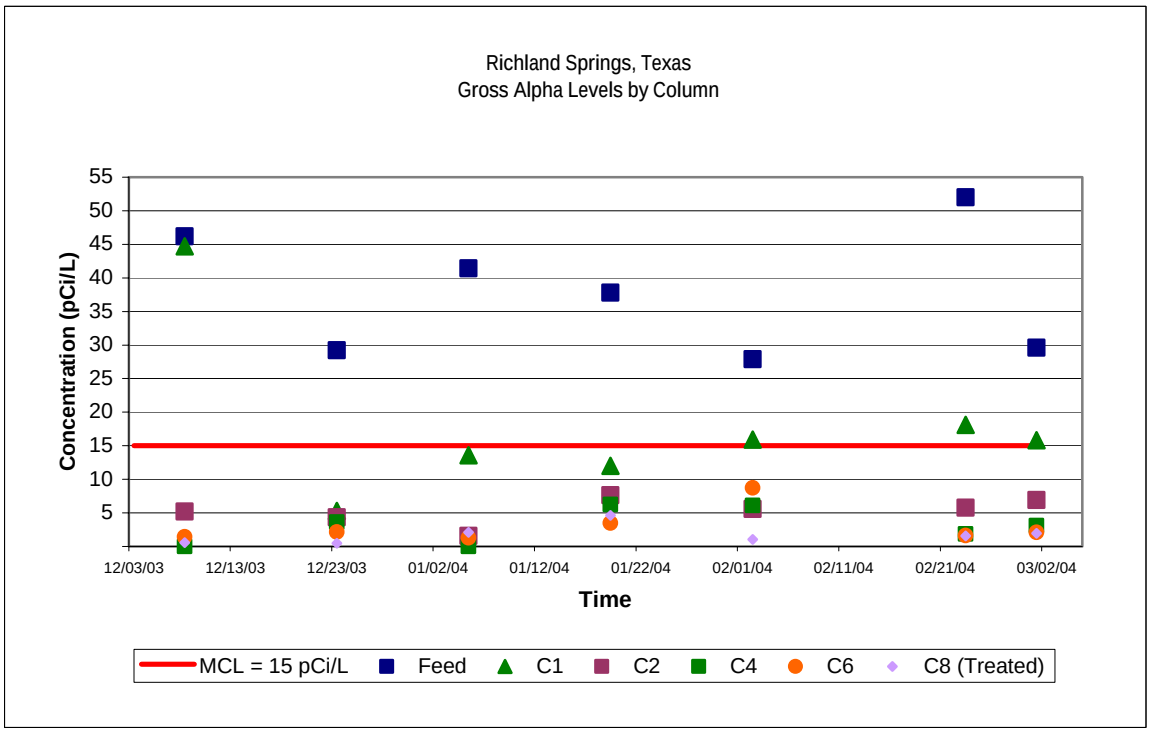

Figure 2

The results are also shown in Table 1. The average feed concentration of gross alpha, 37.7 pCi/L (pico Curies per Litre) was reduced to 1.7 pCi/L after column 8 and has yet to exceed 4.6 pCi/L. Similarly, the average feed concentration of radium, 33.8 pCi/L, was reduced to 0.9 pCi/L after column 8 and has yet to exceed 1.4 pCi/L. Both discharge concentrations are well below their respective MCL's.

Application Information

The Richland Special Utility District is a public water system with headquarters in Richland Springs, Texas. The District serves water to rural customers in two separate parts. This pilot study was done for the Brady part of the District in McCulloch County, Texas. Water at this site is drawn from the Hickory Underground Aquifer at a depth of 2,600 feet and is provided to about 320 customers.

Technology Overview

Water Remediation Technology's (WRT) Z-88™ Radium Treatment Process utilizes Z-88™ patent pending adsorptive media in a series of up flow treatment vessels to reduce gross alpha and remove radium 226 and 228 from drinking water. The treatment system uses the water pressure generated from the well, approximately 10 to 15 psi, to operate. No chemicals are added to the water for the treatment process. After the media is loaded with radium, it is removed from the circuit and permanently disposed of in a licensed facility. WRT designs, manufactures and provides the facility and produces the media used in the facility. The handling and exchange of new media for spent media, as well as the shipping and disposal into licensed disposal sites, is conducted or arranged for by WRT staff. The Z-88™ process media is ANSI/NSF Standard 61 certified for use in drinking water.

Equipment Overview

The pilot equipment used was a self-contained Z-88™ trailer mounted unit. The treatment train used in this pilot study consists of eight 4" diameter by 4' vertical height columns, each containing 25" of Z-88™ process media mounted on the wall of the trailer. The columns in the pilot unit are clear for visual observation of the media and process. The source water enters the unit through a ¾" diameter hose, passes through a control valve and flow meter, and enters the bottom of the first column. All columns operate in an up-flow mode, with the flow exiting the top of the first column, then following the same flow path through each column in series (see Figure 3). The last component in the system is a safety filter. Sample ports are located prior to the first column, and after each of the columns in the series.

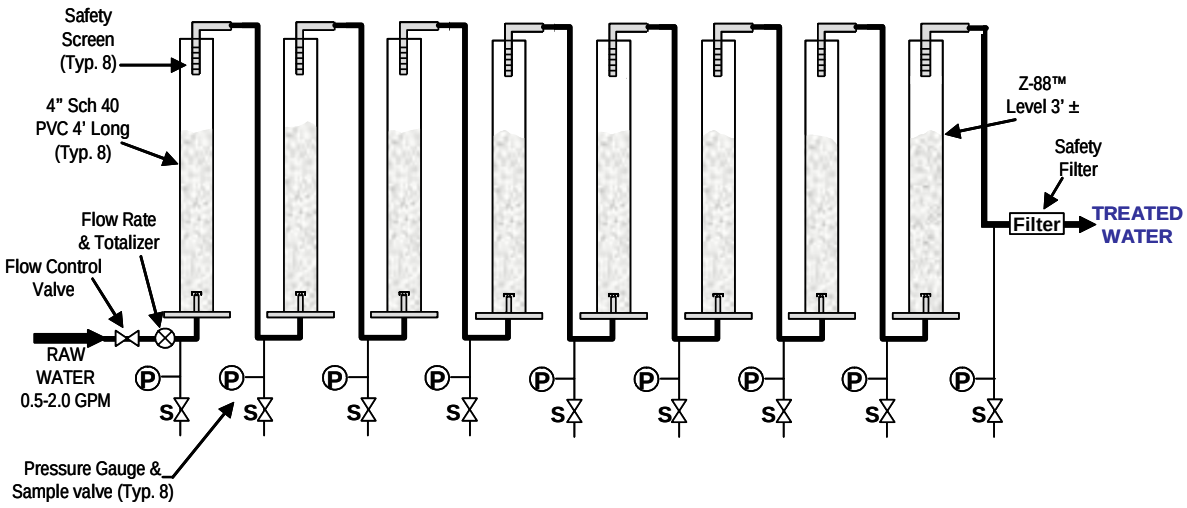

Figure 3. Typical Process Flow Diagram

The pilot unit operating data is used to establish the Empty Bed Contact Time (EBCT) and Hydraulic Loading Rate (HLR) suitable for a full scale system. The purpose of the short columns in the pilot plant is to allow more data to be collected and faster evaluation of the radium loading on the Z-88™ media.

Z-88™ pilot study at Richland SUD.

Statement of Purpose

The levels during the pilot study in the well were as high as 52.0 pCi/L for gross alpha and 44.7 pCi/L for radium, both exceeding the Environmental Protection Agency (EPA) mandated MCL's.

The purposes of this pilot study are to:

- Demonstrate the ability of the WRT Z-88™ Radium Treatment Process to consistently and effectively reduce the gross alpha and radium content to below the MCL on this specific water.
- Demonstrate the reliability and ease of operation of the WRT Process.
- Comply with regulatory piloting requirements.
- Develop design criteria for the full-scale facility.

Delivery and Installation of Pilot Unit

The pilot unit was delivered and installed on December 3, 2003. Set up consists of securing the trailer and connecting the water source and a discharge line. The pilot study began the same day. Initial water samples were taken at that time. Data used in writing this report was collected over a 90 day test period, with some additional data gathered after the approved test protocol was completed. All testing was completed by April 27, 2004.

Operator training for pilot unit operation, monitoring and sampling was conducted on the day of installation, and a schedule for sampling was established. Samples were collected from ½" valves located in the feed line and after discharge from each respective test column, at sample intervals prescribed by the Texas Department of Environmental Protection. The agreed upon test protocol is attached as Appendix A.

Analytical

Radiological samples were sent to ACZ Laboratories, Inc., a National Environmental Laboratory Accreditation Program certified laboratory, for analysis. Methods for analysis were:

Gross Alpha	EPA M900.0
Radium 226	EPA M9345
Radium 228	EPA M9320

Results

The sampling results are shown in Tables 2 and 3. Feed samples were collected immediately prior to the first column of Z-88™, and labeled "Feed". Samples taken after each column are labeled, C1 for example, and show the discharge level for that column. Analytical laboratory certificates are attached as Appendix B. Figures 1 and 2 show gross alpha and combined radium 226 and 228 levels in the feed water entering the pilot unit, and treated water exiting the pilot unit. The graphs clearly show that the pilot unit successfully reduced the gross alpha levels to below the MCL of 15 pCi/L and combined radium levels to below the MCL of 5 pCi/L.

Table 2. Gross Alpha Test Results

Gross Alpha	Column Concentrations (pCi/L)					
Date	Feed	C1	C2	C4	C6	C8
12/3/03						
12/8/03	46.2	44.7	5.2	0.0	1.5	0.6
12/23/03	29.2	5.3	4.4	3.6	2.2	0.5
1/5/04	41.4	13.6	1.6	0.0	1.3	2.1
1/19/04	37.8	12.0	7.6	6.2	3.5	4.6
2/2/04	27.9	15.9	5.6	6.1	8.7	1.1
2/23/04	52.0	18.1	5.8	1.9	1.6	1.6
3/1/04	29.6	15.8	6.9	3.1	2.1	2.0

Table 3. Radium Test Results

Ra-226	Column Concentrations (pCi/L)					
Date	Feed	C1	C2	C4	C6	C8
12/3/03						
12/8/03	14.4	1.3	0.4	0.3	0.2	0.3
12/23/03	0.3	0.1	0.0	0.1	0.1	
1/5/04	13.6	3.3	0.8	0.5	0.3	0.6
1/19/04	15.7	5.1	1.9	0.3	0.2	0.1
2/2/04	15.6	5.8	2.0	0.3	0.2	0.0
2/23/04	13.7	6.9	3.1	0.5	0.2	0.1
3/1/04	14.0	8.4	3.6	0.6	0.3	0.2

Ra-228	Column Concentrations (pCi/L)					
Date	Feed	C1	C2	C4	C6	C8
12/3/03						
12/8/03	13.1	1.8	1.0	1.2	1.8	0.7
12/23/03	21.6	5.6	2.9	3.8	3.6	
1/5/04	22.6	6.9	2.4	0.9	0.7	0.8
1/19/04	23.0	14.7	5.5	1.2	0.4	1.1
2/2/04	19.9	11.9	3.5	4.3	0.4	0.7
2/23/04	31.0	19.8	9.8	1.0	0.4	0.4
3/1/04	18.4	10.8	3.8	0.9	1.1	0.6

Ra Combined	Column Concentrations (pCi/L)					
Date	Feed	C1	C2	C4	C6	C8
12/3/03						
12/8/03	27.5	3.1	1.4	1.5	2.0	1.0
12/23/03	21.9	5.7	2.9	3.9	3.7	
1/5/04	36.2	10.3	3.2	1.4	1.0	1.4
1/19/04	38.7	19.8	7.4	1.6	0.6	1.2
2/2/04	35.5	17.7	5.4	4.6	0.6	0.7
2/23/04	44.7	26.7	12.8	1.4	0.6	0.6
3/1/04	32.4	19.2	7.4	1.5	1.4	0.8

One requirement of the pilot study test protocol was to split two samples and send them simultaneously to ACZ Labs, the laboratory providing the analysis for this pilot study, and the Texas Department of Health - Bureau of Laboratories for comparison and validation of data. Richland SUD also elected to send some additional samples to Jordan Laboratories, Incorporated for a third comparison of results.

The results are provided in Table 4 and 5 below. Support documentation for these tables are attached as Appendix C and D respectively.

Table 4. Gross Alpha and Radium Split Test Results

Gross Alpha	Column Concentrations (pCi/L)								
1/19/04	Feed	C1	C2	C3	C4	C5	C6	C7	C8
ACZ Labs	37.8	12.0	7.6		6.2		3.5		4.6
Texas Health Dept	55.6	20.9	8.5		2.0		2.0		2.0
Ra-226	**Column Concentrations (pCi/L)**								
1/19/04	**Feed**	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**
ACZ Labs	15.7	5.1	1.9		0.3		0.2		0.1
Texas Health Dept	10.3	5.2	1.1		0.2		0.2		0.2
Ra-228	**Column Concentrations (pCi/L)**								
1/19/04	**Feed**	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**
ACZ Labs	23.0	14.7	5.5		1.2		0.4		1.1
Texas Health Dept	24.4	10.1	3.0		1.0		1.0		1.0
Ra Combined	**Column Concentrations (pCi/L)**								
1/19/04	**Feed**	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**
ACZ Labs	38.7	19.8	7.4		1.6		0.6		1.2
Texas Health Dept	34.7	15.3	4.1		1.2		1.2		1.2

Gross Alpha	Column Concentrations (pCi/L)								
3/1/04	Feed	C1	C2	C3	C4	C5	C6	C7	C8
ACZ Labs	29.6	15.8	6.9	5.4	3.1	1.8	2.1	0.3	0.3
Texas Health Dept	52.9	24.4	10.9	4.6	2.1	2.0	2.0	2.0	2.0
Ra-226	**Column Concentrations (pCi/L)**								
3/1/04	**Feed**	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**
ACZ Labs	14.0	8.4	3.6	1.4	0.6	0.4	0.3	0.1	0.2
Texas Health Dept	9.5	6.0	2.6	1.0	0.4	0.2	0.2	0.2	0.2
Ra-228	**Column Concentrations (pCi/L)**								
3/1/04	**Feed**	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**
ACZ Labs	18.4	10.8	3.8	2.0	0.9	0.8	1.1	1.0	0.6
Texas Health Dept	25.8	15.6	6.6	1.7	1.0	1.0	1.0	1.0	1.0
Ra Combined	**Column Concentrations (pCi/L)**								
3/1/04	**Feed**	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**
ACZ Labs	32.4	19.2	7.4	3.4	1.5	1.1	1.4	1.1	0.8
Texas Health Dept	35.3	21.6	9.2	2.7	1.4	1.2	1.2	1.2	1.2

Table 5. Gross Alpha and Radium Split Test Results

Gross Alpha	Column Concentrations (pCi/L)		
Jordan Labs	Feed	C1	C8
1/12/04	199.0	40.0	2.8
1/30/04			
Ra-226	**Column Concentrations (pCi/L)**		
Jordan Labs	**Feed**	**C1**	**C8**
1/12/04	13.0	5.4	0.0
1/30/04	13.0	6.6	0.6
Ra-228	**Column Concentrations (pCi/L)**		
Jordan Labs	**Feed**	**C1**	**C8**
1/12/04	38.0	16.0	0.0
1/30/04	36.0	17.0	2.0
Ra Combined	**Column Concentrations (pCi/L)**		
Jordan Labs	**Feed**	**C1**	**C8**
1/12/04	51.0	21.4	0.0
1/30/04	49.0	23.6	2.6

The effects of shutting the system down for short to intermediate periods was investigated as an additional component of this pilot study. On March 3, 2004 samples were taken from column 1 and the discharge water (column 8) and then the flow was stopped. The flow was restarted 3 hours later at which time samples were taken from column 1 at restart, 2 minutes after restart, and again at 4 minutes after restart. A final sample was taken of the discharge water at 20 minutes after restart. The water was turned off on March 4, 2004. The results from these samples are shown in Table 6. Support documentation for Table 6 is attached as Appendix B.

Table 6. Gross Alpha and Radium Test Restart

	Column Concentrations (pCi/L)					
3/3/04	**RBI** Column 1	**RBF** Discharge	**RA0** Column 1 (at restart)	**RA2** Column 1 (2 min. after restart)	**RA4** Column 1 (4 min. after restart)	**RAF** Discharge (20 min. after restart)
Gross Alpha	18.1	3.7	3.5	11.3	18.7	1.6
Ra-226	7.7	0.2	8.6	6.9	6.5	0.1
Ra-228	15.9	1.5	20.9	15.1	15.7	0.5
Ra Combined	23.6	1.7	29.5	22.0	22.2	0.7

On March 8, 2004 the water was restarted and samples were taken from column 1 at restart, 2 minutes after restart, and again at 4 minutes after restart. A final sample was taken of the discharge water at 20 minutes after restart. The water was left flowing until April 7, 2004 when the pump failed and the water was shut off to the trailer. The results from these samples are shown in Table 7. Support documentation for Table 7 is attached as Appendix B.

Table 7. Gross Alpha and Radium Test Restart

	Column Concentrations (pCi/L)			
3/8/04	**RD0** Column 1 (at restart)	**RD2** Column 1 (2 min. after restart)	**RD4** Column 1 (4 min. after restart)	**RDF** Discharge (20 min. after restart)
Gross Alpha	14.4	9.9	10.0	3.9
Ra-226	5.7	5.7	5.4	0.2
Ra-228	14.9	15.2	9.5	0.1
Ra Combined	20.6	20.9	14.8	0.3

On April 27, the water was once again restarted and a sample was taken immediately from column 1. One hour later samples were taken at the feed, column 1, column 4 and the discharge water. The water was then turned off and the pilot trailer was removed. The results from these samples are shown in Table 8. Support documentation for Table 8 is attached as Appendix B.

Table 8. Gross Alpha and Radium Test Restart

	Column Concentrations (pCi/L)				
4/27/04	**RSIO** Column 1 (at restart)	**Feed** (1 hr. after restart)	**Column 1** (1 hr. after restart)	**Column 4** (1 hr. after restart)	**Discharge** (1 hr. after restart)
Gross Alpha	38.1	35.2	21.6	1.0	2.9
Ra-226	9.4	13.4	7.3	0.8	0.2
Ra-228	15.2	28.7	20.0	1.3	0.0
Ra Combined	24.6	42.1	27.3	2.2	0.2

Water Quality

A water quality analysis was performed on feed water to the pilot unit and on treated water exiting the WRT pilot unit treatment process to document any changes in water quality through the Z-88™ treatment process. The results of those tests are shown in Table 8. There is some beneficial reduction of metallic cations in addition to reduction of gross alpha, and removal of radium. Support documentation for Table 9 is attached as Appendix E.

Table 9. Water Quality Data entering and exiting the Z-88™ treatment process

Richland Springs, Texas – Water Quality Data			
Item	**Pre WRT Process**	**units**	**Post WRT Process**
Alkalinity	302	mg/L	302
Antimony	<	mg/L	<
Arsenic	0.0010	mg/L	0.0009
Barium	0.0625	mg/L	0.0054
Beryllium	<	mg/L	<
Cadmium	<	mg/L	<
Calcium	54.1	mg/L	44.9
Chromium	0.0003	mg/L	0.0003
Chloride	32	mg/L	33
Copper	0.0410	mg/L	0.0105
Fluoride	0.7	mg/L	0.7
Hardness	338	mg/L	284
Iron	0.50	mg/L	0.32
Lead	0.0052	mg/L	0.0013
Magnesium	49.3	mg/L	41.8
Manganese	0.015	mg/L	0.012
Mercury	<	mg/L	<
Potassium	14.4	mg/L	12.2
Selenium	<	mg/L	<
Sodium	40.4	mg/L	34.3
Sulfate	60	mg/L	60
Thallium	<	mg/L	<
Total Dissolved Solids	432	mg/L	408
Uranium	<	mg/L	<
Zinc	0.03	mg/L	0.03

Note: < is below detection levels

Hydraulic Loading Rate, EBCT

The flow rate during the pilot test period averaged 1.10 GPM, which equates to 12.6 gallons per minute per square foot HLR. The pilot unit treated a total of 150,258 gallons from 12/03/03 to 3/1/04. The total gallons treated during the pilot study are summarized in Table 10 below. Support documentation for Table 10 is attached as Appendix G.

The EBCT at this HLR through eight columns, each containing 25 inches of media, is 9.9 minutes.

Table 10. Cumulative treated flow in gallons

Sample Data	Treated Flow in Gallons
12/3/03	137
12/8/03	8,645
12/23/03	34,568
1/5/04	57,654
1/19/04	82,162
2/2/04	101,589
2/23/04	138,296
3/1/04	150,395

Radon occurs in drinking water as a result of the radioactive decay process of radium. A sample was collected during this study to determine if significant radon was generated by the capture of radium by the WRT media and to evaluate the general level of radon in the product water. Table 11 contains the radon test results taken during the pilot study on February 23, which shows a general reduction from 200 pCi/L at the well to 107 pCi/L after Column 8. The limit for radon is 300 pCi/L. Samples were also taken on April 27 when the system had been restarted after being shut off for a period of time. This data is also shown in Table 11 below. It is concluded that the WRT process does not contribute a significant amount of radon to the water. Support documentation for Table 11 is attached as Appendix F.

Table 11. Radon Test Results

Radon	Column Concentrations (pCi/L)		
Date	Well	Feed	C8
2/23/04	200	145	107
4/27/04	356	156	152

Pilot Plant Radiation Safety

The pilot unit is designed to collect naturally occurring radioactive material while in operation. Because of this action, it will gradually become radioactive as the test proceeds. WRT has both predicted and monitored the level of radiation present in numerous demonstrations.

The total amount of radiation that members of the public can be exposed to is 2 mrem per hour and 100 mrem over the course of a year. WRT's maximum measured activity is less than half of the hourly exposure limit. Due to the limited amount of operator attention necessary for the pilot test, the annual exposure limit is also readily met.

WRT has prepared a safety plan for its tests that includes radiation level monitoring, logging time spent in proximity to a test unit, emergency procedures to be followed and an introduction to radiation safety for operators. Operators are instructed in radiation safety before the pilot test is started.

Any full scale system will include appropriate equipment, radiation level monitoring, and a corresponding safety plan approved by regulatory authorities.

Radioactivity data was collected during this test by monitoring the exposure rate at the center point of each column. Figure 4, below, shows an increase in activity, as expected, as the pilot test proceeds. The data also shows the highest level of activity in the first columns as there is more radium collected at these sites than at the last columns. This data was collected with a Ludlum 2401-P survey meter.

Landauer provided radiation dosimetery badges during this test. Two badges were used, one at the center of column one (at the highest radiation location), and one in a control, or unaffected location. The badges are read every two months, and the results are included in Appendix H. The first two month period, November to December 2003, had an exposure of 72 mrem for the column one location. The second period, January to February 2004, had an additional exposure of 565 mrem. The final period, March to April 2004, had a further increase of 500 mrem.

The average hourly exposure, over the course of this test, was 0.33 mrem per hour. The highest two month average exposure was 0.39 mrem per hour which occurred during January and February, 2004.

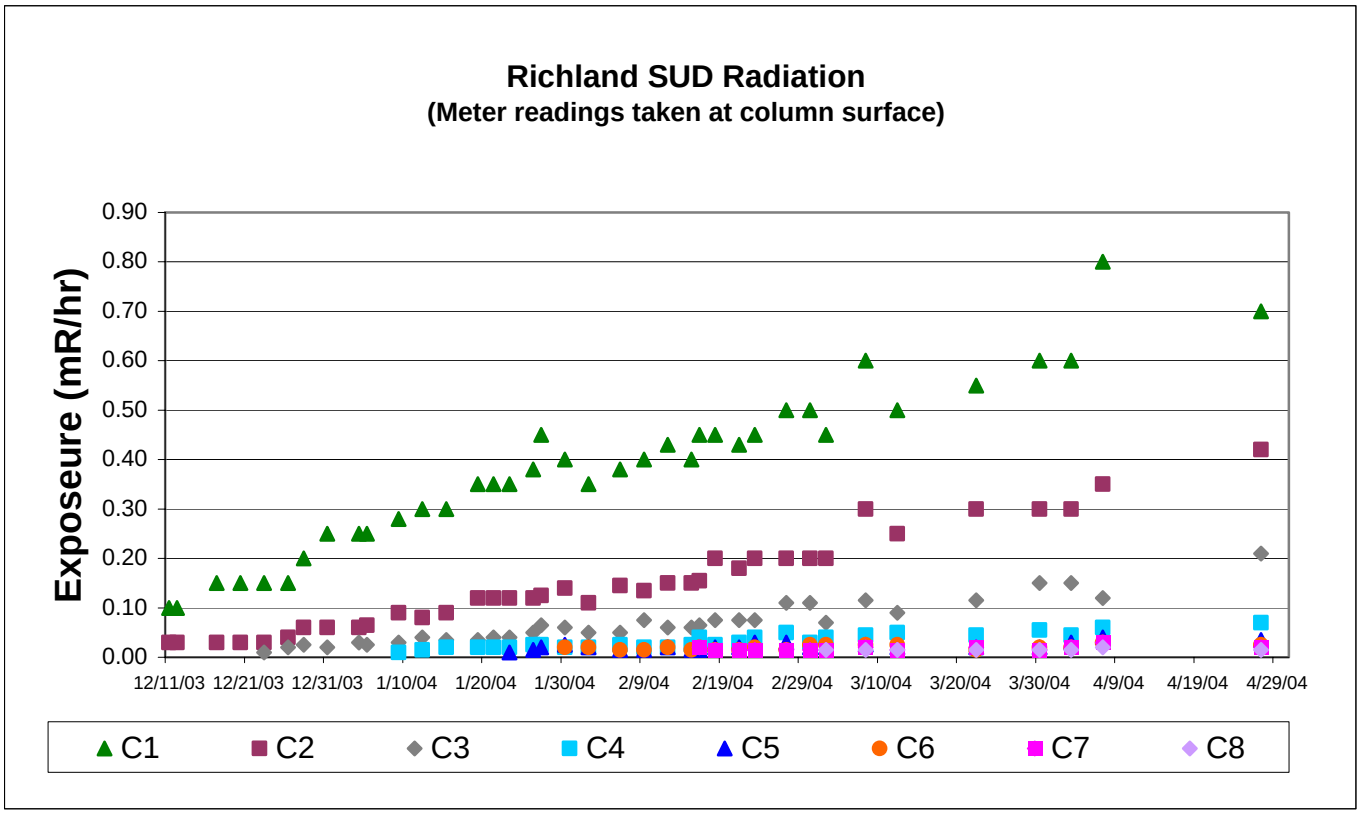

Figure 4

Operational Results

An operation log was maintained during the pilot study, and is attached as Appendix G. The pilot unit effectively removed radium and gross alpha to acceptable levels throughout the course of this test without any significant operating problems.

Conclusion

The WRT Z-88™ Radium Treatment Process consistently produced gross alpha and combined radium 226 and 228 discharge levels below the EPA mandated MCL of 15 pCi/L and 5 pCi/L respectively. Radon levels generally decreased through the process. Water produced at startup fully met all MCL's. Full scale plant design parameters such as HLR and EBCT requirements, can be determined from the pilot study data collected and will be incorporated into the basis of design.

WRT would like to thank the personnel and staff of the Richland Special Utility District for their cooperation and assistance during this test.

Appendices available upon request.