Pilot Study Report

for

Z-88® Radium Removal System

conducted for

Village of Ransom, Illinois
Well No. 4

August 19, 2015

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Executive Summary

This radium removal pilot study was conducted for the Village of Ransom, Illinois at their Well No. 4 treatment facility. Ransom's water system contains concentrations of radium in excess of the Maximum Contaminant Levels (MCL).

The Village of Ransom selected Water Remediation Technology's (WRT) Z-88® Radium Treatment Process as a possible cost effective solution for their radium problem. WRT provided a 0.98 GPM (gallons per minute) treatment system, which was delivered and installed on November 6, 2013. The pilot treatment system commenced operating when delivered and was abruptly shut down on February 13, 2014 due to a malfunction of the small pump that was feeding the pilot unit. Once the pump was repaired and placed back in service, the radium removal pilot system was scheduled for restart.

The purpose of this pilot study is to document the effectiveness of the WRT system on high radium water and to provide information necessary to meet regulatory compliance.

The treatment system successfully met radium and gross alpha compliance at all times during the pilot study. The system was in first in operation for 93 days duration and then following restart on January 26, 2015 for an additional 63 days prior to writing this report. The radium removal system pilot unit effectively reduced the level of radium (Figure 1) and gross alpha (Figure 2) to less than the MCL .

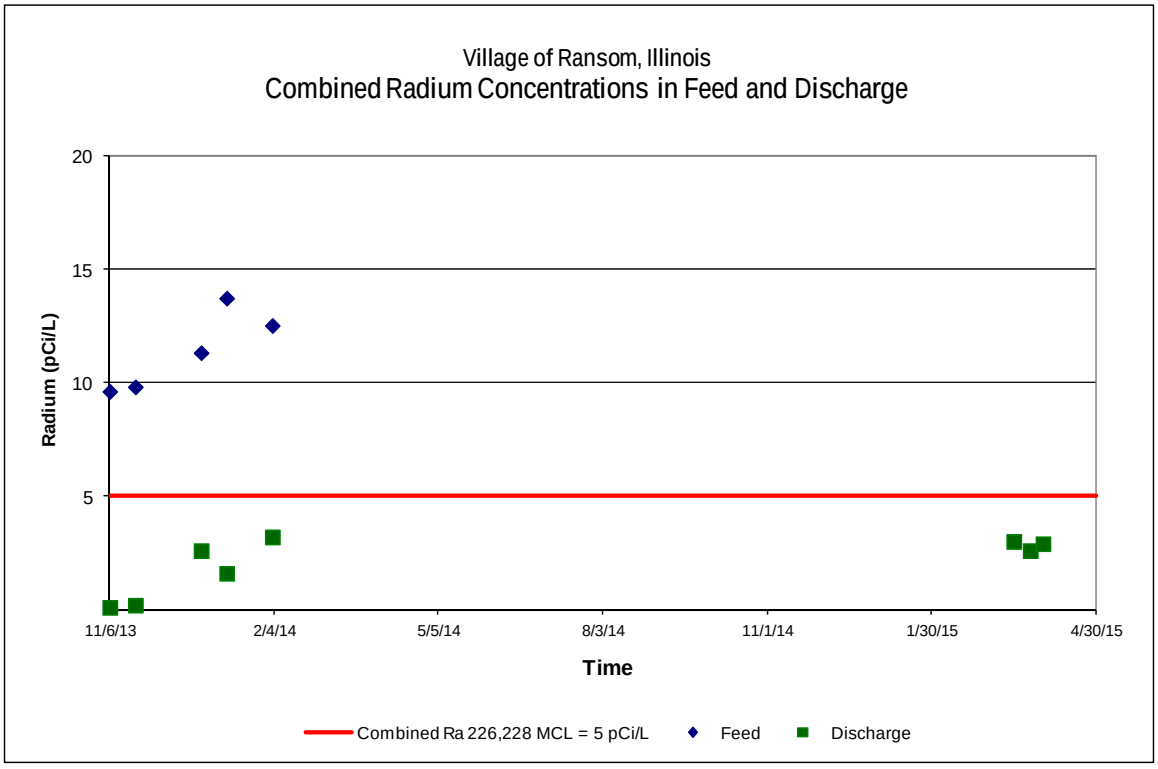

Figure 1

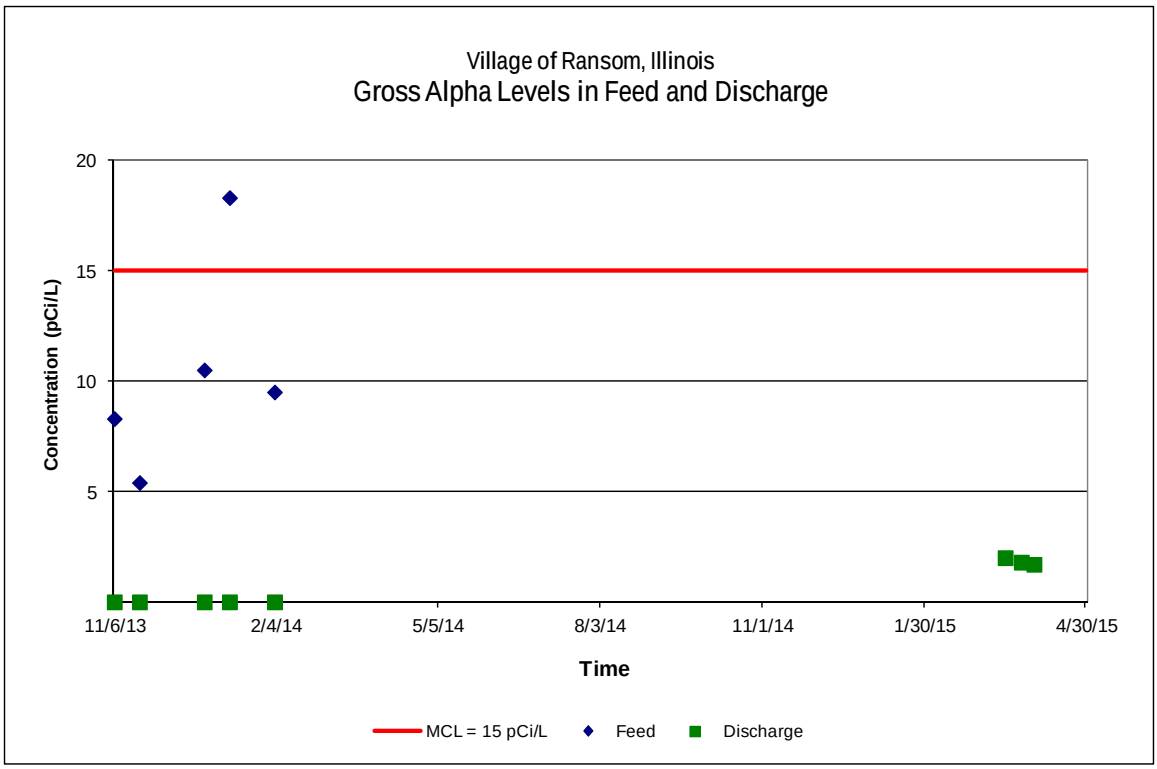

Figure 2

The results are also shown in Table 1. The average feed concentration of combined radium, 11.4 pCi/L, was reduced to an average of 2.0 pCi/L; well below the MCL of 5 pCi/L. The average feed concentration of gross alpha, 18.3 pCi/L, was reduced to 0.7 pCi/L; also well below the MCL of 15 pCi/L.

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

Combined Radium	Feed (pCi/L)	Discharge @ Column 2 (pCi/L)
Combined Ra 226, 228 MCL	**—**	**5.0**
Average	11.4	2.0
Highest value	13.7	3.2
Lowest Value	9.6	0.1
Gross Alpha	**Feed (pCi/L)**	**Discharge @ Column 2 (pCi/L)**
Gross Alpha MCL	**—**	**15.0**
Average	10.4	0.7
Highest value	18.3	0.0
Lowest Value	8.3	2.0

Application Information

The Village of Ransom, Illinois is in the county of LaSalle, located 90 miles southwest of Chicago. The pilot study was conducted at Ransom's Well No. 4 treatment facility, which is the only water source for the approximate 400 residents in the Village of Ransom. Well No. 4 pumps an average of 85 gallons per minute, from a depth of 180 feet.

Technology Overview

Water Remediation Technology's (WRT) Z-88® Radium Treatment Process utilizes proprietary adsorptive media in a series of down-flow treatment vessels to remove radium from drinking water. The water is moved through the treatment system using the water pressure generated from the well source. 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 equipment and media used in the facility. The handling and exchange of new media to replace spent media, as well as the shipping and disposal into licensed disposal sites, is handled by WRT. The treatment media are ANSI/NSF Standard 61 certified for use in drinking water.

Equipment Overview

The pilot equipment was installed in the Village of Ransom's Well No. 4 treatment facility. The treatment train used for this pilot study consists of two 4-inch diameter by 4-foot vertical height columns each containing approximately 25 inches of Z-88® media. 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-inch diameter hose, passes through a control valve and flow meter, and enters the top of the first column. Both columns operate in a down-flow configuration, with the flow exiting the bottom of the first column, entering at the top of the second column, then following the same flow path 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. The water feeding the radium removal pilot system was taken prior to any treatment, aeration or chemical disinfection injection.

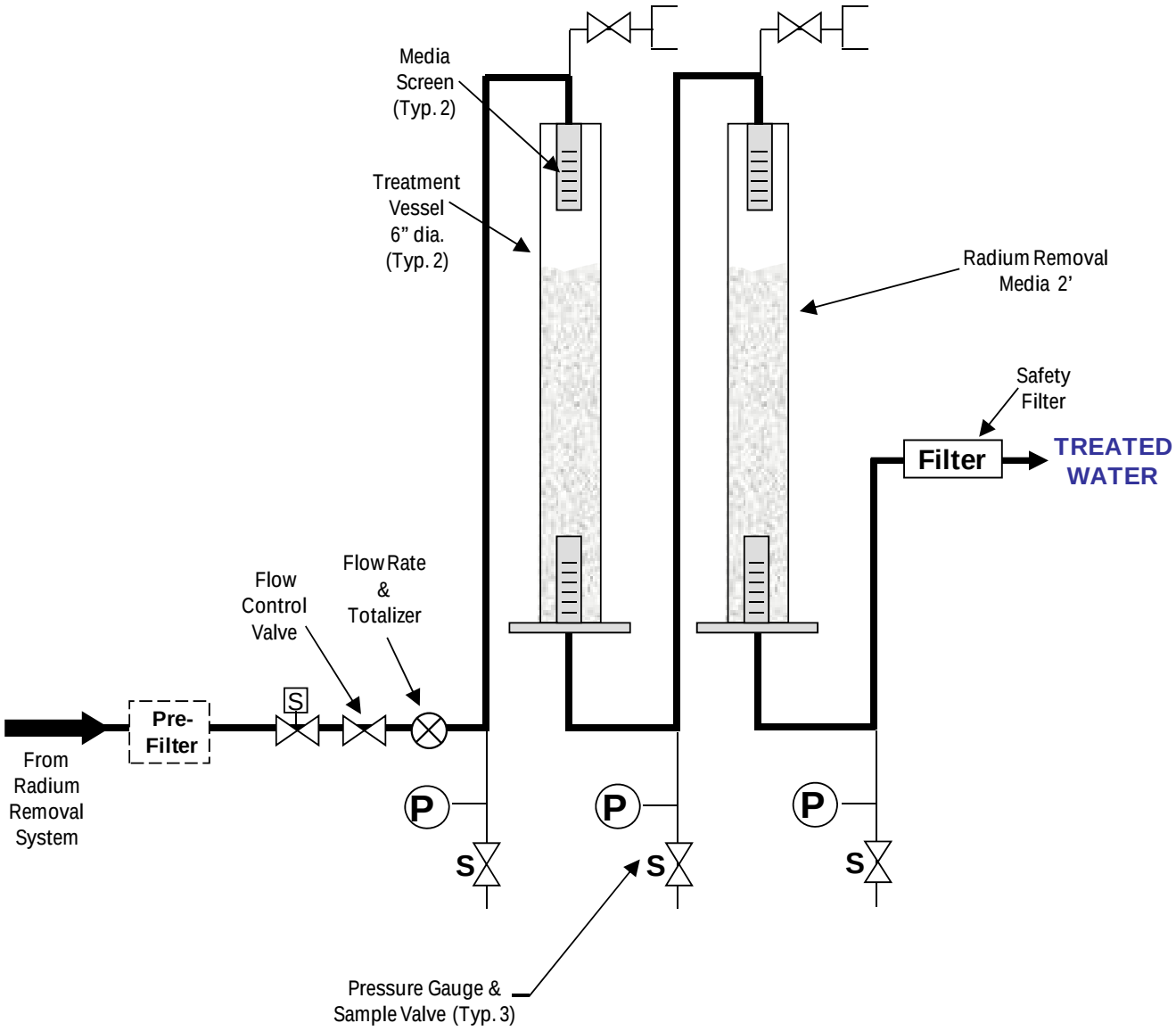

Figure 3. Simplified Process Flow Diagram.

Village of Ransom's Z-88®
Radium treatment system.

Statement of Purpose

The combined radium levels in the raw water during the pilot study were as high as 13.7 pCi/L, exceeding the Environmental Protection Agency (EPA) mandated combined radium MCL of 5 pCi/L. The gross alpha water's highest result of 18.3 pCi/L, exceeding the gross alpha MCL of 15 pCi/L.

The purposes of this pilot study are to:

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

Delivery and Installation of the Treatment System

The treatment system was delivered and installed on November 6, 2013. Set up consists of mounting the columns to a frame and connecting the water source and discharge line. The pilot study began the same day. Data was collected for 156 days total prior to writing this report.

Operator training for system operation, monitoring and sampling was conducted on the day of installation, and a schedule for sampling was established. Samples were collected by the Village of Ransom personnel from sample valves located in the feed line and after discharge from each respective treatment vessel, at pre-determined sample intervals.

Analytical

The samples were delivered to ATI Environmental, Inc. Midwest Laboratory located in Northbrook, Illinois for radium and gross alpha analysis. Samples for inorganic water quality were sent to Test Inc. located in Peru, Illinois. Both laboratories are National Environmental Laboratory Accreditation Program certified laboratories. Methods for analysis were:

Gross Alpha	900.0
Radium 226	903.1
Radium 228	Ra-05

Results

The sampling results are shown in Tables 2 and 3. Feed samples were collected immediately prior to the first treatment vessel. Samples were taken immediately after column no. 1 (C-1), and at the discharge point (C-2). Analytical laboratory certificates are attached as Appendix A. Figures 4, and 5 show combined radium 226 and 228 and gross alpha levels in the feed water entering the pilot unit, and treated water exiting the pilot unit. The graphs show that the pilot unit successfully reduced combined radium in the treated water to significantly below the required MCL.

Table 2. Radium Test Results

Radium 226	Column Concentrations (pCi/L)			
Date	Feed	C-1	C-2	MCL
11/6/13	3.5	0.2	0.1	—
11/20/13	3.5	1.0	0.2	—
12/26/13	2.5	0.6	0.3	—
1/9/14	4.3	1.0	0.6	—
2/3/14	3.6	2.3	1.1	
3/16/15			1.3	
3/25/15			1.2	
4/1/15			1.3	—
Radium 228	**Column Concentrations (pCi/L)**			
Date	Feed	C-1	C-2	MCL
11/6/13	6.1	0.0	0.0	—
11/20/13	6.3	1.8	0.0	—
12/26/13	8.8	1.1	2.3	—
1/9/14	9.4	2.4	1.0	—
2/3/14	8.9	4.0	2.1	—
3/16/15			1.7	—
3/25/15			1.4	—
4/1/15			1.6	—
Combined Radium	**Column Concentrations (pCi/L)**			
Date	Feed	C-1	C-2	MCL
11/6/13	9.6	0.2	0.1	5.0
11/20/13	9.8	2.8	0.2	5.0
12/26/13	11.3	1.7	2.6	5.0
1/9/14	13.7	3.4	1.6	5.0
2/3/14	12.5	6.3	3.2	5.0
3/16/15			3.0	5.0
3/25/15			2.6	5.0
4/1/15			2.9	5.0

Note: Negative results are recorded as 0.0

Figure 4 below, presents in graph format, the data in Table 2.

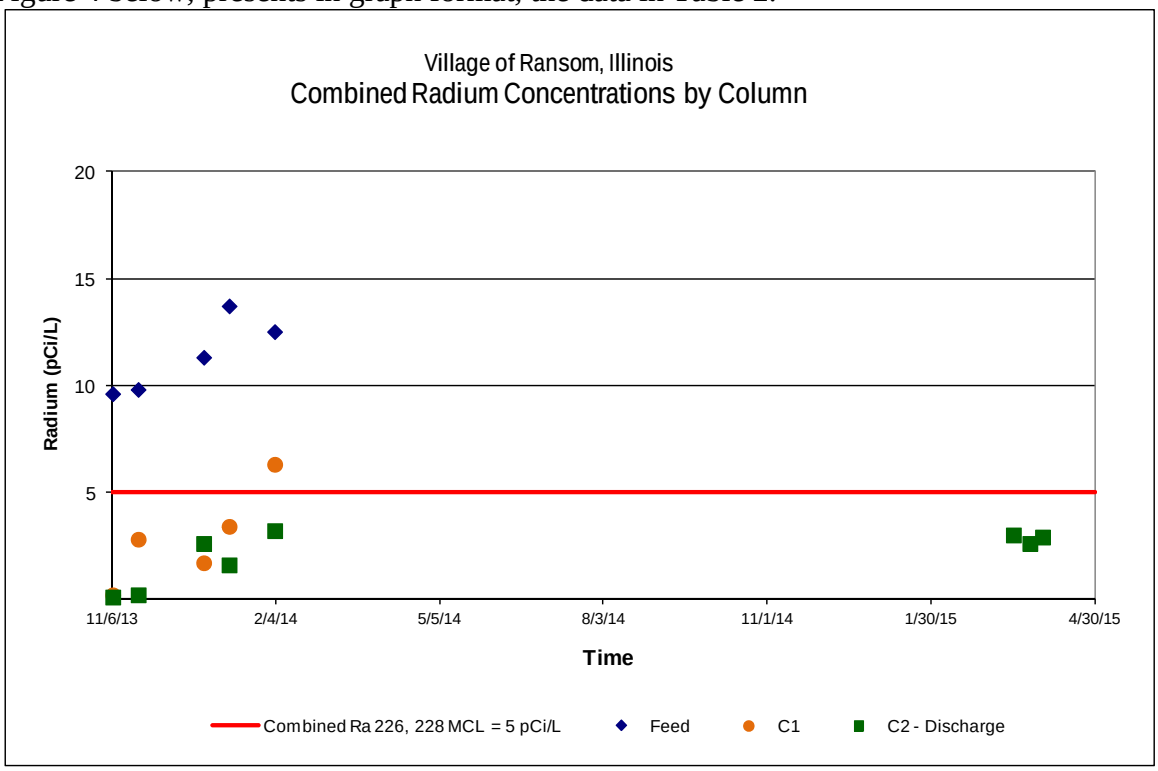

Figure 4

Table 3. Gross Alpha Test Results

Gross Alpha	Column Concentrations (pCi/L)			
Date	Feed	C-1	C-2	MCL
11/6/13	8.3	0.0	0.0	15.0
11/20/13	5.4	2.7	0.0	15.0
12/26/13	10.5	0.0	0.0	15.0
1/9/14	18.3	3.0	0.0	15.0
2/3/14	9.5	2.8	0.0	15.0
3/16/15			2.0	15.0
3/25/15			1.8	15.0
4/1/15			1.7	15.0

Note: Negative results are recorded as 0.0

Figure 5 below, presents in graph format, the data in Table 3.

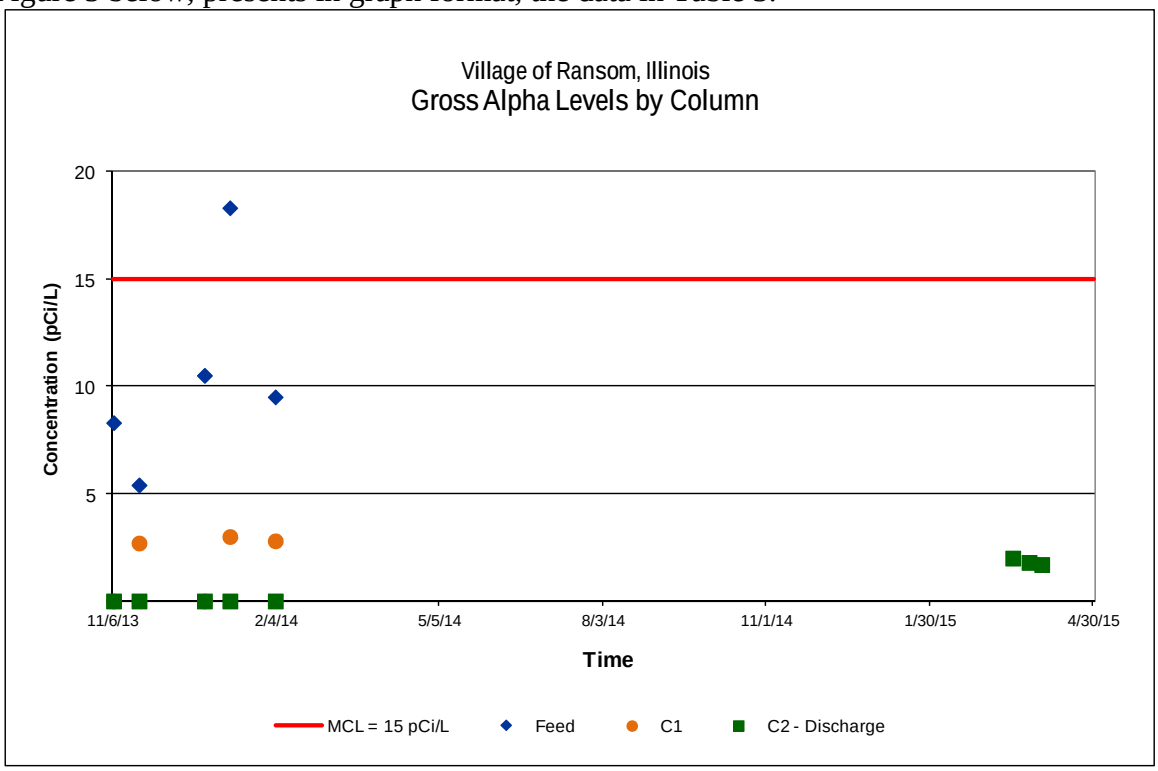

Figure 5

Water Quality

A water quality analysis was performed on the feed water to the treatment system and on the treated water exiting the WRT system to document any changes in water quality through the treatment process. The results of those tests are shown in Table 4. Other than the reduction of radium and gross alpha, there is no significant change to the water quality. The WRT Z-88® media will remove barium from the feed water. This is recognized from previous WRT testing and is demonstrated in the water quality test results. The barium removal at these concentrations does not affect the operational performance of the Z-88® media. Inlet iron levels in the raw water are notably high at 7.36 mg/L. Much of the iron appeared to be insoluble as the pilot unit prefilter cartridges required multiple replacements during the course of the pilot testing. A combination of the prefilter units and the Z-88® radium removal media beds effectively removed nearly all of the incoming iron to very low levels on 0.01 mg/L. Adequate prefiltration of the raw water prior to radium removal treatment is required to maintain good flow performance through the Z-88® media beds. Support documentation for Table 4 is attached as Appendix B.

Table 4. Water Quality Test Results

Village of Ransom, Illinois WATER QUALITY DATA			
Item	**Pre WRT Process**	**units**	**Post WRT Process**
Alkalinity as CaCO3	342	mg/L	338
Arsenic	<0.0005	mg/L	<0.0005
Barium	0.172	mg/L	0.107
Beryllium	<0.001	mg/L	<0.001
Cadmium	0.010	mg/L	0.011
Calcium	54.5	mg/L	54.8
Chloride	307	mg/L	305
Chromium	0.002	mg/L	<0.002
Copper	0.008	mg/L	<0.003
Floride	1.26	mg/L	1.27
Hardness (EDTA) as CaCO3	272	mg/L	272
Iron	7.36	mg/L	0.010
Lead	0.0074	mg/L	<0.005
Magnesium	28.1	mg/L	27.8
Manganese	0.006	mg/L	0.003
Mercury	<0.0001	mg/L	<0.0001
Nickel	0.002	mg/L	0.004
Nitrate as N	<0.050	mg/L	<0.050
Nitrite as N	<0.010	mg/L	<0.010
pH	7.41	unit	7.48
Phosphate	0.18	mg/L	0.18
Phosphorus	0.09	mg/L	0.09
Potassium	16.9	mg/L	16.7
Selenium	<0.002	mg/L	<0.002
Silica	8.6	mg/L	8.72
Sodium	204	mg/L	204
Strontium	2.34	mg/L	2.26
Sulfate	46	mg/L	62
Thallium	<0.002	mg/L	<0.002
Total Dissolved Solids @ 180oC	796	mg/L	872
TOC (Total Organic Carbon)	<1.00	mg/L	<1.00
Uranium	0.01	pCi/L	0.67
Zinc	0.127	mg/L	0.011

Note: < is non-detectable levels. Values in brackets represent results greater than or equal to the LOD (Limit of Detection), but less than the LOQ (Limit of Quantitation) and are within a region of “Less-Certain Quantitation”.

Hydraulic Loading Rate (HLR) and Empty-bed Contact Time (EBCT)

The pilot unit operated nominally at 1.1 gallons per minute, for a HLR of 12.6 gallons per minute per square foot. Apart from the shutdown period, the pilot unit ran 8 hours per day, 5 days per week during this test. The total gallons treated during the pilot study are summarized in Table 6 and Appendix C.

The EBCT at this HLR through four columns, each containing 25 inches of media, is 4.9 minutes.

Table 6. Cumulative treated flow in gallons

Sample Data	Treated Flow in Gallons
11/6/13	38
11/20/13	15,648
12/26/13	24,046
1/9/14	53,602
2/3/14	75,894
1/26/15	0.5*
3/16/15	20,635
3/25/15	26,069

* Cumulative totalizer flow was reset to zero on 1/26/15 when new flow meter was installed and pilot unit was restarted.

Radiation Safety

The pilot unit is designed to collect naturally occurring radioactive material while in operation. Because of this action, it gradually becomes radioactive during normal operation. WRT both predicts and monitors the level of radiation present in the treatment system.

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.

Operational Results

An operation log was maintained during the pilot study, and is attached as Appendix C. The treatment system operated easily and reliably during the study with some notable reductions in flow rate due to inlet filter cartridge blinding from inlet raw water solids collection. A small booster pump required replacement to maintain adequate inlet pressure and pilot unit flow rate at approximately 52,000 gallons throughput. Once replaced, pilot system design flow rate or 1.1 nominal gpm was adjusted and maintained daily.

Conclusion

The WRT Z-88® Radium Treatment Process consistently reduced the combined radium 226 and 228 and gross alpha discharge to levels well below the required MCLs.

WRT would like to thank the personnel and staff of the Village of Ransom and McClure Engineering for their cooperation and participation in this study.