

Protecting Our Water Environment



Metropolitan Water Reclamation District of Greater Chicago

***MONITORING AND RESEARCH
DEPARTMENT***

REPORT NO. 12-57

***RADIOLOGICAL MONITORING OF THE RAW SEWAGE,
FINAL EFFLUENT, SLUDGE, AND BIOSOLIDS OF THE
METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO
2011 ANNUAL REPORT***

DECEMBER 2012

Metropolitan Water Reclamation District of Greater Chicago
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METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO
2011 ANNUAL REPORT

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TABLE OF CONTENTS

	<u>Page</u>
LIST OF TABLES	iii
ACKNOWLEDGMENT	vii
DISCLAIMER	vii
SUMMARY AND CONCLUSIONS	viii
INTRODUCTION	1
MATERIALS AND METHODS	3
Sample Collection	3
Raw Sewage	3
Final Effluent	3
Biosolids	3
Sample Analysis	3
RESULTS AND DISCUSSION	4
Stickney Water Reclamation Plant	4
Calumet Water Reclamation Plant	4
Terrence J. O'Brien Water Reclamation Plant	13
John E. Egan Water Reclamation Plant	13
Hanover Park Water Reclamation Plant	19
James C. Kirie Water Reclamation Plant	19
Lemont Water Reclamation Plant	28
Hanover Park Water Reclamation Plant Lagoons	36

TABLE OF CONTENTS (Continued)

	<u>Page</u>
Gross Alpha and Gross Beta Radioactivity in John E. Egan and Stickney Water Reclamation Plants Centrifuge Cake Biosolids	36
Radium-226, Radium-228, and Strontium-90 Radioactivity in the Raw Sewage and Final Effluent of the Water Reclamation Plants	41
Gamma Radioactivity in John E. Egan and Stickney Water Reclamation Plants Centrifuge Cake Biosolids	41

LIST OF TABLES

Table No.		Page
1	Gross Alpha Radioactivity in Stickney Water Reclamation Plant Raw Sewage and Final Effluent on a Monthly Basis – 2011	5
2	Yearly Average Gross Alpha Radioactivity in Stickney Water Reclamation Plant Raw Sewage, Final Effluent, and Anaerobically Digested Biosolids from 1996 Through 2011	6
3	Gross Beta Radioactivity in Stickney Water Reclamation Plant Raw Sewage and Final Effluent on a Monthly Basis – 2011	7
4	Yearly Average Gross Beta Radioactivity in Stickney Water Reclamation Plant Raw Sewage, Final Effluent, and Anaerobically Digested Biosolids from 1996 Through 2011	8
5	Gross Alpha Radioactivity in Calumet Water Reclamation Plant Raw Sewage and Final Effluent on a Monthly Basis – 2011	9
6	Yearly Average Gross Alpha Radioactivity in Calumet Water Reclamation Plant Raw Sewage, Final Effluent, and Anaerobically Digested Biosolids from 1996 Through 2011	10
7	Gross Beta Radioactivity in Calumet Water Reclamation Plant Raw Sewage and Final Effluent on a Monthly Basis – 2011	11
8	Yearly Average Gross Beta Radioactivity in Calumet Water Reclamation Plant Raw Sewage, Final Effluent, and Anaerobically Digested Biosolids from 1996 Through 2011	12
9	Gross Alpha Radioactivity in Terrence J. O’Brien Water Reclamation Plant Raw Sewage and Final Effluent on a Monthly Basis – 2011	14
10	Yearly Average Gross Alpha Radioactivity in Terrence J. O’Brien Water Reclamation Plant Raw Sewage, Final Effluent, and Waste-Activated Sludge from 1996 Through 2011	15
11	Gross Beta Radioactivity in Terrence J. O’Brien Water Reclamation Plant Raw Sewage and Final Effluent on a Monthly Basis – 2011	16

LIST OF TABLES (Continued)

<u>Table No.</u>		<u>Page</u>
12	Yearly Average Gross Beta Radioactivity in Terrence J. O'Brien Water Reclamation Plant Raw Sewage, Final Effluent, and Waste-Activated Sludge from 1996 Through 2011	17
13	Gross Alpha Radioactivity in John E. Egan Water Reclamation Plant Raw Sewage and Final Effluent on a Monthly Basis – 2011	18
14	Yearly Average Gross Alpha Radioactivity in John E. Egan Water Reclamation Plant Raw Sewage, Final Effluent, and Anaerobically Digested Biosolids from 1996 Through 2011	20
15	Gross Beta Radioactivity in John E. Egan Water Reclamation Plant Raw Sewage and Final Effluent on a Monthly Basis – 2011	21
16	Yearly Average Gross Beta Radioactivity in John E. Egan Water Reclamation Plant Raw Sewage, Final Effluent, and Anaerobically Digested Biosolids from 1996 Through 2011	22
17	Gross Alpha Radioactivity in Hanover Park Water Reclamation Plant Raw Sewage and Final Effluent on a Monthly Basis – 2011	23
18	Yearly Average Gross Alpha Radioactivity in Hanover Park Water Reclamation Plant Raw Sewage, Final Effluent, and Anaerobically Digested Biosolids from 1996 Through 2011	24
19	Gross Beta Radioactivity in Hanover Park Water Reclamation Plant Raw Sewage and Final Effluent on a Monthly Basis – 2011	25
20	Yearly Average Gross Beta Radioactivity in Hanover Park Water Reclamation Plant Raw Sewage, Final Effluent, and Anaerobically Digested Biosolids from 1996 Through 2011	26
21	Gross Alpha Radioactivity in James C. Kirie Water Reclamation Plant Raw Sewage and Final Effluent on a Monthly Basis – 2011	27

LIST OF TABLES (Continued)

<u>Table No.</u>		<u>Page</u>
22	Yearly Average Gross Alpha Radioactivity in James C. Kirie Water Reclamation Plant Raw Sewage, Final Effluent, and Waste-Activated Sludge from 1996 Through 2011	29
23	Gross Beta Radioactivity in James C. Kirie Water Reclamation Plant Raw Sewage and Final Effluent on a Monthly Basis – 2011	30
24	Yearly Average Gross Beta Radioactivity in James C. Kirie Water Reclamation Plant Raw Sewage, Final Effluent, and Waste-Activated Sludge from 1996 Through 2011	31
25	Gross Alpha Radioactivity in Lemont Water Reclamation Plant Raw Sewage and Final Effluent on a Monthly Basis – 2011	32
26	Yearly Average Gross Alpha Radioactivity in Lemont Water Reclamation Plant Raw Sewage, Final Effluent, and Waste-Activated Sludge from 1996 Through 2011	33
27	Gross Beta Radioactivity in Lemont Water Reclamation Plant Raw Sewage and Final Effluent on a Monthly Basis – 2011	34
28	Yearly Average Gross Beta Radioactivity in Lemont Water Reclamation Plant Raw Sewage, Final Effluent, and Waste-Activated Sludge from 1996 Through 2011	35
29	Gross Alpha and Gross Beta Radioactivity in Hanover Park Water Reclamation Plant Lagooned Biosolids – 2011	37
30	Yearly Average Gross Alpha Radioactivity in Hanover Park Water Reclamation Plant Lagooned Biosolids from 1998 Through 2011	38
31	Yearly Average Gross Beta Radioactivity in Hanover Park Water Reclamation Plant Lagooned Biosolids from 1998 Through 2011	39

LIST OF TABLES (Continued)

<u>Table No.</u>		<u>Page</u>
32	Gross Alpha and Gross Beta Radioactivity in John E. Egan and Stickney Water Reclamation Plants Centrifuge Cake Biosolids – 2011	40
33	Concentration of Radium-226, Radium-228, and Strontium-90 in Raw Sewage of the Water Reclamation Plants – 2011	42
34	Concentration of Radium-226, Radium-228, and Strontium-90 in Final Effluent of the Water Reclamation Plants – 2011	43
35	Concentration of Gamma-Emitting Radionuclides in John E. Egan and Stickney Water Reclamation Plants Centrifuge Cake Biosolids – 2011	45
36	Concentration of Gamma-Emitting Radionuclides in Hanover Park Water Reclamation Plant Lagooned Biosolids – 2011	47
37	Yearly Average Potassium-40, Radium-226, and Cesium-137 Radioactivity (pCi/g dw) in Hanover Park Water Reclamation Plant Lagooned Biosolids from 1998 Through 2011	48

The author wishes to acknowledge Mr. Harold Robinson for sample preparation. Special thanks are due to Ms. Kathleen Quinlan for typing the report.

DISCLAIMER

Mention of proprietary equipment and chemicals in this report does not constitute endorsement by the Metropolitan Water Reclamation District of Greater Chicago.

SUMMARY AND CONCLUSIONS

The discharge of radioactive materials into the sanitary sewer system of the Metropolitan Water Reclamation District of Greater Chicago (District) is regulated by the Illinois Emergency Management Agency, Division of Nuclear Safety (IEMA-DNS). In Illinois, hospitals, industries, research organizations, and other radioactive material license holders are authorized to dispose of radionuclides into the District's sanitary sewer system in accordance with 32 Illinois Administrative Code, Section 340.1030. Naturally occurring radionuclides in groundwater and stormwater runoff also enter the sanitary sewer system.

The purpose of wastewater treatment is to reduce or remove pollutants from raw sewage to ensure adequate effluent quality before it is discharged to surface water. The low concentrations of radioactive material from natural and man-made sources discharged into the sanitary sewer system may become concentrated in the sewage sludge during wastewater treatment and sludge processing.

This study was conducted to determine the concentration of radioactive material in raw sewage, final effluent, and biosolids at the facilities owned and operated by the District.

One raw sewage and one final effluent sample (composited over a period of 24 hours) were collected once a month from each of the District's seven Water Reclamation Plants (WRPs). Centrifuge cake biosolids samples were collected once per quarter from the John E. Egan (Egan) and Stickney WRPs. Biosolids samples from the Hanover Park WRP East lagoon and Hanover Park WRP West lagoon were collected in February, May, August, and November 2011. Centrifuge cake biosolids samples from the Egan and Stickney WRPs were collected in March, June, September, and November 2011.

The raw sewage and final effluent, samples from all WRPs, lagooned biosolids samples from the Hanover Park WRP, and centrifuge cake biosolids samples from the Egan and Stickney WRPs were analyzed for gross alpha and gross beta radioactivity. Lagooned biosolids samples from Hanover Park WRP and quarterly centrifuge cake biosolids samples from Egan and Stickney WRPs were also analyzed for gamma-emitting radionuclides.

The analytical data demonstrate that radioactivity in the final effluent of all the WRPs is generally lower than the corresponding raw sewage of the WRP. This indicates that the WRPs remove radioactivity from the raw sewage. The 2011 monitoring data was compared with the historical data of the last fifteen years. The data show that there was not a major change in the radioactivity concentrations of raw sewage and final effluent samples of the WRPs over the last sixteen years.

The amount of gross alpha and gross beta radioactivity in the final effluent is less than the allowable contaminant levels in the drinking water standards set by the United States Environmental Protection Agency (USEPA) National Primary Drinking Water Regulations, 40 CFR Part 141, published in 2000. The USEPA limit for gross alpha radioactivity (excluding radon and uranium) is 15 pCi/L and for gross beta radioactivity (excluding naturally occurring potassium-40)

the limit is 50 pCi/L. The gross beta radioactivity in the final effluent is also less than the General Use Water Quality Standard, 100 pCi/L, established by the Illinois Pollution Control Board (IPCB), 35C IAC, Section 302.207. The radium-226 and radium-228 combined concentration, and the strontium-90 concentration in the effluent is also less than the General Use Water Quality Standards of 3.75 pCi/L and 2.0 pCi/L respectively. There are no IPCB standards for gross alpha radioactivity in General Use waters. However, the District uses the IPCB General Use water limit for gross beta radioactivity as the standard for monitoring effluents. The monitoring data indicate that the discharge of the final effluent from the seven WRPs meets the standard all the time and is unlikely to have any adverse effect on the radiological quality of the receiving waters.

Measurable concentrations of gross alpha and gross beta radioactivity were found in Hanoover Park WRP lagooned biosolids and in the Egan and Stickney WRPs biosolids. These biosolids samples were also analyzed for 27 specific radionuclides by gamma spectroscopy. Of these radionuclides, eight were detected in measurable quantities. All these radionuclides are of natural origin except cesium-137, which is a man-made radionuclide.

The radioactivity concentration found in the District biosolids does not pose any significant risk to human health or the environment. In 2011, the IEMA exempted the District from radioactivity monitoring of its biosolids. Therefore, the District terminated the radiological monitoring of its biosolids effective December 31, 2011.

INTRODUCTION

The District is located within the boundaries of Cook County, Illinois, and serves an area of 883 square miles. The area served by the District includes the City of Chicago and 125 suburban communities with a combined population of 5.25 million people. In addition, a waste-load equivalent of 5.1 million people is contributed within the District's service area by industrial and commercial sources. On the average, the District treats 1.5 billion gallons per day of wastewater at its seven WRPs.

The discharge of radionuclides to the District's sewerage system is regulated by the IEMA-DNS. Radioactivity in the sewerage system may come from a variety of sources including industries, hospitals, and research organizations. Naturally occurring and atmospheric fallout radionuclides also enter the sewerage system from groundwater and through stormwater runoff. Radionuclides in the sanitary sewer system pass through the wastewater treatment process where some fraction of these radionuclides is removed from the wastewater and becomes concentrated in the biosolids, or remains in solution and passes with the effluent to the receiving water. Radioactivity contained in WRP effluents and the potential radioactivity concentration in municipal biosolids may be of environmental concern because of the discharge of effluents to receiving waters and the landfilling or land application of biosolids as fertilizer and soil conditioner.

The District monitors the quality of its raw sewage and effluents, from all WRPs, monthly for gross alpha and gross beta radioactivity. The raw sewage and final effluent samples are also analyzed quarterly for radium-226, radium-228 and strontium-90 radioactivity. Samples of centrifuge cake biosolids from the Egan and Stickney WRPs and lagooned biosolids from the Hanover Park WRP are analyzed quarterly for gross alpha, gross beta, and gamma emitting radionuclides. Although there were no regulatory standards for radioactivity, the District expanded its database to include the radiological characteristics of its biosolids to be prepared to address any future regulatory limits on radioactivity in biosolids.

This report presents the gross alpha, gross beta, radium-226, radium-228, and strontium-90 radioactivity concentrations in raw sewage and final effluent from the District's seven WRPs. The concentrations of gross alpha and gross beta radioactivity and gamma-emitting radionuclides in quarterly samples of centrifuge cake biosolids and lagooned biosolids samples are also reported. The 2011 radiological monitoring data are compared with the historical data of the last fifteen years.

Since 1996, the District has been monitoring the radioactivity in anaerobically digested sludge from the Calumet, Egan, Hanover Park and Stickney WRPs, waste-activated sludge from the Lemont WRP, lagooned biosolids from the Hanover Park WRP, and biosolids samples from the District's solids drying areas. The District believed that it collected sufficient data to minimize the impact of future rulemaking on the monitoring requirements for the beneficial use of its biosolids and discontinued the monitoring from the beginning of 2011. However, the District began the monitoring of radioactivity concentration in centrifuge cake biosolids from the Egan and Stickney WRPs on a quarterly basis that might be necessary to minimize the impact of future rulemaking.

The IEMA adopted final rules in 2011 and exempted the District from the radioactivity monitoring requirements in biosolids produced at its WRPs. Therefore, the District terminated the radiological monitoring of its biosolids effective December 31, 2011.

MATERIALS AND METHODS

Sample Collection

Raw Sewage. One raw sewage sample (composited over a period of 24 hours) was collected once a month from the Stickney, Egan, Terrence J. O'Brien (O'Brien {formally North Side}), James C. Kirie (Kirie), Hanover Park, Calumet, and Lemont WRPs. The samples were preserved with hydrochloric acid.

Final Effluent. One final effluent sample (composited over a period of 24 hours) was collected once a month from the effluent sampler at all the WRPs. The samples were preserved with hydrochloric acid.

Biosolids. Lagooned biosolids samples were collected quarterly from Hanover Park WRP East, and Hanover Park WRP West lagoons, and centrifuge cake biosolids were collected quarterly from the Egan and Stickney WRPs.

Sample Analysis

The raw sewage, final effluent, sludge and biosolids samples were analyzed by the District's radiochemistry laboratory from the inception of the program through 2007. The samples collected in 2008 and 2011 were analyzed by the Environmental Inc., Midwest Laboratory (EIML) and samples collected in 2009 and 2010 were analyzed by Eberline Analytical Corporation.

The sludge and biosolids samples were also analyzed for gamma-emitting radionuclides by the District's radiochemistry laboratory from the inception of the program through 2007. The samples collected in 2008 and 2011 were analyzed by the EIML and samples collected in 2009 and 2010 were analyzed by Eberline Analytical Corporation.

RESULTS AND DISCUSSION

Stickney Water Reclamation Plant

In 2011, the gross alpha radioactivity in the raw sewage of the Stickney WRP ranged from less than 1.7 to 22.2 pCi/L (Table 1). The gross alpha activity in the effluent was below the detection limit (1.6 to 4.7 pCi/L) (Table 1).

The yearly average gross alpha radioactivity in the Stickney WRP raw sewage, final effluent, and anaerobically digested biosolids from 1996 to 2011 are summarized in Table 2. The gross alpha radioactivity in raw sewage was below the detection limit (3.6 to 6.3 pCi/L) with detected values ranging from 4.6 to 8.6 pCi/L. The gross alpha radioactivity in the effluent was below the detection limit (2.3 to 5.2 pCi/L). The gross alpha radioactivity in anaerobically digested biosolids ranged from 5.2 to 12.4 pCi/g dw. The analysis of biosolids was terminated in 2011.

The gross beta radioactivity in the raw sewage of the Stickney WRP ranged from 5.5 to 29.2 pCi/L, and in the effluent it ranged from 3.4 to 9.9 pCi/L (Table 3).

The yearly average gross beta radioactivity in the Stickney WRP raw sewage, final effluent, and anaerobically digested biosolids from 1996 to 2011 are summarized in Table 4. The gross beta radioactivity in the raw sewage ranged from 11.7 to 29.3 pCi/L, and in the effluent it ranged from 5.8 to 11.4 pCi/L. The gross beta radioactivity in anaerobically digested biosolids ranged from 20.5 to 27.3 pCi/g dw. The analysis of biosolids was terminated in 2011.

Calumet Water Reclamation Plant

In 2011, the gross alpha radioactivity in the raw sewage of the Calumet WRP was below the detection limit (2.0 to 3.0 pCi/L) with the detected values ranging from 2.4 to 18.6 pCi/L (Table 5). The gross alpha radioactivity in the effluent was below the detection limit (1.7 to 5.2 pCi/L) (Table 5).

The yearly average gross alpha radioactivity in the Calumet WRP raw sewage, final effluent, and anaerobically digested biosolids from 1996 to 2011 are summarized in Table 6. The gross alpha radioactivity in the raw sewage was below the detection limit (3.5 to 5.5 pCi/L). The gross alpha radioactivity in the effluent was also below the detection limit (2.3 to 5.1 pCi/L) except for 2011 which was 4.2 pCi/L. The gross alpha radioactivity in anaerobically digested biosolids ranged from 5.1 to 17.6 pCi/g dw. The analysis of biosolids was terminated in 2011.

The gross beta radioactivity in the raw sewage of the Calumet WRP ranged from 2.9 to 26.3 pCi/L, and in the effluent it ranged from 1.6 to 8.0 pCi/L (Table 7).

The yearly average gross beta radioactivity in the Calumet WRP raw sewage, final effluent, and anaerobically digested biosolids from 1996 to 2011 are summarized in Table 8. The gross beta radioactivity in the raw sewage ranged from 7.2 to 24.9 pCi/L and in the effluent it

TABLE 1: GROSS ALPHA RADIOACTIVITY IN STICKNEY WATER RECLAMATION PLANT RAW SEWAGE AND FINAL EFFLUENT ON A MONTHLY BASIS - 2011

Month	Raw Sewage Gross Alpha (pCi/L)	Effluent Gross Alpha (pCi/L)
January	2.4	<4.0
February	<4.6	<4.7
March	<3.8	<2.5
April	4.6	<2.1
May	8.9	<1.9
June	15.9	<2.0
July	13.2	<1.9
August	22.2	<1.6
September	4.6	<1.6
October	4.0	<2.0
November	7.6	<1.6
December	<1.7	<2.0

< = The quantity listed is the smallest amount that could be measured at the 95 percent confidence level (lower limit of detection).

TABLE 2: YEARLY AVERAGE GROSS ALPHA RADIOACTIVITY IN STICKNEY WATER RECLAMATION PLANT RAW SEWAGE, FINAL EFFLUENT, AND ANAEROBICALLY DIGESTED BIOSOLIDS FROM 1996 THROUGH 2011

Year ¹	Raw Sewage Gross Alpha (pCi/L)	Effluent Gross Alpha (pCi/L)	Biosolids ² Gross Alpha (pCi/g dw)
1996	<3.8	<3.1	5.3
1997	<3.6	<3.1	5.3
1998	4.6	<2.6	5.2
1999	5.0	<3.6	6.1
2000	<5.0	<4.6	7.5
2001	6.1	<4.4	12.3
2002	<5.2	<4.7	11.3
2003	5.0	<3.6	11.7
2004	<6.0	<4.1	12.1
2005	<6.3	<4.3	11.3
2006	6.2	<4.8	10.4
2007	<6.1	<5.2	9.9
2008	8.6	<4.0	12.4
2009	<4.8	<3.6	9.6
2010	5.5	<3.2	7.0
2011	7.6	<2.3	-

¹ Am-241 self-absorption standards were used up to June 30, 2001, and Th-230 self- absorption standards were used from July 1, 2001 for generating attenuation curve for gross alpha radioactivity.

² Gross alpha radioactivity analysis in biosolids was terminated in 2011.

< = The quantity listed is the smallest amount that could be measured at the 95 percent confidence level (lower limit of detection).

TABLE 3: GROSS BETA RADIOACTIVITY IN STICKNEY WATER RECLAMATION PLANT RAW SEWAGE AND FINAL EFFLUENT ON A MONTHLY BASIS – 2011

Month	Raw Sewage Gross Beta (pCi/L)	Effluent Gross Beta (pCi/L)
January	7.2	9.9
February	7.6	8.8
March	13.4	6.4
April	12.4	7.9
May	11.4	4.4
June	21.2	5.7
July	18.4	5.4
August	29.2	4.2
September	5.5	3.9
October	7.6	4.8
November	9.4	3.4
December	5.7	5.0

< = The quantity listed is the smallest amount that could be measured at the 95 percent confidence level (lower limit of detection).

TABLE 4: YEARLY AVERAGE GROSS BETA RADIOACTIVITY IN STICKNEY WATER RECLAMATION PLANT RAW SEWAGE, FINAL EFFLUENT, AND ANAEROBICALLY DIGESTED BIOSOLIDS FROM 1996 THROUGH 2011

Year	Raw Sewage Gross Beta (pCi/L)	Effluent Gross Beta (pCi/L)	Biosolids ¹ Gross Beta (pCi/g dw)
1996	11.7	5.9	22.8
1997	20.4	9.0	23.4
1998	26.4	11.4	23.6
1999	28.9	11.1	25.9
2000	29.3	9.8	27.2
2001	19.7	9.2	27.3
2002	17.3	9.0	24.7
2003	16.6	7.7	24.8
2004	17.7	9.8	24.8
2005	17.4	8.8	23.2
2006	15.9	8.4	25.4
2007	17.0	8.4	26.1
2008	17.9	7.8	26.8
2009	12.6	8.1	24.6
2010	13.5	8.0	20.5
2011	12.4	5.8	-

¹Gross beta radioactivity analysis in biosolids was terminated in 2011.

TABLE 5: GROSS ALPHA RADIOACTIVITY IN CALUMET WATER RECLAMATION PLANT RAW SEWAGE AND FINAL EFFLUENT ON A MONTHLY BASIS – 2011

Month	Raw Sewage Gross Alpha (pCi/L)	Effluent Gross Alpha (pCi/L)
January	<2.4	<3.1
February	<2.5	<2.4
March	<2.7	<5.2
April	<3.0	<1.7
May	<2.9	<1.7
June	2.4	<1.8
July	<2.6	<1.8
August	18.6	<2.0
September	<2.5	<1.7
October	3.8	<2.1
November	4.6	<2.0
December	<2.0	<1.8

< = The quantity listed is the smallest amount that could be measured at the 95 percent confidence level (lower limit of detection).

TABLE 6: YEARLY AVERAGE GROSS ALPHA RADIOACTIVITY IN CALUMET WATER RECLAMATION PLANT RAW SEWAGE, FINAL EFFLUENT, AND ANAEROBICALLY DIGESTED BIOSOLIDS FROM 1996 THROUGH 2011

Year ¹	Raw Sewage Gross Alpha (pCi/L)	Effluent Gross Alpha (pCi/L)	Biosolids ² Gross Alpha (pCi/g dw)
1996	<3.7	<3.5	5.9
1997	<4.0	<3.5	5.1
1998	<3.8	<3.0	6.1
1999	<4.6	<3.8	6.5
2000	<4.7	<4.5	8.4
2001	<5.1	<4.5	12.6
2002	<4.8	<4.1	12.1
2003	<4.3	<3.8	12.4
2004	<4.8	<4.4	14.1
2005	<5.3	<4.5	13.6
2006	<5.3	<5.0	12.8
2007	<5.5	<5.1	11.5
2008	<4.6	<2.3	17.6
2009	<3.5	<3.2	11.4
2010	<4.2	<3.2	11.0
2011	4.2	<2.3	ND ³

¹Am-241 self-absorption standards were used up to June 30, 2001, and Th-230 self-absorption standards were used from July 1, 2001 for generating attenuation curve for gross alpha radioactivity.

²Gross alpha radioactivity analysis in biosolids was terminated in 2011.

³No data.

< = The quantity listed is the smallest amount that could be measured at the 95 percent confidence level (lower limit of detection).

TABLE 7: GROSS BETA RADIOACTIVITY IN CALUMET WATER RECLAMATION PLANT RAW SEWAGE AND FINAL EFFLUENT ON A MONTHLY BASIS – 2011

Month	Raw Sewage Gross Beta (pCi/L)	Effluent Gross Beta (pCi/L)
January	3.2	8.0
February	5.2	5.3
March	2.9	4.9
April	6.0	1.6
May	6.6	3.2
June	4.1	2.5
July	5.7	2.8
August	26.3	4.0
September	6.3	3.4
October	8.1	4.6
November	6.4	4.0
December	5.1	3.9

< = The quantity listed is the smallest amount that could be measured at the 95 percent confidence level (lower limit of detection).

TABLE 8: YEARLY AVERAGE GROSS BETA RADIOACTIVITY IN CALUMET WATER RECLAMATION PLANT RAW SEWAGE, FINAL EFFLUENT, AND ANAEROBICALLY DIGESTED BIOSOLIDS FROM 1996 THROUGH 2011

Year	Raw Sewage Gross Beta (pCi/L)	Effluent Gross Beta (pCi/L)	Biosolids ¹ Gross Beta (pCi/g dw)
1996	9.3	6.9	21.5
1997	18.6	11.2	21.4
1998	19.5	13.2	23.7
1999	24.9	14.1	22.6
2000	22.0	10.2	25.2
2001	13.6	9.4	24.1
2002	15.9	9.4	21.0
2003	15.1	9.6	23.7
2004	12.3	9.2	24.8
2005	12.1	8.3	23.2
2006	11.4	8.1	26.2
2007	9.8	6.9	25.5
2008	8.5	7.0	30.6
2009	10.3	9.0	25.5
2010	9.3	7.7	22.6
2011	7.2	4.0	-

¹Gross beta radioactivity analysis in biosolids was terminated in 2011.

ranged from 4.0 to 14.1 pCi/L. The gross beta radioactivity in anaerobically digested biosolids ranged from 21.0 to 30.6 pCi/g dw. The analysis of biosolids was terminated in 2011.

Terrence J. O'Brien Water Reclamation Plant

In 2011, the gross alpha radioactivity in the raw sewage of the O'Brien WRP was below the detection limit (1.6 to 3.6 pCi/L) with the detected values of 5.5 pCi/L in April (Table 9). The gross alpha radioactivity in the effluent was below the detection limits (1.5 to 3.7 pCi/L) (Table 9).

The yearly average gross alpha radioactivity in the O'Brien WRP raw sewage, final effluent, and waste-activated sludge from 1996 to 2011 are summarized in Table 10. The gross alpha radioactivity in the raw sewage was below the detection limit (2.8 to 5.0 pCi/L). The gross alpha radioactivity in the effluent was also below the detection limit (2.1 to 4.9 pCi/L). The gross alpha radioactivity in waste-activated sludge ranged from 2.6 to 7.8 pCi/g dw. The analysis of sludge was terminated in 2011.

The gross beta radioactivity in the raw sewage of the O'Brien WRP ranged from 2.4 to 7.5 pCi/L, and in the effluent it ranged from 2.0 to 5.9 pCi/L (Table 11).

The yearly average gross beta radioactivity in the O'Brien WRP raw sewage, final effluent, and waste-activated sludge from 1996 to 2011 are summarized in Table 12. The gross beta radioactivity in the raw sewage ranged from 5.1 to 20.4 pCi/L and in the effluent it ranged from 4.2 to 10.9 pCi/L. The gross beta radioactivity in waste-activated sludge ranged from 12.8 to 16.2 pCi/g dw. The analysis of sludge was terminated in 2011.

John E. Egan Water Reclamation Plant

In 2011, the gross alpha radioactivity in the raw sewage of the Egan WRP was below the detection limits (1.4 to 3.0 pCi/L) with the detected values ranging from 2.7 to 3.6 pCi/L (Table 13). The gross alpha radioactivity in the effluent was below the detection limits (1.6 to 5.4 pCi/L).

TABLE 9: GROSS ALPHA RADIOACTIVITY IN TERRENCE J. O'BRIEN WATER
RECLAMATION PLANT RAW SEWAGE AND FINAL EFFLUENT
ON A MONTHLY BASIS – 2011

Month	Raw Sewage Gross Alpha (pCi/L)	Effluent Gross Alpha (pCi/L)
January	<3.6	<2.9
February	<3.6	<3.7
March	<2.8	<3.2
April	5.5	<1.8
May	<2.8	<1.9
June	<2.3	<2.0
July	<2.2	<1.7
August	<3.4	<1.6
September	<2.5	<1.6
October	<2.5	<1.8
November	<2.5	<1.7
December	<1.6	<1.5

< = The quantity listed is the smallest amount that could be measured at the 95 percent confidence level (lower limit of detection).

TABLE 10: YEARLY AVERAGE GROSS ALPHA RADIOACTIVITY IN TERRENCE J. O'BRIEN WATER RECLAMATION PLANT RAW SEWAGE, FINAL EFFLUENT, AND WASTE-ACTIVATED SLUDGE FROM 1996 THROUGH 2011

Year ¹	Raw Sewage Gross Alpha (pCi/L)	Effluent Gross Alpha (pCi/L)	Sludge ² Gross Alpha (pCi/g dw)
1996	<3.3	<3.0	3.5
1997	<3.6	<3.3	2.6
1998	<3.3	<2.8	3.0
1999	<4.0	<3.5	3.7
2000	<4.9	<4.1	4.9
2001	<4.9	<4.5	7.8
2002	<4.0	<4.0	6.6
2003	<3.6	<3.5	6.2
2004	<4.1	<3.6	7.8
2005	<4.4	<3.8	7.1
2006	<4.8	<4.8	7.2
2007	<5.0	<4.9	7.0
2008	<2.8	<2.3	7.8
2009	<3.1	<3.4	6.8
2010	<2.8	<2.9	6.6
2011	<2.9	<2.1	-

¹ Am-241 self-absorption standards were used up to June 30, 2001, and Th-230 self-absorption standards were used from July 1, 2001 for generating attenuation curve for gross alpha radioactivity.

² Gross Alpha radioactivity analysis in sludge was terminated in 2011.

< = The quantity listed is the smallest amount that could be measured at the 95 percent confidence level (lower limit of detection).

TABLE 11: GROSS BETA RADIOACTIVITY IN TERRENCE J. O'BRIEN WATER
RECLAMATION PLANT RAW SEWAGE AND FINAL EFFLUENT
ON A MONTHLY BASIS – 2011

Month	Raw Sewage Gross Beta (pCi/L)	Effluent Gross Beta (pCi/L)
January	6.3	5.9
February	3.9	5.3
March	3.2	4.3
April	7.0	3.0
May	5.5	3.8
June	6.4	5.9
July	5.0	5.9
August	7.5	2.0
September	4.2	2.8
October	6.0	4.0
November	3.7	3.8
December	2.4	3.3

<= The quantity listed is the smallest amount that could be measured at the 95 percent confidence level (lower limit of detection).

TABLE 12: YEARLY AVERAGE GROSS BETA RADIOACTIVITY IN TERRENCE J. O'WATER RECLAMATION PLANT RAW SEWAGE, FINAL EFFLUENT, AND WASTE-ACTIVATED SLUDGE FROM 1996 THROUGH 2011

Year	Raw Sewage Gross Beta (pCi/L)	Effluent Gross Beta (pCi/L)	Sludge ¹ Gross Beta (pCi/g dw)
1996	8.5	5.7	14.8
1997	16.1	<7.8	14.0
1998	18.4	9.8	14.4
1999	19.1	10.9	13.6
2000	20.4	8.9	15.0
2001	12.8	8.5	15.8
2002	11.3	8.4	12.8
2003	10.0	7.9	13.3
2004	10.9	9.3	12.8
2005	10.3	7.4	13.5
2006	10.1	8.0	14.4
2007	9.0	6.5	14.4
2008	7.5	6.3	16.2
2009	7.0	7.3	15.0
2010	7.9	8.8	13.7
2011	5.1	4.2	-

¹Gross beta radioactivity analysis in sludge was terminated in 2011 .

< = The quantity listed is the smallest amount that could be measured at the 95 percent confidence level (lower limit of detection).

TABLE 13: GROSS ALPHA RADIOACTIVITY IN JOHN E. EGAN WATER RECLAMATION PLANT RAW SEWAGE AND FINAL EFFLUENT ON A MONTHLY BASIS – 2011

Month	Raw Sewage Gross Alpha (pCi/L)	Effluent Gross Alpha (pCi/L)
January	2.7	<2.5
February	<2.4	<2.1
March	<2.7	<5.4
April	<2.6	<2.4
May	<2.4	<2.0
June	3.6	<2.1
July	<2.3	<1.6
August	3.1	<1.9
September	<1.4	<2.0
October	<3.0	<1.9
November	<2.4	<1.7
December	<1.8	<1.9

<= The quantity listed is the smallest amount that could be measured at the 95 percent confidence level (lower limit of detection).

The yearly average gross alpha radioactivity in the Egan WRP raw sewage, final effluent, and anaerobically digested biosolids from 1996 to 2011 are summarized in [Table 14](#). The gross alpha radioactivity in the raw sewage was below the detection limit (2.5 to 5.4 pCi/L). The gross alpha radioactivity in the effluent was also below the detection limit (2.0 to 5.2 pCi/L). The gross alpha radioactivity in anaerobically digested biosolids ranged from 4.4 to 13.8 pCi/g dw. The analysis of biosolids was terminated in 2011.

The gross beta radioactivity levels in the raw sewage of the Egan WRP ranged from 3.9 to 10.3 pCi/L, and in the effluent it ranged from 2.8 to 6.6 pCi/L ([Table 15](#)).

The yearly average gross beta radioactivity at the Egan WRP raw sewage, final effluent, and anaerobically digested biosolids from 1996 to 2011 are summarized in [Table 16](#). The gross beta radioactivity in the raw sewage ranged from 6.2 to 22.5 pCi/L and in the effluent it ranged from 5.0 to 12.7 pCi/L. The gross beta radioactivity in anaerobically digested biosolids ranged from 15.1 to 21.7 pCi/g dw. The analysis of biosolids was terminated in 2011.

Hanover Park Water Reclamation Plant

In 2011, the gross alpha radioactivity levels in the raw sewage of the Hanover Park WRP were below the detection limit (1.9 to 6.6 pCi/L) with the detected values ranging from 2.7 to 3.1 pCi/L ([Table 17](#)). The gross alpha radioactivity in the effluent was also below the detection limits (1.5 to 3.4 pCi/L) ([Table 17](#)).

The yearly average gross alpha radioactivity in the Hanover Park WRP raw sewage, final effluent, and anaerobically digested biosolids from 1996 to 2011 are summarized in [Table 18](#). The gross alpha radioactivity in the raw sewage was below the detection limit (2.6 to 5.0 pCi/L). The gross alpha radioactivity in the effluent was also below the detection limit (1.9 to 5.0 pCi/L). The gross alpha radioactivity in anaerobically digested biosolids ranged from 3.2 to 10.2 pCi/g dw. The analysis of biosolids was terminated in 2011.

The gross beta radioactivity levels in the raw sewage of the Hanover Park WRP ranged from 3.2 to 10.7 pCi/L and in the effluent it ranged from 2.9 to 12.7 pCi/L ([Table 19](#)).

The yearly average gross beta radioactivity in the Hanover Park WRP raw sewage, final effluent, and anaerobically digested biosolids from 1996 to 2011 are summarized in [Table 20](#). The gross beta radioactivity in the raw sewage ranged from 5.8 to 20.3 pCi/L and in the effluent it ranged from 5.8 to 11.7 pCi/L. The gross beta radioactivity in anaerobically digested biosolids ranged from 11.2 to 15.5 pCi/g dw. The analysis of biosolids was terminated in 2011.

James C. Kirie Water Reclamation Plant

In 2011, the gross alpha radioactivity levels in the raw sewage of the Kirie WRP were below the detection limit (1.4 to 5.2 pCi/L), except for the August sample which was 9.1 pCi/L ([Table 21](#)).

TABLE 14: YEARLY AVERAGE GROSS ALPHA RADIOACTIVITY IN JOHN E. EGAN WATER RECLAMATION PLANT RAW SEWAGE, FINAL EFFLUENT, AND ANAEROBICALLY DIGESTED BIOSOLIDS FROM 1996 THROUGH 2011

Year ¹	Raw Sewage Gross Alpha (pCi/L)	Effluent Gross Alpha (pCi/L)	Biosolids ² Gross Alpha (pCi/g dw)
1996	<3.6	<3.2	5.6
1997	<3.7	<3.3	4.4
1998	<3.8	<3.0	4.8
1999	<4.0	<3.5	5.2
2000	<4.5	<4.1	6.9
2001	<5.0	<4.6	10.5
2002	<4.8	<4.8	10.2
2003	<4.2	<3.6	9.7
2004	<4.4	<3.8	9.9
2005	<4.8	<4.2	10.1
2006	<4.8	<4.8	9.8
2007	<5.4	<5.2	9.3
2008	<2.8	<2.0	13.8
2009	<4.4	<3.3	9.5
2010	<4.1	<3.7	7.7
2011	<2.5	<2.3	-

¹ Am-241 self-absorption standards were used up to June 30, 2001, and Th-230 self-absorption standards were used from July 1, 2001 for generating attenuation curve for gross alpha radioactivity.

² Gross alpha radioactivity analysis in biosolids was terminated in 2011.

< = The quantity listed is the smallest amount that could be measured at the 95 percent confidence level (lower limit of detection).

TABLE 15: GROSS BETA RADIOACTIVITY IN JOHN E. EGAN WATER
RECLAMATION PLANT RAW SEWAGE AND FINAL EFFLUENT
ON A MONTHLY BASIS – 2011

Month	Raw Sewage Gross Beta (pCi/L)	Effluent Gross Beta (pCi/L)
January	10.3	4.2
February	6.9	5.9
March	3.0	6.6
April	6.6	6.0
May	5.1	3.8
June	7.2	4.7
July	7.3	5.3
August	9.4	5.3
September	3.9	5.8
October	5.3	4.4
November	4.5	5.7
December	4.3	2.8

TABLE 16: YEARLY AVERAGE GROSS BETA RADIOACTIVITY IN JOHN E. EGAN WATER RECLAMATION PLANT RAW SEWAGE, FINAL EFFLUENT, AND ANAEROBICALLY DIGESTED BIOSOLIDS FROM 1996 THROUGH 2011

Year	Raw Sewage Gross Beta (pCi/L)	Effluent Gross Beta (pCi/L)	Biosolids ¹ Gross Beta (pCi/g dw)
1996	10.8	6.9	20.3
1997	17.5	11.9	19.0
1998	19.1	12.7	20.5
1999	22.5	12.3	19.7
2000	20.8	10.6	21.3
2001	16.0	9.5	20.7
2002	15.4	12.0	18.3
2003	14.0	10.5	18.6
2004	13.9	11.3	19.3
2005	13.7	10.9	17.6
2006	13.0	11.0	18.5
2007	11.4	8.7	18.2
2008	9.0	6.8	21.7
2009	10.4	8.1	18.1
2010	11.4	11.0	15.1
2011	6.2	5.0	-

¹ Gross beta radioactivity analysis in biosolids was terminated in 2011.

TABLE 17: GROSS ALPHA RADIOACTIVITY IN HANOVER PARK WATER
RECLAMATION PLANT RAW SEWAGE AND FINAL EFFLUENT
ON A MONTHLY BASIS – 2011

Month	Raw Sewage Gross Alpha (pCi/L)	Effluent Gross Alpha (pCi/L)
January	<6.6	<2.4
February	<1.9	<3.4
March	<2.2	<3.0
April	<2.6	<1.9
May	2.7	<2.0
June	<1.9	<1.8
July	<2.4	<1.7
August	<2.9	<1.7
September	<2.4	<1.5
October	3.1	<1.9
November	<2.3	<1.5
December	<1.9	<1.9

< = The quantity listed is the smallest amount that could be measured at the 95 percent confidence level (lower limit of detection).

TABLE 18: YEARLY AVERAGE GROSS ALPHA RADIOACTIVITY IN HANOVER PARK WATER RECLAMATION PLANT RAW SEWAGE, FINAL EFFLUENT, AND ANAEROBICALLY DIGESTED BIOSOLIDS FROM 1996 THROUGH 2011

Year ¹	Raw Sewage Gross Alpha (pCi/L)	Effluent Gross Alpha (pCi/L)	Biosolids ² Gross Alpha (pCi/g dw)
1996	<3.4	<3.1	4.7
1997	<3.6	<3.3	3.2
1998	<3.5	<3.0	4.0
1999	<4.2	<3.5	4.3
2000	<4.6	<4.2	5.7
2001	<4.7	<4.4	9.4
2002	<4.5	<4.0	8.0
2003	<4.1	<3.5	7.1
2004	<4.4	<3.7	8.2
2005	<4.6	<4.1	8.0
2006	<5.0	<4.6	7.5
2007	<5.0	<5.0	7.0
2008	<2.7	<1.9	10.2
2009	<2.6	<3.5	7.2
2010	<3.2	<2.7	6.3
2011	<2.7	<2.1	-

¹Am-241 self-absorption standards were used up to June 30, 2001, and Th-230 self-absorption standards were used from July 1, 2001 for generating attenuation curve for gross alpha radioactivity.

²Gross alpha radioactivity analysis in biosolids was terminated in 2011.

< = The quantity listed is the smallest amount that could be measured at the 95 percent confidence level (lower limit of detection).

TABLE 19: GROSS BETA RADIOACTIVITY IN HANOVER PARK
 WATER RECLAMATION PLANT RAW SEWAGE AND
 FINAL EFFLUENT ON A MONTHLY BASIS – 2011

Month	Raw Sewage Gross Beta (pCi/L)	Effluent Gross Beta (pCi/L)
January	10.7	4.4
February	7.6	12.7
March	4.4	8.1
April	3.3	4.6
May	3.2	4.0
June	4.9	5.1
July	7.4	6.1
August	6.3	4.8
September	5.4	6.2
October	7.0	5.5
November	6.1	4.9
December	3.5	2.9

TABLE 20: YEARLY AVERAGE GROSS BETA RADIOACTIVITY IN HANOVER PARK WATER RECLAMATION PLANT RAW SEWAGE, FINAL EFFLUENT, AND ANAEROBICALLY DIGESTED BIOSOLIDS FROM 1996 THROUGH 2011

Year	Raw Sewage Gross Beta (pCi/L)	Effluent Gross Beta (pCi/L)	Biosolids ¹ Gross Beta (pCi/g dw)
1996	19.7	6.6	13.2
1997	14.3	9.3	11.8
1998	20.3	10.3	13.5
1999	18.4	10.8	13.0
2000	16.1	9.5	13.8
2001	14.2	9.6	14.2
2002	14.5	11.7	12.0
2003	13.5	10.6	12.0
2004	13.6	11.0	12.1
2005	13.3	10.8	12.3
2006	12.9	11.2	13.6
2007	9.8	9.2	13.0
2008	8.9	8.1	15.5
2009	10.8	8.6	12.0
2010	9.7	9.1	11.2
2011	5.8	5.8	-

¹ Gross beta radioactivity analysis in biosolids was terminated in 2011.

TABLE 21: GROSS ALPHA RADIOACTIVITY IN JAMES C. KIRIE WATER
RECLAMATION PLANT RAW SEWAGE AND FINAL EFFLUENT
ON A MONTHLY BASIS – 2011

Month	Raw Sewage Gross Alpha (pCi/L)	Effluent Gross Alpha (pCi/L)
January	<5.2	<3.2
February	<2.8	<2.1
March	<2.0	<4.7
April	<1.4	<2.4
May	<2.6	<2.2
June	<2.2	<2.3
July	<2.7	<2.0
August	9.1	<1.9
September	<2.5	<2.0
October	<2.7	<2.4
November	<2.5	<2.2
December	<1.8	<1.7

< = The quantity listed is the smallest amount that could be measured at the 95 percent confidence level (lower limit of detection).

The gross alpha radioactivity in the effluent was below the detection limit (1.7 to 4.7 pCi/L) (Table 21).

The yearly average gross alpha radioactivity in the Kirie WRP raw sewage, final effluent, and waste-activated sludge from 1996 to 2011 are summarized in Table 22. The gross alpha radioactivity in the raw sewage was below the detection limit (3.1 to 5.6 pCi/L). The gross alpha radioactivity in the effluent was also below the detection limit (2.3 to 5.6 pCi/L). The gross alpha radioactivity in waste-activated sludge ranged from 3.1 to 9.3 pCi/g dw. The analysis of sludge was terminated in 2011.

The gross beta radioactivity level in the raw sewage of the Kirie WRP ranged from 1.6 pCi/L to 21.2 pCi/L, and in the effluent it ranged from 3.0 to 7.7 pCi/L (Table 23).

The yearly average gross beta radioactivity in the Kirie WRP raw sewage, final effluent, and waste-activated sludge from 1996 to 2011 are summarized in Table 24. The gross beta radioactivity in the raw sewage ranged from 6.6 to 22.7 pCi/L and in the effluent it ranged from 5.6 to 16.8 pCi/L. The gross beta radioactivity in waste-activated sludge ranged from 13.3 to 17.7 pCi/g dw. The analysis of sludge was terminated in 2011.

Lemont Water Reclamation Plant

In 2011, the gross alpha radioactivity levels in the raw sewage of the Lemont WRP ranged from 4.9 to 44.2 pCi/L (Table 25). The gross alpha radioactivity in the effluent ranged from 2.8 to 10.8 pCi/L, except for the March sample which was less than 6.4 pCi/L (Table 25).

The yearly average gross alpha radioactivity in the Lemont WRP raw sewage, final effluent, and waste-activated sludge from 1996 to 2011 are summarized in Table 26. The gross alpha radioactivity in the raw sewage ranged from 13.4 to 44.4 pCi/L. The gross alpha radioactivity in the effluent was below the detection limit (5.0 to 10.8 pCi/L), except for 2008, 2009, and 2011 samples which were 6.7, 8.9, and 6.7 pCi/L respectively. The gross alpha radioactivity in the waste-activated sludge ranged from 38.9 to 141.1 pCi/g dw. The analysis of sludge was terminated in 2011.

The gross beta radioactivity levels in the raw sewage of the Lemont WRP ranged from 8.9 to 46.3 pCi/L, and in the effluent it ranged from 8.6 to 17.8 pCi/L (Table 27).

The yearly average gross beta radioactivity at the Lemont WRP raw sewage, final effluent, and waste-activated sludge from 1996 to 2011 are summarized in Table 28. The gross beta radioactivity in the raw sewage ranged from 17.2 to 66.0 pCi/L and in the effluent it ranged from 13.4 to 24.9 pCi/L. The gross beta radioactivity in waste-activated sludge ranged from 44.5 to 121.9 pCi/g dw. The analysis of sludge was terminated in 2011.

TABLE 22: YEARLY AVERAGE GROSS ALPHA RADIOACTIVITY IN JAMES C. KIRIE WATER RECLAMATION PLANT RAW SEWAGE, FINAL EFFLUENT, AND WASTE-ACTIVATED SLUDGE FROM 1996 THROUGH 2011

Year ¹	Raw Sewage Gross Alpha (pCi/L)	Effluent Gross Alpha (pCi/L)	Sludge ² Gross Alpha (pCi/g dw)
1996	<3.7	<3.3	5.0
1997	<3.8	<3.4	3.1
1998	<3.6	<2.8	3.2
1999	<4.2	<3.7	4.1
2000	<4.6	<4.5	4.8
2001	<5.3	<4.9	9.2
2002	<4.6	<4.1	7.4
2003	<4.2	<3.8	7.2
2004	<4.9	<4.2	7.1
2005	<5.1	<4.7	7.9
2006	<5.3	<4.8	6.8
2007	<5.6	<5.6	6.8
2008	<3.1	<2.3	9.3
2009	<3.7	<3.6	8.6
2010	<3.4	<4.2	7.5
2011	<3.1	<2.4	-

¹Am-241 self-absorption standards were used up to June 30, 2001, and Th-230 self-absorption standards were used from July 1, 2001 for generating attenuation curve for gross alpha radioactivity.

²Gross alpha radioactivity analysis in sludge was terminated in 2011.

< = The quantity listed is the smallest amount that could be measured at the 95 percent confidence level (lower limit of detection).

TABLE 23: GROSS BETA RADIOACTIVITY IN JAMES C. KIRIE WATER
RECLAMATION PLANT RAW SEWAGE AND FINAL EFFLUENT
ON A MONTHLY BASIS – 2011

Month	Raw Sewage Gross Beta (pCi/L)	Effluent Gross Beta (pCi/L)
January	7.1	7.7
February	8.5	5.8
March	3.4	6.7
April	1.6	6.4
May	<2.6	3.0
June	3.9	4.9
July	6.3	6.2
August	21.2	3.1
September	4.4	5.2
October	6.5	7.0
November	9.6	7.7
December	3.9	3.7

<= The quantity listed is the smallest amount that could be measured at the 95 percent confidence level (lower limit of detection).

TABLE 24: YEARLY AVERAGE GROSS BETA RADIOACTIVITY IN JAMES C. KIRIE WATER RECLAMATION PLANT RAW SEWAGE, FINAL EFFLUENT, AND WASTE-ACTIVATED SLUDGE FROM 1996 THROUGH 2011

Year	Raw Sewage Gross Beta (pCi/L)	Effluent Gross Beta (pCi/L)	Sludge ¹ Gross Beta (pCi/g dw)
1996	11.6	8.1	16.8
1997	19.2	12.6	14.6
1998	22.3	15.6	14.2
1999	21.4	15.5	13.5
2000	22.7	16.8	14.8
2001	17.6	13.3	15.8
2002	17.4	14.8	14.0
2003	16.1	12.2	13.5
2004	15.7	12.9	13.3
2005	16.1	15.2	14.8
2006	13.4	12.6	13.7
2007	13.0	11.1	14.6
2008	11.8	8.7	17.7
2009	9.6	8.0	15.8
2010	10.5	9.3	14.1
2011	6.6	5.6	-

¹Gross beta radioactivity analysis in sludge was terminated in 2011.

TABLE 25: GROSS ALPHA RADIOACTIVITY IN LEMONT WATER
 RECLAMATION PLANT RAW SEWAGE AND FINAL EFFLUENT
 ON A MONTHLY BASIS – 2011

Month	Raw Sewage Gross Alpha (pCi/L)	Effluent Gross Alpha (pCi/L)
January	17.0	9.3
February	44.2	6.3
March	4.9	<6.4
April	9.1	7.6
May	13.2	2.8
June	10.8	3.9
July	15.6	4.7
August	13.2	3.2
September	13.6	10.8
October	10.8	4.8
November	8.4	5.6
December	6.2	6.1

<= The quantity listed is the smallest amount that could be measured at the 95 percent confidence level (lower limit of detection).

TABLE 26: YEARLY AVERAGE GROSS ALPHA RADIOACTIVITY IN LEMONT WATER RECLAMATION PLANT RAW SEWAGE, FINAL EFFLUENT, AND WASTE-ACTIVATED SLUDGE FROM 1996 THROUGH 2011

Year ¹	Raw Sewage Gross Alpha (pCi/L)	Effluent Gross Alpha (pCi/L)	Sludge ² Gross Alpha (pCi/g dw)
1996	13.4	<5.4	45.3
1997	21.1	<5.9	38.9
1998	22.8	<5.0	48.8
1999	35.4	<6.8	76.6
2000	44.4	<7.9	106.1
2001	33.3	<9.1	141.1
2002	23.8	<9.7	121.2
2003	16.4	<9.3	86.5
2004	18.6	<8.6	100.2
2005	24.2	<10.5	110.4
2006	16.1	<10.1	90.0
2007	15.2	<10.8	76.8
2008	23.6	6.7	124.8
2009	16.5	8.9	70.0
2010	21.0	6.7	71.0
2011	13.9	<6.0	-

¹Am-241 self-absorption standards were used up to June 30, 2001, and Th-230 self-absorption standards were used from July 1, 2001 for generating attenuation curve for gross alpha radioactivity.

²Gross alpha radioactivity analysis in sludge was terminated in 2011.

< = The quantity listed is the smallest amount that could be measured at the 95 percent confidence level (lower limit of detection).

TABLE 27: GROSS BETA RADIOACTIVITY IN LEMONT WATER
RECLAMATION PLANT RAW SEWAGE AND FINAL EFFLUENT
ON A MONTHLY BASIS – 2011

Month	Raw Sewage Gross Beta (pCi/L)	Effluent Gross Beta (pCi/L)
January	18.2	17.8
February	46.3	16.4
March	8.9	11.3
April	12.4	14.8
May	9.7	8.6
June	20.7	13.4
July	18.5	11.8
August	15.8	12.6
September	14.2	16.6
October	14.5	11.7
November	14.8	14.6
December	12.2	11.2

TABLE 28: YEARLY AVERAGE GROSS BETA RADIOACTIVITY IN LEMONT WATER RECLAMATION PLANT RAW SEWAGE, FINAL EFFLUENT, AND WASTE-ACTIVATED SLUDGE FROM 1996 THROUGH 2011

Year	Raw Sewage Gross Beta (pCi/L)	Effluent Gross Beta (pCi/L)	Sludge ¹ Gross Beta (pCi/g dw)
1996	26.6	13.4	73.4
1997	44.3	20.8	77.0
1998	42.4	19.4	84.1
1999	59.1	21.8	101.4
2000	66.0	22.0	121.9
2001	50.0	22.3	90.7
2002	37.1	24.1	79.5
2003	26.4	18.4	61.1
2004	28.3	19.3	63.4
2005	34.9	24.9	68.6
2006	26.4	21.7	64.2
2007	26.3	20.0	64.8
2008	27.0	18.8	107.4
2009	24.8	19.9	48.3
2010	24.4	18.9	44.5
2011	17.2	13.4	-

¹Gross beta radioactivity analysis in sludge was terminated in 2011.

Hanover Park Water Reclamation Plant Lagoons

Table 29 presents the gross alpha and gross beta radioactivity concentrations in the Hanover Park WRP lagooned biosolids for 2011.

Average gross alpha radioactivity in the Hanover Park WRP East lagooned biosolids was 9.1 pCi/g dw and ranged from 7.7 to 10.5 pCi/g dw. Average gross alpha radioactivity in the Hanover Park WRP West lagooned biosolids was 10.5 pCi/g dw and ranged from 7.8 to 12.1 pCi/g dw.

Average gross beta radioactivity in the Hanover Park WRP East lagooned biosolids was 15.2 pCi/g dw and ranged from 13.8 to 16.0 pCi/g dw. Average gross beta radioactivity in the Hanover Park WRP West lagooned biosolids was 14.4 pCi/g dw and ranged from 12.5 to 16.8 pCi/g dw.

The yearly average gross alpha radioactivity in Hanover Park WRP lagooned biosolids, since the inception of this program, from 1998 to 2011 is summarized in Table 30. The gross alpha radioactivity in the lagooned biosolids ranged from 4.6 pCi/g dw at Hanover Park WRP West lagoon in 1999 to 13.8 pCi/g dw at Hanover Park WRP West lagoon in 2004.

The yearly average gross beta radioactivity in the Hanover Park WRP lagooned biosolids from 1998 to 2011 is summarized in Table 31. The gross beta radioactivity in lagooned biosolids ranged from 11.6 pCi/g dw at the Hanover Park WRP West Lagoon in 2003 to 18.1 pCi/g dw at the Hanover Park WRP West Lagoon in 1999.

Gross Alpha and Gross Beta Radioactivity in John E. Egan and Stickney Water Reclamation Plants Centrifuge Cake Biosolids

Table 32 presents the gross alpha and gross beta radioactivity concentrations in Egan and Stickney WRP centrifuge cake biosolids in 2011.

Average gross alpha radioactivity in Egan WRP biosolids was 11.3 pCi/g dw and ranged from 9.6 to 13.6 pCi/g dw. Average gross alpha radioactivity in Stickney WRP biosolids was 12.8 pCi/g and ranged from 10.6 to 14.6 pCi/g dw.

Average gross beta radioactivity in the Egan WRP was 20.0 pCi/g dw and ranged from 13.8 to 27.3 pCi/g dw. The average gross beta radioactivity in the Stickney WRP was 26.8 pCi/g dw and ranged from 23.4 to 28.4 pCi/gdw.

TABLE 29: GROSS ALPHA AND GROSS BETA RADIOACTIVITY IN HANOVER PARK
WATER RECLAMATION PLANT LAGOONED BIOSOLIDS – 2011

Lagoon Location	No. of Samples	Gross Alpha (pCi/g dw)			Gross Beta (pCi/g dw)		
		Average	Minimum	Maximum	Average	Minimum	Maximum
East	4	9.1	7.7	10.5	15.2	13.8	16.0
West	4	10.5	7.8	12.1	14.4	12.5	16.8

TABLE 30: YEARLY AVERAGE GROSS ALPHA RADIOACTIVITY IN HANOVER PARK WATER RECLAMATION PLANT LAGOONED BIOSOLIDS FROM 1998 THROUGH 2011

Year ¹	Hanover Park East Gross Alpha (pCi/g dw)	Hanover Park West Gross Alpha (pCi/g dw)
1998	6.2	6.5
1999	5.0	4.6
2000	NA	NA
2001	13.6	13.2
2002	9.1	13.7
2003	9.0	8.6
2004	13.3	13.8
2005	9.4	9.7
2006	10.8	10.9
2007	9.4	7.9
2008	12.2	12.5
2009	7.0	8.8
2010	8.4	9.2
2011	9.1	10.5

¹Am-241 self-absorption standards were used up to June 30, 2001, and Th-230 self-absorption standards were used from July 1, 2001 for generating attenuation curve for gross alpha radioactivity.

NA = Not analyzed.

TABLE 31: YEARLY AVERAGE GROSS BETA RADIOACTIVITY IN HANOVER PARK WATER RECLAMATION PLANT LAGOONED BIOSOLIDS FROM 1998 THROUGH 2011

Year	Hanover Park East Gross Beta (pCi/g dw)	Hanover Park West Gross Beta (pCi/g dw)
1998	15.2	17.2
1999	15.2	18.1
2000	NA	NA
2001	13.6	14.8
2002	14.1	15.3
2003	13.8	11.6
2004	14.8	14.8
2005	14.8	13.4
2006	14.6	12.8
2007	12.9	12.9
2008	16.0	16.4
2009	15.4	15.3
2010	12.8	12.4
2011	15.2	14.4

NA = Not analyzed.

TABLE 32: GROSS ALPHA AND GROSS BETA RADIOACTIVITY IN JOHN E. EGAN AND STICKNEY
WATER RECLAMATION PLANTS CENTRIFUGE CAKE BIOSOLIDS – 2011

Location	No. of Samples	Gross Alpha (pCi/g dw)			Gross Beta (pCi/g dw)		
		Average	Minimum	Maximum	Average	Minimum	Maximum
John E. Egan	4	11.3	9.6	13.6	20.0	13.8	27.3
Stickney	4	12.8	10.6	14.6	26.8	23.4	28.4

Radium-226, Radium-228, and Strontium-90 Radioactivity in the Raw Sewage and Final Effluent of the Water Reclamation Plants

In 2011, four raw sewage and four effluent samples each from the District's seven WRPs were analyzed for the concentration of radium-226, radium-228, and strontium-90 radioactivity. Tables 33 and 34 show the average concentration of these radionuclides in the four raw sewage and final effluent samples, respectively, from the WRPs for 2011. The average radium-226 radioactivity concentration in the raw sewage ranged from less than 0.3 pCi/L at the North Side WRP to 5.5 pCi/L the Lemont WRP. The average radium-228 radioactivity concentration in the raw sewage of the WRPs was below the detection limit (1.8 to 2.0 pCi/L) except for the Calumet and Westside WRPs (2.0 pCi/L) and Lemont WRP (4.1 pCi/L). The average strontium-90 radioactivity concentration was below the detection limit (1.1 to 1.3 pCi/L) at all the WRPs. The radium-226 radioactivity concentration in final effluent was below the detection limit (0.3 pCi/L) except for Lemont WRP (2.5 pCi/L). The radium-228 concentration in final effluent was below the detection limit (1.5 to 2.5 pCi/L) except for Lemont WRP (3.2 pCi/L). The strontium-90 radioactivity concentration in final effluent at all the WRPs was below the detection limit (1.1 to 1.2 pCi/L).

Gamma Radioactivity in John E. Egan and Stickney Water Reclamation Plants Centrifuge Cake Biosolids

In 2011, four biosolids each for Egan and Stickney WRPs; and Hanover Park WRP East and West lagoons were analyzed for gamma-emitting radionuclides. The following is a list of radionuclides monitored:

Beryllium-7	Silver-108m	Barium-133
Sodium-22	Silver-110	Bismuth-207
Potassium-40	Antimony-125	Bismuth-212
Manganese-54	Cesium-134	Lead-212
Cobalt-57	Cesium-137	Bismuth-214
Cobalt-60	Cerium-144	Lead-214
Zinc-65	Europium-152	Radium-226
Niobium-94	Gadolinium-153	Radium-228
Ruthenium-106	Europium-154	Protactinium-231

TABLE 33: CONCENTRATION OF RADIUM-226, RADIUM-228, AND STRONTIUM-90 IN
RAW SEWAGE OF THE WATER RECLAMATION PLANTS – 2011

Sample Location WRP	No. of Samples	Radium-226 (pCi/L)			Radium-228 (pCi/L)			Strontium-90 (pCi/L)		
		Ave.	Min.	Max.	Ave.	Min.	Max.	Ave.	Min.	Max.
Calumet	4	0.4	<0.2	0.5	2.0	<1.5	2.9	<1.1	<1.0	<1.3
John E. Egan	4	0.4	<0.3	0.4	<1.9	<1.6	<2.2	<1.2	<1.0	<1.4
Hanover Park	4	0.4	<0.2	0.5	<1.9	<1.6	<2.1	<1.2	<0.9	<1.4
Kirie	4	0.3	<0.3	0.3	<2.0	<1.7	<2.6	<1.3	<1.1	<1.6
Lemont	4	5.5	3.1	6.8	4.1	2.5	5.6	<1.1	<1.0	<1.3
North Side	4	<0.3	<0.3	0.3	<2.0	<1.6	<2.3	<1.2	<1.0	<1.6
Southwest	4	0.9	<0.3	1.7	<1.8	<1.6	<2.0	<1.2	<1.0	<1.3
Westside	4	0.5	<0.2	0.9	2.0	<1.4	3.0	<1.2	<1.1	<1.3

TABLE 34: CONCENTRATION OF RADIUM-226, RADIUM-228, AND STRONTIUM-90 IN FINAL EFFLUENT OF THE WATER RECLAMATION PLANTS – 2011

Sample Location WRP	No. of Samples	Radium-226 (pCi/L)			Radium-228 (pCi/L)			Strontium-90 (pCi/L)		
		Ave.	Min.	Max.	Ave.	Min.	Max.	Ave.	Min.	Max.
Calumet	4	<0.3	<0.2	<0.3	<1.6	<1.5	<1.7	<1.2	<1.0	<1.4
John E. Egan	4	<0.3	<0.3	<0.4	<1.9	<1.7	<2.2	<1.2	<1.0	<1.4
Hanover Park	4	<0.3	<0.3	<0.4	<1.8	<1.6	<2.0	<1.1	<1.0	<1.2
Kirie	4	<0.3	<0.2	<0.4	<1.8	<1.6	<2.2	<1.1	<1.0	<1.2
Lemont	4	2.5	1.8	3.3	3.2	2.2	<4.4	<1.1	<0.8	<1.3
North Side	4	<0.3	<0.2	<0.3	<2.5	<1.5	<3.5	<1.1	<1.0	<1.2
Stickney	4	<0.3	<0.2	<0.4	<1.5	<1.4	<1.6	<1.1	<0.9	<1.3

Of the 27 radionuclides analyzed, nine were detected at measurable levels. All of these radionuclides are of natural origin except for Cesium-137 which is a man-made radionuclide.

Table 35 presents the concentrations of gamma-emitting radionuclides in the centrifuge cake biosolids from the Egan and Stickney for 2011.

Table 36 presents the concentration of gamma-emitting radionuclides in the Hanover Park WRP lagooned biosolids for 2011.

The yearly average potassium-40, radium-226, and cesium-137 radioactivity in the Hanover Park WRP lagooned biosolids from 1998 to 2011 is summarized in Table 37. The yearly average potassium-40 radioactivity at the Hanover Park East lagoon ranged from 2.8 to 6.9 pCi/g dw. The yearly average radium-226 radioactivity ranged from 1.8 to 6.7 pCi/g dw, and cesium-137 radioactivity ranged from non-detectable levels to 0.2 pCi/g dw. The yearly average potassium-40 radioactivity at the Hanover Park West lagooned biosolids ranged from 3.5 to 6.7 pCi/g dw, radium-226 radioactivity ranged from 1.5 to 5.7 pCi/g dw, and cesium-137 radioactivity ranged from non-detectable levels to 0.3 pCi/g dw.

TABLE 35: CONCENTRATION OF GAMMA-EMITTING RADIONUCLIDES
IN JOHN E. EGAN AND STICKNEY WATER RECLAMATION PLANTS
CENTRIFUGE CAKE BIOSOLIDS – 2011

Sample Location WRP	No. of Samples	Average	Minimum	Maximum
Potassium-40 (pCi/gdw)				
John E. Egan	4	5.8	4.0	9.8
Stickney	4	8.3	5.4	9.9
Radium-226 (pCi/gdw)				
John E. Egan	4	4.3	3.6	4.7
Stickney	4	3.9	3.3	4.3
Cesium-137 (pCi/gdw)				
John E. Egan	4	0.006	0.03	0.13
Stickney	4	0.007	0.04	0.09
Beryllium-7 (pCi/gdw)				
John E. Egan	4	11.3	2.8	25.3
Stickney	4	13.1	7.8	23.0
Bismuth-212 (pCi/gdw)				
John E. Egan	4	0.7	0.6	0.8
Stickney	4	0.7	0.6	0.8

TABLE 35 (Continued): CONCENTRATION OF GAMMA-EMITTING RADIONUCLIDES
 IN JOHN E. EGAN AND STICKNEY WATER RECLAMATION PLANTS
 CENTRIFUGE CAKE BIOSOLIDS – 2011

Sample Location WRP	No. of Samples	Average	Minimum	Maximum
Lead-212 (pCi/gdw)				
John E. Egan	4	0.5	0.4	0.6
Stickney	4	0.5	0.4	0.6
Bismuth-214 (pCi/gdw)				
John E. Egan	4	1.3	0.7	1.5
Stickney	4	1.1	0.8	1.3
Lead-214 (pCi/gdw)				
John E. Egan	4	1.3	0.7	1.6
Stickney	4	1.0	0.8	1.3
Radium-228 (pCi/gdw)				
John E. Egan	4	1.2	1.1	1.4
Stickney	4	1.2	1.0	1.4

TABLE 36: CONCENTRATION OF GAMMA-EMITTING RADIONUCLIDES IN HANOVER PARK WATER RECLAMATION PLANT LAGOONED BIOSOLIDS - 2011

Radionuclides	No. of Samples	Hanover Park East Lagoon (pCi/g dw)	Hanover Park West Lagoon (pCi/g dw)
Beryllium-7	4	1.8	1.5
Potassium-40	4	5.9	4.8
Cesium-137	4	0.04	0.03
Bismuth-212	4	0.8	0.6
Lead-212	4	0.6	0.3
Bismuth-214	4	1.8	1.3
Lead-214	4	1.9	0.9
Radium-226	4	6.4	4.7
Radium-228	4	1.0	1.0

TABLE 37: YEARLY AVERAGE POTASSIUM-40, RADIUM-226, AND CESIUM-137 RADIOACTIVITY (pCi/g dw)
IN HANOVER PARK WATER RECLAMATION PLANT LAGOONED BIOSOLIDS FROM 1998 THROUGH 2011

Year	Hanover Park WRP East Lagoon			Hanover Park WRP West Lagoon		
	Potassium-40	Radium-226	Cesium-137	Potassium-40	Radium-226	Cesium-137
1998	4.4	5.2	0.2	4.8	5.1	0.3
1999	5.0	4.4	ND	4.6	4.2	ND
2000	NA	NA	NA	NA	NA	NA
2001	4.0	4.6	ND	4.2	5.7	ND
2002	5.0	4.2	ND	5.3	4.7	ND
2003	3.8	3.8	ND	3.5	3.7	ND
2004	2.8	3.7	ND	4.1	4.2	ND
2005	4.7	3.9	ND	4.5	3.8	ND
2006	4.2	3.9	0.04	3.8	3.6	0.04
2007	3.9	4.0	ND	4.2	3.8	ND
2008	6.5	6.7	ND	4.7	4.4	0.05
2009	6.9	1.8	ND	6.7	1.8	ND
2010	6.3	1.8	ND	6.0	1.5	ND
2011	5.9	6.4	0.04	4.8	4.7	0.03

ND = Not detected.
NA = Not analyzed.