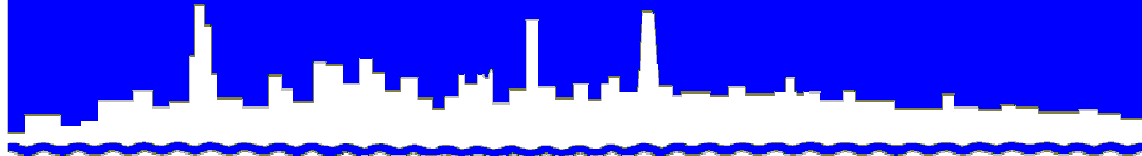


Protecting Our Water Environment



Metropolitan Water Reclamation District of Greater Chicago

***RESEARCH AND DEVELOPMENT
DEPARTMENT***

REPORT NO. 07-69

***RADIOLOGICAL MONITORING OF THE RAW SEWAGE,
FINAL EFFLUENT, SLUDGES, AND BIOSOLIDS OF THE
METROPOLITAN WATER RECLAMATION
DISTRICT OF GREATER CHICAGO
2006 ANNUAL REPORT***

NOVEMBER 2007

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METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO
2006 ANNUAL REPORT

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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 (IAC), 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.

There have been several reported cases of radioactive contamination in wastewater treatment plants (WRPs) in the United States in the past quarter century (1).

This study was conducted to determine the radioactivity concentration in raw sewage, final effluent, waste-activated sludge, anaerobically digested biosolids, and air-dried biosolids at the facilities owned and operated by the District. Radiological monitoring was conducted to develop baseline data on radioactivity occurring in the District's sewage sludge and biosolids, and to compare the current radioactivity levels with the radioactivity levels in the past.

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 WRPs. Sewage sludge and biosolids samples were also collected once a month from all the WRPs. Biosolids samples from the Hanover Park WRP East lagoon were collected in May and July of 2006 and Hanover Park WRP West lagoon were collected in January, May and July of 2006. Final air-dried biosolids samples from the Calumet WRP East, Harlem Avenue Solids Management Area (HASMA), Lawndale Avenue Solids Management Area (LASMA), Marathon, Stony Island and Vulcan solids drying areas were collected monthly from May through September 2006, and from Calumet WRP West solids drying area, samples were collected in June, July and September 2006.

The raw sewage, final effluent, waste-activated sludge, anaerobically digested biosolids, lagooned biosolids, and biosolids samples from the WRPs were analyzed for gross alpha and gross beta radioactivity. Biosolids samples from the District's solids drying areas, lagooned biosolids samples from Hanover Park WRP, and quarterly sludge and biosolids samples from Hanover Park, Stickney, Calumet, John E. Egan (Egan), and Lemont 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. Analytical data also indicate that the radioactivity removed is concentrated in the sewage sludge generated at the various WRPs. The 2006 radiological monitoring data was compared with the historical data of the last ten years. The data show that there was not a major change in the radioactivity concentrations of sludge and biosolids samples of the WRPs over the last eleven 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 (2). 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) and published in 1999, 35C IAC, Section 302.207(3). 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 is not likely to have any adverse effect on the radiological quality of the Chicago area waterways.

Measurable concentrations of gross alpha and gross beta radioactivity were found in Hanover Park WRP lagooned biosolids. The average gross alpha radioactivity in the lagooned biosolids ranged from 10.8 to 10.9 pCi/g dw. The average gross beta radioactivity in the lagooned biosolids ranged from 12.8 to 14.6 pCi/g dw.

Measurable concentrations of gross alpha and gross beta radioactivity were found in biosolids samples collected from all of the solids drying areas of the District. The average gross alpha and beta radioactivity of biosolids from these areas ranged from 8.9 to 14.8 pCi/g dw and 24.4 to 27.9 pCi/g dw, respectively.

Samples of the anaerobically digested biosolids from four WRPs (Calumet, Egan, Hanover Park, and Stickney), waste-activated sludge from the Lemont WRP, lagooned biosolids from Hanover Park WRP, and biosolids samples from the solids drying areas were further analyzed for 27 specific radionuclides by gamma spectroscopy. Of these radionuclides, nine were detected in measurable quantities in these samples. Eight of these radionuclides are of natural origin, and one, cesium-137, is a manmade radionuclide.

Average potassium-40 radioactivity in the WRP sludge and biosolids samples ranged from 5.3 to 10.3 pCi/g dw, radium-226 radioactivity ranged from 3.4 to 56.7 pCi/g dw, and cesium-137 radioactivity ranged from not detectable to 0.06 pCi/g dw.

Average potassium-40 radioactivity in Hanover Park lagooned biosolids ranged from 3.8 to 4.2 pCi/g dw, and radium-226 radioactivity ranged from 3.6 to 3.9 pCi/g dw. Average cesium-137 radioactivity was 0.04 pCi/g dw in Hanover Park WRP lagooned biosolids.

Average potassium-40 and radium-226 radioactivity in all biosolids samples taken from the District biosolids drying areas ranged from 7.6 to 12.5 pCi/g dw and 3.0 to 4.9 pCi/g dw, respectively. The average cesium-137 radioactivity ranged from 0.04 to 0.07 pCi/g dw. The average radioactivity concentration of the other six naturally occurring radionuclides in biosolids ranged from a non-detectable level to 11.1 pCi/g dw.

The presence of unduly high levels of radioactivity in biosolids is of environmental concern. The District routinely monitors the radiological quality of its biosolids to see if any unusually high radioactivity concentrations are occurring. This helps the District ensure worker safety, minimize the buildup of radionuclides in landfills, and ensure that the biosolids are low in radioactivity and suitable for land application as fertilizer. Radioactivity concentrations found in the District's biosolids in 2006 do not pose any significant risk to human health or the environment.

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 (4). 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, effluents, sludges, and biosolids for possible radioactive contamination. As a part of its monitoring program, the District's Radiochemistry Laboratory routinely analyzes raw sewage, final effluent, and sludge samples from all the WRPs, and biosolids samples from solids drying areas for gross alpha and gross beta radioactivity. Samples of the anaerobically digested biosolids from four WRPs (Calumet, Egan, Hanover Park, and Stickney), waste-activated sludge from the Lemont WRP, lagooned biosolids from the Hanover Park WRP, and biosolids samples from the District's solids drying areas are also examined for gamma-emitting radionuclides. In 1996, the Radiochemistry Section expanded its monitoring program of District sludges and biosolids in response to the increased emphasis on sludge characteristics brought about by adoption of USEPA sludge regulations (40 CFR Part 503). Although there are no standards for radioactivity in these regulations, the District expanded its database on 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 and gross beta radioactivity concentrations in raw sewage, final effluent, sewage sludge, and biosolids from the District's seven WRPs and biosolids from the District's solids drying areas. The concentrations of gross alpha and gross beta radioactivity and gamma-emitting radionuclides in quarterly samples of anaerobically digested biosolids, lagooned biosolids, and air-dried biosolids samples are also reported. The 2006 radiological monitoring data are compared with the historical data of the last ten years.

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, 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.

Sludge and Biosolids. Anaerobically digested biosolids samples were collected monthly from the Stickney, Calumet, Egan, and Hanover Park WRPs. Waste-activated sludge samples were collected monthly from the Lemont, North Side, and Kirie WRPs; these WRPs do not have digesters.

Lagooned biosolids samples were collected quarterly from Hanover Park WRP East, and Hanover Park WRP West lagoons.

Final air-dried biosolids samples were collected from solids drying areas of the District. The samples analyzed for radioactivity included biosolids from the Marathon Drying Cells, LASMA Drying Cells, Vulcan Drying Cells, HASMA Drying Cells, Stony Island Drying Area, Calumet WRP East Drying Area, and Calumet WRP West Drying Area.

Analytical Methodology

Gross Alpha and Gross Beta Radioactivity. *Raw Sewage and Final Effluent.* Gross alpha and gross beta radioactivity concentrations in the samples were determined using U.S. Environmental Protection Agency, Environmental Monitoring and Support Laboratory Procedure, March 1979.

A known volume of a thoroughly mixed sample was transferred to a beaker. Nitric acid (3M, 20 mL) was added to the beaker. The sample was evaporated to near dryness on a hot plate at low heat. It was then quantitatively transferred with nitric acid (3M) to a tared stainless steel planchet and dried under an infrared lamp, followed by oven drying at 103°C to constant weight. The sample was counted for gross alpha and gross beta radioactivity on a Tenelec LB5100 Gas Proportional Counter. A National Institute of Standards and Technology (NIST) traceable cesium-137 standard from North American Scientific, Inc. was used for

calibration of counters and self-absorption for gross beta determination. For gross alpha radioactivity determination, a NIST traceable americium-241 standard was used up to June 2001, and a thorium-230 standard was used since July 1, 2001.

Sludge and Biosolids. Gross alpha and gross beta radioactivity concentrations in the samples were determined using Standard Methods for the Examination of Water and Wastewater, 20th Edition, (Standard Methods 1998) procedures as follows:

A thoroughly mixed liquid sludge or biosolids sample (40 to 50 g) or air-dried biosolids sample (4 to 5 g) was transferred to a tared evaporating dish. The sample was dried to constant weight at 103°C. The difference in weight over the empty dish represents the total solids. The sample was then incinerated at 550°C to constant weight. The residue in the dish represents the fixed solids. The fixed solids were ground to a fine powder, and a weighed portion of the powder (80 to 100 mg) was transferred to a tared stainless steel planchet. The residue was distributed to a uniform thickness and spread with a few drops of 0.5 percent (w/v) acrylic (Lucite) solution in acetone. It was then dried to constant weight at 103°C and counted for gross alpha and gross beta radioactivity on a Tennelec LB5100 Gas Proportional Counter. A NIST traceable cesium-137 standard from North American Scientific, Inc. was used for efficiency calibration of gas proportional counters and self-absorption for gross beta determination. For gross alpha radioactivity determination, a NIST traceable americium-241 standard was used for the efficiency calibration of the counters and self-absorption for gross alpha determination up to June 2001, and a thorium-230 standard was used since July 1, 2001, in accordance with the USEPA requirements. The higher gross alpha radioactivity concentration in sludge and biosolids that has been observed since 2001 is due to the fact that thorium-230 efficiency calibration has been used since that time for gross alpha determination.

Gamma Radioactivity. Gamma radioactivity in the sludge and biosolids samples was determined as follows:

The sludge or biosolids sample was dried on a hot plate at low heat. It was then ground and passed through a 30-mesh sieve. The sieved material was packed in a tared 3-oz canister, weighed, and sealed with a vinyl electrical tape to avoid loss of gaseous progeny of uranium and thorium. The sample was stored for at least 30-days for radium-radon to reach equilibrium before counting. The sample was analyzed by a gamma spectroscopy system equipped with a high-purity germanium detector and Genie-2000 software analysis package from Canberra Industries. The radium-226 radioactivity concentration was calculated from a 186 KeV photopeak, cesium-137 radioactivity from a 661.6 KeV photopeak, and potassium-40 radioactivity from a 1461 KeV photopeak. The energy and efficiency calibration of the system was verified before the sample was counted using a NIST traceable mixed gamma standard from North American Scientific, Inc.

Calculations

Gross alpha and gross beta radioactivity in sludge and biosolids samples were calculated as pCi/g dw using the following equation:

$$\text{Radioactivity (pCi/g dw)} = \frac{\text{Net cpm} \times A}{2.22 \times \text{counting efficiency} \times B \times C}$$

where:

cpm = counts per minute

A = wt. of fixed solids in evaporating dish, g

B = wt. of fixed solids in planchet, g

C = wt. of total solids in evaporating dish, g

2.22 = conversion factor from disintegrations per minute (dpm) to picocurie (pCi)

Gross alpha and gross beta radioactivity in the raw sewage and effluent were calculated as pCi/L using the following equation:

$$\text{Radioactivity (pCi/L)} = \frac{\text{Net cpm}}{2.22 \times \text{counting efficiency} \times \text{sample volume}}$$

Lower Limit of Detection (LLD)

The LLD is the smallest quantity of sample radioactivity that will yield a net count for which there is a predetermined level of confidence that radioactivity is present (5). The LLD that has a 95 percent probability of being detected was calculated as follows:

$$\text{LLD (pCi/L)} = \frac{4.66 \sqrt{B}}{2.22 \times E \times V \times T \times F}$$

Where:

B = background counts

E = fractional counting efficiency

V = sample volume in liters

T = counting time in minutes

F = gamma fraction for the isotope line (applied only to gamma spectroscopic measurements)

4.66 = $2\sqrt{2K}$, where K is the value for upper percentile of the standardized normal variate corresponding to the preselected risk (5%) for concluding falsely that activity is present.

When the sample radioactivity was less than the LLD, the radioactivity concentration was reported as below the detection limit.

For calculation purposes, less than LLD values were considered as real numbers; i.e., <1 was considered as 1. Average gross alpha, gross beta and gamma radioactivity was calculated by adding radioactivity concentrations in the set of samples and dividing the sum by the number of samples in the set. If any value in the individual data set with the less than symbol was higher than the average value, then the average value was reported with the less than symbol. If all the values in the individual data set with the less than symbol were lower than the average value, then the average value was reported without the less than symbol.

In a set of data points with a combination of real number and LLD values, the highest real number was considered as the maximum value if the number was higher than the highest LLD value of the data set, otherwise LLD was reported as the maximum value. The lowest real number was considered as the minimum value if the number was lower than the lowest LLD value of the data set, otherwise LLD was reported as the minimum value.

The LLD is inversely proportional to the counting efficiency and varies with the nature of the sample. A sample with a higher total solids content results in a greater thickness of solids in the counting planchet. The higher solids content in the planchet leads to a lower counting efficiency and a higher detection limit. Consequently, the detection limit will vary with the solids content of the samples and the thickness of the solids in the planchet.

RESULTS AND DISCUSSION

Stickney WRP

In 2006, the gross alpha radioactivity in the raw sewage of the Stickney WRP ranged from 3.4 to 10.4 pCi/L (Table 1). The gross alpha radioactivity in the effluent was below the detection limit (3.2 to 9.0 pCi/L) (Table 1). The gross alpha radioactivity in anaerobically digested biosolids ranged from 7.1 to 14.5 pCi/g dw (Table 1).

The yearly average gross alpha radioactivity in the Stickney WRP raw sewage, final effluent, and anaerobically digested biosolids from 1996 to 2006 are summarized in Table 2. The gross alpha radioactivity in the raw sewage ranged from less than 3.6 pCi/L to less than 6.3 pCi/L with detected values ranging from 4.6 to 6.2 pCi/L. The gross alpha radioactivity in the effluent was below the detection limit (2.6 to 4.8 pCi/L). The gross alpha radioactivity in anaerobically digested biosolids ranged from 5.2 to 12.3 pCi/g dw.

The gross beta radioactivity in the raw sewage of the Stickney WRP ranged from 9.7 to 24.1 pCi/L, and in the effluent it ranged from less than 4.8 to 10.9 pCi/L (Table 3). The gross beta radioactivity in anaerobically digested biosolids ranged from 15.0 to 29.4 pCi/g dw (Table 3).

The yearly average gross beta radioactivity in the Stickney WRP raw sewage, final effluent, and anaerobically digested biosolids from 1996 to 2006 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 5.9 to 11.4 pCi/L. The gross beta radioactivity in anaerobically digested biosolids ranged from 22.8 to 27.3 pCi/g dw.

Calumet WRP

In 2006, the gross alpha radioactivity in the raw sewage of the Calumet WRP was below the detection limit (3.4 to 6.8 pCi/L) except for January and July samples which were 6.7 and 6.5 pCi/L, respectively (Table 5). The gross alpha radioactivity in the effluent was also below the detection limit (3.2 to 8.8 pCi/L) (Table 5). The gross alpha radioactivity in anaerobically digested biosolids ranged from 8.8 to 15.4 pCi/g dw (Table 5).

The yearly average gross alpha radioactivity in the Calumet WRP raw sewage, final effluent, and anaerobically digested biosolids from 1996 to 2006 are summarized in Table 6. The gross alpha radioactivity in the raw sewage was below the detection limit (3.7 to 5.3 pCi/L). The gross alpha radioactivity in the effluent was also below the detection limit (3.0 to 5.0 pCi/L). The gross alpha radioactivity in anaerobically digested biosolids ranged from 5.1 to 14.1 pCi/g dw.

TABLE 1: GROSS ALPHA RADIOACTIVITY IN STICKNEY WRP RAW SEWAGE,
FINAL EFFLUENT, AND ANAEROBICALLY DIGESTED BIOSOLIDS
ON A MONTHLY BASIS - 2006

Month	Raw Sewage Gross Alpha (pCi/L)	Effluent Gross Alpha (pCi/L)	Biosolids Gross Alpha (pCi/g dw)
January	6.6	<4.8	8.7
February	<4.8	<4.3	7.1
March	6.8	<9.0	8.1
April	<7.2	<5.9	13.7
May	7.0	<3.7	10.8
June	<5.4	<5.2	12.1
July	3.7	<3.2	11.2
August	<5.6	<5.4	8.4
September	7.6	<5.0	9.0
October	10.4	<3.2	9.9
November	<5.3	<4.3	14.5
December	3.4	<3.6	10.8

< = 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 WRP
 RAW SEWAGE, FINAL EFFLUENT, AND ANAEROBICALLY DIGESTED BIOSOLIDS
 FROM 1996 THROUGH 2006

Year*	Raw Sewage Gross Alpha (pCi/L)	Effluent Gross Alpha (pCi/L)	Biosolids 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

* 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.

< = 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 WRP RAW SEWAGE,
FINAL EFFLUENT, AND ANAEROBICALLY DIGESTED BIOSOLIDS
ON A MONTHLY BASIS – 2006

Month	Raw Sewage Gross Beta (pCi/L)	Effluent Gross Beta (pCi/L)	Biosolids Gross Beta (pCi/g dw)
January	20.9	10.6	23.6
February	17.1	9.2	28.2
March	19.4	<9.1	15.0
April	17.1	8.3	24.8
May	14.1	10.9	24.7
June	14.0	10.1	25.5
July	11.0	5.3	24.8
August	15.0	9.9	29.2
September	12.8	5.5	27.4
October	24.1	7.8	27.7
November	15.2	8.8	29.4
December	9.7	<4.8	24.8

< = 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 WRP
 RAW SEWAGE, FINAL EFFLUENT, AND ANAEROBICALLY DIGESTED BIOSOLIDS
 FROM 1996 THROUGH 2006

Year	Raw Sewage Gross Beta (pCi/L)	Effluent Gross Beta (pCi/L)	Biosolids 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

TABLE 5: GROSS ALPHA RADIOACTIVITY IN CALUMET WRP RAW SEWAGE,
FINAL EFFLUENT, AND ANAEROBICALLY DIGESTED BIOSOLIDS
ON A MONTHLY BASIS - 2006

Month	Raw Sewage Gross Alpha (pCi/L)	Effluent Gross Alpha (pCi/L)	Biosolids Gross Alpha (pCi/g dw)
January	6.7	<5.2	12.2
February	<4.7	<4.6	8.8
March	<6.6	<8.8	12.9
April	<6.8	<6.5	14.8
May	<3.9	<3.7	15.4
June	<6.1	<5.5	14.3
July	6.5	<3.4	14.8
August	<6.1	<6.0	11.0
September	<4.6	<4.7	12.4
October	<3.4	<3.2	11.2
November	<4.9	<4.6	14.5
December	<3.7	<3.5	11.0

< = 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 WRP
RAW SEWAGE, FINAL EFFLUENT, AND ANAEROBICALLY DIGESTED BIOSOLIDS
FROM 1996 THROUGH 2006

Year*	Raw Sewage Gross Alpha (pCi/L)	Effluent Gross Alpha (pCi/L)	Biosolids 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

* 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.

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

The gross beta radioactivity in the raw sewage of the Calumet WRP ranged from 5.2 to 17.5 pCi/L, and in the effluent it ranged from less than 4.4 pCi/L to 12.2 pCi/L (Table 7). The gross beta radioactivity in Calumet WRP anaerobically digested biosolids ranged from 22.3 to 31.2 pCi/g dw (Table 7).

The yearly average gross beta radioactivity in the Calumet WRP raw sewage, final effluent, and anaerobically digested biosolids from 1996 to 2006 are summarized in Table 8. The gross beta radioactivity in the raw sewage ranged from 9.3 to 24.9 pCi/L and in the effluent it ranged from 6.9 to 14.1 pCi/L. The gross beta radioactivity in anaerobically digested biosolids ranged from 21.0 to 26.2 pCi/g dw.

North Side WRP

In 2006, the gross alpha radioactivity in the raw sewage of the North Side WRP was below the detection limit (3.3 to 9.3 pCi/L) (Table 9). The gross alpha radioactivity in the effluent was also below the detection limits (3.2 to 9.6 pCi/L) except for October sample which was 3.4 pCi/L (Table 9). The gross alpha radioactivity in waste-activated sludge ranged from 4.7 to 8.7 pCi/g dw (Table 9).

The yearly average gross alpha radioactivity in the North Side WRP raw sewage, final effluent, and waste-activated sludge from 1996 to 2006 are summarized in Table 10. The gross alpha radioactivity in the raw sewage was below the detection limit (3.3 to 4.9 pCi/L). The gross alpha radioactivity in the effluent was also below the detection limit (2.8 to 4.8 pCi/L). The gross alpha radioactivity in waste-activated sludge ranged from 2.6 to 7.8 pCi/g dw.

The gross beta radioactivity in the raw sewage of the North Side WRP ranged from 7.5 to 13.7 pCi/L, and in the effluent it ranged from below the detection limit (4.8 pCi/L) to 16.5 pCi/L (Table 11). The gross beta radioactivity in North Side WRP waste-activated sludge ranged from 11.5 to 17.7 pCi/g dw (Table 11).

The yearly average gross beta radioactivity in the North Side WRP raw sewage, final effluent, and waste-activated sludge from 1996 to 2006 are summarized in Table 12. The gross beta radioactivity in the raw sewage ranged from 8.5 to 20.4 pCi/L and in the effluent it ranged from 5.7 to 10.9 pCi/L. The gross beta radioactivity in waste-activated sludge ranged from 12.8 to 15.8 pCi/g dw.

John E. Egan WRP

In 2006 the gross alpha radioactivity in the raw sewage of the Egan WRP was below the detection limits (3.6 to 6.3 pCi/L) (Table 13). The gross alpha radioactivity in the effluent was also below the detection limits (3.4 to 6.3 pCi/L) except for May sample which was 4.7 pCi/L (Table 13). The gross alpha radioactivity in anaerobically digested biosolids samples ranged from 7.0 to 15.3 pCi/g dw (Table 13).

TABLE 7: GROSS BETA RADIOACTIVITY IN CALUMET WRP RAW SEWAGE,
FINAL EFFLUENT, AND ANAEROBICALLY DIGESTED BIOSOLIDS
ON A MONTHLY BASIS – 2006

Month	Raw Sewage Gross Beta (pCi/L)	Effluent Gross Beta (pCi/L)	Biosolids Gross Beta (pCi/g dw)
January	12.5	10.6	22.3
February	16.6	11.3	23.9
March	12.2	<9.1	24.4
April	9.7	5.4	23.6
May	9.0	6.2	28.2
June	17.5	9.9	31.2
July	11.2	5.8	25.9
August	13.3	12.2	27.3
September	5.2	8.7	25.8
October	8.2	<4.4	26.9
November	13.2	8.9	28.1
December	7.6	<4.8	27.1

< = 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 WRP
 RAW SEWAGE, FINAL EFFLUENT, AND ANAEROBICALLY DIGESTED BIOSOLIDS
 FROM 1996 THROUGH 2006

Year	Raw Sewage Gross Beta (pCi/L)	Effluent Gross Beta (pCi/L)	Biosolids 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

TABLE 9: GROSS ALPHA RADIOACTIVITY IN NORTH SIDE WRP RAW SEWAGE,
FINAL EFFLUENT, AND WASTE-ACTIVATED SLUDGE
ON A MONTHLY BASIS – 2006

Month	Raw Sewage Gross Alpha (pCi/L)	Effluent Gross Alpha (pCi/L)	Sludge Gross Alpha (pCi/g dw)
January	<5.0	<4.6	7.9
February	<4.0	<3.9	4.7
March	<9.3	<9.6	7.9
April	<5.5	<5.2	8.7
May	<3.9	<3.7	7.6
June	<5.0	<5.5	7.2
July	<3.3	<3.2	8.0
August	<5.5	<5.5	6.9
September	<4.6	<5.0	6.9
October	<3.3	3.4	6.7
November	<4.1	<4.0	8.0
December	<3.5	<3.6	5.8

< = 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 NORTH SIDE WRP RAW SEWAGE, FINAL EFFLUENT, AND WASTE-ACTIVATED SLUDGE FROM 1996 THROUGH 2006

Year*	Raw Sewage Gross Alpha (pCi/L)	Effluent Gross Alpha (pCi/L)	Sludge 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

* 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.

< = 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 NORTH SIDE WRP RAW SEWAGE,
FINAL EFFLUENT, AND WASTE-ACTIVATED SLUDGE
ON A MONTHLY BASIS – 2006

Month	Raw Sewage Gross Beta (pCi/L)	Effluent Gross Beta (pCi/L)	Sludge Gross Beta (pCi/g dw)
January	13.2	5.6	12.4
February	10.4	7.8	14.0
March	9.8	<9.3	11.5
April	9.6	5.4	17.7
May	9.5	7.7	17.0
June	8.8	16.5	14.0
July	8.2	7.5	15.1
August	13.7	9.7	13.6
September	7.5	6.4	13.3
October	10.7	7.7	14.9
November	10.8	7.4	12.4
December	8.4	<4.8	16.4

< = 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 NORTH SIDE WRP
 RAW SEWAGE, FINAL EFFLUENT, AND WASTE-ACTIVATED SLUDGE
 FROM 1996 THROUGH 2006

Year	Raw Sewage Gross Beta (pCi/L)	Effluent Gross Beta (pCi/L)	Sludge 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

< = 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 WRP RAW SEWAGE,
FINAL EFFLUENT, AND ANAEROBICALLY DIGESTED BIOSOLIDS
ON A MONTHLY BASIS – 2006

Month	Raw Sewage Gross Alpha (pCi/L)	Effluent Gross Alpha (pCi/L)	Biosolids Gross Alpha (pCi/g dw)
January	<6.2	<5.9	8.0
February	<4.7	<4.6	7.2
March	<5.5	<4.9	12.2
April	<6.3	<6.3	15.3
May	<4.1	4.7	9.6
June	<5.4	<5.6	9.1
July	<3.7	<3.7	9.4
August	<5.8	<5.7	9.8
September	<5.0	<4.8	7.0
October	<3.6	<3.4	7.8
November	<4.4	<4.3	12.5
December	<3.6	<3.6	10.0

< = 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 2006 are summarized in [Table 14](#). The gross alpha radioactivity in the raw sewage was below the detection limit (3.6 to 5.0 pCi/L). The gross alpha radioactivity in the effluent was also below the detection limit (3.0 to 4.8 pCi/L). The gross alpha radioactivity in anaerobically digested biosolids ranged from 4.4 to 10.5 pCi/g dw.

The gross beta radioactivity levels in the raw sewage of the Egan WRP ranged from 9.4 to 16.3 pCi/L, and in the effluent it ranged from 6.7 to 13.3 pCi/L ([Table 15](#)). The gross beta radioactivity in Egan WRP anaerobically digested biosolids ranged from 14.4 to 22.6 pCi/g dw.

The yearly average gross beta radioactivity at the Egan WRP raw sewage, final effluent, and anaerobically digested biosolids from 1996 to 2006 are summarized in [Table 16](#). The gross beta radioactivity in the raw sewage ranged from 10.8 to 22.5 pCi/L and in the effluent it ranged from 6.9 to 12.7 pCi/L. The gross beta radioactivity in anaerobically digested biosolids ranged from 17.6 to 21.3 pCi/g dw.

Hanover Park WRP

In 2006, the gross alpha radioactivity levels in the raw sewage of the Hanover Park WRP were below the detection limit (3.5 to 7.0 pCi/L) except for May sample which was 4.8 pCi/L ([Table 17](#)). The gross alpha radioactivity in the effluent was also below the detection limits (3.4 to 6.0 pCi/L) ([Table 17](#)). The gross alpha radioactivity in anaerobically digested biosolids ranged from 4.0 to 13.0 pCi/g dw ([Table 17](#)).

The yearly average gross alpha radioactivity in the Hanover Park WRP raw sewage, final effluent, and anaerobically digested biosolids from 1996 to 2006 are summarized in [Table 18](#). The gross alpha radioactivity in the raw sewage was below the detection limit (3.4 to 5.0 pCi/L). The gross alpha radioactivity in the effluent was also below the detection limit (3.0 to 4.6 pCi/L). The gross alpha radioactivity in anaerobically digested biosolids ranged from 3.2 to 9.4 pCi/g dw.

The gross beta radioactivity levels in the raw sewage of the Hanover Park WRP ranged from 6.1 to 17.9 pCi/L, and in the effluent it ranged from 5.7 to 14.2 pCi/L ([Table 19](#)). The gross beta radioactivity in the Hanover Park WRP anaerobically digested biosolids ranged from 10.4 to 15.4 pCi/g dw ([Table 19](#)).

The yearly average gross beta radioactivity in the Hanover Park WRP raw sewage, final effluent, and anaerobically digested biosolids from 1996 to 2006 are summarized in [Table 20](#). The gross beta radioactivity in the raw sewage ranged from 9.7 to 20.3 pCi/L and in the effluent it ranged from 6.6 to 11.7 pCi/L. The gross beta radioactivity in anaerobically digested biosolids ranged from 11.8 to 14.2 pCi/g dw.

TABLE 14: YEARLY AVERAGE GROSS ALPHA RADIOACTIVITY IN JOHN E. EGAN WRP RAW SEWAGE, FINAL EFFLUENT, AND ANAEROBICALLY DIGESTED BIOSOLIDS FROM 1996 THROUGH 2006

Year*	Raw Sewage Gross Alpha (pCi/L)	Effluent Gross Alpha (pCi/L)	Biosolids 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

* 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.

< = 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 WRP RAW SEWAGE,
FINAL EFFLUENT, AND ANAEROBICALLY DIGESTED BIOSOLIDS
ON A MONTHLY BASIS – 2006

Month	Raw Sewage Gross Beta (pCi/L)	Effluent Gross Beta (pCi/L)	Biosolids Gross Beta (pCi/g dw)
January	15.1	12.2	15.2
February	12.4	8.5	16.6
March	13.3	12.4	18.3
April	11.7	9.4	19.2
May	10.7	10.1	14.4
June	16.0	13.2	20.4
July	11.6	13.3	19.0
August	13.8	12.9	19.5
September	14.7	11.8	18.5
October	16.3	13.2	18.9
November	11.4	8.4	22.6
December	9.4	6.7	19.4

TABLE 16: YEARLY AVERAGE GROSS BETA RADIOACTIVITY IN JOHN E. EGAN
WRP RAW SEWAGE, FINAL EFFLUENT, AND ANAEROBICALLY DIGESTED
BIOSOLIDS FROM 1996 THROUGH 2006

Year	Raw Sewage Gross Beta (pCi/L)	Effluent Gross Beta (pCi/L)	Biosolids 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

TABLE 17: GROSS ALPHA RADIOACTIVITY IN HANOVER PARK WRP RAW SEWAGE, FINAL EFFLUENT, AND ANAEROBICALLY DIGESTED BIOSOLIDS ON A MONTHLY BASIS – 2006

Month	Raw Sewage Gross Alpha (pCi/L)	Effluent Gross Alpha (pCi/L)	Biosolids Gross Alpha (pCi/g dw)
January	<6.0	<5.7	5.3
February	<4.8	<4.5	4.0
March	<5.6	<5.0	9.3
April	<6.1	<6.0	13.0
May	4.8	<3.9	7.9
June	<7.0	<5.2	10.2
July	<3.6	<3.4	7.7
August	<5.7	<5.6	7.0
September	<4.7	<4.6	5.8
October	<3.7	<3.5	5.5
November	<4.4	<4.3	6.9
December	<3.5	<3.6	7.9

< = 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 WRP RAW SEWAGE, FINAL EFFLUENT, AND ANAEROBICALLY DIGESTED BIOSOLIDS FROM 1996 THROUGH 2006

Year*	Raw Sewage Gross Alpha (pCi/L)	Effluent Gross Alpha (pCi/L)	Biosolids 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

* 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.

< = 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 WRP RAW SEWAGE,
FINAL EFFLUENT, AND ANAEROBICALLY DIGESTED BIOSOLIDS
ON A MONTHLY BASIS – 2006

Month	Raw Sewage Gross Beta (pCi/L)	Effluent Gross Beta (pCi/L)	Biosolids Gross Beta (pCi/g dw)
January	17.9	11.2	10.4
February	13.0	14.2	14.6
March	11.1	9.7	13.7
April	11.7	8.8	12.9
May	8.9	7.4	14.4
June	16.0	13.5	15.1
July	12.6	13.3	13.5
August	14.5	13.4	13.7
September	14.5	13.8	12.6
October	16.4	11.9	12.5
November	11.8	11.5	15.4
December	6.1	5.7	14.1

TABLE 20: YEARLY AVERAGE GROSS BETA RADIOACTIVITY IN HANOVER PARK
WRP RAW SEWAGE, FINAL EFFLUENT, AND ANAEROBICALLY DIGESTED
BIOSOLIDS FROM 1996 THROUGH 2006

Year	Raw Sewage Gross Beta (pCi/L)	Effluent Gross Beta (pCi/L)	Biosolids Gross Beta (pCi/g dw)
1996	9.7	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

James C. Kirie WRP

In 2006, the gross alpha radioactivity levels in the raw sewage of the Kirie WRP was below the detection limit (3.7 to 10.3 pCi/L) except for May and December samples which were 5.0 and 4.2 pCi/L, respectively (Table 21). The gross alpha radioactivity in the effluent was below the detection limit (3.7 to 6.8 pCi/L, Table 21). The gross alpha radioactivity in waste-activated sludge ranged from 3.4 to 9.0 pCi/g dw (Table 21).

The yearly average gross alpha radioactivity in the Kirie WRP raw sewage, final effluent, and waste-activated sludge from 1996 to 2006 are summarized in Table 22. The gross alpha radioactivity in the raw sewage was below the detection limit (3.6 to 5.3 pCi/L). The gross alpha radioactivity in the effluent was also below the detection limit (2.8 to 4.9 pCi/L). The gross alpha radioactivity in waste-activated sludge ranged from 3.1 to 9.2 pCi/g dw.

The gross beta radioactivity level in the raw sewage of Kirie WRP ranged from 6.5 to 20.3 pCi/L, and in the effluent it ranged from less than 5.1 to 19.6 pCi/L (Table 23). The gross beta radioactivity in Kirie WRP waste-activated sludge ranged from 9.9 to 15.9 pCi/g dw (Table 23).

The yearly average gross beta radioactivity in the Kirie WRP raw sewage, final effluent, and waste-activated sludge from 1996 to 2006 are summarized in Table 24. The gross beta radioactivity in the raw sewage ranged from 11.6 to 22.7 pCi/L and in the effluent it ranged from 8.1 to 16.8 pCi/L. The gross beta radioactivity in waste-activated sludge ranged from 13.3 to 16.8 pCi/g dw.

Lemont WRP

In 2006, the gross alpha radioactivity levels in the raw sewage of the Lemont WRP ranged from less than 9.4 pCi/L to 28.6 pCi/L (Table 25). The gross alpha radioactivity in the effluent ranged from less than 6.7 pCi/L to 13.2 pCi/L (Table 25). The gross alpha radioactivity in the waste-activated sludge ranged from 51.5 to 117.3 pCi/g dw (Table 25).

The yearly average gross alpha radioactivity in the Lemont WRP raw sewage, final effluent, and waste-activated sludge from 1996 to 2006 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 10.5 pCi/L). The gross alpha radioactivity in the waste-activated sludge ranged from 38.9 to 141.1 pCi/g dw.

The gross beta radioactivity levels in the raw sewage of the Lemont WRP ranged from 16.6 to 38.4 pCi/L, and in the effluent it ranged from 13.9 to 31.3 pCi/L (Table 27). The gross beta radioactivity in Lemont waste-activated sludge ranged from 38.4 to 92.1 pCi/g dw (Table 27).

TABLE 21: GROSS ALPHA RADIOACTIVITY IN JAMES C. KIRIE WRP RAW SEWAGE, FINAL EFFLUENT, AND WASTE-ACTIVATED SLUDGE ON A MONTHLY BASIS – 2006

Month	Raw Sewage Gross Alpha (pCi/L)	Effluent Gross Alpha (pCi/L)	Sludge Gross Alpha (pCi/g dw)
January	<5.2	<5.3	5.9
February	<4.6	<4.7	3.4
March	<10.3	<5.1	8.9
April	<5.8	<6.8	9.0
May	5.0	<3.7	6.8
June	<5.7	<5.0	8.5
July	<3.7	<3.9	5.9
August	<6.0	<6.0	6.8
September	<4.8	<4.8	6.1
October	<3.8	<3.7	6.8
November	<4.6	<4.6	7.4
December	4.2	<4.1	5.9

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

TABLE 22: YEARLY AVERAGE GROSS ALPHA RADIOACTIVITY IN JAMES C. KIRIE WRP RAW SEWAGE, FINAL EFFLUENT, AND WASTE-ACTIVATED SLUDGE FROM 1996 THROUGH 2006

Year*	Raw Sewage Gross Alpha (pCi/L)	Effluent Gross Alpha (pCi/L)	Sludge 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

* 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.

< = 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 WRP RAW SEWAGE,
 FINAL EFFLUENT, AND WASTE-ACTIVATED SLUDGE
 ON A MONTHLY BASIS – 2006

Month	Raw Sewage Gross Beta (pCi/L)	Effluent Gross Beta (pCi/L)	Sludge Gross Beta (pCi/g dw)
January	14.6	10.2	9.9
February	13.4	13.4	13.4
March	15.1	14.7	14.9
April	6.5	16.5	14.1
May	12.3	11.6	14.3
June	16.9	8.8	13.5
July	15.0	12.5	12.7
August	20.3	14.6	15.2
September	9.9	19.6	14.5
October	14.8	12.9	15.9
November	13.5	11.2	11.5
December	8.9	<5.1	14.9

< = 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 WRP RAW SEWAGE, FINAL EFFLUENT, AND WASTE-ACTIVATED SLUDGE FROM 1996 THROUGH 2006

Year	Raw Sewage Gross Beta (pCi/L)	Effluent Gross Beta (pCi/L)	Sludge 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

TABLE 25: GROSS ALPHA RADIOACTIVITY IN LEMONT WRP RAW SEWAGE, FINAL EFFLUENT, AND WASTE-ACTIVATED SLUDGE ON A MONTHLY BASIS – 2006

Month	Raw Sewage Gross Alpha (pCi/L)	Effluent Gross Alpha (pCi/L)	Sludge Gross Alpha (pCi/g dw)
January	<10.4	<9.8	51.5
February	28.4	11.8	60.9
March	12.4	<13.2	116.6
April	<10.8	<10.3	84.1
May	15.4	<6.7	105.6
June	18.4	<10.1	92.4
July	28.6	13.2	96.1
August	16.1	<12.0	117.3
September	<9.4	<8.9	90.4
October	15.4	7.7	83.6
November	12.7	<8.9	79.1
December	15.9	8.7	102.7

< = 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 WRP
 RAW SEWAGE, FINAL EFFLUENT, AND WASTE-ACTIVATED SLUDGE
 FROM 1996 THROUGH 2006

Year*	Raw Sewage Gross Alpha (pCi/L)	Effluent Gross Alpha (pCi/L)	Sludge 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

* 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.

< = 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 WRP RAW SEWAGE,
FINAL EFFLUENT, AND WASTE-ACTIVATED SLUDGE
ON A MONTHLY BASIS – 2006

Month	Raw Sewage Gross Beta (pCi/L)	Effluent Gross Beta (pCi/L)	Sludge Gross Beta (pCi/g dw)
January	27.7	18.6	38.4
February	38.2	28.4	50.3
March	22.0	23.6	65.5
April	16.8	18.2	51.3
May	23.5	16.6	66.2
June	31.3	25.0	57.6
July	38.4	23.8	66.7
August	32.3	31.3	72.7
September	23.7	16.7	78.2
October	18.3	13.9	64.8
November	28.1	25.0	66.6
December	16.6	18.9	92.1

The yearly average gross beta radioactivity at the Lemont WRP raw sewage, final effluent, and waste-activated sludge from 1996 to 2006 are summarized in [Table 28](#). The gross beta radioactivity in the raw sewage ranged from 26.4 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 61.1 to 121.9 pCi/g dw.

Hanover Park WRP Lagoons

[Table 29](#) presents the gross alpha and gross beta radioactivity concentrations in Hanover Park WRP lagooned biosolids for 2006.

Average gross alpha radioactivity in Hanover Park WRP East lagooned biosolids was 10.8 pCi/g dw and ranged from 9.4 to 12.3 pCi/g dw. Average gross alpha radioactivity in Hanover Park WRP West lagooned biosolids was 10.9 pCi/g dw and ranged from 9.6 to 13.4 pCi/g dw.

Average gross beta radioactivity in Hanover Park WRP East lagooned biosolids was 14.6 pCi/g dw and ranged from 13.3 to 15.9 pCi/g dw. Average gross beta radioactivity in Hanover Park WRP West lagooned biosolids was 12.8 pCi/g dw and ranged from 10.2 to 15.4 pCi/g dw.

The yearly average gross alpha radioactivity in Hanover Park WRP lagooned biosolids, since the inception of this program, from 1998 to 2006 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 2006 is summarized in [Table 31](#). The gross beta radioactivity in lagooned biosolids ranged from 11.6 pCi/g dw at Hanover Park WRP West Lagoon in 2003 to 18.1 pCi/g dw at Hanover Park WRP West Lagoon in 1999.

Gross Alpha and Gross Beta Radioactivity in District Biosolids

[Table 32](#) presents the gross alpha and gross beta radioactivity concentrations in biosolids from the District's solids drying areas for 2006.

Average gross alpha radioactivity in biosolids ranged from 8.9 pCi/g dw at the Vulcan drying site to 14.8 pCi/g dw at the Calumet West drying site. Average gross beta radioactivity in biosolids ranged from 24.4 pCi/g dw at the Calumet West drying site to 27.9 pCi/g dw at the Marathon drying site.

The yearly average gross alpha radioactivity in the District's biosolids from 1996 to 2006 is summarized in [Table 33](#). The gross alpha radioactivity in the biosolids ranged from 5.1 pCi/g dw at Vulcan drying site in 1996 to 22.6 pCi/g dw at RASMA drying site in 2004.

TABLE 28: YEARLY AVERAGE GROSS BETA RADIOACTIVITY IN LEMONT WRP
 RAW SEWAGE, FINAL EFFLUENT, AND WASTE-ACTIVATED SLUDGE
 FROM 1996 THROUGH 2006

Year	Raw Sewage Gross Beta (pCi/L)	Effluent Gross Beta (pCi/L)	Sludge 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

TABLE 29: GROSS ALPHA AND GROSS BETA RADIOACTIVITY IN HANOVER PARK
WRP LAGOONED BIOSOLIDS – 2006

Lagoon Location	No. of Samples	Gross Alpha (pCi/g dw)			Gross Beta (pCi/g dw)		
		Average	Minimum	Maximum	Average	Minimum	Maximum
East	2	10.8	9.4	12.3	14.6	13.3	15.9
West	3	10.9	9.6	13.4	12.8	10.2	15.4

TABLE 30: YEARLY AVERAGE GROSS ALPHA RADIOACTIVITY IN HANOVER PARK
WRP LAGOONED BIOSOLIDS FROM 1998 THROUGH 2006

Year*	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	N/A	N/A
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

* 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.

N/A = Not Analyzed

TABLE 31: YEARLY AVERAGE GROSS BETA RADIOACTIVITY IN HANOVER PARK
WRP LAGOONED BIOSOLIDS FROM 1998 THROUGH 2006

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	N/A	N/A
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

N/A = Not Analyzed

TABLE 32: GROSS ALPHA AND GROSS BETA RADIOACTIVITY IN DISTRICT AIR-DRIED BIOSOLIDS - 2006

Sample Location	No. of Samples	Gross Alpha (pCi/g dw)			Gross Beta (pCi/g dw)		
		Average	Minimum	Maximum	Average	Minimum	Maximum
LASMA	5	10.2	5.9	14.2	27.0	26.4	27.6
Calumet East	5	10.9	8.7	13.2	25.2	20.0	27.1
Calumet West	3	14.8	13.5	17.1	24.4	23.1	25.4
HASMA	5	12.8	3.8	20.6	27.5	22.4	30.4
Marathon	5	12.6	7.8	15.1	27.9	24.2	38.3
Stony Island	5	12.7	7.4	17.9	27.1	23.4	30.6
Vulcan	5	8.9	4.1	12.6	25.5	18.3	29.2

TABLE 33: YEARLY AVERAGE GROSS ALPHA RADIOACTIVITY IN DISTRICT AIR-DRIED BIOSOLIDS
FROM 1996 THROUGH 2006

Year*	Gross Alpha Radioactivity (pCi/g dw)							
	Calumet East	Calumet West	LASMA	HASMA	Marathon	Stony Island	Vulcan	RASMA
1996	N/A	N/A	7.1	5.7	6.6	6.1	5.1	5.6
1997	N/A	N/A	7.2	8.2	6.9	6.6	6.6	8.1
1998	7.7	7.4	7.5	7.9	8.1	7.6	7.7	8.1
1999	6.9	7.4	6.8	7.4	6.8	7.9	6.0	6.7
2000	10.3	12.1	9.8	12.1	11.7	10.5	9.2	11.4
2001	13.1	17.6	17.5	16.4	17.5	15.2	15.8	17.7
2002	12.4	16.6	14.4	14.9	15.0	13.5	15.0	15.2
2003	16.2	17.0	15.7	16.8	15.4	14.6	15.8	16.6
2004	15.4	20.5	14.9	15.8	15.0	17.2	16.2	22.6

TABLE 33 (Continued): YEARLY AVERAGE GROSS ALPHA RADIOACTIVITY IN DISTRICT AIR-DRIED BIOSOLIDS FROM 1996 THROUGH 2006

Year*	Gross Alpha Radioactivity (pCi/g dw)							
	Calumet East	Calumet West	LASMA	HASMA	Marathon	Stony Island	Vulcan	RASMA
2005	11.8	13.7	16.0	17.8	17.2	13.6	15.5	15.3
2006	10.9	14.9	10.2	12.8	12.6	12.7	8.9	N/S

* 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.

N/A = Not Analyzed

N/S = No Sample

The yearly average gross beta radioactivity in the District's biosolids from 1996 to 2006 is summarized in [Table 34](#). The gross beta radioactivity in the biosolids ranged from 21.0 pCi/g dw at Calumet West drying site in 2001 to 30.2 pCi/g dw at RASMA drying site in 2000.

Gamma Radioactivity in District WRP Sludges and Biosolids

In 2006, 20 sludge samples from five WRPs, 37 biosolids samples from seven solids drying sites, and 5 biosolids samples from Hanover Park WRP 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	Actinium-228
Ruthenium-106	Europium-154	Protactinium-231

Of the 27 radionuclides analyzed, 9 were detected at measurable levels. Of these, 8 radionuclides are of natural origin, and one, cesium-137, is a manmade radionuclide.

[Table 35](#) presents the concentrations of gamma-emitting radionuclides in the sludge and biosolids from the District WRPs for 2006. Average potassium-40 radioactivity ranged from 5.3 pCi/g dw at the Hanover Park WRP to 10.3 pCi/g dw at the Stickney WRP. Average radium-226 radioactivity ranged from 3.4 pCi/g dw at the Stickney WRP to 56.7 pCi/g dw at the Lemont WRP. Average cesium-137 radioactivity was 0.05 pCi/g at the Stickney WRP and 0.06 pCi/g dw at the Calumet WRP. Cesium-137 was not detected at the Hanover Park, Egan, and Lemont WRPs. Average beryllium-7 radioactivity ranged from non-detectable levels at the Hanover Park WRP to 10.2 pCi/g dw at the Stickney WRP. Average bismuth-212, lead 212, bismuth-214, lead-214, and actinium-228 radioactivity at the Calumet, Egan, Hanover Park, and Stickney WRPs was relatively low, and ranged from non-detectable levels to 1.4 pCi/g dw. At the Lemont WRP average bismuth-212 radioactivity was 3.0 pCi/g dw, lead-212 was 3.5 pCi/g dw, bismuth-214 was 25.9 pCi/g dw, lead-214 was 28.4 pCi/g dw, and actinium-228 was 23.5 pCi/g dw. These radionuclides are the decay products of either naturally occurring uranium or thorium.

TABLE 34: YEARLY AVERAGE GROSS BETA RADIOACTIVITY IN DISTRICT AIR-DRIED BIOSOLIDS
FROM 1996 THROUGH 2006

Year	Gross Beta Radioactivity (pCi/g dw)							
	Calumet East	Calumet West	LASMA	HASMA	Marathon	Stony Island	Vulcan	RASMA
1996	N/A	N/A	23.0	23.8	27.5	22.5	22.4	24.2
1997	N/A	N/A	25.2	26.3	23.2	26.1	26.4	26.0
1998	23.8	21.8	23.8	24.4	24.9	24.5	24.9	24.9
1999	23.7	24.4	21.5	28.6	25.4	25.0	22.8	24.6
2000	27.5	27.1	28.0	27.6	29.7	28.6	26.3	30.2
2001	23.4	21.0	25.8	25.0	24.2	25.0	23.2	26.7
2002	24.7	22.1	24.9	25.7	27.4	23.8	26.7	27.0
2003	25.3	26.5	26.8	25.0	25.6	23.3	24.9	26.5
2004	21.8	22.5	24.3	23.8	24.1	25.0	24.2	25.2

TABLE 34 (Continued): YEARLY AVERAGE GROSS BETA RADIOACTIVITY IN DISTRICT AIR-DRIED BIOSOLIDS FROM 1996 THROUGH 2006

Year	Gross Beta Radioactivity (pCi/g dw)							
	Calumet East	Calumet West	LASMA	HASMA	Marathon	Stony Island	Vulcan	RASMA
2005	24.7	24.1	22.2	26.8	27.7	26.2	27.4	26.6
2006	25.2	24.4	27.0	27.5	27.9	27.1	25.5	N/S

N/A = Not Analyzed

N/S = No Sample

TABLE 35: CONCENTRATION OF GAMMA-EMITTING RADIONUCLIDES IN WRP SLUDGES AND BIOSOLIDS - 2006

Sample Location WRP	No. of Samples	Potassium-40 (pCi/g dw)			Radium-226 (pCi/g dw)			Cesium-137 (pCi/g dw)		
		Ave.	Min.	Max.	Ave.	Min.	Max.	Ave.	Min.	Max.
Calumet	4	9.4	8.1	10.4	4.5	4.1	5.1	0.06	0.04	0.07
John E. Egan	4	8.9	7.4	10.3	3.9	3.7	4.3	ND	ND	ND
Hanover Park	4	5.3	5.1	5.6	3.8	3.4	4.1	ND	ND	ND
Stickney	4	10.3	9.2	11.5	3.4	3.2	3.4	0.05	0.04	0.06
Lemont	4	6.7	5.5	7.3	56.7	45.0	68.2	ND	ND	ND

TABLE 35 (Continued): CONCENTRATION OF GAMMA-EMITTING RADIONUCLIDES IN WRP SLUDGES AND BIOSOLIDS - 2006

Sample Location WRP	No. of Samples	Beryllium-7 (pCi/g dw)			Bismuth-212 (pCi/g dw)			Lead-212 (pCi/g dw)		
		Ave.	Min.	Max.	Ave.	Min.	Max.	Ave.	Min.	Max.
Calumet	4	7.2	4.2	10.4	0.3	ND	0.4	0.5	0.4	0.6
John E. Egan	4	4.2	2.7	5.6	0.3	ND	0.4	0.3	0.3	0.4
Hanover Park	4	ND	ND	0.97	ND	ND	ND	0.2	0.2	0.3
Stickney	4	10.2	5.7	15.2	0.3	ND	0.3	0.5	0.3	0.5
Lemont	4	3.5	1.8	5.3	3.0	2.1	3.7	3.5	2.5	4.4

TABLE 35 (Continued): CONCENTRATION OF GAMMA-EMITTING RADIONUCLIDES IN WRP SLUDGES AND BIOSOLIDS - 2006

Sample Location WRP	No. of Samples	Bismuth-214 (pCi/g dw)			Lead-214 (pCi/g dw)			Actinium-228 (pCi/g dw)		
		Ave.	Min.	Max.	Ave.	Min.	Max.	Ave.	Min.	Max.
Calumet	4	1.2	0.9	1.7	1.4	1.1	2.0	1.3	1.1	1.5
John E. Egan	4	1.1	0.9	1.3	1.3	1.0	1.5	1.1	1.0	1.2
Hanover Park	4	0.9	0.8	1.0	1.0	0.9	1.1	0.8	0.7	0.8
Stickney	4	1.0	0.8	1.1	1.1	0.9	1.2	0.9	0.8	0.9
Lemont	4	25.9	20.5	31.6	28.4	22.4	34.4	23.5	19.3	28.8

ND = Not Detected.

The village of Lemont uses groundwater for its community water supply. This groundwater contains naturally occurring radium-226. The village uses an ion exchange system to remove radium-226 from groundwater. The backwash water from the Lemont community water supply system is discharged into the Lemont WRP. The District treats the raw sewage containing this radium-226 at the Lemont WRP to remove contaminants. The radium-226 removed during the wastewater treatment process is concentrated in sludge. The Lemont WRP does not have sludge treatment facilities, and it was transported by truck to the Stickney WRP to be treated in 2006.

The yearly average potassium-40, radium-226, and cesium-137 radioactivity in the District's WRPs sludges and biosolids from 1997 to 2006 are summarized in [Tables 36, 37, and 38](#), respectively. The potassium-40 radioactivity in the WRP sludge ranged from 2.4 pCi/g dw at the Hanover Park WRP in 1997 to 11.7 pCi/g dw at the Stickney WRP in 1998. The radium-226 radioactivity in the WRP sludges, excluding Lemont WRP, ranged from 2.1 pCi/g dw at the Stickney WRP in 1999 to 5.5 pCi/g dw at the Calumet WRP in 2004. The radium-226 radioactivity at the Lemont WRP ranged from 44.9 pCi/g dw in 1997 to 86.8 pCi/g dw in 2001. The cesium-137 radioactivity in the WRP sludges ranged from non-detectable levels to 0.11 pCi/g dw in 1998 at the Stickney WRP.

[Table 39](#) presents the concentration of gamma-emitting radionuclides in Hanover Park WRP lagooned biosolids for 2006. The data presents an average of two samples analyzed from both Hanover Park WRP East and West lagoons. The potassium-40 radioactivity at the Hanover Park WRP East and West lagoons was 4.2 and 3.8 pCi/g dw, respectively. The radium-226 radioactivity was 3.9 pCi/g dw in the Hanover Park East lagoon and 3.6 pCi/g dw in the Hanover Park West lagooned biosolids. Cesium-137 radioactivity was 0.04 pCi/g dw at the two lagooned biosolids. The radioactivity concentration of other naturally occurring radionuclides ranged from 0.2 to 1.8 pCi/g dw.

The yearly average potassium-40, radium-226, and cesium-137 radioactivity in the Hanover Park WRP lagooned biosolids from 1998 to 2006 is summarized in [Table 40](#). The yearly average potassium-40 radioactivity at the Hanover Park East lagoon ranged from 2.8 to 5.0 pCi/g dw. The yearly average radium-226 radioactivity ranged from 3.7 to 5.2 pCi/g dw, and cesium-137 radioactivity ranged from non-detectable levels to 0.2 pCi/g dw.

The yearly average potassium-40 radioactivity in the Hanover Park West lagooned biosolids ranged from 3.5 to 5.3 pCi/g dw, radium-226 radioactivity ranged from 3.6 to 5.7 pCi/g dw, and cesium-137 radioactivity ranged from non-detectable levels to 0.3 pCi/g dw.

[Table 41](#) presents the concentration of gamma-emitting radionuclides in the District's biosolids collected from 7 solids drying sites in 2006. The average potassium-40 radioactivity ranged from 7.6 pCi/g dw in the Calumet West biosolids to 12.5 pCi/g dw in the LASMA biosolids. The overall concentration range of potassium-40 for the District's biosolids was 7.0 to 15.2 pCi/g dw. The average radium-226 radioactivity ranged from 3.0 pCi/g dw in the LASMA biosolids to 4.9 pCi/g dw in the Calumet West biosolids. The overall concentration range of radium-226 for the District's biosolids was from 2.5 to 5.3 pCi/g dw. The average cesium-137

TABLE 36: YEARLY AVERAGE POTASIUM-40 RADIOACTIVITY (pCi/g dw) IN WRP SLUDGES AND BIOSOLIDS FROM 1997 THROUGH 2006

Year	Calumet	Egan	Hanover Park	Stickney	Lemont
1997	7.5	6.1	2.4	9.1	6.1
1998	9.0	10.1	5.1	11.7	8.5
1999	8.3	8.8	5.3	10.9	8.3
2000	7.6	8.1	4.1	10.4	8.5
2001	8.5	8.9	5.2	11.0	9.5
2002	8.5	8.3	4.9	11.1	7.9
2003	8.8	7.4	5.0	10.3	7.2
2004	8.6	8.2	4.6	9.8	6.3
2005	8.3	6.9	4.7	9.9	6.1
2006	9.4	8.9	5.3	10.3	6.7

TABLE 37: YEARLY AVERAGE RADIUM-226 RADIOACTIVITY (pCi/g dw) IN WRP SLUDGES AND BIOSOLIDS FROM 1997 THROUGH 2006

Year	Calumet	Egan	Hanover Park	Stickney	Lemont
1997	4.5	3.8	3.8	3.4	44.9
1998	4.5	4.5	4.7	3.4	55.8
1999	4.2	3.8	3.1	2.1	74.6
2000	4.6	4.3	4.4	4.0	80.2
2001	4.8	4.6	4.3	3.5	86.8
2002	4.0	4.2	3.8	3.4	85.0
2003	4.2	4.0	3.4	3.3	58.0
2004	5.5	3.8	3.6	4.0	65.6
2005	4.4	3.9	3.1	3.5	70.8
2006	4.5	3.9	3.8	3.4	56.7

TABLE 38: YEARLY AVERAGE CESIUM-137 RADIOACTIVITY (pCi/g dw) IN WRP SLUDGES AND BIOSOLIDS FROM 1997 THROUGH 2006

Year	Calumet	Egan	Hanover Park	Stickney	Lemont
1997	0.08	0.03	ND	0.10	0.06
1998	0.09	0.04	0.02	0.11	ND
1999	0.10	0.02	ND	0.10	ND
2000	0.06	ND	ND	0.08	ND
2001	0.06	ND	ND	0.07	ND
2002	0.06	ND	ND	0.08	ND
2003	0.07	ND	ND	0.06	ND
2004	0.06	ND	ND	0.05	ND
2005	0.05	ND	ND	0.06	ND
2006	0.06	ND	ND	0.05	ND

ND = Not Detected

TABLE 39: CONCENTRATION (pCi/g dw) OF GAMMA-EMITTING RADIONUCLIDES IN HANOVER PARK WRP LAGOONED BIOSOLIDS - 2006

Radionuclides	No. of Samples	Hanover Park East Lagoon	Hanover Park West Lagoon
Beryllium-7	2	1.8	1.5
Potassium-40	2	4.2	3.8
Cesium-137	2	0.04	0.04
Bismuth-212	2	0.3	0.3
Lead-212	2	0.3	0.2
Bismuth-214	2	0.7	0.8
Lead-214	2	0.8	0.9
Radium-226	2	3.9	3.6
Actinium-228	2	0.8	0.7

TABLE 40: YEARLY AVERAGE POTASSIUM-40, RADIUM-226, AND CESIUM-137 RADIOACTIVITY (pCi/g dw)
IN HANOVER PARK WRP LAGOONED BIOSOLIDS FROM 1998 THROUGH 2006

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	N/A	N/A	N/A	N/A	N/A	N/A
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

ND = Not Detected
N/A = Not Analyzed

TABLE 41: CONCENTRATION OF GAMMA-EMITTING RADIONUCLIDES IN DISTRICT AIR-DRIED BIOSOLIDS – 2006

Sample Location	No. of Samples	Potassium-40 (pCi/g dw)			Radium-226 (pCi/g dw)			Cesium-137 (pCi/g dw)		
		Ave.	Min.	Max.	Ave.	Min.	Max.	Ave.	Min.	Max.
Calumet East	5	8.6	7.6	9.5	4.5	3.8	5.1	0.07	0.05	0.08
Calumet West	3	7.6	7.4	7.8	4.9	4.6	5.3	0.06	0.05	0.06
Stony Island	5	8.9	7.7	10.5	4.2	3.9	4.7	0.07	0.05	0.09
HASMA	5	9.2	7.0	10.8	3.9	3.4	4.6	0.07	0.04	0.09
LASMA	5	12.5	8.6	15.2	3.0	2.7	3.4	0.04	ND	0.06
Marathon	5	12.1	9.7	15.1	3.2	2.5	3.8	0.05	ND	0.08
Vulcan	5	9.6	8.9	10.4	3.7	3.4	4.1	0.07	0.04	0.08

TABLE 41 (Continued): CONCENTRATION OF GAMMA-EMITTING RADIONUCLIDES IN DISTRICT AIR-DRIED BIOSOLIDS – 2006

Sample Location	No. of Samples	Beryllium-7 (pCi/g dw)			Bismuth-212 (pCi/g dw)			Lead-212 (pCi/g dw)		
		Ave.	Min.	Max.	Ave.	Min.	Max.	Ave.	Min.	Max.
Calumet East	5	11.1	1.1	15.4	0.4	ND	0.5	0.6	0.4	0.7
Calumet West	3	ND	ND	1.2	0.6	0.6	0.7	1.0	1.0	1.0
Stony Island	5	3.6	ND	14.6	0.5	0.4	0.7	0.7	0.5	1.0
HASMA	5	2.4	ND	4.8	0.5	ND	0.7	0.7	0.4	1.0
LASMA	5	5.8	ND	24.2	0.4	0.3	0.5	0.6	0.4	0.7
Marathon	5	1.2	ND	1.2	0.4	0.4	0.5	0.7	0.6	0.7
Vulcan	5	1.2	ND	1.2	0.5	0.4	0.5	0.7	0.6	0.9

TABLE 41 (Continued): CONCENTRATION OF GAMMA-EMITTING RADIONUCLIDES IN DISTRICT AIR-DRIED BIOSOLIDS – 2006

Sample Location	No. of Samples	Bismuth-214 (pCi/g dw)			Lead-214 (pCi/g dw)			Actinium-228 (pCi/g dw)		
		Ave.	Min.	Max.	Ave.	Min.	Max.	Ave.	Min.	Max.
Calumet East	5	1.2	1.0	1.3	1.4	1.1	1.5	1.0	ND	1.4
Calumet West	3	1.3	1.2	1.4	1.5	1.4	1.6	1.0	0.9	1.0
Stony Island	5	1.1	0.8	1.4	1.2	1.0	1.6	1.0	0.9	1.0
HASMA	5	1.0	0.8	1.3	1.2	0.9	1.5	0.8	ND	1.0
LASMA	5	0.9	0.8	1.1	1.0	0.9	1.2	0.8	0.8	0.9
Marathon	5	0.9	0.9	1.0	1.0	1.0	1.1	0.8	0.7	1.0
Vulcan	5	0.9	0.7	1.0	1.1	0.8	1.2	0.9	0.8	0.9

ND = Not Detected.

radioactivity ranged from 0.04 pCi/g dw in the LASMA biosolids to 0.07 pCi/g dw in the Calumet East, Stony Island, HASMA and Vulcan biosolids. The overall concentration range of cesium-137 radioactivity for the District's biosolids was from non-detectable levels to 0.09 pCi/g dw. Average beryllium-7, bismuth-212, lead-212, bismuth-214, lead-214, and actinium-228 radioactivity ranged from non-detectable levels to 11.1 pCi/g dw.

The yearly average potassium-40, radium-226, and cesium-137 radioactivity in the District's biosolids from 1996 to 2006 are summarized in Tables 42, 43, and 44, respectively. The potassium-40 radioactivity in the biosolids ranged from 7.0 pCi/g dw at the Calumet West drying site in 1996 and Calumet East drying site in 2004 to 14.4 pCi/g dw at the HASMA drying site in 2002. The radium-226 radioactivity in the biosolids ranged from 2.9 pCi/g dw at the Vulcan drying site in 1999 to 5.2 pCi/g dw at the Calumet West drying site in 2001. The cesium-137 radioactivity in biosolids ranged from 0.04 pCi/g dw at the LASMA drying site in 2006 to 0.6 pCi/g dw at the Stony Island drying site in 1996.

TABLE 42: YEARLY AVERAGE POTASIUM-40 RADIOACTIVITY (pCi/g dw) IN DISTRICT AIR-DRIED BIOSOLIDS FROM 1996 THROUGH 2006

Year	Calumet East	Calumet West	LASMA	HASMA	Marathon	Stony Island	Vulcan	RASMA
1996	7.4	7.0	9.0	9.6	9.7	8.6	9.9	10.4
1997	10.2	10.1	9.8	10.0	8.8	9.0	9.7	9.8
1998	9.8	8.6	11.7	9.7	10.8	8.9	9.8	9.3
1999	11.3	9.3	10.7	10.6	10.4	10.0	12.4	10.9
2000	10.4	9.9	9.4	9.6	10.2	10.3	10.0	10.4
2001	10.4	7.4	9.9	11.1	10.3	8.9	11.3	11.3
2002	10.9	7.1	10.8	14.4	11.6	9.4	11.3	11.5
2003	11.4	11.8	10.4	10.0	11.0	8.9	9.9	10.4
2004	7.0	7.5	9.7	8.8	10.5	8.8	9.2	9.4
2005	8.0	9.7	8.6	9.2	10.0	8.8	9.9	9.9
2006	8.6	7.6	12.5	9.2	12.1	8.9	9.6	NS

NS = No Sample

TABLE 43: YEARLY AVERAGE RADIUM-226 RADIOACTIVITY (pCi/g dw) IN DISTRICT AIR-DRIED BIOSOLIDS FROM 1996 THROUGH 2006

Year	Calumet East	Calumet West	LASMA	HASMA	Marathon	Stony Island	Vulcan	RASMA
1996	4.6	4.5	4.3	4.1	3.9	3.6	3.6	4.0
1997	3.6	3.7	3.1	3.4	3.1	3.3	3.1	3.0
1998	3.6	4.3	4.0	3.6	4.0	3.8	3.0	3.5
1999	3.8	4.1	3.7	3.5	3.5	3.6	2.9	3.6
2000	3.4	4.4	3.5	4.0	3.7	3.6	4.0	3.5
2001	4.6	5.2	3.9	3.6	4.3	4.4	4.0	3.8
2002	4.6	4.5	4.0	3.5	3.8	4.0	3.6	4.0
2003	4.4	4.6	4.0	3.9	3.8	3.8	4.0	3.8
2004	4.8	4.8	4.1	3.8	3.8	4.0	3.9	3.7
2005	4.7	4.3	3.7	4.0	3.8	4.0	3.7	3.8
2006	4.5	4.9	3.0	3.9	3.2	4.2	3.7	NS

NS = No Sample

TABLE 44: YEARLY AVERAGE CESIUM-137 RADIOACTIVITY (pCi/g dw) IN DISTRICT AIR-DRIED BIOSOLIDS FROM 1996 THROUGH 2006

Year	Calumet East	Calumet West	LASMA	HASMA	Marathon	Stony Island	Vulcan	RASMA
1996	0.2	0.3	0.4	0.4	0.4	0.6	0.4	0.3
1997	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
1998	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
1999	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
2000	0.09	0.08	0.1	0.11	0.09	0.09	0.09	0.1
2001	0.06	0.08	0.09	0.07	0.09	0.09	0.07	0.08
2002	0.05	0.07	0.09	0.08	0.09	0.08	0.08	0.09
2003	0.07	0.07	0.09	0.09	0.08	0.07	0.08	0.08
2004	0.06	0.06	0.08	0.07	0.06	0.07	0.07	0.06
2005	0.06	0.06	0.06	0.08	0.08	0.07	0.07	0.07
2006	0.07	0.06	0.04	0.07	0.05	0.07	0.07	NS

NS = No Sample

REFERENCES

1. General Accounting Office, Nuclear Regulation - Action Needed to Control Radioactive Contamination at Sewage Treatment Plants, Report No. GAO/RCED-94-133, 1994.
2. U. S. Environmental Protection Agency. National Primary Drinking Water Regulations; Radionuclides: Final Rule. 40 CFR Part 141. Federal Register 65(236): 76707-76753; 2000.
3. State of Illinois Rules and Regulations, Title 35: Environmental Protection, Subtitle C: Water Pollution, Chapter I: Pollution Control Board, 302.207, 1999.
4. Interagency Steering Committee on Radiation Standards. ISCORS Assessment of Radioactivity in Sewage Sludge: Radiological Survey Results and Analysis; ISCORS Technical Report 2003-02, 2003.
5. Standard Methods for the Examination of Water and Wastewater, 20th Edition, American Public Health Association, 1998.