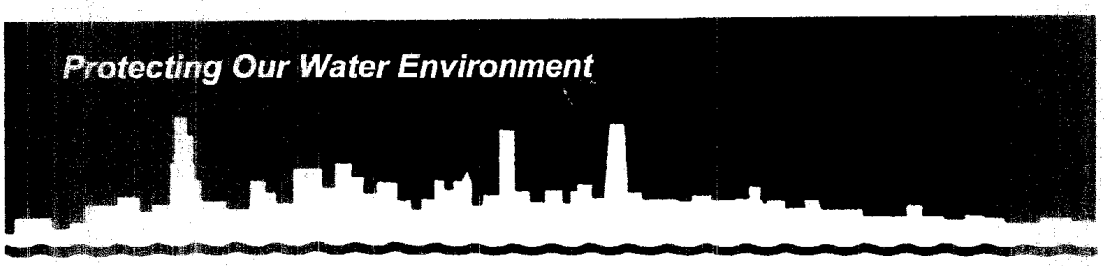

Metropolitan Water Reclamation District of Greater Chicago

RESEARCH AND DEVELOPMENT DEPARTMENT

REPORT NO. 03-2

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

2001 ANNUAL REPORT

January 2003

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RADIOLOGICAL MONITORING OF THE RAW SEWAGE, FINAL EFFLUENT, SLUDGES, AND BIOSOLIDS OF THE METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO 2001 ANNUAL REPORT

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Special thanks are due to Mrs. Nancy Urlacher 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 Department of Nuclear Safety (IDNS). 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 in the United States over the last 20 years (1).

This study was conducted to determine the radioactivity concentration in raw sewage, final effluent, waste-activated

sludge, anaerobically digested sludge, and biosolids at the facilities owned and operated by the District. The radioactivity removal efficiency by the wastewater treatment process at all the water reclamation plants (WRPs) was calculated. 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 sample (composited over a period of 24 hours) was collected once a week, and one final effluent sample (composited over a period of 24 hours) was collected once a month from each of the District's seven WRPs. Sewage sludge samples were collected once a month from all the WRPs. Sludge samples from the Hanover Park WRP East and West lagoons were collected in April, July, and October of 2001. Final air-dried biosolids samples from the Calumet WRP East, Calumet WRP West, Ridgeland Avenue Solids Management Area (RASMA), Stony Island, Harlem Avenue Solids Management Area (HASMA), Lawndale Avenue Solids Management Area (LASMA), Marathon, and Vulcan drying areas were collected monthly from May through September 2001.

The raw sewage, final effluent, waste-activated sludge, anaerobically digested sludge, lagooned sludge, 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 sludge samples from Hanover Park WRP, and quarterly sludge samples from Hanover Park, Stickney, Calumet, Egan, and Lemont WRPs were also analyzed for gamma-emitting radonuclides.

The analytical data demonstrates 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 2001 radiological monitoring data was compared with the historical data of the last five years. The data show that there was not a major change in the radioactivity concentrations of sludge samples of the WRPs over the last six years except for the Lemont WRP.

The amount of gross alpha and gross beta radioactivity in the final effluent is less than the allowable contaminant levels in 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 standards 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 District waterways.

Measurable concentrations of gross alpha and gross beta radioactivity were found in Hanover Park WRP lagooned sludge. The average gross alpha radioactivity in the lagooned sludge ranged from 13.2 to 13.6 pCi/g dw. The average gross beta radioactivity in the lagooned sludge ranged from 13.6 to 14.8 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 13.2 to 17.7 pCi/g dw and 21.0 to 26.7 pCi/g dw, respectively.

Samples of the anaerobically digested sludge from four WRPs (Calumet, John E. Egan [Egan], Hanover Park, and Stickney), waste-activated sludge from the Lemont WRP, lagooned sludge 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 samples ranged from 5.2 to 11.0 pCi/g dw, radium-226 radioactivity ranged from 3.5 to 86.8 pCi/g dw, and cesium-137 radioactivity ranged from not detectable to 0.07 pCi/g dw.

Potassium-40 radioactivity in Hanover Park lagooned sludge ranged from 3.8 to 4.7 pCi/g dw, and radium-226 radioactivity ranged from 4.5 to 6.7 pCi/g dw. Cesium-137 radioactivity was not detected in Hanover Park WRP lagooned sludge.

Average potassium-40 and radium-226 radioactivity in all biosolids samples taken from the District sludge drying areas ranged from 7.4 to 11.3 pCi/g dw and 3.6 to 5.2 pCi/g dw, respectively. The average cesium-137 radioactivity ranged from 0.06 to 0.09 pCi/g dw. The average radioactivity concentration of the other six naturally occurring radionuclides in biosolids ranged from a non-detectable level to 4.1 pCi/g dw.

Currently, USEPA is working on standards for radioactivity in biosolids. 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.

INTRODUCTION

The District is located within the boundaries of Cook County, Illinois, and serves an area of 872 square miles. The area served by the District includes the city of Chicago and 125 suburban communities with a combined population of 5.1 million people. In addition, a waste load equivalent of 4.9 million people is contributed within the District's service area by industrial and commercial sources. On the average the District treats 1,500 million gallons per day (MGD) of wastewater at its seven WRPs.

The discharge of radionuclides to the District's sewerage system is regulated by the IDNS. 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 enter the wastewater treatment process where some fraction of these radionulides are removed from the wastewater and become concentrated in the sludge, or remain in solution and pass with the effluent to the receiving water. Radioactivity contained in WRP effluents and the potential radioactivity concentration in municipal sludge may be of environmental concern because of

the discharge of effluents to receiving waters, and the land application or landfilling 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 sludge from four WRPs (Calumet, Egan, Hanover Park, and Stickney), waste-activated sludge from the Lemont WRP, lagooned sludge from the Hanover Park WRP, and biosolids samples from the District's drying areas are also examined for gamma-emitting radionuclides. In 1996, the Radiochemistry Section expanded its monitoring program of District sludges 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, and sewage sludge from the District's seven WRPs and biosolids from the District's solids drying areas. The radioactivity removal efficiency of the seven WRPs is also reported. The concentrations of gross alpha and gross beta radioactivity and gamma-emitting radionuclides in quarterly samples of anaerobically digested sludge, lagooned sludge, and biosolids samples are also reported. The 2001 radiological monitoring data is compared with the historical data of the last five years.

MATERIALS AND METHODS

Sample Collection

RAW SEWAGE

One raw sewage sample (composited over a period of 24 hours) was collected once a week 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 composite 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.

SEWAGE SLUDGE

Anaerobically digested sludge 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 SLUDGE

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

BIOSOLIDS

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, RASMA 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 Tennelec 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, NIST traceable americium-241 standard was used up to June 2001, and 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 sludge sample (25 to 50 g) or 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, NIST traceable americium-241 standard was used for the efficiency calibration of the counters 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 in 2001 was due to the fact that thorium-230 efficiency calibration was used 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 Ginie-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:

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 dpm to pCi

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

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

The radioactivity removal efficiency was calculated on a monthly basis using the following equation:

Radioactivity Removal Efficiency (%) =

$$100 \times \frac{\text{(Raw Sewage Radioactivity Conc. - Final Effluent Radioactivity Conc.)}}{\text{Raw Sewage Radioactivity Conc.}}$$

where:

Raw sewage radioactivity concentration is the average of concentration of alpha/beta radioactivity in weekly raw sewage samples collected during a month.

Final effluent radioactivity concentration is the alpha/beta radioactivity in the monthly effluent composite sample.

Radioactivity removal efficiency could not be calculated for the samples whose gross alpha/beta radioactivity concentration was below the detection limit.

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 (4). The LLD that has a 95 percent probability of being detected was calculated as follows:

$$\text{LLD (pCi/L)} = \frac{4.66\ (B)^{1/2}}{2.22 \times E \times V \times T \times F}$$

where:

B = background counts

E = counting efficiency

V = sample volume in liters

T = counting time

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

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 and gross beta radioactivity for raw sewage was calculated by adding radioactivity concentrations in weekly samples and dividing the sum by the number of weekly samples collected during the month. 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 2001, the gross alpha radioactivity in the raw sewage of the Stickney WRP ranged from below the detection limit (4.1 pCi/L) to 11.7 pCi/L (Table 1). The gross alpha radioactivity in the effluent was below the detection limit (3.7 to 5.2 pCi/L), except for the September sample, 3.8 pCi/L (Table 1). The gross alpha radioactivity in anaerobically digested sludge ranged from 3.8 to 18.6 pCi/g dw (Table 1). The gross alpha radioactivity removal efficiency could not be calculated because the effluent radioactivity was below the detection limits except for the September sample, 47.2%.

The yearly average gross alpha radioactivity at the Stickney WRP raw sewage, final effluent, and anaerobically digested sludge from 1996 to 2001 are summarized in Table 2. The gross alpha radioactivity in the raw sewage ranged from below the detection limit (3.6 pCi/L) to 6.1 pCi/L. The gross alpha radioactivity in the effluent was below the detection limit (2.6 to 4.6 pCi/L) and the gross alpha radioactivity in anaerobically digested sludge ranged from 5.2 to 12.3 pCi/g dw.

The gross beta radioactivity in the raw sewage of the Stickney WRP ranged from 12.6 to 29.8 pCi/L, and in the effluent it ranged from 6.1 to 15.9 pCi/L (Table 3). The gross beta

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TABLE 1

GROSS ALPHA RADIOACTIVITY IN STICKNEY WRP RAW SEWAGE, FINAL EFFLUENT, AND ANAEROBICALLY DIGESTED SLUDGE, AND RADIOACTIVITY REMOVAL EFFICIENCY OF THE WRP ON A MONTHLY BASIS - 2001

Month	Raw Sewage Gross Alpha (pCi/L)	Effluent Gross Alpha (pCi/L)	Radioactivity Removal Eff. (%)	Sludge Gross Alpha (pCi/g dw)
January	<4.3	<4.5	*	3.8
February	<4.1	<3.7	*	9.4
March	<4.4	<4.7	*	8.4
April	<4.5	<3.8	*	5.8
May	5.4	<4.6	*	17.6
June	<5.5	<4.6	*	8.7
July	6.6	<4.0	*	18.6
August	11.7	<5.2	*	18.4
September	7.2	3.8	47.2	16.7
October	6.9	<4.6	*	13.2
November	8.1	<5.0	*	16.6
December	4.5	<3.9	*	10.6

*Values could not be calculated because the effluent radioactivity was below the detection limit.

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

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TABLE 2

YEARLY AVERAGE GROSS ALPHA RADIOACTIVITY IN STICKNEY WRP RAW SEWAGE, FINAL EFFLUENT, AND ANAEROBICALLY DIGESTED SLUDGE FROM 1996 THROUGH 2001

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

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

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TABLE 3

GROSS BETA RADIOACTIVITY IN STICKNEY WRP RAW SEWAGE, FINAL EFFLUENT, AND ANAEROBICALLY DIGESTED SLUDGE, AND RADIOACTIVITY REMOVAL EFFICIENCY OF THE WRP ON A MONTHLY BASIS - 2001

Month	Raw Sewage Gross Beta (pCi/L)	Effluent Gross Beta (pCi/L)	Radioactivity Removal Eff. (%)	Sludge Gross Beta (pCi/g dw)
January	19.4	8.6	55.7	21.3
February	29.8	10.3	65.4	29.4
March	22.4	15.9	29.0	30.0
April	24.8	10.6	57.2	31.2
May	20.8	6.7	67.8	26.4
June	26.2	6.1	76.7	25.0
July	15.3	9.5	37.9	25.1
August	19.3	8.4	56.5	28.9
September	13.5	8.8	34.8	31.2
October	12.6	7.6	39.7	29.4
November	18.9	9.0	52.4	24.9
December	13.5	8.9	34.1	24.6

radioactivity removal efficiency of the Stickney WRP ranged from 29.0 to 76.7 percent. The gross beta radioactivity in anaerobically digested sludge ranged from 21.3 to 31.2 pCi/g dw (Table 3).

The yearly average gross beta radioactivity at the Stickney WRP raw sewage, final effluent, and anaerobically digested sludge from 1996 to 2001 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 sludge ranged from 22.8 to 27.3 pCi/g dw.

Calumet WRP

In 2001, the gross alpha radioactivity in the raw sewage of the Calumet WRP was below the detection limit (4.2 to 6.5 pCi/L, Table 5). The gross alpha radioactivity in the effluent was also below the detection limit (3.5 to 5.7 pCi/L, Table 5). The gross alpha radioactivity in anaerobically digested sludge ranged from 5.3 to 18.0 pCi/g dw (Table 5). The gross alpha radioactivity removal efficiency could not be calculated because the raw sewage and the effluent radioactivity were below the detection limit.

The yearly average gross alpha radioactivity at the Calumet WRP raw sewage, final effluent, and anaerobically digested

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TABLE 4

YEARLY AVERAGE GROSS BETA RADIOACTIVITY IN STICKNEY WRP RAW SEWAGE, FINAL EFFLUENT, AND ANAEROBICALLY DIGESTED SLUDGE FROM 1996 THROUGH 2001

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

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TABLE 5

GROSS ALPHA RADIOACTIVITY IN CALUMET WRP RAW SEWAGE, FINAL EFFLUENT, AND ANAEROBICALLY DIGESTED SLUDGE, AND RADIOACTIVITY REMOVAL EFFICIENCY OF THE WRP ON A MONTHLY BASIS - 2001

Month	Raw Sewage Gross Alpha (pCi/L)	Effluent Gross Alpha (pCi/L)	Radioactivity Removal Eff. (%)	Sludge Gross Alpha (pCi/g dw)
January	<4.2	<4.2	*	5.3
February	<4.3	<3.7	*	8.8
March	<4.5	<4.8	*	8.4
April	<4.6	<4.2	*	8.3
May	<4.6	<4.5	*	13.4
June	<5.2	<5.2	*	14.2
July	<6.5	<4.5	*	17.5
August	<6.0	<5.7	*	16.4
September	<5.8	<3.5	*	18.0
October	<5.3	<5.1	*	12.3
November	<5.9	<4.8	*	17.3
December	<4.4	<4.1	*	10.9

*Values could not be calculated because the raw sewage and the effluent radioactivity was below the detection limit.

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

sludge from 1996 to 2001 are summarized in Table 6. The gross alpha radioactivity in the raw sewage was below the detection limit (3.7 to 5.1 pCi/L). In the effluent the gross alpha radioactivity was also below the detection limit (3.0 to 4.5 pCi/L). The gross alpha radioactivity in anaerobically digested sludge ranged from 5.1 to 12.6 pCi/g dw.

The gross beta radioactivity in the raw sewage of the Calumet WRP ranged from 11.8 to 20.2 pCi/L, and in the effluent it ranged from <7.0 to 12.6 pCi/L (Table 7). The gross beta radioactivity removal efficiency of the Calumet WRP ranged from -5.9 to 47.0 percent. The gross beta radioactivity in Calumet WRP anaerobically digested sludge ranged from 19.5 to 29.7 pCi/g dw (Table 7).

The yearly average gross beta radioactivity at the Calumet WRP raw sewage, final effluent, and anaerobically digested sludge from 1996 to 2001 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 sludge ranged from 21.4 to 25.2 pCi/g dw.

North Side WRP

In 2001, the gross alpha radioactivity in the raw sewage of the North Side WRP was below the detection limit (4.2 to 6.4

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TABLE 6

YEARLY AVERAGE GROSS ALPHA RADIOACTIVITY IN CALUMET WRP RAW SEWAGE, FINAL EFFLUENT, AND ANAEROBICALLY DIGESTED SLUDGE FROM 1996 THROUGH 2001

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

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

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TABLE 7

GROSS BETA RADIOACTIVITY IN CALUMET WRP RAW SEWAGE, FINAL EFFLUENT, AND ANAEROBICALLY DIGESTED SLUDGE, AND RADIOACTIVITY REMOVAL EFFICIENCY OF THE WRP ON A MONTHLY BASIS - 2001

Month	Raw Sewage Gross Beta (pCi/L)	Effluent Gross Beta (pCi/L)	Radioactivity Removal Eff. (%)	Sludge Gross Beta (pCi/g dw)
January	12.5	<7.0	*	19.5
February	13.6	8.1	40.4	20.2
March	11.9	12.6	-5.9	25.4
April	16.8	9.0	46.4	26.2
May	11.8	10.9	7.6	23.2
June	20.2	10.7	47.0	25.3
July	14.6	8.1	44.5	22.8
August	13.4	8.3	38.0	23.9
September	12.7	10.1	20.5	29.7
October	12.4	11.5	7.2	22.5
November	11.8	10.1	14.4	24.4
December	11.9	6.9	42.0	25.7

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

*Value could not be calculated because the effluent radioactivity was below the detection limit.

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TABLE 8

YEARLY AVERAGE GROSS BETA RADIOACTIVITY IN CALUMET WRP RAW SEWAGE, FINAL EFFLUENT, AND ANAEROBICALLY DIGESTED SLUDGE FROM 1996 THROUGH 2001

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

pCi/L, Table 9). The gross alpha radioactivity in the effluent was also below the detection limits (3.5 to 6.5 pCi/L), except for the September sample, 4.9 pCi/L (Table 9). The gross alpha radioactivity in waste-activated sludge ranged from 3.2 to 12.1 pCi/g dw (Table 9). The gross alpha radioactivity removal efficiency could not be calculated because the raw sewage radioactivity was below the detection limit.

The yearly average gross alpha radioactivity at the North Side WRP raw sewage, final effluent, and waste-activated sludge from 1996 to 2001 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), and in the effluent it was also below the detection limit (2.8 to 4.5 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 9.8 to 20.2 pCi/L, and in the effluent it ranged from below the detection limit (6.1 pCi/L) to 14.4 pCi/L (Table 11). The gross beta radioactivity removal efficiency of the North Side WRP ranged from -15.2 to 59.4 percent (Table 11). The gross beta radioactivity in North Side WRP waste-activated sludge ranged from 11.0 to 21.2 pCi/g dw (Table 11).

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TABLE 9

GROSS ALPHA RADIOACTIVITY IN NORTH SIDE WRP RAW SEWAGE, FINAL EFFLUENT, AND WASTE-ACTIVATED SLUDGE, AND RADIOACTIVITY REMOVAL EFFICIENCY OF THE WRP ON A MONTHLY BASIS - 2001

Month	Raw Sewage Gross Alpha (pCi/L)	Effluent Gross Alpha (pCi/L)	Radioactivity Removal Eff. (%)	Sludge Gross Alpha (pCi/g dw)
January	<4.3	<4.4	*	3.2
February	<4.4	<3.5	*	5.3
March	<4.4	<4.5	*	5.6
April	<4.2	<3.8	*	4.3
May	<4.7	<6.5	*	9.9
June	<5.5	<4.7	*	10.7
July	<5.3	<4.0	*	9.0
August	<6.4	<5.2	*	12.1
September	<5.3	4.9	*	7.8
October	<4.5	<4.7	*	11.6
November	<4.9	<4.8	*	8.7
December	<4.4	<3.6	*	5.5

*Values could not be calculated because the raw sewage radioactivity was below the detection limit.

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

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TABLE 10

YEARLY AVERAGE GROSS ALPHA RADIOACTIVITY IN NORTH SIDE WRP RAW SEWAGE, FINAL EFFLUENT, AND WASTE-ACTIVATED SLUDGE FROM 1996 THROUGH 2001

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

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

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TABLE 11

GROSS BETA RADIOACTIVITY IN NORTH SIDE WRP RAW SEWAGE, FINAL EFFLUENT, AND WASTE-ACTIVATED SLUDGE, AND RADIOACTIVITY REMOVAL EFFICIENCY OF THE WRP ON A MONTHLY BASIS - 2001

Month	Raw Sewage Gross Beta (pCi/L)	Effluent Gross Beta (pCi/L)	Radioactivity Removal Eff. (%)	Sludge Gross Beta (pCi/g dw)
January	13.0	9.1	30.0	11.0
February	12.5	<6.2	*	19.9
March	12.5	14.4	-15.2	21.2
April	20.2	8.2	59.4	16.8
May	15.5	<6.1	*	14.4
June	14.8	8.9	39.9	15.1
July	11.4	8.8	22.8	14.8
August	11.7	8.2	22.9	19.1
September	10.5	8.4	20.0	15.2
October	9.8	7.8	20.4	17.4
November	10.8	8.4	22.2	11.9
December	10.5	7.8	25.7	13.1

*Values could not be calculated because the effluent radioactivity was below the detection limit.

< = 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 beta radioactivity at the North Side WRP raw sewage, final effluent, and waste-activated sludge from 1996 to 2001 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 13.6 to 15.8 pCi/g dw.

John E. Egan WRP

In 2001, the gross alpha radioactivity in the raw sewage of the Egan WRP was below the detection limits (3.9 to 6.1 pCi/L) except for the July sample, 7.2 pCi/L (Table 13). The gross alpha radioactivity in the effluent was below the detection limits (3.4 to 7.0 pCi/L, Table 13). The gross alpha radioactivity in anaerobically digested sludge samples ranged from 4.4 to 15.2 pCi/g dw (Table 13). The gross alpha radioactivity removal efficiency could not be calculated because the effluent radioactivity was below the detection limit.

The yearly average gross alpha radioactivity at the Egan WRP raw sewage, final effluent, and anaerobically digested sludge from 1996 to 2001 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

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TABLE 12

YEARLY AVERAGE GROSS BETA RADIOACTIVITY IN NORTH SIDE WRP RAW SEWAGE, FINAL EFFLUENT, AND WASTE-ACTIVATED SLUDGE FROM 1996 THROUGH 2001

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

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

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TABLE 13

GROSS ALPHA RADIOACTIVITY IN JOHN E. EGAN WRP RAW SEWAGE, FINAL EFFLUENT, AND ANAEROBICALLY DIGESTED SLUDGE, AND RADIOACTIVITY REMOVAL EFFICIENCY OF THE WRP ON A MONTHLY BASIS - 2001

Month	Raw Sewage Gross Alpha (pCi/L)	Effluent Gross Alpha (pCi/L)	Radioactivity Removal Eff. (%)	Sludge Gross Alpha (pCi/g dw)
January	<4.1	<4.3	*	4.4
February	<3.9	<3.5	*	7.0
March	<4.5	<4.7	*	6.2
April	<4.4	<4.3	*	7.5
May	<4.9	<7.0	*	13.2
June	<5.2	<5.0	*	10.1
July	7.2	<4.2	*	13.1
August	<6.1	<5.2	*	12.6
September	<5.4	<3.4	*	12.1
October	<4.7	<5.0	*	13.4
November	<5.2	<5.2	*	15.2
December	<4.4	<4.0	*	11.0

*Values could not be calculated because the effluent radioactivity was below the detection limit.

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

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE 14

YEARLY AVERAGE GROSS ALPHA RADIOACTIVITY IN JOHN E. EGAN WRP RAW SEWAGE, FINAL EFFLUENT, AND ANAEROBICALLY DIGESTED SLUDGE FROM 1996 THROUGH 2001

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

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

(3.0 to 4.6 pCi/L). The gross alpha radioactivity in anaerobically digested sludge 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 12.0 to 24.7 pCi/L, and in the effluent it ranged from 7.5 to 13.5 pCi/L (Table 15). The gross beta radioactivity removal efficiency of the Egan WRP ranged from 27.5 to 56.4 percent. The gross beta radioactivity in Egan WRP anaerobically digested sludge ranged from 17.4 to 23.2 pCi/g dw.

The yearly average gross beta radioactivity at the Egan WRP raw sewage, final effluent, and anaerobically digested sludge from 1996 to 2001 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 sludge ranged from 19.0 to 21.3 pCi/g dw.

Hanover Park WRP

In 2001, the gross alpha radioactivity levels in the raw sewage of the Hanover Park WRP were below the detection limit (3.8 to 5.6 pCi/L, Table 17). The gross alpha radioactivity in the effluent was also below the detection limits (3.2 to 5.8 pCi/L, Table 17). The gross alpha radioactivity removal efficiency could not be calculated because the raw sewage and the

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TABLE 15

GROSS BETA RADIOACTIVITY IN JOHN E. EGAN WRP RAW SEWAGE, FINAL EFFLUENT, AND ANAEROBICALLY DIGESTED SLUDGE, AND RADIOACTIVITY REMOVAL EFFICIENCY OF THE WRP ON A MONTHLY BASIS - 2001

Month	Raw Sewage Gross Beta (pCi/L)	Effluent Gross Beta (pCi/L)	Radioactivity Removal Eff. (%)	Sludge Gross Beta (pCi/g dw)
January	17.2	7.5	56.4	18.0
February	15.8	9.0	43.0	17.4
March	24.7	13.5	45.3	20.2
April	12.9	8.2	36.4	22.7
May	15.6	9.9	36.5	22.5
June	20.4	9.0	55.9	19.6
July	15.3	10.1	34.0	18.7
August	16.3	9.8	39.9	20.6
September	14.2	10.3	27.5	23.2
October	12.0	8.6	28.3	22.6
November	14.6	9.4	35.6	21.9
December	12.6	8.5	32.5	21.3

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TABLE 16

YEARLY AVERAGE GROSS BETA RADIOACTIVITY IN JOHN E. EGAN WRP RAW SEWAGE, FINAL EFFLUENT, AND ANAEROBICALLY DIGESTED SLUDGE FROM 1966 THROUGH 2001

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

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TABLE 17

GROSS ALPHA RADIOACTIVITY IN HANOVER PARK WRP RAW SEWAGE, FINAL EFFLUENT, AND ANAEROBICALLY DIGESTED SLUDGE, AND RADIOACTIVITY REMOVAL EFFICIENCY OF THE WRP ON A MONTHLY BASIS - 2001

Month	Raw Sewage Gross Alpha (pCi/L)	Effluent Gross Alpha (pCi/L)	Radioactivity Removal Eff. (%)	Sludge Gross Alpha (pCi/g dw)
January	<4.0	<4.1	*	4.3
February	<3.8	<3.4	*	6.6
March	<4.5	<5.0	*	5.8
April	<4.3	<4.2	*	5.6
May	<5.6	<5.8	*	11.4
June	<5.0	<4.8	*	12.9
July	<5.1	<4.0	*	12.2
August	<5.1	<4.8	*	12.5
September	<5.0	<3.2	*	9.1
October	<4.7	<4.7	*	8.0
November	<5.2	<4.9	*	16.1
December	<4.2	<3.9	*	8.2

*Values could not be calculated because the raw sewage and the effluent radioactivity was below the detection limit.

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

effluent radioactivity were below the detection limit. The gross alpha radioactivity in anaerobically digested sludge ranged from 4.3 to 16.1 pCi/g dw (Table 17).

The yearly average gross alpha radioactivity at the Hanover Park WRP raw sewage, final effluent, and anaerobically digested sludge from 1996 to 2001 are summarized in Table 18. The gross alpha radioactivity in the raw sewage was below the detection limit (3.4 to 4.7 pCi/L), and the gross alpha radioactivity in the effluent was also below the detection limit (3.0 to 4.4 pCi/L). The gross alpha radioactivity in anaerobically digested sludge 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 9.9 to 25.9 pCi/L, and in the effluent it ranged from <6.9 to 12.6 pCi/L (Table 19). The gross beta radioactivity removal efficiency of the Hanover Park WRP ranged from -11.7 to 72.2 percent (Table 19). The gross beta radioactivity in the Hanover Park WRP anaerobically digested sludge ranged from 12.6 to 16.4 pCi/g dw (Table 19).

The yearly average gross beta radioactivity at the Hanover Park WRP raw sewage, final effluent, and anaerobically digested sludge from 1996 to 2001 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 10.8

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TABLE 18

YEARLY AVERAGE GROSS ALPHA RADIOACTIVITY IN HANOVER PARK WRP RAW SEWAGE, FINAL EFFLUENT, AND ANAEROBICALLY DIGESTED SLUDGE FROM 1996 THROUGH 2001

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

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

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TABLE 19

GROSS BETA RADIOACTIVITY IN HANOVER PARK WRP RAW SEWAGE, FINAL EFFLUENT, AND ANAEROBICALLY DIGESTED SLUDGE, AND RADIOACTIVITY REMOVAL EFFICIENCY OF THE WRP ON A MONTHLY BASIS - 2001

Month	Raw Sewage Gross Beta (pCi/L)	Effluent Gross Beta (pCi/L)	Radioactivity Removal Eff. (%)	Sludge Gross Beta (pCi/g dw)
January	13.7	<6.9	*	12.6
February	12.6	6.7	46.8	13.2
March	11.9	12.6	-5.9	13.8
April	12.9	10.4	19.4	16.4
May	22.4	12.2	45.5	12.9
June	25.9	7.2	72.2	15.2
July	12.6	12.1	4.0	13.8
August	14.2	10.4	26.8	13.3
September	11.1	12.4	-11.7	16.1
October	11.8	9.1	22.9	12.7
November	11.7	9.0	23.1	16.2
December	9.9	6.8	31.3	14.8

*Values could not be calculated because the effluent radioactivity was below the detection limit.

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

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TABLE 20

YEARLY AVERAGE GROSS BETA RADIOACTIVITY IN HANOVER PARK WRP RAW SEWAGE, FINAL EFFLUENT, AND ANAEROBICALLY DIGESTED SLUDGE FROM 1996 THROUGH 2001

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

pCi/L. The gross beta radioactivity in anaerobically digested sludge ranged from 11.8 to 14.2 pCi/g dw.

James C. Kirie WRP

In 2001, the gross alpha radioactivity levels in the raw sewage of the Kirie WRP were below the detection limit (4.0 to 6.3 pCi/L) except for the July and November samples, 7.6 pCi/L and 7.0 pCi/L respectively (Table 21). The gross alpha radioactivity in the effluent was below the detection limits (3.6 to 7.1 pCi/L, Table 21). The gross alpha radioactivity removal efficiency could not be calculated because the effluent radioactivity was below the detection limit. The gross alpha radioactivity in waste-activated sludge ranged from 3.0 to 17.1 pCi/g dw (Table 21).

The yearly average gross alpha radioactivity at the Kirie WRP raw sewage, final effluent, and waste-activated sludge from 1996 to 2001 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 12.2 to 25.4 pCi/L, and in the effluent

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TABLE 21

GROSS ALPHA RADIOACTIVITY IN JAMES C. KIRIE WRP RAW SEWAGE, FINAL EFFLUENT, AND WASTE-ACTIVATED SLUDGE, AND RADIOACTIVITY REMOVAL EFFICIENCY OF THE WRP ON A MONTHLY BASIS - 2001

Month	Raw Sewage Gross Alpha (pCi/L)	Effluent Gross Alpha (pCi/L)	Radioactivity Removal Eff. (%)	Sludge Gross Alpha (pCi/g dw)
January	<4.1	<4.3	*	3.0
February	<4.0	<3.8	*	6.4
March	<4.5	<5.4	*	5.1
April	<4.4	<4.4	*	6.3
May	<5.1	<7.1	*	9.6
June	<5.1	<5.4	*	8.5
July	7.6	<4.6	*	10.5
August	<6.3	<5.3	*	17.1
September	<5.7	<3.6	*	11.4
October	<4.9	<5.2	*	14.8
November	7.0	<5.9	*	10.5
December	<4.6	<4.3	*	6.8

*Values could not be calculated because the effluent radioactivity was below the detection limit.

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

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TABLE 22

YEARLY AVERAGE GROSS ALPHA RADIOACTIVITY IN JAMES C. KIRIE WRP RAW SEWAGE, FINAL EFFLUENT, AND WASTE-ACTIVATED SLUDGE FROM 1996 THROUGH 2001

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

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

it ranged from 10.7 to 16.8 pCi/L (Table 23). The gross beta radioactivity removal efficiency of the Kirie WRP ranged from -1.4 to 57.9 percent (Table 23). The gross beta radioactivity in Kirie WRP waste-activated sludge ranged from 10.3 to 19.7 pCi/g dw (Table 23).

The yearly average gross beta radioactivity at the Kirie WRP raw sewage, final effluent, and waste-activated sludge from 1996 to 2001 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 13.5 to 16.8 pCi/g dw.

Lemont WRP

In 2001, the gross alpha radioactivity levels in the raw sewage of the Lemont WRP ranged from 15.8 to 69.7 pCi/L (Table 25). The gross alpha radioactivity in the effluent ranged from below the detection limit (5.7 pCi/L) to 19.1 pCi/L (Table 25). The gross alpha radioactivity in the waste-activated sludge ranged from 81.4 to 180.5 pCi/g dw (Table 25).

The yearly average gross alpha radioactivity at the Lemont WRP raw sewage, final effluent, and waste-activated sludge from 1996 to 2001 are summarized in Table 26. The gross alpha radioactivity in the raw sewage ranged from 13.4

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TABLE 23

GROSS BETA RADIOACTIVITY IN JAMES C. KIRIE WRP RAW SEWAGE, FINAL EFFLUENT, AND WASTE-ACTIVATED SLUDGE, AND RADIOACTIVITY REMOVAL EFFICIENCY OF THE WRP ON A MONTHLY BASIS - 2001

Month	Raw Sewage Gross Beta (pCi/L)	Effluent Gross Beta (pCi/L)	Radioactivity Removal Eff. (%)	Sludge Gross Beta (pCi/g dw)
January	25.4	10.7	57.9	10.3
February	15.9	10.7	32.7	17.3
March	15.8	15.3	3.2	16.9
April	17.8	13.6	23.6	17.0
May	21.4	12.8	40.2	13.9
June	18.9	13.5	28.6	15.4
July	18.4	16.8	8.7	11.4
August	20.7	13.4	35.3	19.7
September	13.9	14.1	-1.4	17.7
October	12.2	11.6	4.9	17.8
November	16.9	15.4	8.9	17.8
December	14.2	11.2	21.1	14.6

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TABLE 24

YEARLY AVERAGE GROSS BETA RADIOACTIVITY IN JAMES C. KIRIE WRP RAW SEWAGE, FINAL EFFLUENT, AND WASTE-ACTIVATED SLUDGE FROM 1996 THROUGH 2001

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

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TABLE 25

GROSS ALPHA RADIOACTIVITY IN LEMONT WRP RAW SEWAGE, FINAL EFFLUENT, AND WASTE-ACTIVATED SLUDGE, AND RADIOACTIVITY REMOVAL EFFICIENCY OF THE WRP ON A MONTHLY BASIS - 2001

Month	Raw Sewage Gross Alpha (pCi/L)	Effluent Gross Alpha (pCi/L)	Radioactivity Removal Eff. (%)	Sludge Gross Alpha (pCi/g dw)
January	24.0	< 7.1	*	81.4
February	31.1	< 5.9	*	171.1
March	28.3	< 7.9	*	86.4
April	15.8	< 6.8	*	134.6
May	27.2	< 7.5	*	130.8
June	28.2	< 5.7	*	152.0
July	30.1	8.2	72.8	135.1
August	42.7	<6.4	*	180.5
September	44.5	19.1	57.1	145.8
October	27.3	11.0	59.7	170.6
November	30.6	<12.1	*	173.6
December	69.7	<11.8	*	130.9

*Values could not be calculated because the effluent radioactivity was below the detection limit.

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

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TABLE 26

YEARLY AVERAGE GROSS ALPHA RADIOACTIVITY IN LEMONT WRP RAW SEWAGE, FINAL EFFLUENT, AND WASTE-ACTIVATED SLUDGE FROM 1996 TO 2001

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

to 44.4 pCi/L. The gross alpha radioactivity in the effluent was below the detection limit (5.0 to 9.1 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 32.7 to 81.7 pCi/L, and in the effluent it ranged from 11.7 to 28.5 pCi/L (Table 27). The gross beta radioactivity removal efficiency of the Lemont WRP ranged from 19.3 to 74.7 percent. The gross beta radioactivity in Lemont waste-activated sludge ranged from 56.2 to 149.7 pCi/g dw (Table 27).

The yearly average gross beta radioactivity at the Lemont WRP raw sewage, final effluent, and waste-activated sludge from 1996 to 2001 are summarized in Table 28. The gross beta radioactivity in the raw sewage ranged from 26.6 to 66.0 pCi/L and in the effluent it ranged from 13.4 to 22.3 pCi/L. The gross beta radioactivity in waste-activated sludge ranged from 73.4 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 sludge for 2001.

Average gross alpha radioactivity in Hanover Park WRP East lagooned sludge was 13.6 pCi/g dw and ranged from 12.2 to

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TABLE 27

GROSS BETA RADIOACTIVITY IN LEMONT WRP RAW SEWAGE, FINAL EFFLUENT, AND WASTE-ACTIVATED SLUDGE, AND RADIOACTIVITY REMOVAL EFFICIENCY OF THE WRP ON A MONTHLY BASIS - 2001

Month	Raw Sewage Gross Beta (pCi/L)	Effluent Gross Beta (pCi/L)	Radioactivity Removal Eff. (%)	Sludge Gross Beta (pCi/g dw)
January	81.7	25.2	69.2	106.4
February	67.0	22.8	66.0	149.7
March	43.8	25.9	40.9	90.0
April	41.3	21.1	48.9	58.0
May	45.3	21.4	52.8	61.3
June	59.4	15.0	74.7	73.8
July	38.4	25.4	33.8	56.2
August	41.2	11.7	71.6	105.7
September	44.2	28.5	35.5	77.6
October	51.9	23.0	55.7	112.1
November	32.7	26.4	19.3	89.3
December	52.6	20.6	60.8	108.6

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TABLE 28

YEARLY AVERAGE GROSS BETA RADIOACTIVITY IN LEMONT WRP RAW SEWAGE, FINAL EFFLUENT, AND WASTE-ACTIVATED SLUDGE FROM 1996 THROUGH 2001

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

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TABLE 29

GROSS ALPHA AND GROSS BETA RADIOACTIVITY IN HANOVER PARK WRP LAGOONED SLUDGE - 2001

Lagoon Location	No. of Samples	Gross Alpha (pCi/g dw)			Gross Beta (pCi/g dw)		
		Average	Minimum	Maximum	Average	Minimum	Maximum
East	3	13.6	12.2	14.8	13.6	13.3	13.7
West	3	13.2	11.3	15.3	14.8	14.4	15.5

14.8 pCi/g dw. Average gross alpha radioactivity in Hanover Park WRP West lagooned sludge was 13.2 pCi/g dw and ranged from 11.3 to 15.3 pCi/g dw.

Average gross beta radioactivity in Hanover Park WRP East lagooned sludge was 13.6 pCi/g dw and ranged from 13.3 to 13.7 pCi/g dw. Average gross beta radioactivity in Hanover Park WRP West lagooned sludge was 14.8 pCi/g dw and ranged from 14.4 to 15.5 pCi/g dw.

The yearly average gross alpha radioactivity in Hanover Park WRP lagooned sludge from 1998 to 2001 is summarized in Table 30. The gross alpha radioactivity in the lagooned sludge ranged from 4.6 pCi/g dw at Hanover Park WRP West lagoon in 1999 to 13.6 pCi/g dw at Hanover Park WRP East lagoon in 2001.

The yearly average gross beta radioactivity in the Hanover Park WRP lagooned sludge from 1998 to 2001 is summarized in Table 31. The gross beta radioactivity in lagooned sludge ranged from 13.6 pCi/g dw at Hanover Park WRP East in 2001 to 18.1 pCi/g dw at Hanover Park WRP West 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 2001.

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TABLE 30

YEARLY AVERAGE GROSS ALPHA RADIOACTIVITY IN HANOVER PARK WRP LAGOONED SLUDGE - FROM 1998 THROUGH 2001

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

N/A = Not available

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE 31

YEARLY AVERAGE GROSS BETA RADIOACTIVITY IN HANOVER PARK WRP LAGOONED SLUDGE - FROM 1998 THROUGH 2001

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

N/A = Not available

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TABLE 32

GROSS ALPHA AND GROSS BETA RADIOACTIVITY IN DISTRICT BIOSOLIDS - 2001

Sample Location	No. of Samples	Gross Alpha (pCi/g dw)			Gross Beta (pCi/g dw)		
		Average	Minimum	Maximum	Average	Minimum	Maximum
LASMA	5	17.5	15.4	20.2	25.8	23.0	28.2
Calumet East	5	13.1	9.1	16.4	23.4	12.0	26.1
Calumet West	5	17.6	13.5	20.9	21.0	17.1	24.4
HASMA	5	16.4	11.1	21.5	25.0	21.3	27.8
Marathon	5	17.5	14.9	21.6	24.2	22.7	25.6
Stony Island	5	15.2	11.9	20.1	25.0	22.1	27.7
Vulcan	5	15.8	10.7	20.4	23.2	17.5	28.3
RASMA	5	17.7	15.7	19.0	26.7	24.6	29.0

Average gross alpha radioactivity in biosolids ranged from 13.1 pCi/g dw at the Calumet East drying site to 17.7 pCi/g dw at the RASMA drying site. Average gross beta radioactivity in biosolids ranged from 21.0 pCi/g dw at the Calumet West drying site to 26.7 pCi/g dw at the RASMA drying site.

The yearly average gross alpha radioactivity in the District's biosolids from 1996 to 2001 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 17.7 pCi/g dw at RASMA drying site in 2001.

The yearly average gross beta radioactivity in the District's biosolids from 1996 to 2001 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 2001, 20 sludge samples from five WRPs, 40 biosolids samples from eight solids drying sites, and 2 biosolids samples from Hanover Park WRP lagoons were analyzed for gamma-emitting radionuclides. The following is a list of radionuclides monitored:

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TABLE 33

YEARLY AVERAGE GROSS ALPHA RADIOACTIVITY IN DISTRICT BIOSOLIDS
FROM 1996 THROUGH 2001

	Gross Alpha Radioactivity (pCi/g dw)							
Year	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

N/A = Not available

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TABLE 34

YEARLY AVERAGE GROSS BETA RADIOACTIVITY IN DISTRICT BIOSOLIDS
FROM 1996 THROUGH 2001

	Gross Beta Radioactivity (pCi/g dw)							
Year	Calumet East	Calumet West	LASMA	HASMA	Marathon	Stony Island	Vulcan	RASMA
1996	NA	NA	23.0	23.8	27.5	22.5	22.4	24.2
1997	NA	NA	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

NA = Not available

Beryllium-7	Silver-108M	Europium-155
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	Actinum-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 from the District WRPs for 2001. Average potassium-40 radioactivity ranged from 5.2 pCi/g dw at the Hanover Park WRP to 11.0 pCi/g dw at the Stickney WRP. Average radium-226 radioactivity ranged from 3.5 pCi/g dw at Stickney WRP to 86.8 pCi/g dw at the Lemont WRP. Average cesium-137 radioactivity was 0.06 pCi/g at the Calumet WRP and 0.07 pCi/g dw at the Stickney WRP. Cesium-137 was not detected at Hanover Park, Egan, and Lemont WRPs. Average beryllium-7 radioactivity ranged from non-detected at Hanover Park WRP to 12.8 pCi/g dw at Stickney WRP. Average bismuth-212, lead 212, bismuth-214, lead-214, and actinium-228 radioactivity

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TABLE 35

CONCENTRATION OF GAMMA-EMITTING RADIONUCLIDES IN WRP SLUDGES - 2001

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	5	8.5	7.1	9.3	4.8	3.9	5.5	0.06	0.04	0.08
John E. Egan	5	8.9	7.1	10.8	4.6	4.0	6.5	ND	ND	0.06
Hanover Park	5	5.2	4.0	6.4	4.3	3.2	4.7	ND	ND	ND
Stickney	5	11.0	9.8	13.3	3.5	2.0	4.0	0.07	ND	0.11
Lemont	4	9.5	8.1	12.8	86.8	68.9	119	ND	ND	ND

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE 35 (Continued)

CONCENTRATION OF GAMMA-EMITTING RADIONUCLIDES IN WRP SLUDGES - 2001

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	5	9.9	1.9	22.4	0.4	0.3	0.4	0.5	0.3	0.6
John E. Egan	5	4.8	1.0	11.6	0.4	ND	0.5	0.4	0.3	0.6
Hanover Park	5	ND	ND	2.0	ND	ND	ND	0.3	0.2	0.4
Stickney	5	12.8	3.1	20.1	0.4	ND	0.4	0.4	0.4	0.6
Lemont	4	ND	ND	8.4	6.1	4.4	8.4	6.5	4.5	8.7

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE 35 (Continued)

CONCENTRATION OF GAMMA-EMITTING RADIONUCLIDES IN WRP SLUDGES - 2001

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	5	1.6	1.3	2.2	1.8	1.4	2.4	1.4	1.1	1.7
John E. Egan	5	1.4	1.0	2.3	1.5	1.1	2.6	1.2	1.0	1.7
Hanover Park	5	1.2	0.9	1.5	1.3	1.0	1.6	1.0	0.7	1.2
Stickney	5	1.2	0.9	1.7	1.3	1.0	1.9	1.1	1.0	1.4
Lemont	4	40.5	32.6	60.3	44.7	35.6	67.6	27.9	2.73	46.7

ND = Not detected.

at the Calumet, Egan, Hanover Park, and Stickney WRPs was relatively low, and ranged from not detected to 1.8 pCi/g dw. At the Lemont WRP bismuth-212 radioactivity was 6.1 pCi/g dw, lead-212 was 6.5 pCi/g dw, bismuth-214 was 40.5 pCi/g dw, lead-214 was 44.7 pCi/g dw, and actinium-228 was 27.9 pCi/g dw. These radionuclides are the decay products of either naturally occurring uranium or thorium.

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 wastewater treatment process is concentrated in sludge. The Lemont WRP does not have sludge treatment facilities, and it is transported by truck to either the Calumet or Stickney WRP to be treated at these facilities.

The yearly average potassium-40, radium-226, and cesium-137 radioactivity in District's WRPs sludges from 1997 to 2001 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 Hanover Park in 1997 to 11.7 pCi/g dw at Stickney WRP in 1998. The radium-226 radioactivity in the WRP sludges,

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TABLE 36

YEARLY AVERAGE POTASIUM-40 RADIOACTIVITY IN WRP SLUDGES
FROM 1997 THROUGH 2001

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

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TABLE 37

YEARLY AVERAGE RADIUM-226 RADIOACTIVITY IN WRP SLUDGES
FROM 1997 THROUGH 2001

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

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TABLE 38

YEARLY AVERAGE CESIUM-137 RADIOACTIVITY IN WRP SLUDGES
FROM 1997 THROUGH 2001

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

ND = Not Detected

excluding Lemont WRP, ranged from 2.1 pCi/g dw at Stickney WRP in 1999 to 4.8 pCi/g dw at Calumet WRP in 2001. The radium-226 radioactivity at 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 Stickney WRP.

Table 39 presents the concentration of gamma-emitting radionuclides in Hanover Park WRP lagooned sludge for 2001. The potassium-40 radioactivity at Hanover Park WRP East and West lagoons was 4.0 and 4.2 pCi/g dw, respectively. The radium-226 radioactivity was 4.6 pCi/g dw at Hanover Park East lagoon and 5.7 pCi/g dw at Hanover West lagooned sludge. Cesium-137 radioactivity was not detected at any of the two lagooned sludge. The radioactivity concentration of other naturally occurring radionuclides ranged from not detected to 1.6 pCi/g dw.

The yearly average potassium-40, radium-226, and cesium-137 radioactivity in Hanover Park WRP lagooned sludge from 1998 to 2001 is summarized in Table 40. The yearly average potassium-40 radioactivity at Hanover Park East lagoon ranged from 4.0 to 5.0 pCi/g dw. The radium-226 radioactivity ranged from 4.4 to 5.2 pCi/g dw, and cesium-137 radioactivity ranged from non-detectable levels to 0.2 pCi/g dw.

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE 39

CONCENTRATION OF GAMMA-EMITTING RADIONCULIDES IN HANOVER PARK WRP LAGOONED SLUDGE - 2001

Radionuclides	No. of Samples	Hanover Park East Lagoon	Hanover Park West Lagoon
Beryllium-7	2	ND	ND
Potassium-40	2	4.0	4.2
Cesium-137	2	ND	ND
Bismuth-212	2	ND	ND
Lead-212	2	0.4	0.5
Bismuth-214	2	0.6	1.5
Lead-214	2	0.7	1.6
Radium-226	2	4.6	5.7
Actinium-228	2	0.9	1.1

ND = Not Detected

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TABLE 40

YEARLY AVERAGE POTASSIUM-40, RADIUM-226, AND CESIUM-137 RADIOACTIVITY
IN HANOVER PARK WRP LAGOONED SLUDGE
FROM 1998 THROUGH 2001

	Hanover Park WRP East Lagoon			Hanover Park WRP West Lagoon		
Year	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

ND = Not Detected
NA = No analysis

The yearly average potassium-40 radioactivity at Hanover Park West lagooned sludge ranged from 4.2 to 4.8 pCi/g dw, radium-226 radioactivity ranged from 4.2 to 5.7 pCi/g dw, and cesium-137 radioactivity ranged from non-detectable to 0.3 pCi/g dw.

Table 41 presents the concentration of gamma-emitting radionuclides in the District's biosolids collected from 8 solids drying sites in 2001. The average potassium-40 radioactivity ranged from 7.4 pCi/g dw in Calumet West biosolids to 11.3 pCi/g dw in RASMA and Vulcan biosolids. The overall concentration range of potasium-40 for District's biosolids was 3.4 to 13.8 pCi/g dw. The average cesium-137 radioactivity ranged from 0.06 pCi/g dw in Calumet East biosolids to 0.09 pCi/g dw in Stony Island, LASMA, and Marathon biosolids. The overall concentration range of cesium-137 radioactivity for the District's biosolids was from non-detectable levels to 0.11 pCi/g dw. The average radium-226 radioactivity ranged from 3.6 pCi/g dw in HASMA biosolids to 5.2 pCi/g dw in Calumet West biosolids. The overall concentration range of radium-226 for the District's biosolids was from non-detectable levels to 5.9 pCi/g dw. Average beryllium-7 radioactivity was not detected at Calumet West, RASMA, HASMA, LASMA, Marathon, and Vulcan drying sites, and ranged from 2.2 to 6.8 pCi/g dw at the Calumet East drying site, and 4.1 to 8.1 pCi/g dw at

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TABLE 41

CONCENTRATION OF GAMMA-EMITTING RADIONUCLIDES IN DISTRICT BIOSOLIDS - 2001

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	10.4	3.4	13.8	4.6	3.5	5.6	0.06	ND	0.08
Calumet West	5	7.4	6.6	8.1	5.2	4.7	5.9	0.08	0.06	0.10
RASMA	5	11.3	9.4	12.3	3.8	ND	4.9	0.08	0.07	0.10
Stony Island	5	8.9	8.2	9.6	4.4	3.8	4.9	0.09	0.06	0.10
HASMA	5	11.1	9.6	12.4	3.6	2.2	4.4	0.07	0.05	0.09
LASMA	5	9.9	8.9	10.7	3.9	1.8	4.8	0.09	0.07	0.10
Marathon	5	10.3	9.8	11.0	4.3	4.0	4.5	0.09	0.07	0.11
Vulcan	5	11.3	9.8	13.8	4.0	3.7	4.3	0.07	0.05	0.09

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE 41 (Continued)

CONCENTRATION OF GAMMA-EMITTING RADIONUCLIDES IN DISTRICT BIOSOLIDS - 2001

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	2.2	ND	6.8	0.6	ND	0.7	0.8	0.2	1.0
Calumet West	5	ND	ND	0.5	0.6	0.5	0.7	0.8	0.0	1.0
RASMA	5	ND	ND	1.0	0.5	0.4	0.7	0.8	0.7	0.9
Stony Island	5	4.1	ND	8.1	0.4	0.4	0.5	0.6	0.5	0.6
HASMA	5	ND	ND	0.5	0.5	0.4	0.5	0.8	0.6	0.8
LASMA	5	ND	ND	ND	0.6	0.5	0.6	0.8	0.6	1.0
Marathon	5	ND	ND	ND	0.5	0.4	0.6	0.8	0.7	0.8
Vulcan	5	ND	ND	ND	0.5	0.4	0.6	0.7	0.7	0.8

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE 41 (Continued)

CONCENTRATION OF GAMMA-EMITTING RADIONUCLIDES IN DISTRICT BIOSOLIDS - 2001

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	1.5	0.8	2.1	1.6	0.9	2.3	1.0	0.9	1.1
Calumet West	5	1.6	1.3	2.1	1.9	1.5	2.3	1.0	0.9	1.1
RASMA	5	1.4	1.1	1.7	1.5	1.2	1.9	0.9	0.9	1.0
Stony Island	5	1.3	0.9	1.6	1.4	1.0	1.8	1.1	0.9	1.2
HASMA	5	1.2	0.9	1.6	1.4	1.0	1.9	0.9	0.8	1.0
LASMA	5	1.5	1.1	1.8	1.6	1.3	2.0	0.9	0.9	1.0
Marathon	5	1.3	1.1	1.6	1.5	1.3	1.8	0.8	0.8	1.0
Vulcan	5	1.2	0.9	1.4	1.3	1.0	1.5	0.8	0.8	0.9

ND = Not Detected.

the Stony Island drying site. Average bismuth-212, lead-212, bimuth-214, lead-214, and actinium-228 radioactivity ranged from 0.4 to 1.9 pCi/g dw.

The yearly average potassium-40, radium-226, and cesium-137 radioactivity in the District's biosolids from 1996 to 2001 are summarized in Tables 42, 43, and 44, respectively. The potassium-40 radioactivity in the biosolids ranged from 7.0 pCi/d dw at Calumet West drying site in 1996 to 12.4 pCi/g at Vulcan drying site in 1999. The radium-226 radioactivity in the biosolids ranged from 2.9 pCi/g dw at Vulcan drying site in 1999 to 5.2 pCi/g dw at Calumet West drying site in 2001. The cesium-137 radioactivity in biosolids ranged from 0.06 pCi/g dw at Calumet East drying site in 2001 to 0.6 pCi/g dw at Stony Island drying site in 1996.

Although the current Part 503 Sewage Sludge Regulations do not include a radioactivity limit, the USEPA is currently working on the standards for radioactivity in biosolids.

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE 42

YEARLY AVERAGE POTASIUM-40 RADIOACTIVITY IN BIOSOLIDS
FROM 1996 THROUGH 2001

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

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE 43

YEARLY AVERAGE RADIUM-226 RADIOACTIVITY IN BIOSOLIDS
FROM 1996 THROUGH 2001

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

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE 44

YEARLY AVERAGE CESIUM-137 RADIOACTIVITY IN BIOSOLIDS
FROM 1996 THROUGH 2001

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

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