Protecting Our Water Environment

Metropolitan Water Reclamation District of Greater Chicago

RESEARCH AND DEVELOPMENT DEPARTMENT

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

2000 ANNUAL REPORT

December 2001

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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 Department of Nuclear Safety (IDNS). In Illinois, hospitals, industries, research organizations, and other radioactive material license holders are allowed 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. 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, anaerobic digester draw 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 also conducted to develop baseline data on radioactivity occurring in the District's sewage sludge and biosolids.

Weekly samples of raw sewage and monthly samples of final effluent were collected from the District's seven WRPs. Sewage sludge samples were collected on a monthly basis from all the WRPs. 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 2000. The raw sewage, final effluent, waste activated sludge, and anaerobically digested sludge samples from the WRPs were analyzed for gross alpha and gross beta radioactivity. Biosolids samples from the District's solids drying areas were also analyzed for gross alpha and gross beta radioactivity.

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 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 limits for gross alpha radioactivity (excluding radon and uranium) are 15 pCi/L and for gross beta radioactivity (excluding naturally occurring potassium-40) are 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. Hence, 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 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 9.2 to 12.1 pCi/g dw and 26.3 to 30.2 pCi/g dw, respectively.

Samples of the anaerobically digested sludge draw from four WRPs (Calumet, John E. Egan [Egan], Hanover Park, and Stickney), waste-activated sludge from the Lemont WRP, and biosolids samples from the solids drying areas were further analyzed for 21 specific radionuclides by gamma spectroscopy. Of these, only potassim-40, radium-226, and cesium-137 were detected in measurable quantities in these samples. Two of these radionuclides, potassium-40 and radium-226, are of natural origin. The third radionuclide, cesium-137, is a man-made radionuclide.

Average potassium-40 radioactivity in the WRP sludge samples ranged from 4.1 to 10.4 pCi/g dw, radium-226 radioactivity ranged from 4.0 to 80.2 pCi/g dw, and cesium-137 radioactivity ranged from not detectable to 0.08 pCi/g dw.

Average potassium-40 and radium-226 radioactivity in all biosolids samples taken from the District sludge drying areas ranged from 9.4 to 10.4 pCi/g dw and 3.4 to 4.4 pCi/g dw, respectively. The average cesium-137 radioactivity ranged from 0.08 to 0.11 pCi/g dw. Currently, there are no USEPA standards for radioactivity in biosolids.

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 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 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 land application or landfilling of biosolids (final sludge product destined for disposal) 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 radiological characteristics of its biosolids to be prepared to address any future revision of the regulatory limits on gamma-emitting radionuclides.

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 digester draw and biosolids samples are also reported.

MATERIALS AND METHODS

Sample Collection

RAW SEWAGE

Composite samples of raw sewage were collected on a weekly basis 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 week 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.

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

RAW SEWAGE AND FINAL EFFLUENT

Gross alpha and gross beta radioactivity concentrations in the samples were determined using Standard Methods for the Examination of Water and Wastewater, 1998, (Standard Methods) procedures.

A known volume of a thoroughly mixed sample was transferred to a tared evaporating dish. Methyl orange indicator solution (1 to 2 drops) was added to it. Drops of nitric acid (1N) were added until the indicator color changed to pink. The sample was evaporated on a hot plate at low heat to about 5 to 10 ml. It was then transferred quantitatively 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.

SLUDGE AND BIOSOLIDS

Gross alpha and gross beta radioactivity concentrations in the samples were determined using Standard Methods 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.

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 and weighed. 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 energy and efficiency calibration of the system was verified before the sample was counted using a National Institute of Standards and Technology (NIST) traceable standard.

Calculations

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

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

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 (%) =

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

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. 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 2000, the gross alpha radioactivity levels in the raw sewage of the Stickney WRP was below the detection limit (4.1 to 6.1 pCi/L, Table 1). The gross alpha radioactivity in the effluent was also below the detection limit (3.1 to 6.8 pCi/L, Table 1). The gross alpha radioactivity in anaerobically digested sludge ranged from 5.6 to 10.9 pCi/g dw (Table 1). The gross alpha radioactivity removal efficiency values could not be calculated because the effluent radioactivity was below the detection limits. The gross beta radioactivity levels in the raw sewage of the Stickney WRP ranged from 13.5 to 38.7 pCi/L, and in the effluent it ranged from below the detection limit (6.5 pCi/L) to 15.7 pCi/L (Table 2). The gross beta radioactivity removal efficiency of the Stickney WRP ranged from 36.3 to 76.1 percent. The gross beta radioactivity in anaerobically digested sludge ranged from 21.5 to 31.9 pCi/g dw (Table 2).

Calumet WRP

In 2000, gross alpha radioactivity levels in the raw sewage of the Calumet WRP were below the detection limit (3.7 to 5.7 pCi/L, Table 3). The gross alpha radioactivity in the effluent was also below the detection limit (3.2 to 6.2 pCi/L),

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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 - 2000

Month	Raw Sewage Gross Alpha (pCi/L)	Effluent Gross Alpha (pCi/L)	Radioactivity Removal Eff. (%)	Digested Sludge Gross Alpha (pCi/g dw)
January	<4.1	<3.5	*	7.3
February	<4.2	<5.6	*	5.6
March	<6.1	<5.7	*	8.4
April	<6.0	<4.7	*	7.4
May	<4.9	<3.2	*	6.1
June	<5.4	<6.8	*	6.6
July	<4.4	<5.7	*	7.4
August	<4.7	<3.1	*	10.9
September	<5.2	<4.2	*	8.6
October	5.6	<3.9	*	7.5
November	<4.4	<4.4	*	7.2
December	<5.0	<4.3	*	7.0

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

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

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TABLE 2

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 - 2000

Month	Raw Sewage Gross Beta (pCi/L)	Effluent Gross Beta (pCi/L)	Radioactivity Removal Eff. (%)	Digested Sludge Gross Beta (pCi/g dw)
January	36.7	10.4	71.7	25.9
February	31.9	15.7	50.8	21.5
March	38.7	13.4	65.4	25.6
April	33.0	<6.9	*	26.7
May	28.4	<6.6	*	31.9
June	18.6	9.4	49.5	30.8
July	13.5	8.6	36.3	28.3
August	38.3	9.6	74.9	27.8
September	23.2	<6.5	*	30.2
October	34.3	8.2	76.1	27.8
November	24.2	8.7	64.0	27.6
December	30.1	13.7	54.5	22.1

*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 95 percent confidence level (lower limit of detection).

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TABLE 3

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 - 2000

Month	Raw Sewage Gross Alpha (pCi/L)	Effluent Gross Alpha (pCi/L)	Radioactivity Removal Eff. (%)	Digested Sludge Gross Alpha (pCi/g dw)
January	<4.1	<3.5	*	8.3
February	<3.7	<5.5	*	9.7
March	<5.4	<5.8	*	7.6
April	<5.0	<4.4	*	8.5
May	<4.4	<3.2	*	7.3
June	<5.7	<6.2	*	8.8
July	<4.5	<5.3	*	8.9
August	<4.9	3.5	*	9.5
September	<4.9	<4.1	*	8.7
October	<5.3	<4.1	*	8.5
November	<3.8	<4.6	*	8.0
December	<4.7	<4.3	*	7.1

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

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

except for the August sample which was 3.5 pCi/L (Table 3). The gross alpha radioactivity in anaerobically digested sludge ranged from 7.1 to 9.7 pCi/g dw (Table 3). The gross alpha radioactivity removal efficiency value could not be calculated because the effluent or raw sewage radioactivity was below the detection limits.

The gross beta radioactivity levels in the raw sewage of the Calumet WRP ranged from 11.9 to 36.4 pCi/L, and in the effluent it ranged from 7.9 to 13.9 pCi/L (Table 4). The gross beta radioactivity removal efficiency of the Calumet WRP ranged from 11.5 to 76.1 percent. The gross beta radioactivity in Calumet WRP anaerobically digested sludge ranged from 21.4 to 29.1 pCi/g dw (Table 4).

North Side WRP

In 2000, gross alpha radioactivity level in the raw sewage of the North Side WRP was below the detection limit (3.5 to 5.0 pCi/L, Table 5). The gross alpha radioactivity in the effluent was also below the detection limits (3.1 to 5.0 pCi/L, Table 5). The gross alpha radioactivity in waste-activated sludge ranged from 3.7 to 7.1 pCi/g dw (Table 5). The gross alpha radioactivity removal efficiency values could not be calculated because the effluent radioactivity was below the detection limit.

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TABLE 4

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 - 2000

Month	Raw Sewage Gross Beta (pCi/L)	Effluent Gross Beta (pCi/L)	Radioactivity Removal Eff. (%)	Digested Sludge Gross Beta (pCi/g dw)
January	15.7	13.9	11.5	22.3
February	19.2	11.6	39.6	24.9
March	20.9	11.5	45.0	21.4
April	36.4	8.7	76.1	23.6
May	26.1	11.3	56.7	23.1
June	11.9	9.1	23.5	27.5
July	27.7	10.8	61.0	29.1
August	24.0	8.6	64.2	26.8
September	17.1	10.0	41.5	27.8
October	28.4	7.9	72.2	27.6
November	19.4	9.9	49.0	24.4
December	17.3	8.9	48.6	24.2

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TABLE 5

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 - 2000

Month	Raw Sewage Gross Alpha (pCi/L)	Effluent Gross Alpha (pCi/L)	Radioactivity Removal Eff. (%)	Waste-Activated Sludge Gross Alpha (pCi/g dw)
January	<3.5	<3.4	*	3.9
February	<4.1	<4.8	*	NS
March	<4.8	<4.3	*	4.3
April	<4.4	<4.3	*	4.4
May	<4.1	<3.1	*	5.4
June	<4.4	<4.1	*	3.7
July	<4.7	<5.0	*	3.8
August	<4.4	<3.2	*	6.9
September	<4.5	<4.5	*	7.1
October	<5.0	<4.3	*	5.3
November	<4.1	<4.6	*	4.7
December	<4.6	<4.0	*	4.2

*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 95 percent confidence level (lower limit of detection).

NS = No sample

The gross beta radioactivity levels in the raw sewage of the North Side WRP ranged from 12.9 to 27.5 pCi/L, and in the effluent it ranged from below detection limit (6.6 pCi/L) to 12.5 pCi/L (Table 6). The gross beta radioactivity removal efficiency of the North Side WRP ranged from 24.8 to 66.3 percent (Table 6). The gross beta radioactivity in North Side WRP waste-activated sludge sample ranged from 9.6 to 22.0 pCi/g dw (Table 6).

John E. Egan WRP

In 2000, the gross alpha radioactivity levels in the raw sewage of the Egan WRP were below the detection limits (3.9 to 5.0 pCi/L, Table 7). The gross alpha radioactivity in the effluent was also below the detection limits (3.1 to 5.1 pCi/L, Table 7). The gross alpha radioactivity in anaerobically digested sludge samples ranged from 5.5 to 7.8 pCi/g dw (Table 7). The gross alpha radioactivity removal efficiency values could not be calculated because the effluent radioactivity was below the detection limit.

The gross beta radioactivity levels in the raw sewage of the Egan WRP ranged from 14.4 to 29.4 pCi/L, and in the effluent it ranged from below the detection limit (6.7 pCi/L) to 16.2 pCi/L (Table 8). The gross beta radioactivity removal efficiency of the Egan WRP ranged from 26.5 to 68.7 percent.

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TABLE 6

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 - 2000

Month	Raw Sewage Gross Beta (pCi/L)	Effluent Gross Beta (pCi/L)	Radioactivity Removal Eff. (%)	Waste-Activated Sludge Gross Beta (pCi/g dw)
January	25.9	11.7	54.8	11.3
February	20.8	12.5	39.9	NS
March	22.6	<6.6	*	14.9
April	25.9	10.5	59.4	15.0
May	24.9	8.4	66.3	22.0
June	27.5	10.0	63.3	16.2
July	14.4	8.2	43.0	11.8
August	19.9	7.8	60.8	16.0
September	13.7	7.8	43.1	18.7
October	18.5	<6.8	*	14.1
November	17.8	6.9	61.2	15.0
December	12.9	9.7	24.8	9.6

*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 95 percent confidence level (lower limit of detection).

NS = No sample

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TABLE 7

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 - 2000

Month	Raw Sewage Gross Alpha (pCi/L)	Effluent Gross Alpha (pCi/L)	Radioactivity Removal Eff. (%)	Digested Sludge Gross Alpha (pCi/g dw)
January	<3.9	<3.2	*	7.6
February	<4.1	<4.6	*	6.7
March	<5.0	<4.5	*	5.5
April	<4.7	<4.4	*	5.7
May	<4.2	<3.2	*	7.4
June	<4.3	<4.3	*	6.5
July	<4.7	<5.1	*	7.5
August	<4.4	<3.1	*	7.6
September	<4.9	<4.3	*	6.7
October	<5.0	<4.5	*	6.4
November	<4.2	<4.4	*	7.8
December	<4.2	<3.9	*	7.6

*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 95 percent confidence level (lower limit of detection).

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TABLE 8

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 - 2000

Month	Raw Sewage Gross Beta (pCi/L)	Effluent Gross Beta (pCi/L)	Radioactivity Removal Eff. (%)	Digested Sludge Gross Beta (pCi/g dw)
January	25.0	16.2	35.2	26.7
February	15.4	10.6	31.2	18.8
March	24.9	13.2	47.0	19.0
April	23.2	<6.7	*	20.9
May	19.1	9.6	49.7	22.4
June	19.7	12.2	38.1	23.5
July	16.6	12.2	26.5	22.7
August	24.1	8.5	64.7	19.9
September	29.4	9.2	68.7	21.6
October	19.2	11.4	40.6	20.8
November	14.4	7.0	51.4	19.4
December	18.9	10.6	43.9	19.4

*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 95 percent confidence level (lower limit of detection).

The gross beta radioactivity in anaerobically digested sludge ranged from 18.8 to 26.7 pCi/g dw.

Hanover Park WRP

In 2000, the gross alpha radioactivity levels in the raw sewage of the Hanover Park WRP were below the detection limit (3.9 to 5.5 pCi/L, Table 9). The gross alpha radioactivity in the effluent was also below the detection limits (3.1 to 5.7 pCi/L, Table 9). The gross alpha radioactivity removal efficiency could not be calculated because the effluent radioactivity was below the detection limit. The gross alpha radioactivity in anaerobically digested sludge ranged from 4.8 to 7.2 pCi/g dw (Table 9).

The gross beta radioactivity levels in the raw sewage of the Hanover Park WRP ranged from 11.9 to 21.0 pCi/L, and in the effluent it ranged from 7.1 to 12.6 pCi/L (Table 10). The gross beta radioactivity removal efficiency of the Hanover Park WRP ranged from 21.0 to 60.9 percent (Table 10). The gross beta radioactivity in the Hanover Park WRP anaerobically digested sludge ranged from 11.9 to 15.2 pCi/g dw (Table 10).

James C. Kirie WRP

In 2000, the gross alpha radioactivity levels in the raw sewage of the Kirie WRP were below the detection limit (3.7 to

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TABLE 9

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 - 2000

Month	Raw Sewage Gross Alpha (pCi/L)	Effluent Gross Alpha (pCi/L)	Radioactivity Removal Eff. (%)	Sludge Gross Alpha (pCi/g dw)
January	<3.9	<3.4	*	5.5
February	<4.3	<4.5	*	5.0
March	<4.8	<4.4	*	6.2
April	<4.6	<4.4	*	4.8
May	<4.2	<3.2	*	6.5
June	<4.8	<4.2	*	5.4
July	<4.5	<5.7	*	6.2
August	<4.5	<3.1	*	7.2
September	<5.1	<4.4	*	5.7
October	<5.5	<4.3	*	5.8
November	<4.3	<4.4	*	5.0
December	<4.3	<3.9	*	5.4

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

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

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TABLE 10

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 - 2000

Month	Raw Sewage Gross Beta (pCi/L)	Effluent Gross Beta (pCi/L)	Radioactivity Removal Eff. (%)	Sludge Gross Beta (pCi/g dw)
January	17.0	12.6	25.9	13.5
February	19.4	12.1	37.6	11.9
March	19.2	7.5	60.9	13.5
April	13.5	8.8	34.8	13.6
May	21.0	12.0	42.8	14.6
June	12.1	8.0	33.9	15.2
July	13.8	8.4	39.1	14.2
August	14.7	10.4	29.2	15.2
September	14.0	7.1	49.3	14.1
October	19.2	7.6	60.4	14.3
November	17.4	10.2	41.4	13.7
December	11.9	9.4	21.0	12.2

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

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

5.2 pCi/L, Table 11). The gross alpha radioactivity in the effluent was below the detection limits (4.0 to 5.7 pCi/L) except for the May and August samples which were 3.8 and 3.7 pCi/L, respectively (Table 11). The gross alpha radioactivity in waste-activated sludge ranged from 3.3 to 6.9 pCi/g dw (Table 11).

The gross beta radioactivity level in the raw sewage of Kirie WRP ranged from 18.2 to 29.2 pCi/L, and in the effluent it ranged from 11.7 to 20.8 pCi/L (Table 12). The gross beta radioactivity removal efficiency of the Kirie WRP ranged from 2.9 to 48.6 percent (Table 12). The gross beta radioactivity in Kirie WRP waste-activated sludge ranged from 8.1 to 21.6 pCi/g dw (Table 12).

Lemont WRP

In 2000, the gross alpha radioactivity levels in the raw sewage of the Lemont WRP ranged from 14.3 to 132.6 pCi/L (Table 13). The gross alpha radioactivity in the effluent was below the detection limit (5.3 to 11.3 pCi/L, Table 13). The gross alpha radioactivity in the waste-activated sludge ranged from 79.9 to 131.0 pCi/g dw (Table 13).

The gross beta radioactivity levels in the raw sewage of the Lemont WRP ranged from 34.4 to 159.2 pCi/L, and in the effluent it ranged from 14.8 to 30.4 pCi/L (Table 14). The gross

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TABLE 11

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 - 2000

Month	Raw Sewage Gross Alpha (pCi/L)	Effluent Gross Alpha (pCi/L)	Radioactivity Removal Eff. (%)	Sludge Gross Alpha (pCi/g dw)
January	<3.7	<4.0	*	5.0
February	<4.0	<4.6	*	3.8
March	<5.0	<4.8	*	4.5
April	<4.7	<4.6	*	4.4
May	<4.2	3.8	*	4.1
June	<4.4	<4.3	*	4.6
July	<4.9	<5.7	*	6.9
August	<5.2	3.7	*	5.8
September	<4.9	<4.6	*	6.4
October	<5.2	<4.5	*	3.5
November	<4.6	<5.1	*	5.1
December	<4.6	<4.2	*	3.3

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

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

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TABLE 12

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 - 2000

Month	Raw Sewage Gross Beta (pCi/L)	Effluent Gross Beta (pCi/L)	Radioactivity Removal Eff. (%)	Sludge Gross Beta (pCi/g dw)
January	29.2	20.8	28.8	13.3
February	20.6	20.0	2.9	10.2
March	21.2	19.2	9.0	14.5
April	18.6	11.7	37.1	13.3
May	19.3	16.0	20.6	18.9
June	18.7	14.0	25.1	16.0
July	18.2	13.6	25.3	17.2
August	26.7	18.1	32.2	15.7
September	23.2	18.6	19.8	21.6
October	27.3	17.4	36.3	14.3
November	28.6	14.7	48.6	14.4
December	21.0	18.0	14.3	8.1

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE 13

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 - 2000

Month	Raw Sewage Gross Alpha (pCi/L)	Effluent Gross Alpha (pCi/L)	Radioactivity Removal Eff. (%)	Sludge Gross Alpha (pCi/g dw)
January	24.3	< 6.0	*	117.8
February	23.1	< 9.6	*	131.0
March	132.6	<10.1	*	105.8
April	24.9	< 7.5	*	92.9
May	14.3	< 5.3	*	82.6
June	16.3	<11.3	*	79.9
July	32.6	< 9.7	*	86.6
August	67.2	< 5.4	*	106.2
September	44.0	< 7.2	*	103.0
October	64.5	< 7.4	*	108.6
November	59.5	< 7.7	*	128.5
December	30.1	< 7.5	*	130.4

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

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TABLE 14

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 - 2000

Month	Raw Sewage Gross Beta (pCi/L)	Effluent Gross Beta (pCi/L)	Radioactivity Removal Eff. (%)	Sludge Gross Beta (pCi/g dw)
January	53.0	30.4	42.6	131.0
February	51.5	27.9	45.8	130.6
March	159.2	21.4	86.6	109.5
April	44.9	29.2	35.0	104.0
May	36.0	15.7	56.4	102.8
June	34.4	20.2	41.9	90.9
July	53.2	23.4	56.1	109.4
August	91.8	19.5	78.8	130.8
September	63.9	22.0	65.6	122.1
October	83.6	17.5	79.1	137.4
November	69.6	14.8	78.7	151.6
December	50.3	21.5	57.2	142.8

from 35.0 to 86.6 percent. The gross beta radioactivity in Lemont waste-activated sludge ranged from 90.9 to 151.6 pCi/g dw (Table 14).

Gross Alpha and Gross Beta Radioactivity in District Biosolids

Table 15 presents the gross alpha and gross beta radioactivity concentrations in biosolids samples analyzed from District's solids drying areas.

Average gross alpha radioactivity ranged from 9.2 pCi/g dw at the Vulcan Drying Cells to 12.1 pCi/g dw at the Calumet West and HASMA Drying Cells. Average gross beta radioactivity ranged from 26.3 pCi/g dw at the Vulcan Drying Cells to 30.2 pCi/g dw at the RASMA Drying Cells.

Gamma Radioactivity in District WRP Sludges and Biosolids

In 2000, 19 sludge samples from five WRPs, and 40 biosolids samples from eight solids drying sites were analyzed for gamma-emitting radionuclides. The following is a list of radionuclides monitored:

Sodium-22	Silver-110m	Niobium-94
Potassium-40	Cesium-134	Gadolinium-153
Cobalt-57	Cesium-137	Bismuth-207
Cobalt-60	Antimony-125	Radium-226
Manganese-54	Zinc-65	Ruthenium-106

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE 15

GROSS ALPHA AND GROSS BETA RADIOACTIVITY IN DISTRICT BIOSOLIDS - 2000

Sample Location	No. of Samples	Gross Alpha (pCi/g dw)			Gross Beta (pCi/g dw)		
		Average	Minimum	Maximum	Average	Minimum	Maximum
LASMA	5	9.8	7.3	11.9	28.0	25.7	31.3
Calumet East	5	10.3	8.7	11.5	27.5	23.5	30.7
Calumet West	5	12.1	8.7	14.5	27.1	24.6	31.0
HASMA	5	12.1	8.8	14.2	27.6	26.8	28.8
Marathon	5	11.7	10.1	14.2	29.7	29.2	30.6
Stony Island	5	10.5	7.9	13.8	28.6	26.5	30.6
Vulcan	5	9.2	6.8	10.4	26.3	24.2	28.0
RASMA	5	11.4	9.7	13.6	30.2	28.8	33.6

Cerium-144	Protactinium-231	Europium-155
Silver-108m	Europium-152	Europium-154

Of the 21 radionuclides analyzed, only 3 (potassium-40, radium-226, and cesium-137) were detected at measurable levels. Of these 3 radionuclides, potassium-40 and radium-226 are of natural origin, and cesium-137 is a man-made radionuclide.

The results of the analysis for gamma-emitting radionuclides on sludge samples from WRPs and biosolids samples from drying areas are presented in Table 16 and 17, respectively.

Table 16 presents the concentrations of gamma-emitting radionuclides in the sludge from the District WRPs. Average potassium-40 radioactivity ranged from 4.1 pCi/g dw at the Hanover Park WRP to 10.4 pCi/g dw at the Stickney WRP. Average radium-226 radioactivity ranged from 4.0 pCi/g dw at Stickney WRP to 80.2 pCi/g dw at the Lemont WRP. Average cesium-137 radioactivity was 0.06 pCi/g at the Calumet WRP, and 0.08 pCi/g dw at the Stickney WRP. Cesium-137 was not detected at Hanover Park, Egan, and Lemont WRPs.

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

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TABLE 16

CONCENTRATION OF GAMMA-EMITTING RADIONUCLIDES IN WRP SLUDGES - 2000

Sample Location WRP	No. of Samples	Potassium-40 (pCi/g dw)			Radium-226 (pCi/g dw)			Cesium-137 (pCi/g dw)		
		Average	Min.	Max.	Average	Min.	Max.	Average	Min.	Max.
Calumet	3	7.6	7.1	8.0	4.6	4.4	4.8	0.06	0.05	0.07
John E. Egan	4	8.1	7.2	9.1	4.3	4.0	4.5	ND	ND	ND
Hanover Park	4	4.1	3.8	4.5	4.4	4.2	4.5	ND	ND	ND
Stickney	4	10.4	9.9	10.9	4.0	3.6	4.2	0.08	0.06	0.10
Lemont	4	8.5	7.8	9.8	80.2	69.2	97.3	ND	ND	ND

ND = Not detected.

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE 17

CONCENTRATION OF GAMMA-EMITTING RADIONUCLIDES IN DISTRICT BIOSOLIDS - 2000

Samples 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	8.4	12.3	3.4	1.5	4.4	0.09	0.08	0.11
Calumet West	5	9.9	5.5	15.3	4.4	3.9	4.9	0.08	0.06	0.10
RASMA	5	10.4	9.5	11.3	3.5	0.8	4.4	0.10	0.09	0.11
Stony Island	5	10.3	8.9	12.4	3.6	1.9	4.4	0.09	0.08	0.11
HASMA	5	9.6	8.8	10.4	4.0	3.6	4.3	0.11	0.08	0.15
LASMA	5	9.4	9.0	10.2	3.5	1.1	4.2	0.10	0.08	0.12
Marathon	5	10.2	8.9	11.6	3.7	1.7	4.5	0.09	0.08	0.11
Vulcan	5	10.0	8.9	11.1	4.0	3.6	4.6	0.09	0.08	0.10

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 discharged to either the Calumet or Stickney WRP to be treated at these facilities.

Table 17 presents concentrations of gamma-emitting radionuclides in the District's biosolids. The average potassium-40 activity ranged from 9.4 pCi/g dw in LASMA biosolids to 10.4 pCi/g dw in Calumet East and RASMA biosolids. The overall concentration range of potasium-40 for District's biosolids was 5.5 to 15.3 pCi/g. The average cesium-137 radioactivity ranged from 0.08 pCi/g dw in Calumet West biosolids to 0.11 pCi/g dw in HASMA biosolids. The overall concentration range of cesium-137 radioactivity for District's biosolids was 0.06 to 0.15 pCi/g. Average radium-226 radioactivity ranged from 3.4 pCi/g dw in Calumet East biosolids to 4.4 pCi/g dw in Calumet West biosolids. The overall concentration range of radium-226 for District's biosolids was 0.8 to 4.9 pCi/g.

Currently, there are no USEPA standards for acceptable concentration of radionuclides in sewage sludge and biosolids.

REFERENCES

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3. State of Illinois Rules and Regulations, Title 35: Environmental Protection, Subtitle C: Water Pollution, Chapter I: Pollution Control Board, 302.207, 1999.