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

1998 ANNUAL REPORT

September 2000

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RADIOLOGICAL MONITORING OF THE RAW SEWAGE, FINAL EFFLUENT, SLUDGES, AND BIOSOLIDS OF THE METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO 1998 ANNUAL REPORT

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DISCLAIMER

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

SUMMARY AND CONCLUSIONS

The discharge of radioactive materials into sanitary sewer systems is regulated by the Nuclear Regulatory Commission (NRC). In Illinois, hospitals, industries, research organizations, and other radioactive material license holders are allowed to dispose of radionuclides into the 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 sewerage system. There have been several reported cases of radioactive contamination in wastewater treatment plants in United States over the last 20 years (1).

This study was conducted to determine the radioactivity concentration in raw sewage, final effluent, return sludge, digester draw sludge, lagooned sludge, and biosolids at the facilities owned and operated by the Metropolitan Water Reclamation District of Greater Chicago (District). The radioactivity removal efficiency by the wastewater treatment process at all the water reclamations plants (WRPs) was calculated. The radiological monitoring was conducted to develop baseline data on radioactivity occurring in the District's sewage sludge.

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. Lagooned sludge samples from the Hanover Park East and Hanover Park West lagoons were collected once per quarter. Air-dried sludge samples (biosolids) from the Calumet East, Calumet West, Ridgeland, Stony Island, HASMA, LASMA, Marathon, and Vulcan drying sites were collected monthly from May through September 1998, and were analyzed for gross alpha and gross beta radioactivity. Samples of digester draw from the WRPs and lagooned sludge from Hanover Park WRP collected once per quarter were analyzed for gamma-emitting radionuclides. Biosolids samples from the District sludge drying sites were also analyzed for gamma-emitting radionuclides.

The analytical data demonstrate that radioactivity in the final effluent of all the WRPs is generally lower than the corresponding raw sewage of the WRP. This indicates that the WRPs are removing radioactivity from the raw sewage. Analytical data also indicate that of the radioactivity removed, 2.9 percent to 87.0 percent, is concentrated in the sewage sludge.

The amount of gross alpha and gross beta radioactivity in the final effluent is less than the allowable contaminant levels in community water standards set by the United States Environmental Protection Agency (USEPA) National Primary Drinking Water Regulations, 40 CFR Part 141. The USEPA limits for gross alpha radioactivity (including radium-226, but excluding radon and uranium) are 15 pCi/L and for gross beta radioactivity 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, estab-

lished by the Illinois Pollution Control Board (IPCB), found at 35C IAC, Section 302.207. Hence, the discharge of the final effluent from the seven WRPs has no adverse effect on the radiological quality of the Chicago waterways system. There are no IPCB standards for gross alpha radioactivity in General Use waters.

Measurable concentrations of gross alpha and gross beta radioactivity were found in Hanover Park lagooned sludge. The average gross alpha radioactivity in lagooned sludge ranged from 6.2 pCi/g dry weight (dw) to 6.5 pCi/g dw. The average gross beta radioactivity in lagooned sludge ranged from 15.2 pCi/g dw to 17.2 pCi/g dw.

Measurable concentrations of gross alpha and gross beta radioactivity were found in biosolid samples from all the sludge drying sites of the District. The average gross alpha radioactivity of biosolids from these sites ranged from 7.4 pCi/g dw to 8.1 pCi/g dw. The average gross beta radioactivity of biosolids ranged from 21.8 pCi/g dw to 24.9 pCi/g dw.

Samples of digester draw sludge from four WRPs, return sludge sample from Lemont WRP, lagooned sludge from the Hanover Park WRP, and biosolid samples from sludge drying sites were further analyzed for 24 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 radio-

nuclide and may have arisen from fallout of nuclear weapons testing.

Average potassium-40 radioactivity ranged from 5.1 pCi/g dw to 11.7 pCi/g dw, radium-226 radioactivity ranged from 3.4 pCi/g dw to 55.8 pCi/g dw and cesium-137 radioactivity ranged from 0.02 pCi/g dw to 0.11 pCi/g dw in the WRP sludge samples.

Average potassium-40 radioactivity ranged from 4.4 pCi/g dw to 4.8 pCi/g dw, radium-226 radioactivity ranged from 5.1 pCi/g dw to 5.2 pCi/g dw and cesium-137 radioactivity ranged from 0.02 pCi/g dw to 0.03 pCi/g dw in Hanover Park lagooned sludge samples.

Average potassium-40 and radium-226 radioactivity ranged from 8.6 pCi/g dw to 11.7 pCi/g dw and 3.0 pCi/g dw to 4.3 pCi/g dw, respectively, and the average cesium-137 radioactivity was 0.1 pCi/g dw in all the biosolids samples taken from District sludge drying sites. Currently, there are no USEPA standards for the 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 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 Nuclear Regulatory Commission (NRC). 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. Any radioactivity discharged via the effluent to the receiving water and the potential concentration of radioactive material in municipal sludge may be of environmental concern because of landfilling and land application of biosolids (final sludge product destined for disposal) as fertilizer and soil conditioner.

The District monitors the quality of its influents, 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 sludge drying sites for gross alpha and gross beta radioactivity. Samples of digester draw sludge from four WRPs, return sludge sample from the Lemont WRP, lagooned sludge from the Hanover Park WRP and biosolids samples from the District's drying sites 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, it was felt that the District should expand its database on radiological characteristics of its biosolids as future revision of the regulations may include limits on gamma-emitting radionuclides.

This report describes 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 sludge drying sites. 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, lagooned sludge, 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, John E. Egan (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. Undigested return sludge samples were collected monthly from the Lemont, North Side, and Kirie WRPs, as these WRPs do not have digesters.

LAGOONED SLUDGE

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

BIOSOLIDS

Air-dried biosolids samples were collected from various sludge drying areas. The samples analyzed for radioactivity included biosolids from the Marathon Drying Cells, Lawndale Avenue Sludge Management Area (LASMA) Drying Cells, Vulcan Drying Cells, Harlem Avenue Sludge Management Area (HASMA) Drying Cells, Ridgeland Avenue Sludge Management Area (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 (Standard Methods 1995) procedures.

A known volume of a thoroughly mixed grab 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 SAMPLES

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) 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 to constant weight at 550°C. 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% (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 samples was determined as follows:

The sludge 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 GammaTrac software analysis

package from Oxford Instruments Inc. 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 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 influent 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 estimated on a monthly basis using the following equation:

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

where:

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

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

The 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 activity was less than the LLD, the radioactivity concentration was reported as below the detection limit.

For calculation purposes, less than lower limit of detection 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.

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 1998, the gross alpha radioactivity levels in the raw sewage of the Stickney WRP ranged from <3.4 (below the detection limit) pCi/L to 10.1 pCi/L, and in the effluent it ranged from below the detection limit (2.2 pCi/L) to 3.2 pCi/L (Table 1). The gross alpha radioactivity in anaerobically digested sludge ranged from 2.5 pCi/g dw to 7.1 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 except for September and November samples. The radioactivity removal efficiency that could be calculated for the two months only was 50 percent and 68.3 percent, respectively.

The gross beta radioactivity levels in the raw sewage of the Stickney WRP ranged from 15.6 pCi/L to 38.2 pCi/L, and in the effluent it ranged from 6.9 pCi/L to 15.0 pCi/L (Table 2). The gross beta radioactivity removal efficiency of the Stickney WRP ranged from 27.5 percent to 74.2 percent. The gross beta radioactivity in anaerobically digested sludge ranged from 11.6 pCi/g dw to 28.4 pCi/g dw (Table 2).

Calumet WRP

In 1998, gross alpha radioactivity levels in the raw sewage of the Calumet WRP ranged from below the detection limit (2.6 pCi/L) to 4.8 pCi/L, and in the effluent it ranged from below the detection limit (2.4 pCi/L) to 4.4 pCi/L (Table 3).

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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 - 1998

Month	Raw Sewage Gross Alpha (pCi/L)	Effluent Gross Alpha (pCi/L)	Radioactivity Removal Eff. (%)	Sludge Gross Alpha (pCi/g dw)
January	3.0	<2.8	*	5.6
February	3.1	<2.3	*	4.2
March	<3.4	<3.1	*	2.5
April	4.5	<2.2	*	5.2
May	4.3	<2.9	*	4.9
June	3.9	<2.8	*	4.2
July	4.1	<2.2	*	6.1
August	4.6	<2.4	*	7.1
September	4.8	2.4	50.0	6.2
October	3.4	<2.2	*	6.8
November	10.1	3.2	68.3	4.6
December	5.7	<2.3	*	4.8

*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 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 - 1998

Month	Raw Sewage Gross Beta (pCi/L)	Effluent Gross Beta (pCi/L)	Radioactivity Removal Eff. (%)	Sludge Gross Beta (pCi/g dw)
January	15.6	9.4	39.7	24.8
February	20.7	15.0	27.5	24.0
March	19.3	11.6	39.9	11.6
April	26.7	6.9	74.2	28.4
May	26.9	12.5	53.5	26.3
June	29.0	9.0	69.0	22.2
July	26.4	9.8	62.9	26.0
August	23.9	8.2	65.7	24.0
September	29.2	14.5	50.3	25.0
October	31.5	11.2	64.4	23.0
November	38.2	14.9	61.0	25.9
December	25.1	14.2	43.4	22.4

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHCAGO

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 - 1998

Month	Raw Sewage Gross Alpha (pCi/L)	Effluent Gross Alpha (pCi/L)	Radioactivity Removal Eff. (%)	Sludge Gross Alpha (pCi/g dw)
January	<2.9	<3.0	*	5.0
February	<2.6	2.6	*	5.3
March	<3.1	<3.2	*	6.1
April	4.5	<2.4	*	5.7
May	<3.2	<3.1	*	6.8
June	3.8	<2.4	*	6.9
July	4.8	4.3	10.4	8.6
August	4.3	<2.7	*	N/A
September	3.4	4.4	*	5.8
October	4.4	2.9	34.1	5.6
November	3.9	<2.5	*	6.9
December	4.5	<2.4	*	5.1

*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).

N/A = Not Available.

The gross alpha radioactivity in anaerobically digested sludge ranged from 5.0 pCi/g dw to 8.6 pCi/g dw (Table 3). The gross alpha radioactivity removal efficiency value could not be calculated because the effluent radioactivity was below the detection limits except for July and October samples. The radioactivity removal efficiency that could be calculated for the two months only was 10.4 percent and 34.1 percent, respectively.

The gross beta radioactivity levels in the raw sewage of the Calumet WRP ranged from 13.3 pCi/L to 28.6 pCi/L, and in the effluent it ranged from 9.8 pCi/L to 19.7 pCi/L (Table 4). The gross beta radioactivity removal efficiency of the Calumet WRP ranged from 10.8 percent to 58.4 percent. The gross beta radioactivity in Calumet anaerobically digested sludge ranged from 21.5 pCi/g dw to 26.3 pCi/g dw (Table 4).

North Side WRP

In 1998, gross alpha radioactivity level in the raw sewage of the North Side WRP ranged from below the detection limit (2.6 pCi/L) to 4.8 pCi/L. The gross alpha radioactivity in the effluent ranged from below the detection limits (2.2 pCi/L) to 3.3 pCi/L (Table 5). The gross alpha radioactivity in return sludge ranged from 2.2 pCi/g dw to 4.6 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 except for the June and November samples. The radio-

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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 - 1998

Month	Raw Sewage Gross Beta (pCi/L)	Effluent Gross Beta (pCi/L)	Radioactivity Removal Eff. (%)	Sludge Gross Beta (pCi/g dw)
January	13.3	10.3	22.6	21.5
February	13.6	11.4	16.2	22.5
March	13.5	14.8	*	25.4
April	18.8	10.3	45.2	25.2
May	17.1	14.0	18.1	23.2
June	22.3	13.2	40.8	24.7
July	28.6	19.7	31.1	26.3
August	18.8	9.8	47.9	N/A
September	23.8	9.9	58.4	24.1
October	21.8	15.8	27.5	23.4
November	23.0	11.2	51.3	24.9
December	19.5	17.4	10.8	21.5

*Values could not be calculated because the effluent radioactivity was higher than the influent radioactivity.
N/A = Not Available.

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TABLE 5

GROSS ALPHA RADIOACTIVITY IN NORTH SIDE WRP RAW SEWAGE, FINAL EFFLUENT, AND RETURN SLUDGE, AND RADIOACTIVITY REMOVAL EFFICIENCY OF THE WRP ON A MONTHLY BASIS - 1998

Month	Raw Sewage Gross Alpha (pCi/L)	Effluent Gross Alpha (pCi/L)	Radioactivity Removal Eff. (%)	Sludge Gross Alpha (pCi/g dw)
January	<2.6	<2.6	*	2.6
February	2.7	<2.3	*	2.6
March	<2.8	<2.9	*	2.4
April	3.0	3.2	---	3.6
May	<2.8	<3.0	*	3.5
June	3.5	3.0	14.3	3.4
July	3.4	<3.0	*	2.2
August	4.8	<2.7	*	4.6
September	3.8	<2.7	*	3.3
October	<3.2	<3.2	*	3.2
November	3.4	3.3	2.9	3.0
December	3.3	<2.2	*	2.2

*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).

activity removal efficiency that could be calculated for these months only was 14.3 percent and 2.9 percent, respectively.

The gross beta radioactivity levels in the raw sewage of the North Side WRP ranged from 13.7 pCi/L to 24.5 pCi/L, and in the effluent it ranged from 5.1 pCi/L to 11.7 pCi/L (Table 6). The gross beta radioactivity removal efficiency of the North Side WRP ranged from 19.6 percent to 74.0 percent (Table 6). The gross beta radioactivity in North Side return sludge sample ranged from 10.0 pCi/g dw to 18.9 pCi/g dw (Table 6).

John E. Egan WRP

In 1998, the gross alpha radioactivity levels in the raw sewage of the Egan WRP ranged from below the detection limit (2.9 pCi/L) to 4.4 pCi/L. The gross alpha radioactivity in the effluent ranged from below the detection limits (2.4 pCi/L) to 3.7 pCi/L (Table 7). The gross alpha radioactivity in anaerobically digested sludge samples ranged from 3.8 pCi/g dw to 6.3 pCi/g dw (Table 7). The gross alpha radioactivity removal efficiency that could only be calculated for August, September, and December ranged from 5.1 percent to 22.0 percent.

The gross beta radioactivity levels in the raw sewage of the Egan WRP ranged from 15.0 pCi/L to 23.6 pCi/L, and in the effluent it ranged from 6.7 pCi/L to 18.1 pCi/L (Table 8). The estimated gross beta radioactivity removal efficiency of the Egan WRP ranged from 8.0 percent to 67.8 percent. The gross beta radioac

TABLE 6

GROSS BETA RADIOACTIVITY IN NORTH SIDE WRP RAW SEWAGE, FINAL EFFLUENT, AND RETURN SLUDGE, AND RADIOACTIVITY REMOVAL EFFICIENCY OF THE WRP ON A MONTHLY BASIS - 1998

Month	Raw Sewage Gross Beta (pCi/L)	Effluent Gross Beta (pCi/L)	Radioactivity Removal Eff. (%)	Sludge Gross Beta (pCi/g dw)
January	13.7	10.1	26.3	12.2
February	15.4	10.1	34.4	11.1
March	14.3	11.5	19.6	11.7
April	15.8	11.0	30.4	18.9
May	20.3	10.1	50.2	15.5
June	20.7	7.8	62.3	12.8
July	24.5	11.7	52.2	15.2
August	17.7	8.9	49.9	18.1
September	16.6	8.2	23.9	17.9
October	19.6	5.1	74.0	15.3
November	20.7	10.9	47.3	13.9
December	22.2	11.7	47.3	10.0

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

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 - 1998

Month	Raw Sewage Gross Alpha (pCi/L)	Effluent Gross Alpha (pCi/L)	Radioactivity Removal Eff. (%)	Sludge Gross Alpha (pCi/g dw)
January	<2.9	<3.0	*	5.1
February	3.4	<2.5	*	5.2
March	3.1	3.3	---	4.4
April	3.6	<2.5	*	5.0
May	3.6	<3.2	*	3.8
June	4.3	<2.6	*	4.1
July	3.4	<2.7	*	5.7
August	3.9	3.7	5.1	4.9
September	4.3	3.7	12.8	4.3
October	4.0	<3.7	*	6.3
November	4.4	<2.4	*	4.4
December	4.1	3.2	22.0	4.0

*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 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 - 1998

Month	Raw Sewage Gross Beta (pCi/L)	Effluent Gross Beta (pCi/L)	Radioactivity Removal Eff. (%)	Sludge Gross Beta (pCi/g dw)
January	16.3	15.0	8.0	18.0
February	15.0	12.8	14.7	19.8
March	15.6	16.5	----	18.9
April	16.0	8.5	49.9	22.0
May	16.6	10.5	36.7	21.0
June	19.2	15.4	19.8	20.0
July	18.7	12.8	31.6	22.4
August	23.6	12.1	48.7	21.0
September	22.1	10.9	50.7	20.2
October	20.8	6.7	67.8	22.1
November	22.5	18.1	19.6	20.4
December	22.0	12.6	42.7	19.7

tivity in anaerobically digested sludge ranged from 18.0 pCi/g dw to 22.4 pCi/g dw.

Hanover Park WRP

In 1998, gross alpha radioactivity levels in the raw sewage of the Hanover Park WRP ranged from below the detection limit (2.6 pCi/L) to 5.1 pCi/L. The gross alpha radioactivity in the effluent ranged from below the detection limits (2.3 pCi/L) to 3.6 pCi/L (Table 9). The gross alpha radioactivity in anaerobically digested sludge ranged from 3.0 pCi/g dw to 5.5 pCi/g dw (Table 9). The gross alpha radioactivity removal efficiency that could only be calculated for August, September, and November ranged from 10.5 percent to 29.4 percent.

The gross beta radioactivity levels in the raw sewage of the Hanover Park WRP ranged from 12.2 pCi/L to 41.3 pCi/L, and in the effluent it ranged from 7.8 pCi/L to 12.6 pCi/L (Table 10). The estimated gross beta radioactivity removal efficiency of the Hanover Park WRP ranged from 10.6 percent to 79.9 percent (Table 10). The gross beta radioactivity in the Hanover Park WRP anaerobically digested sludge ranged from 11.2 pCi/g dw to 16.2 pCi/g dw (Table 10).

James C. Kirie WRP

In 1998, gross alpha radioactivity levels in the raw sewage of the Kirie WRP ranged from below the detection limit (2.7 pCi/L) to 5.5 pCi/L. The gross alpha radioactivity in the efflu-

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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 - 1998

Month	Raw Sewage Gross Alpha (pCi/L)	Effluent Gross Alpha (pCi/L)	Radioactivity Removal Eff. (%)	Sludge Gross Alpha (pCi/g dw)
January	<2.6	<2.8	*	3.6
February	<2.6	<2.4	*	3.9
March	2.7	<2.9	*	4.2
April	3.9	<2.8	*	4.4
May	3.0	<3.1	*	4.2
June	3.2	<2.5	*	4.9
July	3.4	<3.0	*	5.5
August	3.8	3.4	10.5	4.0
September	3.9	3.4	14.7	3.4
October	<3.7	<3.6	*	3.6
November	5.1	3.6	29.4	3.0
December	3.6	<2.3	*	3.4

*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).

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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 - 1998

Month	Raw Sewage Gross Beta (pCi/L)	Effluent Gross Beta (pCi/L)	Radioactivity Removal Eff. (%)	Sludge Gross Beta (pCi/g dw)
January	13.6	10.3	24.3	13.0
February	12.2	10.9	10.6	14.4
March	13.8	9.1	34.0	13.6
April	17.9	9.8	45.2	15.8
May	17.6	11.2	36.4	14.1
June	15.4	10.5	31.8	16.2
July	20.5	10.2	50.2	14.5
August	31.7	12.6	60.2	13.6
September	23.6	7.8	66.9	11.2
October	41.3	8.3	79.9	12.0
November	20.7	10.6	48.8	12.0
December	15.0	12.2	18.7	12.4

ent ranged from below the detection limits (2.2 pCi/L) to 3.7 pCi/L (Table 11). The gross alpha radioactivity in return sludge ranged from 1.8 pCi/g dw to 4.2 pCi/g dw (Table 11). The gross alpha radioactivity removal efficiency values could not be calculated except for June and July because the effluent radioactivity was below the detection limits in the other months. The radioactivity removal efficiency in these two months was 7.5 percent and 9.7 percent, respectively.

The gross beta radioactivity level in the raw sewage of the Kirie WRP ranged from 15.2 pCi/L to 33.5 pCi/L, and in the effluent it ranged from 7.2 pCi/L to 21.5 pCi/L (Table 12). The estimated gross beta radioactivity removal efficiency of the Kirie WRP ranged from -2.3 percent to 69.5 percent (Table 12). The gross beta radioactivity in Kirie return sludge ranged from 10.8 pCi/g dw to 16.6 pCi/g dw (Table 12).

Lemont WRP

In 1998, the gross alpha radioactivity levels in the raw sewage of the Lemont WRP ranged from 10.2 pCi/L to 32.1 pCi/L (Table 13). The gross alpha radioactivity in the effluent ranged from <4.8 pCi/L to 6.1 pCi/L (Table 13). The gross alpha radioactivity in the return sludge ranged from 31.5 pCi/g dw to 74.3 pCi/g dw (Table 13). The estimated gross alpha radioactivity removal efficiency ranged from 64.8 percent to 87.0 percent.

The gross beta radioactivity levels in the raw sewage of the Lemont WRP ranged from 26.9 pCi/L to 60.8 pCi/L, and in the ef-

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TABLE 11

GROSS ALPHA RADIOACTIVITY IN JAMES C. KIRIE WRP RAW SEWAGE, FINAL EFFLUENT, AND RETURN SLUDGE, AND RADIOACTIVITY REMOVAL EFFICIENCY OF THE WRP ON A MONTHLY BASIS - 1998

Month	Raw Sewage Gross Alpha (pCi/L)	Effluent Gross Alpha (pCi/L)	Radioactivity Removal Eff. (%)	Sludge Gross Alpha (pCi/g dw)
January	<2.7	<3.1	*	3.4
February	3.2	<2.4	*	3.4
March	3.2	<3.1	*	3.1
April	3.7	<2.8	*	1.8
May	<3.0	<3.2	*	3.4
June	4.0	3.7	7.5	4.2
July	3.1	2.8	9.7	2.8
August	3.7	<2.5	*	3.6
September	3.8	<2.2	*	3.3
October	<3.2	<3.5	*	3.7
November	5.5	<2.5	*	3.4
December	3.6	<2.4	*	2.6

*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 12

GROSS BETA RADIOACTIVITY IN JAMES C. KIRIE WRP RAW SEWAGE, FINAL EFFLUENT, AND RETURN SLUDGE, AND RADIOACTIVITY REMOVAL EFFICIENCY OF THE WRP ON A MONTHLY BASIS - 1998

Month	Raw Sewage Gross Beta (pCi/L)	Effluent Gross Beta (pCi/L)	Radioactivity Removal Eff. (%)	Sludge Gross Beta (pCi/g dw)
January	17.1	17.5	-2.3	14.4
February	15.2	10.7	29.6	14.4
March	20.4	18.8	7.8	11.7
April	18.6	12.7	31.7	12.0
May	19.1	13.8	27.7	14.4
June	23.7	16.1	32.1	16.6
July	23.2	20.5	11.6	13.9
August	26.1	16.8	35.6	15.3
September	22.0	16.2	26.4	15.3
October	23.6	7.2	69.5	15.6
November	23.9	14.7	38.5	15.9
December	33.5	21.5	53.3	10.8

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TABLE 13

GROSS ALPHA RADIOACTIVITY IN LEMONT WRP RAW SEWAGE, FINAL EFFLUENT, AND RETURN SLUDGE, AND RADIOACTIVITY REMOVAL EFFICIENCY OF THE WRP ON A MONTHLY BASIS - 1998

Month	Raw Sewage Gross Alpha (pCi/L)	Effluent Gross Alpha (pCi/L)	Radioactivity Removal Eff. (%)	Sludge Gross Alpha (pCi/g dw)
January	18.8	N/A	----	39.6
February	10.2	<4.8	*	53.4
March	17.1	5.4	68.4	41.3
April	14.2	5.0	64.8	46.5
May	21.1	5.9	72.0	48.2
June	27.8	3.6	87.0	48.4
July	23.1	N/A	----	66.2
August	31.6	6.1	80.7	N/A
September	32.1	4.3	86.6	74.3
October	28.8	4.4	84.7	31.5
November	22.3	5.1	77.1	47.4
December	27.5	5.6	79.6	48.5

*Values could not be calculated because the effluent radioactivity was below the detection limit.
N/A = Not Available.

fluent it ranged from 12.3 pCi/L to 27.6 pCi/L (Table 14). The gross beta radioactivity removal efficiency of the Lemont WRP ranged from 20.7 percent to 76.1 percent. The gross beta radioactivity in Lemont return sludge ranged from 53.9 pCi/g dw to 140.6 pCi/g dw (Table 14).

Gross Alpha and Gross Beta Radioactivity in Hanover Park WRP Lagooned Sludge

Table 15 presents the gross alpha and gross beta radioactivity concentration in Hanover Park East and Hanover Park West lagooned sludge.

Average gross alpha radioactivity in Hanover Park East lagooned sludge was 6.2 pCi/g and ranged from 3.8 pCi/g dw to 8.6 pCi/g dw. Average gross alpha radioactivity in Hanover Park West lagooned sludge was 6.5 pCi/g, and ranged from 5.4 pCi/g dw to 8.2 pCi/g dw.

Average gross beta radioactivity in Hanover Park East lagooned sludge was 15.2 pCi/g, and ranged from 13.7 pCi/g dw to 17.9 pCi/g dw. Average gross beta radioactivity in Hanover Park West lagooned sludge was 17.2 pCi/g, and ranged from 13.9 pCi/g dw to 18.8 pCi/g dw.

Gross Alpha and Gross Beta Radioactivity in District Biosolids

Table 16 presents the gross alpha and gross beta radioactivity concentrations in biosolid samples analyzed from District's sludge management areas.

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TABLE 14

GROSS BETA RADIOACTIVITY IN LEMONT WRP RAW SEWAGE, FINAL EFFLUENT, AND RETURN SLUDGE, AND RADIOACTIVITY REMOVAL EFFICIENCY OF THE WRP ON A MONTHLY BASIS - 1998

Month	Raw Sewage Gross Beta (pCi/L)	Effluent Gross Beta (pCi/L)	Radioactivity Removal Eff. (%)	Sludge Gross Beta (pCi/g dw)
January	44.3	N/A	----	66.5
February	27.1	21.5	20.7	78.2
March	30.3	12.3	59.4	75.2
April	26.9	16.7	37.9	79.1
May	42.9	27.6	35.7	85.3
June	45.8	18.0	60.7	86.2
July	40.3	N/A	----	100.4
August	52.6	24.4	53.6	N/A
September	60.8	16.7	72.5	140.6
October	55.2	13.2	76.1	53.9
November	36.9	16.7	54.7	91.7
December	48.0	27.2	43.3	86.0

N/A = Not Available.

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TABLE 15

GROSS ALPHA AND GROSS BETA RADIOACTIVITY IN HANOVER PARK WRP LAGOONED SLUDGE - 1998

Lagoon Location	No. of Samples	Gross Alpha (pCi/g dw)			Gross Beta (pCi/g dw)		
		Average	Minimum	Maximum	Average	Minimum	Maximum
Hanover Park East	4	6.2	3.8	8.6	15.2	13.7	17.9
Hanover Park West	4	6.5	5.4	8.2	17.2	13.9	18.8

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE 16

GROSS ALPHA AND GROSS BETA RADIOACTIVITY OF DISTRICT BIOSOLIDS - 1998

Sample Location	No. of Samples	Gross Alpha (pCi/g dw)			Gross Beta (pCi/g dw)		
		Average	Minimum	Maximum	Average	Minimum	Maximum
LASMA	5	7.5	6.2	8.5	23.8	21.4	24.9
Calumet East	5	7.7	6.4	9.5	23.8	21.0	28.2
Calumet West	5	7.4	7.0	8.2	21.8	20.4	23.7
HASMA	5	7.9	7.3	8.7	24.4	22.9	25.2
Marathon	5	8.1	6.8	8.8	24.9	24.1	25.9
Stony Island	5	7.6	5.9	9.4	24.5	21.8	30.0
Vulcan	5	7.7	6.7	8.9	24.9	22.1	27.3
Ridgeland	5	8.1	6.8	9.0	24.9	23.7	26.2

Average gross alpha radioactivity ranged from 7.4 pCi/g dw at the Calumet West Drying Cells to 8.1 pCi/g dw at the Marathon and Ridgeland Drying Cells. Average gross beta radioactivity ranged from 21.8 pCi/g dw at the Calumet West Drying Cells to 24.9 pCi/g dw at the Marathon, Vulcan, and Ridgeland Drying Cells.

Gamma Radioactivity in District WRP Sludges, and Biosolids

In 1998, 20 sludge samples from five WRPs, 8 sludge samples from lagoons and 40 biosolid samples from eight sludge drying sites were analyzed for specific radionuclides. The following is a list of radionuclides monitored:

Sodium-22	Cadmium-109	Gadolinium-153
Potassium-40	Cesium-134	Bismuth-207
Cobalt-57	Cesium-137	Radium-226
Cobalt-60	Antimony-125	Thorium-229
Manganese-54	Zinc-65	Ruthenium-106
Cerium-144	Protactinium-231	Neptunium-237
Silver-108m	Europium-152	Europium-154
Silver-110m	Europium-155	Americium-241

These radionuclides were selected from a table of radionuclides of concern in remediated soil prepared by the USEPA Office of Radiation and Indoor Air. Of the 24 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 which may be from fallout of nuclear weapon testing.

The results of the sludge samples from WRPs, lagoons and biosolid samples from drying sites are presented in Table 17, 18, and 19, respectively.

Table 17 presents the concentrations of gamma-emitting radionuclides in the sludge from the District WRPs. Average potassium-40 radioactivity ranged from 5.1 pCi/g dw at the Hanover Park WRP to 11.7 pCi/g dw at the Stickney WRP. Average radium-226 radioactivity ranged from 3.4 pCi/g dw at Stickney WRP to 55.8 pCi/g dw at the Lemont WRP. Average cesium-137 radioactivity ranged from <0.06 pCi/g dw at the Lemont WRP to 0.11 pCi/g dw at the Stickney WRP.

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. Because of the high radium-226 concentrations in Lemont WRP sludge, it is mixed with either Calumet or Stickney WRP sludge before drying and final disposal.

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE 17

CONCENTRATION OF GAMMA-EMITTING RADIONUCLIDES IN WRP SLUDGES - 1998

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	4	9.0	8.7	9.5	4.5	4.2	5.1	0.09	0.07	0.11
John E. Egan	4	10.1	7.6	13.3	4.5	3.8	5.1	0.04	0.03	0.05
Hanover Park	4	5.1	4.5	5.5	4.7	3.3	6.9	0.02	0.01	0.03
Stickney	4	11.7	10.8	13.5	3.4	2.9	4.4	0.11	0.10	0.12
Lemont	4	8.5	7.2	10.1	55.8	33.1	74.3	<0.06	0.05	<0.08

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE 18

CONCENTRATION OF GAMMA-EMITTING RADIONUCLIDES IN HANOVER PARK WRP LAGOONED SLUDGE - 1998

Lagoon 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.
Hanover Park East	4	4.4	4.1	4.9	5.2	4.6	6.1	0.02	<0.01	0.04
Hanover Park West	4	4.8	3.2	6.2	5.1	3.4	6.0	0.03	0.02	0.03

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE 19

CONCENTRATION OF GAMMA-EMITTING RADIONUCLIDES IN DISTRICT BIOSOLIDS - 1998

Samples Locati	No. of Samples	Potassium-40 (pCi/g dw) Ave.	Min.	Max.	Radium-226 (pCi/g dw) Ave.	Min.	Max.	Cesium-137 (pCi/g dw) Ave.	Min.	Max.
Calumet East	5	9.8	8.8	11.0	3.6	2.8	4.7	0.1	0.1	0.1
Calumet West	5	8.6	6.6	10.7	4.3	3.4	5.1	0.1	0.1	0.1
Ridgeland	5	9.3	4.2	12.1	3.5	2.1	4.4	0.1	0.1	0.1
Stony Island	5	8.9	8.2	9.9	3.8	2.5	4.6	0.1	0.1	0.1
HASMA	5	9.7	5.2	13.1	3.6	2.7	4.1	0.1	0.1	0.1
LASMA	5	11.7	9.1	16.0	4.0	3.0	4.9	0.1	0.1	0.2
Marathon	5	10.8	9.2	13.2	4.0	2.8	5.2	0.1	0.1	0.2
Vulcan	5	9.8	5.1	11.9	3.0	2.0	4.1	0.1	0.1	0.1

Table 18 presents the concentration of gamma-emitting radionuclides in lagooned sludge. Average potassium-40 radioactivity in Hanover Park East lagooned sludge was 4.4 pCi/g dw (range: 4.1 to 4.9 pCi/g), and in Hanover Park West lagooned sludge, it was 4.8 pCi/g dw (range: 3.2 to 6.2 pCi/g). Average radium-226 radioactivity in Hanover Park East lagooned sludge was 5.2 pCi/g dw (range: 4.6 to 6.1 pCi/g) and in Hanover Park West lagooned sludge it was 5.1 pCi/g dw (range: 3.4 to 6.0 pCi/g). The average cesium-137 activity in Hanover Park East lagooned sludge was 0.02 pCi/g dw (range: <0.01 to 0.04 pCi/g) and at Hanover Park West lagooned sludge 0.03 pCi/g dw (range: 0.02 to 0.03 pCi/g).

Table 19 presents concentrations of gamma-emitting radionuclides in the District's biosolids. The average potassium-40 activity ranged from 8.6 pCi/g dw in Calumet West biosolids to 11.7 pCi/g dw in LASMA biosolids. The overall concentration range of potasium-40 for District's biosolids is 4.2 to 16.0 pCi/g. The average cesium-137 radioactivity was 0.1 pCi/g dw at all the sample locations with a range of 0.1 to 0.2 pCi/g for all biosolids. Average radium-226 radioactivity ranged from 3.0 pCi/g dw in Vulcan biosolids to 4.3 pCi/g dw in Calumet West biosolids. The overall concentration range of radium-226 for District's biosolids is 2.0 to 5.2 pCi/g.

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

REFERENCES

1. General Accounting Office, "Nuclear Regulation - Action Needed to Control Radioactive Contamination at Sewage Treatment Plants," Report No. GAO/RCED-94-133, 1994.