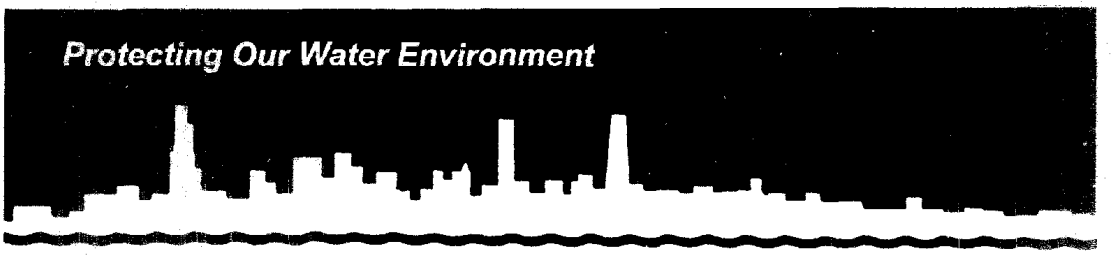

Metropolitan Water Reclamation District of Greater Chicago

RESEARCH AND DEVELOPMENT DEPARTMENT

REPORT NO. 2000-15

THE IMPACT OF ZION NUCLEAR POWER PLANT OPERATION ON LAKE MICHIGAN WATER QUALITY

December 2000

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THE IMPACT OF ZION NUCLEAR POWER PLANT OPERATION ON LAKE MICHIGAN WATER QUALITY

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December 2000

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ACKNOWLEDGMENT

The authors wish to express their appreciation to the former head of the Radiochemistry Section, the late Ms. Lee Kristoff, for the work done from 1973 to 1992. Particular thanks are due to Mr. Wayne Augustine (retired Sanitary Chemist I) for analyzing the samples and tabulating the data collected in this study of 25 years. The authors also wish to thank all the laboratory technicians who assisted in the analysis of samples.

The authors also wish to thank the former head of the Experimental Design and Statistical Evaluation Section, the late Dr. K. C. Rao, and his staff for the data reduction and data entry into the computer from 1973 to 1995. Thanks are due to the Industrial Waste Division field crew for collecting the samples.

Special thanks are due to Ms. Nancy Urlacher for typing this report.

DISCLAIMER

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

SUMMARY

Lake Michigan serves as a supply of drinking water to the Metropolitan Chicago area with a population of about 5.5 million. In 1973, the Zion Nuclear Power Plant (ZNPP) located approximately 40 miles north of Chicago on the shores of Lake Michigan near Zion, Illinois began operation. A radiological monitoring program of Lake Michigan, with respect to the discharges of the ZNPP, was started in 1973 and continued till the ZNPP ceased operation in 1998. The purpose of the monitoring was to study the impact of ZNPP operation on the radiological quality of Lake Michigan water.

For this purpose, a pre-operational measurement of radioactivity in Lake Michigan water was carried out in 1970 by Industrial Bio-Test Laboratories, Inc., Northbrook, Illinois, for Commonwealth Edison Company to obtain background tritium levels. The Illinois Environmental Protection Agency (IEPA), Springfield, Illinois also conducted a study in 1972 to measure the background levels of gross alpha and gross beta radioactivity in Lake Michigan water. A radiological monitoring program was conducted by the Metropolitan Water Reclamation District of Greater Chicago (District) at six different locations in Lake Michigan after the ZNPP went into operation. Sampling was done at the intakes to the water filtration

plants of the cities of Waukegan and Evanston, the Village of Winnetka, at the ZNPP Intake, Discharge, and one location in Lake Michigan near the power plant discharge (Zion-Station). A monitoring of these sampling stations was carried out to determine the radioactivity concentrations of tritium, gross alpha, gross beta, total gamma, cesium-137, and zinc-65.

The tritium concentration in Lake Michigan water samples collected in 1970 prior to the operation of the ZNPP ranged from 0.31 pCi/mL to 0.37 pCi/mL (1).

Sampling of Lake Michigan water during operation of the ZNPP from 1973 to 1998 showed yearly average tritium concentrations at the Waukegan filtration plant intake ranging from 0.10 pCi/mL to 0.30 pCi/mL. At the Winnetka filtration plant intake, the yearly average tritium radioactivity ranged from 0.10 pCi/mL to 0.31 pCi/mL between 1973 and 1998. The yearly average tritium concentration at Evanston filtration plant intake ranged from 0.11 pCi/mL to 0.32 pCi/mL during the operational period of ZNPP.

At the intake of the ZNPP, the yearly average tritium concentration ranged from <0.10 pCi/mL to 0.40 pCi/mL between 1973 and 1998. At the ZNPP discharge, the yearly average tritium concentration ranged from <0.10 pCi/mL to 0.50 pCi/mL, and at Zion-Station the tritium concentration ranged from

<0.10 pCi/mL to 0.40 pCi/mL during the same operational period of the ZNPP.

The radiological monitoring data show that the tritium levels at the six sampling locations throughout the operational period of ZNPP were well below the United States Environmental Protection Agency (USEPA) drinking water standards of 20 pCi/mL for tritium (40 CFR Part 141, July 1, 1989).

The gross alpha radioactivity levels in Lake Michigan water at 12 water filtration plants, including Waukegan, Winnetka, and Evanston, ranged from 0 to 5 pCi/L in 1972. The highest gross alpha radioactivity level was recorded at the Lake Forest water plant. The annual average gross alpha concentration of all the water filtration plants was less than 1 pCi/L (2).

The yearly average of gross alpha radioactivity in Lake Michigan water at the Waukegan, Winnetka, and Evanston filtration plant intakes ranged from 0.04 pCi/L to 1.57 pCi/L, 0.07 pCi/L to 2.02 pCi/L, and 0.05 pCi/L to 1.59 pCi/L, respectively, during the ZNPP operational period of 1973 through 1998.

The gross alpha radioactivity levels at 5 miles offshore in Lake Michigan ranged from 0 to 2 pCi/L in 1972. The average annual alpha radioactivity concentration of all the stations was less than 1 pCi/L (2).

At the ZNPP the yearly average of the gross alpha radioactivity levels at the intake, discharge, and Zion-Station sampling locations ranged from <0.02 pCi/L to 5.14 pCi/L, <0.02 pCi/L to <1.53 pCi/L, and 0.02 pCi/L to <1.10 pCi/L, respectively.

These values are well below the USEPA drinking water standard for maximum contaminant level for gross alpha particle activity (including radium-226 but excluding radon and uranium) in a community water system of 15 pCi/L.

The gross beta radioactivity concentration in Lake Michigan water at 12 filtration plants, including Waukegan, Winnetka, and Evanston, ranged from 0 to 16 pCi/L in 1972. The highest gross beta concentration was measured at Chicago South water filtration plant. The average annual gross beta radioactivity concentration for all the filtration plants was 4 pCi/L (2).

The yearly average of the gross beta radioactivity in Lake Michigan water at the Waukegan, Winnetka, and Evanston water filtration plant intakes ranged from 3.17 pCi/L to 5.64 pCi/L, 2.94 pCi/L to 6.3 pCi/L, and 2.81 pCi/L to 6.16 pCi/L, respectively, during the ZNPP operational period of 1973 through 1998.

The gross beta radioactivity levels at 5 miles offshore in Lake Michigan ranged from 0 to 8 pCi/L in 1972. The annual

average gross beta radioactivity concentration of all the stations was 4 pCi/L (2).

At the ZNPP the yearly average of the gross beta radioactivity levels at the intake and discharge ranged from <0.1 pCi/L to 7.33 pCi/L and <0.1 pCi/L to 5.27 pCi/L, respectively, between 1973 through 1998. For the same period at the Zion-Station, the beta radioactivity levels varied from <0.1 pCi/L to 4.98 pCi/L.

These values are below the USEPA drinking water standard for maximum contaminant levels for gross beta activity in a community water system of 50 pCi/L.

The yearly average total gamma radioactivity in Lake Michigan water at all 3 water filtration plant intakes and at the ZNPP stations was less than 7.1 pCi/L during the entire monitoring period from 1973 to 1998. At the water filtration plant intakes and ZNPP Stations the yearly average cesium-137 radioactivity levels were less than 5 pCi/L between 1973 and 1998. The yearly average zinc-65 radioactivity levels at the water filtration plant intakes and ZNPP Stations were less than 3 pCi/L during the monitoring period from 1973 to 1998.

According to National Primary Drinking Water Regulations (40 CFR Part 141, July 1, 1989), the average annual concentration of beta particles and photon radioactivity from manmade radionuclides in drinking water shall not produce an annual

dose equivalent to the total body or an internal organ greater than 4 millirem/year. If two or more radionuclides are present, the sum of their annual dose equivalent to the total body or to any organ shall not exceed 4 millirem/year. A concentration of 119 pCi/L of cesium-137 or 396 pCi/L of zinc-65 would produce a 4 millirem effective dose equivalent per year assuming a two liter daily intake of water (3). Thus, the Lake Michigan radioactivity levels at the six sampling locations are well below the regulatory limit for drinking water.

The radiological monitoring data of Lake Michigan during the operational period of ZNPP from 1973 to 1998 showed that the radioactivity levels of Lake Michigan water off the shores of Metropolitan Chicago area remained well below the maximum contaminant levels for radioactivity in drinking water standards of USEPA. There was no substantial difference in the radioactivity concentration in Lake Michigan water before and after the operation of the ZNPP. Hence, it can be concluded that the ZNPP operation had no adverse impact on Lake Michigan water quality.

INTRODUCTION

The ZNPP is located on the shores of Lake Michigan approximately 40 miles north of Chicago near Zion, Illinois. The plant consisted of two units of closed cycle pressurized boiling water reactors and used Lake Michigan water to cool its thermal conductor. The plant began operation in June 1973 and ceased operation in February 1998.

Nuclear power generation results in the formation of artificial radioactivity. A low level of radioactivity may be released to the environment under controlled and monitoring conditions. Atmospheric release includes tritium, cobalt-60, strontium-90, and cesium-137. Radionuclides released to the aquatic environment include tritium. The most pressing concern from the public point of view was the Lake Michigan water quality as the ZNPP used lake water for cooling purposes and discharged the coolant back to the lake.

Lake Michigan serves as a supply of drinking water to the Metropolitan Chicago area with a population of about 5.5 million. The most significant pathway by which the radionuclides reach mankind is via the ingestion of water. The mission of the District is to keep the pollution out of Lake Michigan. In order to protect the public health and the environment, the District had a plan to monitor radioactivity in Lake Michigan.

The Research and Development Department of the District conducted a radiological monitoring program of Lake Michigan between Zion and Chicago to determine the impact of the ZNPP operation on Lake Michigan water quality. The radiological monitoring program included a pre-operational radiological analysis of Lake Michigan water and routine radiological monitoring of the lake water. The pre-operational radiological analysis conducted by Industrial Bio-Test Laboratories, Inc., Northbrook, Illinois, in 1970 (1), and the IEPA in 1972 (2) provided the baseline data on the background tritium radioactivity levels and gross alpha/beta radioactivity levels, respectively, for comparison after the ZNPP was in operation.

The routine monitoring program established in 1973 provided the current data on the radiological quality of Lake Michigan water. The monitoring program involved the analysis of Lake Michigan water samples collected at six sampling locations. These locations were the intake to the water filtration plants of the cities of Waukegan and Evanston, the village of Winnetka, the ZNPP cooling water intake, the ZNPP cooling water discharge, and a station in Lake Michigan designated as Zion-Station. The following parameters were measured:

1. gross alpha
2. gross beta
3. total gamma

4. cesium-137

5. zinc-65

6. tritium

Measurement of gross alpha, gross beta, and total gamma radioactivity concentration provided the overall radioactivity levels. Cesium-137 is a fission product with a half-life of 30 years. Zinc-65 is an activation product with a half-life of 245 days. Tritium, a fission and activation product, is a principal contributor to the radioactivity concentrations of nuclear power plant coolant water discharge.

This report summarizes and discusses the results of the radiological monitoring program conducted by the District at the six sampling locations in Lake Michigan during the operational period of the ZNPP from 1973 through 1998.

MATERIALS AND METHODS

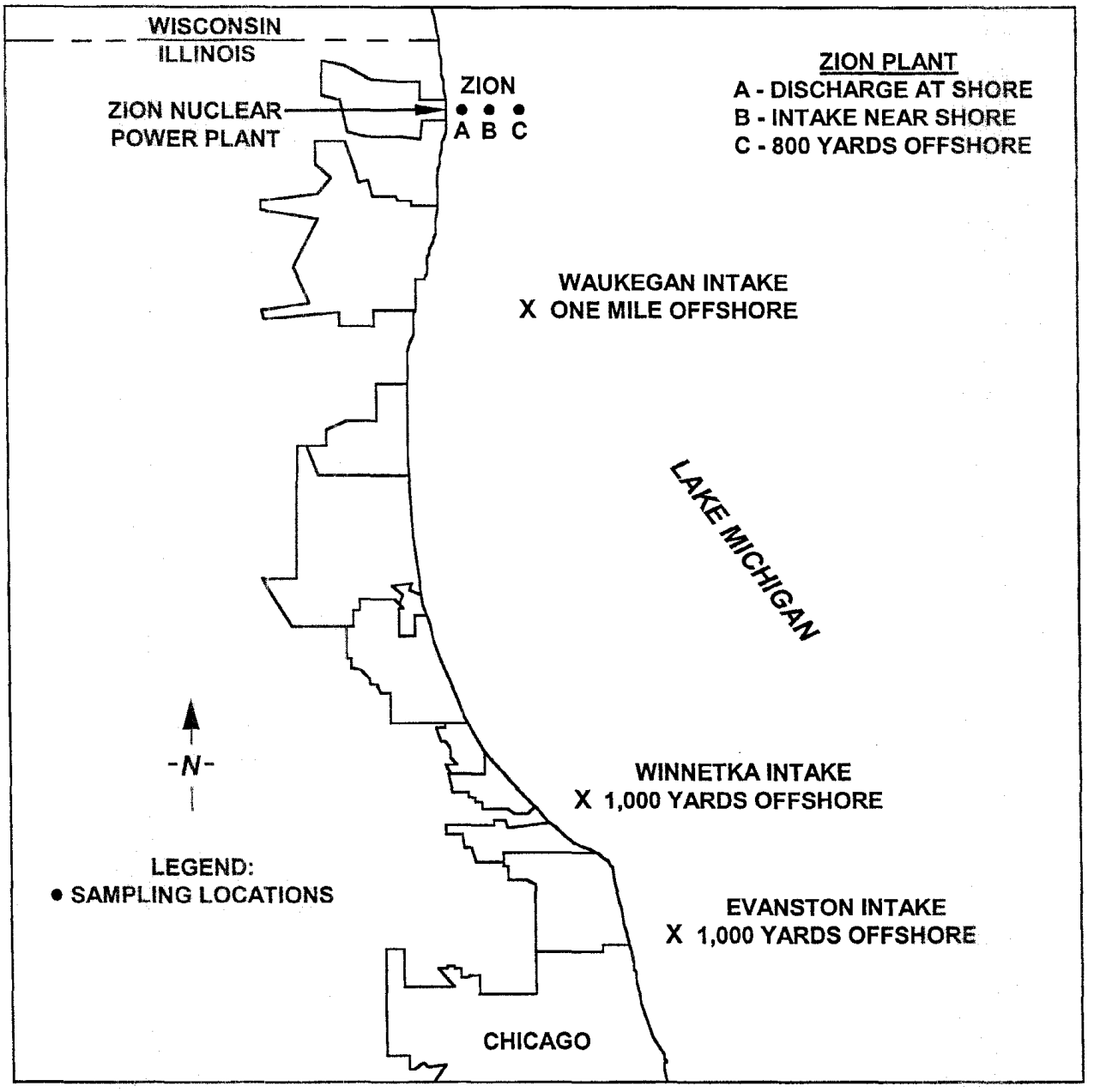
Sample Collection

Water samples were collected from the intakes of the filtration plants of the cities of Waukegan and Evanston, and the Village of Winnetka (Figure 1). At the Waukegan and Evanston Water Filtration Plants, pipes bring raw lake water from the intakes to the plants. The radiological monitoring program samples were collected from sampling spigots installed on these pipes. The Winnetka Water Filtration Plant uses a screen house at the intake which has a number of chambers. Grab samples were collected from one of these chambers. The ZNPP sampling stations (Figure 1) are located at the following distances off the shoreline: Intake - 750 feet, Discharge - 300 feet, and Lake Michigan Zion-Station - 2,400 feet. All three ZNPP sampling locations were along the same latitude (42°6.51′). The water filtration plant stations were sampled monthly.

Two sets of grab water samples from the three ZNPP sampling locations were collected from a boat, at a depth of one meter below the surface, using a two-liter brass Kemmerer sampler. At the intake, the sampling locations were approximately 10 feet away from the intake in the downwind direction. At the discharge, the sampling location was at the point where

Figure 1

SAMPLING STATIONS IN LAKE MICHIGAN FOR MONITORING THE ZION NUCLEAR POWER PLANT



the lake surface no longer showed visible agitation from the discharge flow, also in the downwind direction.

The water samples were collected in two-gallon plastic jugs containing 100 ml of a dilute solution of hydrochloric acid (1:1 v/v) made with distilled water to preserve the samples. Separate samples were collected in 500-mL glass bottles for tritium analysis.

Analytical Methodology

GROSS ALPHA AND GROSS BETA RADIOACTIVITY

A two to four liter aliquot of each sample was separated into suspended and dissolved solids fraction by filtration through an eight micron pore size filter of a Millipore filtering apparatus. The solids on the filter paper were allowed to air-dry prior to weighing. The filtrate was transferred into a beaker, acidified with one molar nitric acid, evaporated to near dryness, transferred into a planchet, evaporated to dryness and flamed to drive off volatile materials. The filter paper was mounted onto 5-cm diameter stainless steel planchets. The dissolved and suspended solids were counted for gross alpha and gross beta radioactivity on a Tennelec LB5100 gas proportional counter. The counter was calibrated

with americium-241 and cesium-137 standards for gross alpha and gross beta activity determinations, respectively.

GAMMA RADIOACTIVITY

The dissolved and suspended solids fractions of a sample were transferred into glass vials (1.4 cm diameter by 11 cm long). These samples were counted for total gamma, cesium-137, and zinc-65 radioactivity using a TM Analytic Gamma Trac, Model 1185, dual channel well counter having a 3" x 3" NaI (T1) detector. The total gamma activity was counted over the energy range of 0.140 to 2 MeV, cesium-137 from 0.561 to 0.761 MeV, and zinc-65 from 1.015 to 1.215 MeV. All activities falling into the respective energy range of cesium-137 and zinc-65 were considered to be due to these radionuclides. The energy calibration of the well counter was conducted using a cesium-137 source.

TRITIUM RADIOACTIVITY

Separate water samples were taken for the determination of tritium. A 100-mL sample was transferred to a 250-mL distillation flask and distilled at 100°C. A 10-mL aliquot of the distillate was mixed with liquid scintillation cocktail in a 20-mL plastic vial. Tritium was measured on a TM Analytic, Model 6881, Mark III liquid scintillation counter.

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 below the LLD, the radioactivity concentration was reported with the less than symbol (<) for tritium, gross alpha, and gross beta. The radioactivity concentration for total gamma, cesium-137, and zinc-65 was reported as non-detectable.

Total radioactivity for gross alpha, gross beta, total gamma, cesium-137, and zinc-65 was calculated by adding the suspended and dissolved solids activity. If the activity was

less than the LLD in any of the two fractions, total activity was reported as less than the LLD, or nd.

For calculation purposes, less than the lower limit of detection (LLD) values were considered as real numbers, i.e., <1 was considered as 1. Yearly average gross alpha and gross beta radioactivity was calculated by adding the monthly activity and dividing the sum by the number of months. 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 the solids in 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.

RESULTS AND DISCUSSION

Tritium

The tritium concentration in Lake Michigan water samples prior to the operation of the ZNPP ranged from 0.31 pCi/mL to 0.37 pCi/mL with a mean of 0.34 pCi/mL for the period of January to December 1970(1).

The yearly average tritium radioactivity levels in Lake Michigan water at Waukegan, Winnetka, and Evanston filtration plant intakes from 1973 to 1998 are summarized in Table 1. The tritium radioactivity at Waukegan, Winnetka, and Evanston filtration plant intakes ranged from 0.10 pCi/mL to 0.30 pCi/mL, 0.10 pCi/mL to 0.31 pCi/mL, and 0.11 pCi/mL to 0.32 pCi/mL, respectively.

The yearly average tritium radioactivity level in Lake Michigan water at the ZNPP sampling locations from 1973 to 1998 is given in Table 2. The tritium radioactivity at ZNPP Intake, Discharge, and Zion-Station locations ranged from <0.10 pCi/mL to 0.40 pCi/mL, <0.10 pCi/mL to 0.50 pCi/mL, and <0.10 pCi/mL to 0.40 pCi/mL, respectively.

The monitoring data indicates that there is no appreciable difference in the tritium concentration of Lake Michigan water prior to the operation of the ZNPP and throughout its operating period of 25 years. The results show that the con-

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE 1

YEARLY AVERAGE TRITIUM RADIOACTIVITY LEVELS (pCi/mL) OF LAKE MICHIGAN WATER FILTRATION PLANTS INTAKES FROM 1973 THROUGH 1998

Year	Waukegan	Winnetka	Evanston
1973	0.30	0.28	0.32
1974	0.28	0.31	0.30
1975	0.27	0.27	0.28
1976	0.25	0.27	0.27
1977	0.19	0.22	0.26
1978	0.26	0.24	0.23
1979	0.19	0.19	0.22
1980	0.23	0.21	0.19
1981	0.20	0.21	0.24
1982	0.18	0.19	0.18
1983	0.19	0.20	0.19
1984	0.17	0.17	0.20
1985	0.14	0.14	0.16
1986	0.19	0.14	0.14
1987	0.13	0.14	0.15
1988	0.14	0.11	0.15
1989	0.12	0.14	0.12
1990	0.14	0.12	0.12
1991	0.14	0.10	0.12

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE 1 (Continued)

YEARLY AVERAGE TRITIUM RADIOACTIVITY LEVELS (pCi/mL) OF LAKE MICHIGAN WATER FILTRATION PLANTS INTAKES FROM 1973 THROUGH 1998

Year	Waukegan	Winnetka	Evanston
1992	0.13	0.15	0.12
1993	0.18	0.13	0.12
1994	0.13	0.11	0.13
1995	0.12	0.10	0.13
1996	0.12	0.12	0.11
1997	0.11	0.10	0.11
1998	0.10	0.10	0.11

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TABLE 2

YEARLY AVERAGE TRITIUM RADIOACTIVITY LEVELS (pCi/mL) OF LAKE MICHIGAN WATER AT THE ZION NUCLEAR POWER PLANT SAMPLING LOCATIONS FROM 1973 THROUGH 1998

Year	Zion Intake	Zion Discharge	Zion Station
1973	0.30	0.25	0.25
1974	NS	NS	NS
1975	0.38	0.25	0.28
1976	NS	NS	NS
1977	NS	NS	NS
1978	NS	NS	NS
1979	0.30	0.32	0.21
1980	0.23	0.20	0.21
1981	0.40	0.50	0.40
1982	NS	NS	NS
1983	0.25	0.20	0.30
1984	0.20	0.27	0.37
1985	0.16	0.20	0.23
1986	0.15	0.15	0.17
1987	0.15	0.15	0.15
1988	0.15	0.15	0.20
1989	0.17	0.20	0.17
1990	0.22	0.20	0.15
1991	0.20	0.17	0.13

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE 2 (Continued)

YEARLY AVERAGE TRITIUM RADIOACTIVITY LEVELS (pCi/mL) OF LAKE MICHIGAN WATER AT THE ZION NUCLEAR POWER PLANT SAMPLING LOCATIONS FROM 1973 THROUGH 1998

Year	Zion Intake	Zion Discharge	Zion Station
1992	0.12	0.12	0.18
1993	0.10	0.20	0.30
1994	0.10	0.13	0.10
1995	0.30	0.35	0.25
1996	0.25	0.20	0.30
1997	0.10	<0.10	<0.10
1998	<0.10	<0.10	0.10

NS = No sample.

tribution of tritium radioactivity from the ZNPP is almost none. The tritium levels observed throughout the monitoring period from 1973 to 1998 are also well below the maximum contaminant limit of 20 pCi/mL for tritium in water as specified by the USEPA National Primary Drinking Water Regulations (40 CFR Part 141, July 1, 1989).

Gross Alpha

The gross alpha concentration in Lake Michigan water at 12 water filtration plants, including Waukegan, Winnetka, and Evanston, in 1972 ranged from 0.0 to 5 pCi/L (2). The annual average gross alpha concentration at the water filtration plants was less than 1 pCi/L (2).

The yearly average gross alpha concentration of Lake Michigan water at Waukegan, Winnetka, and Evanston filtration plant intakes from 1973 to 1998 is summarized in Tables 3, 4, and 5, respectively. The gross alpha concentration at Waukegan, Winnetka, and Evanston filtration plant intakes ranged from 0.04 pCi/L to 1.57 pCi/L, 0.07 pCi/L to 2.02 pCi/L, and 0.05 pCi/L to 1.59 pCi/L, respectively.

The gross alpha concentration at the 5-mile stations in offshore Lake Michigan in 1972 ranged from 0.0 to 2.0 pCi/L. The annual average gross alpha radioactivity concentration of all the stations was less than 1 pCi/L (2).

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE 3

YEARLY AVERAGE GROSS ALPHA RADIOACTIVITY LEVELS (pCi/L) IN LAKE MICHIGAN WATER AT WAUKEGAN FILTRATION PLANT INTAKE FROM 1973 THROUGH 1998

Year	Suspended Solids	Dissolved Solids	Total Solids
1973	0.06	0.05	0.11
1974	0.07	0.03	0.10
1975	0.04	0.02	0.06
1976	0.03	0.03	0.06
1977	0.02	0.03	0.05
1978	0.04	0.04	0.08
1979	0.03	0.02	0.05
1980	0.04	<0.01	<0.05
1981	0.05	0.02	0.07
1982	0.06	0.02	0.08
1983	0.12	0.08	0.20
1984	0.06	0.24	0.30
1985	0.10	0.42	0.52
1986	0.04	0.04	0.08
1987	0.17	0.25	0.42
1988	0.02	0.49	0.51
1989	0.04	0.64	0.68
1990	0.02	0.02	0.04
1991	0.06	0.09	0.15

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE 3 (Continued)

YEARLY AVERAGE GROSS ALPHA RADIOACTIVITY LEVELS (pCi/L) IN LAKE MICHIGAN WATER AT WAUKEGAN FILTRATION PLANT INTAKE FROM 1973 THROUGH 1998

Year	Suspended Solids	Dissolved Solids	Total Solids
1992	0.02	0.08	0.10
1993	0.03	0.05	0.08
1994	0.04	<0.02	<0.06
1995	0.03	0.12	0.15
1996	0.11	<0.88	<0.99
1997	0.11	0.86	0.96
1998	0.20	1.37	1.57

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE 4

YEARLY AVERAGE GROSS ALPHA RADIOACTIVITY LEVELS (pCi/L) IN LAKE MICHIGAN WATER AT WINNETKA FILTRATION PLANT INTAKE FROM 1973 THROUGH 1998

Year	Suspended Solids	Dissolved Solids	Total Solids
1973	0.10	0.03	0.13
1974	0.09	0.06	0.15
1975	0.05	0.05	0.10
1976	0.05	0.04	0.09
1977	0.03	0.04	0.07
1978	0.06	0.05	0.11
1979	0.04	0.03	0.07
1980	0.05	0.03	0.08
1981	0.06	0.02	0.08
1982	0.04	0.04	0.08
1983	0.08	0.27	0.35
1984	0.10	0.24	0.34
1985	0.07	0.04	0.11
1986	0.19	0.13	0.32
1987	0.07	0.19	0.26
1988	0.05	0.08	0.13
1989	0.07	0.26	0.33
1990	0.08	0.08	0.16
1991	0.06	0.10	0.16

METROPOLITAN WATER RECLAMATION DISRICT OF GREATER CHICAGO

TABLE 4 (Continued)

YEARLY AVERAGE GROSS ALPHA RADIOACTIVITY LEVELS (pCi/L) IN LAKE MICHIGAN WATER AT WINNETKA FILTRATION PLANT INTAKE FROM 1973 THROUGH 1998

	Suspended Solids	Dissolved Solids	Total Solids
1992	0.06	0.09	0.15
1993	0.06	0.08	0.14
1994	0.09	0.06	0.15
1995	0.08	0.26	0.34
1996	0.13	<0.83	<0.96
1997	0.12	<0.68	<0.80
1998	0.16	1.86	2.02

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE 5

YEARLY AVERAGE GROSS ALPHA RADIOACTIVITY LEVELS (pCi/L) IN LAKE MICHIGAN WATER AT EVANSTON FILTRATION PLANT INTAKE FROM 1973 THROUGH 1998

Year	Suspended Solids	Dissolved Solids	Total Solids
1973	0.07	0.11	0.18
1974	0.07	0.05	0.12
1975	0.06	0.04	0.10
1976	0.03	0.03	0.06
1977	0.02	0.03	0.05
1978	0.04	0.04	0.08
1979	0.04	0.04	0.08
1980	0.03	0.02	0.05
1981	0.05	0.02	0.07
1982	0.06	0.03	0.09
1983	0.08	0.18	0.26
1984	0.06	0.07	0.13
1985	0.06	0.04	0.10
1986	0.06	<0.01	<0.07
1987	0.08	0.04	0.12
1988	0.06	0.18	0.24
1989	0.08	0.19	0.27
1990	0.04	0.10	0.14
1991	0.23	0.13	0.36

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE 5 (Continued)

YEARLY AVERAGE GROSS ALPHA RADIOACTIVITY LEVELS (pCi/L) IN LAKE MICHIGAN WATER AT EVANSTON FILTRATION PLANT INTAKE FROM 1973 THROUGH 1998

Year	Suspended Solids	Dissolved Solids	Total Solids
1992	0.01	0.07	0.08
1993	0.16	0.06	0.22
1994	0.04	0.03	0.07
1995	0.05	0.12	0.17
1996	0.08	<0.98	<1.06
1997	0.10	<0.62	<0.72
1998	0.14	1.45	1.59

The yearly average gross alpha concentration of Lake Michigan water at the ZNPP Intake, Discharge and Zion-Station from 1973 to 1998 is given in Tables 6, 7, and 8, respectively. The gross alpha concentration at the Zion Intake, Zion Discharge, and Zion-Station ranged from <0.02 pCi/L to 5.14 pCi/L, <0.02 pCi/L to <1.53 pCi/L, and <0.02 pCi/L to <1.10 pCi/L, respectively.

The results show that the contribution of gross alpha radioactivity to Lake Michigan water from the ZNPP is substantially low. The gross alpha radioactivity levels in Lake Michigan water from 1973 to 1998 are also below the maximum contaminant limit of 15 pCi/L for gross alpha (excluding radon and uranium) in water of USEPA National Primary Drinking Water Regulations (40 CFR part 141, July 1, 1989).

Gross Beta

The gross beta concentration in Lake Michigan water at 12 filtration plants including Waukegan, Winnetka, and Evanston filtration plants in 1972 ranged from 0 to 16 pCi/L. The highest gross beta concentration was measured at Chicago South water filtration plant. The annual average gross beta concentration of all the filtration plants was 4 pCi/L (2).

The yearly average gross beta concentration of Lake Michigan water at Waukegan, Winnetka, and Evanston filtration

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE 6

YEARLY AVERAGE GROSS ALPHA RADIOACTIVITY LEVELS (pCi/L) IN LAKE MICHIGAN WATER AT ZION NUCLEAR POWER PLANT INTAKE FROM 1973 THROUGH 1998

Year	Suspended Solids	Dissolved Solids	Total Solids
1973	0.15	0.50	0.65
1974	NS	NS	NS
1975	0.02	0.09	0.11
1976	NS	NS	NS
1977	NS	NS	NS
1978	NS	NS	NS
1979	0.02	0.06	0.08
1980	0.03	<0.01	<0.04
1981	0.05	0.15	0.20
1982	<0.01	<0.01	<0.02
1983	0.05	0.21	0.26
1984	0.05	0.27	0.27
1985	0.02	0.12	0.14
1986	0.03	0.06	0.09
1987	0.05	<0.01	<0.06
1988	0.04	5.10	5.14
1989	0.03	0.22	0.25
1990	0.02	0.11	0.13
1991	0.02	0.05	0.07

METROPOLITAN WATER RECLAMATION DISRICT OF GREATER CHICAGO

TABLE 6 (Continued)

YEARLY AVERAGE GROSS ALPHA RADIOACTIVITY LEVELS (pCi/L) IN LAKE MICHIGAN WATER AT ZION NUCLEAR POWER PLANT INTAKE FROM 1973 THROUGH 1998

Year	Suspended Solids	Dissolved Solids	Total Solids
1992	0.03	0.26	0.29
1993	0.03	0.08	0.11
1994	0.02	<0.02	<0.04
1995	<0.01	<0.02	<0.03
1996	0.07	<0.54	<0.61
1997	0.12	0.42	0.53
1998	0.11	N/A	N/A

NS = No sample.
N/A = Not available.

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE 7

YEARLY AVERAGE GROSS ALPHA RADIOACTIVITY LEVELS (pCi/L) IN LAKE MICHIGAN WATER AT ZION NUCLEAR POWER PLANT DISCHARGE FROM 1973 THROUGH 1998

Year	Suspended Solids	Dissolved Solids	Total Solids
1973	<0.01	0.10	<0.11
1974	NS	NS	NS
1975	0.02	0.08	0.10
1976	NS	NS	NS
1977	NS	NS	NS
1978	NS	NS	NS
1979	0.04	0.03	0.07
1980	0.04	<0.01	<0.05
1981	0.04	<0.01	<0.05
1982	<0.01	<0.01	<0.02
1983	0.08	<0.01	<0.09
1984	0.06	<0.01	<0.07
1985	0.05	<0.01	<0.06
1986	0.04	0.08	0.12
1987	0.03	0.09	0.12
1988	0.04	0.17	0.21
1989	0.02	<0.01	<0.03
1990	0.02	0.14	0.16
1991	0.02	0.05	0.07

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE 7 (Continued)

YEARLY AVERAGE GROSS ALPHA RADIOACTIVITY LEVELS (pCi/L) IN LAKE MICHIGAN WATER AT ZION NUCLEAR POWER PLANT DISCHARGE FROM 1973 THROUGH 1998

Year	Suspended Solids	Dissolved Solids	Total Solids
1992	0.05	0.22	0.27
1993	0.04	0.10	0.14
1994	0.02	<0.02	<0.04
1995	<0.01	<0.02	<0.03
1996	0.07	<1.46	<1.53
1997	0.09	<1.31	<1.40
1998	<0.06	N/A	N/A

NS = No sample.
N/A = Not available.

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE 8

YEARLY AVERAGE GROSS ALPHA RADIOACTIVITY LEVELS (pCi/L) IN LAKE MICHIGAN WATER AT ZION NUCLEAR POWER PLANT STATION FROM 1973 THROUGH 1998

Year	Suspended Solids	Dissolved Solids	Total Solids
1973	0.12	0.20	0.32
1974	NS	NS	NS
1975	<0.01	<0.01	<0.02
1976	NS	NS	NS
1977	NS	NS	NS
1978	NS	NS	NS
1979	<0.01	<0.01	<0.02
1980	0.04	<0.01	<0.05
1981	0.02	0.03	0.05
1982	<0.01	<0.01	<0.02
1983	0.07	0.11	0.18
1984	0.04	<0.01	<0.05
1985	0.02	0.04	0.06
1986	0.03	0.06	0.09
1987	0.03	<0.01	<0.04
1988	0.02	0.12	0.14
1989	<0.01	<0.01	<0.02
1990	<0.01	0.06	<0.07
1991	0.03	0.06	0.09

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE 8 (Continued)

YEARLY AVERAGE GROSS ALPHA RADIOACTIVITY LEVELS (pCi/L) IN LAKE MICHIGAN WATER AT ZION NUCLEAR POWER PLANT STATION FROM 1973 THROUGH 1998

Year	Suspended Solids	Dissolved Solids	Total Solids
1992	0.02	0.05	0.07
1993	0.04	0.02	0.06
1994	0.02	0.17	0.19
1995	0.03	<0.02	<0.05
1996	0.07	<0.54	<0.61
1997	0.07	<1.04	<1.10
1998	0.10	N/A	N/A

NS = No sample.
N/A = Not available.

plant intakes from 1973 to 1998 is summarized in Tables 9, 10, and 11, respectively. The gross beta concentration at Waukegan, Winnetka, and Evanston filtration plant intakes ranged from 3.17 to 5.64 pCi/L, 2.94 to 6.30 pCi/L, and 2.81 to 6.16 pCi/L, respectively.

The gross beta concentration at the 5-mile stations in offshore Lake Michigan in 1972 ranged from 0 to 8 pCi/L. The annual average gross beta radioactivity concentration of all the stations was 4 pCi/L (2).

The yearly average gross beta concentration of Lake Michigan water at the ZNPP Intake, Discharge, and Zion-Station from 1973 to 1998 is given in Tables 12, 13, and 14, respectively. The gross beta concentration at the ZNPP Intake, Discharge, and Zion-Station ranged from <0.1 to 7.33 pCi/L, <0.1 to 5.27 pCi/L, and <0.1 to 4.98 pCi/L, respectively.

The results show that the total beta radioactivity is mostly contained in the dissolved solid fractions of the samples. However, there is no contribution of gross beta radioactivity to Lake Michigan water from the ZNPP. The gross beta radioactivity levels in Lake Michigan water from 1973 to 1998 are below the maximum contaminant level of 50 pCi/L for gross beta in water of USEPA National Primary Drinking Water Regulations (40 CFR part 141, July 1, 1989).

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE 9

YEARLY AVERAGE GROSS BETA RADIOACTIVITY LEVELS (pCi/L) IN LAKE MICHIGAN WATER AT WAUKEGAN FILTRATION PLANT INTAKE FROM 1973 THROUGH 1998

	Suspended Solids	Dissolved Solids	Total Solids
1973	0.88	4.70	5.58
1974	0.68	4.78	5.46
1975	0.45	4.70	5.15
1976	0.32	4.66	4.98
1977	0.47	5.15	5.62
1978	0.64	5.00	5.64
1979	0.49	4.64	5.13
1980	0.35	4.73	5.08
1981	0.59	4.65	5.24
1982	0.58	3.83	4.41
1983	0.89	4.56	5.45
1984	0.62	3.60	4.22
1985	0.52	3.87	4.39
1986	0.60	3.54	4.14
1987	0.93	3.35	4.28
1988	0.80	3.63	4.43
1989	0.56	3.15	3.71
1990	0.35	3.40	3.75
1991	0.65	3.45	4.10

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE 9 (Continued)

YEARLY AVERAGE GROSS BETA RADIOACTIVITY LEVELS (pCi/L) IN LAKE MICHIGAN WATER AT WAUKEGAN FILTRATION PLANT INTAKE FROM 1973 THROUGH 1998

Year	Suspended Solids	Dissolved Solids	Total Solids
1992	0.18	3.48	3.66
1993	0.40	3.08	4.30
1994	0.49	3.51	4.00
1995	0.20	3.87	4.07
1996	0.26	2.99	3.25
1997	0.27	2.90	3.17
1998	0.57	3.47	4.05

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE 10

YEARLY AVERAGE GROSS BETA RADIOACTIVITY LEVELS (pCi/L) IN LAKE MICHIGAN WATER AT WINNETKA FILTRATION PLANT INTAKE FROM 1973 THROUGH 1998

Year	Suspended Solids	Dissolved Solids	Total Solids
1973	1.32	4.98	6.30
1974	1.05	5.15	6.20
1975	0.62	5.01	5.63
1976	0.60	4.87	5.47
1977	0.33	5.29	5.62
1978	0.79	5.34	6.14
1979	0.54	5.43	5.97
1980	0.51	4.89	5.40
1981	0.60	4.48	5.08
1982	0.40	3.87	4.27
1983	0.99	4.05	5.04
1984	0.70	3.68	4.38
1985	0.60	3.09	3.69
1986	0.84	3.61	4.45
1987	0.88	3.18	4.06
1988	0.88	3.55	4.43
1989	0.79	3.18	3.97
1990	0.95	3.57	4.52
1991	0.98	3.42	4.40

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE 10 (Continued)

YEARLY AVERAGE GROSS BETA RADIOACTIVITY LEVELS (pCi/L) IN LAKE MICHIGAN WATER AT WINNETKA FILTRATION PLANT INTAKE FROM 1973 THROUGH 1998

Year	Suspended Solids	Dissolved Solids	Total Solids
1992	0.52	3.76	4.28
1993	0.79	3.78	4.58
1994	0.74	3.92	4.66
1995	0.59	3.79	4.38
1996	0.28	2.75	3.03
1997	0.33	2.61	2.94
1998	0.47	3.50	3.98

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE 11

YEARLY AVERAGE GROSS BETA RADIOACTIVITY LEVELS (pCi/L) IN LAKE MICHIGAN WATER AT EVANSTON FILTRATION PLANT INTAKE FROM 1973 THROUGH 1998

Year	Suspended Solids	Dissolved Solids	Total Solids
1973	0.88	4.77	5.63
1974	0.78	4.83	5.61
1975	0.64	4.93	5.57
1976	0.38	4.78	5.16
1977	0.28	5.26	5.54
1978	0.88	5.28	6.16
1979	0.46	4.53	4.99
1980	0.33	4.70	5.03
1981	0.51	4.29	4.80
1982	0.40	3.95	4.35
1983	0.91	3.59	4.50
1984	0.66	3.32	3.98
1985	0.57	3.38	3.93
1986	0.58	3.25	3.83
1987	1.32	3.05	4.37
1988	0.72	3.66	4.38
1989	1.32	3.34	4.66
1990	0.32	3.48	3.80
1991	1.50	3.54	5.04

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE 11 (Continued)

YEARLY AVERAGE GROSS BETA RADIOACTIVITY LEVELS (pCi/L) IN LAKE MICHIGAN WATER AT EVANSTON FILTRATION PLANT INTAKE FROM 1973 THROUGH 1998

Year	Suspended Solids	Dissolved Solids	Total Solids
1992	0.16	3.44	3.60
1993	1.34	4.18	5.52
1994	0.40	3.60	4.00
1995	0.25	3.62	3.87
1996	0.16	2.65	2.81
1997	0.19	2.66	2.92
1998	0.42	3.18	3.60

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE 12

YEARLY AVERAGE GROSS BETA RADIOACTIVITY LEVELS (pCi/L) IN LAKE MICHIGAN WATER AT ZION NUCLEAR POWER PLANT INTAKE FROM 1973 THROUGH 1998

Year	Suspended Solids	Dissolved Solids	Total Solids
1973	<0.10	<0.10	<0.10
1974	NS	NS	NS
1975	0.22	7.11	7.33
1976	NS	NS	NS
1977	NS	NS	NS
1978	NS	NS	NS
1979	0.14	4.66	4.80
1980	0.22	4.76	4.98
1981	0.29	4.91	5.20
1982	0.17	3.70	3.87
1983	0.40	4.05	4.45
1984	0.20	3.80	4.00
1985	0.18	3.62	3.80
1986	0.52	3.58	4.10
1987	0.92	3.55	4.47
1988	0.85	4.10	4.95
1989	0.23	3.03	3.26
1990	0.15	2.90	3.05
1991	0.27	3.53	3.80

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE 12 (Continued)

YEARLY AVERAGE GROSS BETA RADIOACTIVITY LEVELS (pCi/L) IN LAKE MICHIGAN WATER AT ZION NUCLEAR POWER PLANT INTAKE FROM 1973 THROUGH 1998

Year	Suspended Solids	Dissolved Solids	Total Solids
1992	0.50	4.43	4.93
1993	0.45	4.05	4.50
1994	0.20	3.20	3.40
1995	0.10	3.00	3.10
1996	0.20	2.55	2.75
1997	0.20	1.95	2.15
1998	0.28	3.47	3.75

NS = No sample.

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE 13

YEARLY AVERAGE GROSS BETA RADIOACTIVITY LEVELS (pCi/L) IN LAKE MICHIGAN WATER AT ZION NUCLEAR POWER PLANT DISCHARGE FROM 1973 THROUGH 1998

Year	Suspended Solids	Dissolved Solids	Total Solids
1973	<0.1	<0.1	<0.1
1974	NS	NS	NS
1975	0.30	4.04	4.34
1976	NS	NS	NS
1977	NS	NS	NS
1978	NS	NS	NS
1979	0.29	4.68	4.97
1980	0.33	4.86	5.19
1981	0.28	4.44	4.72
1982	<0.1	3.77	<3.87
1983	0.55	4.10	4.65
1984	0.20	5.07	5.27
1985	0.28	3.38	3.66
1986	0.48	3.62	4.10
1987	0.65	3.33	3.98
1988	0.75	3.95	4.70
1989	0.13	2.93	3.06
1990	0.20	3.55	3.75
1991	0.30	3.50	3.80

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE 13 (Continued)

YEARLY AVERAGE GROSS BETA RADIOACTIVITY LEVELS (pCi/L) IN LAKE MICHIGAN WATER AT ZION NUCLEAR POWER PLANT DISCHARGE FROM 1973 THROUGH 1998

Year	Suspended Solids	Dissolved Solids	Total Solids
1992	0.60	4.30	4.90
1993	0.55	4.25	4.80
1994	0.30	3.20	3.50
1995	0.10	3.20	3.30
1996	0.15	2.65	2.80
1997	0.20	1.90	2.10
1998	<0.16	4.05	<4.21

NS = No sample.

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE 14

YEARLY AVERAGE GROSS BETA RADIOACTIVITY LEVELS (pCi/L) IN LAKE MICHIGAN WATER AT ZION NUCLEAR POWER PLANT STATION FROM 1973 THROUGH 1998

Year	Suspended Solids	Dissolved Solids	Total Solids
1973	<0.1	<0.1	<0.1
1974	NS	NS	NS
1975	0.13	3.90	4.03
1976	NS	NS	NS
1977	NS	NS	NS
1978	NS	NS	NS
1979	0.14	4.66	4.80
1980	0.21	4.60	4.81
1981	0.45	4.19	4.64
1982	<0.10	3.53	<3.63
1983	0.90	3.80	4.70
1984	0.20	3.40	3.60
1985	0.17	3.45	3.62
1986	0.28	3.40	3.68
1987	0.45	3.10	3.55
1988	0.60	4.05	4.65
1989	0.13	2.80	2.93
1990	0.20	2.85	3.05
1991	0.23	3.47	3.70

METROPOLITAN WATER RECLAMATION DISTRICT OF GREATER CHICAGO

TABLE 14 (Continued)

YEARLY AVERAGE GROSS BETA RADIOACTIVITY LEVELS (pCi/L) IN LAKE MICHIGAN WATER AT ZION NUCLEAR POWER PLANT STATION FROM 1973 THROUGH 1998

Year	Suspended Solids	Dissolved Solids	Total Solids
1992	0.28	3.88	4.16
1993	0.60	3.75	4.35
1994	0.20	3.80	4.00
1995	0.10	3.05	3.15
1996	0.20	2.75	2.95
1997	0.20	1.75	1.95
1998	0.24	4.74	4.98

NS = No sample.

Total Gamma, Cesium-137, and Zinc-65

The yearly average total gamma, cesium-137, and zinc-65 radioactivity levels in Lake Michigan water at Waukegan, Winnetka, and Evanston and at Zion Intake, Zion Discharge and at Zion-Station from 1973 to 1998 were also measured. The yearly average concentration of total gamma radioactivity from 1973 to 1998 at the six sampling locations was less than 7.1 pCi/L. The yearly average concentrations of cesium-137 radioactivity levels were less than 5 pCi/L, and the yearly average concentrations of zinc-65 radioactivity levels were less than 3 pCi/L at the six sampling locations.

According to National Primary Drinking Water Regulations (40 CFR Part 141, July 1, 1989), the average annual concentration of beta particle and photon radioactivity from man-made radionuclides in drinking water shall not produce an annual dose equivalent to the total body or any internal organ greater than 4 millirem/year. If two or more radionuclides are present, the sum of their annual dose equivalent to the total body or to any organ shall not exceed 4 millirem/year. A concentration of 119 pCi/L of cesium-137 or 396 pCi/L of zinc-65 produces a 4 millirem effective dose equivalent per year, assuming two liter daily intake of water(3).

The radiological monitoring data indicates that the cesium-137 and zinc-65 radioactivity concentrations in Lake Michigan water from 1973 to 1998 are well below these levels.

CONCLUSIONS

A radiological monitoring program of Lake Michigan to evaluate the impact of the discharges from the ZNPP was conducted from 1973 to 1998. The radiological monitoring program was conducted at six different locations in Lake Michigan after the plant was in operation.

The monitoring data indicates that there was no appreciable difference in the tritium concentration of Lake Michigan water prior to the operation of the ZNPP and throughout its operating period of 25 years. The results show that the contribution of tritium radioactivity from the ZNPP was almost none. The tritium levels observed throughout the monitoring period from 1973 to 1998 were well below the maximum contaminant limit of 20 pCi/mL for tritium specified by the USEPA National Primary Drinking Water Regulations.

The monitoring data show that the contribution of gross alpha radioactivity to Lake Michigan water from the ZNPP at the six sampling locations was substantially low. The gross alpha radioactivity levels in Lake Michigan water from 1973 to 1998 were below the maximum contaminant limit of 15 pCi/L for gross alpha (excluding radon and uranium) specified by the USEPA National Primary Drinking Water Regulations.

The monitoring data show that the contribution of gross beta radioactivity to Lake Michigan water from the ZNPP at the

six sampling locations was substantially low. The gross beta radioactivity levels in Lake Michigan water from 1973 to 1998 were below the maximum contaminant levels of 50 pCi/L for gross beta activity in water as specified by the USEPA National Primary Drinking Water Regulations.

The monitoring data show that the contribution of gamma emitting radionuclides to Lake Michigan water from the ZNPP at the six sampling locations was substantially low. The cesium-137 and zinc-65 radioactivity levels observed throughout the monitoring period of 25 years did not produce any health hazard.

The radiological monitoring data of Lake Michigan during the operational period of the ZNPP from 1973 to 1998 showed that there was no substantial difference in the radioactivity concentration in Lake Michigan water before and after the operation of the ZNPP. Consequently, it can be concluded that the operation of the ZNPP had no adverse impact on the water quality of Lake Michigan.

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