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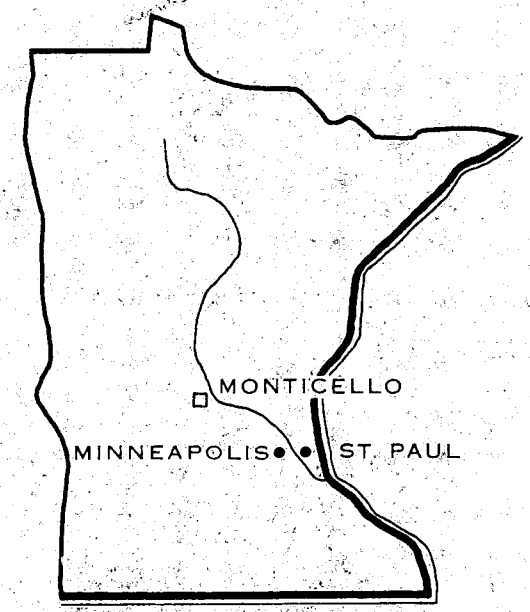
MONTICELLO NUCLEAR GENERATING PLANT

Monticello, Minnesota

UNIT 1



ANNUAL REPORT
to the

UNITED STATES NUCLEAR REGULATORY COMMISSION

Radiation Environmental Monitoring Program

January 1, 1978 to December 31, 1978

NORTHERN STATES POWER COMPANY

MINNEAPOLIS, MINNESOTA

HAZLETON
ENVIRONMENTAL SCIENCES CORPORATION
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NORTHERN STATES POWER COMPANY
MINNEAPOLIS, MINNESOTA

MONTICELLO NUCLEAR GENERATING PLANT
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Radiation Environmental Monitoring Program
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Prepared Under Contract
by
HAZLETON ENVIRONMENTAL SCIENCES CORPORATION

Project No. 5501-08902

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PREFACE

The report was prepared by R. E. Wild, Group Leader, Nuclear Sciences Section, and L. G. Huebner, Director, Nuclear Sciences Section. The staff members of the Nuclear Sciences Section of Hazleton Environmental Sciences Corporation were responsible for the acquisition of the data presented in this report. The staff includes S. J. Bartman, C. A. Johnson, C. Marucut, and L. Nicia. Samples were collected by personnel of Northern States Power Company.

Distribution of this report is made by Northern States Power Company.

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I. Introduction

This report summarizes and interprets results of the operational radiation environmental monitoring program conducted by Hazleton Environmental Sciences Corporation at the Monticello Nuclear Generating Plant, Monticello, Minnesota during the period January - December, 1978. This program monitors the levels of radioactivity in the air, terrestrial, and aquatic environments in order to assess the impact of the plant on its surroundings.

Tabulation of the individual analyses made during the year are not included in this report. These data are included in a reference document (Hazleton Environmental Sciences Corporation 1979) available at Northern States Power Company, Nuclear Support Services Department.

Monticello Nuclear Generating Plant is a 545 MWe boiling water reactor located on the Mississippi River in Wright County, Minnesota, and operated by Northern States Power Company. Initial criticality was achieved on 10 December 1970. Full power was achieved on 5 March 1971 and commercial operation began on 30 June 1971.

II. Summary

The Radiation Environmental Monitoring Program required by the Nuclear Regulatory Commission (NRC) Technical Specifications for the Monticello Nuclear Generating Plant is described. Results for 1978 are summarized and discussed. Results obtained for airborne particulates, natural vegetation, and to a lesser degree for milk show effects of fallout from atmospheric nuclear detonations of a 20 kiloton device on 17 September 1977 and of a less than 20 kiloton device on 14 March 1978. No effect on the environment due to the operation of the Monticello Plant is indicated.

III. Program

A. Program Design and Data Interpretation

The purpose of the radiation environmental monitoring program at the Monticello Nuclear Generating Plant is to assess the impact of the plant on its environment. For this purpose samples are collected from the air, terrestrial, and aquatic environment and analyzed for radioactive content. In addition, ambient gamma radiation levels are monitored by thermoluminescent dosimeters (TLD's).

Sources of environmental radiation include the following:

(1) natural background radiation arising from cosmic rays and primordial radionuclides;

(2) fallout from atmospheric nuclear detonations;

(3) releases from nuclear power plants.

In interpreting the data, effects due to the power plant must be distinguished from those due to other sources.

A major interpretive aid is that the monitoring program at Monticello is designed on the indicator-control concept. Most types of samples are collected both at indicator locations (nearby, downwind, or downstream) and at control locations (distant, upwind, or upstream). A plant effect would be indicated if the radiation level at an indicator location was larger than that at the control location by a significant amount. The difference would have to be greater than could be accounted for by typical fluctuations in radiation levels arising from other sources.

An additional interpretive technique involves analyses for specific radionuclides present in the samples. The plant's monitoring

program includes analyses for tritium, strontium-89, strontium-90, and iodine-131. Most samples are also analyzed for gamma-emitting isotopes with results for the following quantified: zirconium-95, cesium-137, cerium-144, and potassium-40. The first three isotopes were selected because of the different characteristic proportions in which they appear in the fission product mix produced by a reactor and that produced by a nuclear detonation. Each of the three isotopes is produced in roughly equivalent amounts by a reactor: each constitutes about 10% of the total activity of fission products 10 days after reactor shutdown. On the other hand, 10 days after a thermonuclear explosion, the contributions of zirconium-95, cerium-144, and cesium-137 to the activity of the resulting debris are in the approximate ratio 4:1:0.03 (Eisenbud, 1963). Potassium-40 is a naturally-occurring isotope. It was chosen as a calibration monitor and should not be considered a radiological impact indicator.

Other means of distinguishing sources of environmental radiation can be employed in interpreting the data. Current radiation levels can be compared with previous levels, including those measured before the plant became operational. Results of the plant's monitoring program can be related to those obtained in other parts of the world. Finally, results can be related to events known to cause elevated levels of radiation in the environment, e.g., atmospheric nuclear detonations.

B. Program Description

The sampling and analysis schedule is summarized in Table 1 and briefly reviewed below. Table 2 defines the sampling location

codes used in Table 1 and specifies for each location its type (indicator or control) and its distance, direction, and sector relative to the reactor site. To assure that sampling is carried out in a reproducible manner, detailed sampling procedures have been prescribed (Hazleton Environmental Sciences Corporation, 1978).

To monitor the air environment, airborne particulates are collected on membrane filters by continuous pumping at seven locations. Also, airborne iodine is collected by continuous pumping through charcoal filters at three of the locations. Filters are changed and counted weekly. Particulate filters are analyzed for gross beta activity and charcoal filters for iodine-131. A monthly composite of all particulate filters is gamma-scanned on a Ge(Li) detector. Five of the seven locations are indicators, and two are controls (M-1 and M-2). One of the indicators (M-6) is located in the geographical sector expected to be most susceptible to any atmospheric emissions from the plant (highest χ/Q sector).

Ambient gamma radiation is monitored at the same seven locations using CaF_2:Mn thermoluminescent dosimeters (TLD's). The sensors are placed in pairs at each location and are collected and measured quarterly.

Milk samples are collected monthly from five farms (four indicator and one control). All samples are analyzed for iodine-131. In addition, samples from the control location (M-10, Kirchenbauer) and the highest χ/Q location (M-18, Olson) are analyzed for strontium-89 and -90 and for gamma-emitting isotopes.

Natural vegetation (such as grass) is collected semi-annually from three locations (including the highest χ/Q milk

location and the milk control location). Samples are analyzed for gamma-emitting isotopes including iodine-131.

Cabbage is collected annually from the nearest garden and a control location and analyzed for iodine-131. Corn is collected annually from the highest χ/Q farm and a control location and analyzed for gamma-emitting isotopes. Potatoes are collected annually from a farm irrigated with downstream river water and a control location. Analysis is for gamma-emitting isotopes.

The terrestrial environment is also monitored by collection of well water (quarterly), wildlife (semi-annually) and topsoil (every three years).

River water is collected weekly at two locations, one upstream of the plant and one downstream. Monthly composites are analyzed for gamma-emitting isotopes. Quarterly composites are analyzed for tritium.

Drinking water is collected weekly from the City of Minneapolis water supply, which is taken from the Mississippi River downstream of the plant. Monthly composites are analyzed for gross beta activity and gamma-emitting isotopes. Quarterly composites are analyzed for tritium, strontium-89, and strontium-90.

The aquatic environment is also monitored by semi-annual upstream and downstream collections of fish, algae or aquatic insects, aquatic vegetation, and bottom sediments. Shoreline sediment is also collected semi-annually.

C. Laboratory Procedures

All strontium-89 and -90 analyses and iodine-131 analyses

in milk were made by a sensitive radiochemical procedure involving separation of the element of interest by use of an ion-exchange resin and subsequent beta counting.

Gamma-spectroscopic analyses of milk and water were made with a NaI detector. All other gamma-spectroscopic analyses were made with a Ge(Li) detector. Levels of iodine-131 in cabbage and natural vegetation were determined by Ge(Li) spectrometry. Levels of airborne iodine-131 in charcoal samples were measured by Ge(Li) spectrometry.

Tritium levels were determined by liquid scintillation counting.

Analytical procedures used by the Nuclear Sciences Section of Hazleton Environmental Sciences Corporation are specified in detail elsewhere (NALCO Environmental Sciences, 1977a). Procedures are based on those prescribed by the National Center for Radiological Health of the U. S. Public Health Service (U. S. Public Health Service, 1967) and by the Health and Safety Laboratory of the U.S. Atomic Energy Commission (U. S. Atomic Energy Commission, 1972).

Hazleton Environmental Sciences Corporation has a comprehensive quality control/qualtiy assurance program designed to assure the reliability of data obtained. Details are presented elsewhere (NALCO Environmental Sciences, 1971a, 1971b, 1975). The program includes participation in laboratory intercomparison (crosscheck) programs. Results obtained in crosscheck programs are presented in Appendix A.

D. Program Modifications

No program modifications involving changes in the Technical Specifications were made in 1978. A minor change was made in the exact location of placement of TLD's at location M-1. To avoid the elevated background gamma activity apparently resulting from crushed rock used to pave the substation area at M-1, the TLD's were moved 300 feet outside the substation area. The change was made on 3 October 1978.

IV. Results and Discussion

All of the scheduled collections and analyses were made except those listed in Table 3.

All results are summarized in Table 4 in a format recommended by the Nuclear Regulatory Commission in Regulatory Guide 4.8. For each type of analysis of each sampled medium, this table lists the mean and range for all indicator locations and for all control locations. The location with the highest mean and range are also shown.

A. Effects of Chinese Atmospheric Nuclear Detonation

Two atmospheric nuclear detonations by the People's Republic of China had considerable impact on program results in 1978. The first of the detonations occurred on 17 September 1977 and had some residual effect on the results obtained in 1978. The second detonation conducted on 14 March 1978 had a more pronounced effect on the results, especially on air particulates and milk data. A third detonation conducted by China on 14 December 1978 resulted in a very slight increase in gross beta activity in air particulates collected during the last week of December 1978.

This section briefly reviews information about the tests and the environmental effects as reported by the EPA (U. S. Environmental Protection Agency, 1978).

The 17 September test had an estimated yield of 20 kilotons and injected radioactive debris into the upper troposphere (30,000 to 40,000 feet). The leading edge of the contaminated air mass passed over the western edge of the continental United States

on 21 September 1977 and probably reached Minnesota one day later. It caused elevated gross beta activities in air particulates and elevated levels of iodine-131 in milk in nearly all parts of the United States.

The 14 March 1978 test had an estimated yield of less than 20 kilotons. The National Oceanic and Atmospheric Administration predicted that the fallout cloud would reach the United States on March 18. EPA gross beta results for air particulates indicated that the main body of the cloud had reached the central United States by 23 March 1978. Elevated levels of iodine-131 in milk were also detected throughout the United States.

The 14 December 1978 test had an estimated yield of less than 20 kilotons. Results of measurements made by the EPA in response to this test are not yet available. Data collected by Hazleton at seven sites in the north central United States has not shown any significantly elevated activities in 1978 attributable to fallout from this test.

Activity due to fallout prevented observation of the usual spring peak, a phenomenon that is observed worldwide almost annually (Wildon et. al., 1969). These spring peaks have been attributed to fallout of nuclides from the stratosphere (Gold et al., 1964).

B. Program Findings

A number of program findings reflect effects of the Chinese nuclear tests. The chief environmental indicators of test effects were airborne particulates.

1. Ambient Radiation (TLD's)

Indicator TLD's averaged(14.4 mrem/91 days and control TLD's averaged 16.1 mrem/91 days. The doses measured by control TLD's were about 12% higher than indicator TLD's and were due to higher doses measured by TLD's at control location M-1. The control TLD's at location M-1 had been placed inside power station's enclosures above the gravel covered ground. It has been suspected that the gravel was the source of the elevated activity. A study by Northern States Power using PIC confirmed the suspicion that the gravel was the likely source of the elevated activity. Based on the results obtained the TLD's at location M-1 were moved 300 feet beyond the boundaries of the substation on 3 October 1978. The average dose dropped from 20.3 mrem/91 days for the first three quarters to 14.1 mrem/91 days for the last quarter and was in very good agreement with the indicator results. No plant effect on ambient gamma radiation was indicated.

2. Air Particulates

The average annual gross beta activity in airborne particulates was 0.096 pCi/m^3 and about 40% lower than in 1977 (0.158 pCi/m^3). In the first quarter of 1978 weekly gross beta activities were in the range 0.06 to 0.80 pCi/m^3 and averaged

0.147 pCi/m^3. Air particulates collected on 3-28-78, fourteen days after the Chinese nuclear test, were the highest for any week recorded and were by about a factor of 5 higher than the average for the remaining eleven weeks of the first quarter.

Activities remained elevated throughout the second quarter (average 0.136 pCi/m^3) and then dropped to below pre-March nuclear test levels. The average values were 0.060 and 0.043 pCi/m^3 for the third and fourth quarters, respectively. The March peak in gross beta activity was due to fallout from the 14 March 1978 weapons test.

Two pieces of evidence indicate conclusively that the peak observed was not attributable to the plant. In the first place, increases of similar size occurred simultaneously at both the indicator and control locations. Secondly, both rises were observed nationwide at air sampling stations operated by the EPA (U.S. Environmental Protection Agency, 1978).

The gamma scan results were consistent with the above interpretations. In comparison with the January and February levels the activity of cerium-144 and cesium-137 rose in March by a factor of two and remained at that level through June 1978. The activity then gradually decreased to less than 0.001 pCi/m^3 by December 1978. Zirconium-95 was detected in February, March and April composite samples (average 0.006 pCi/m^3) and then fell below detection limit of 0.001 pCi/m^3. The mean annual activities for cerium-144 and cesium-137 were similar to those in 1977, but zirconium-95 activity was only about one-fifth that in 1977. The

distorted ratios of these isotopes were due to very low level and residual effect from the previous tests conducted in 1977.

None of the activities detected were attributable to the plant operation.

3. Airborne Iodine

Airborne iodine-131 results were below the detection limit of 0.02 pCi/m^3 in all but one sample. The slightly elevated activity (0.04 pCi/m^3) was detected in the sample collected 28 March 1978. Gross beta activity was highest during the same collection period. The activity detected was attributable to the Chinese nuclear test. Thus, there was no indication of a plant effect.

4. Milk

Iodine-131 results in milk were below the detection limit of 0.25 pCi/l in all but six samples. Five were detected in milk collected on 11 April 1978 and ranged from 0.28 to 0.95 pCi/l, averaging 0.61 pCi/l. One sample collected on 10 January 1978 from location M-18 (Olson) had iodine-131 activity barely above detection limit (0.28 pCi/l) and was nearly identical to the level (0.32 pCi/l) detected in a sample collected approximately at the same time near Prairie Island Nuclear Plant, indicating that it was residual activity from the nuclear test conducted in the fall of 1977. Zirconium-95 and cerium-144 were not detected.

Strontium-90 results averaged slightly higher at control location (M-10). All results were in the range 2.9 - 13.2 pCi/l, a range consistent with 1976 and 1977 observations at Monticello. Strontium-90 levels in this range are attributable to

worldwide fallout from previous atmospheric nuclear tests and reflect long half-life (28.64) of this isotope.

Most of the cesium-137 results were within the 1976 and 1977 ranges of 2.7 to 11 pCi/l and 4.0 to 22.0 pCi/, respectively, and were in general higher at the control location. Cesium-137 is also a long-lived component (with a half-life of 30.24 yrs.) of worldwide fallout. Finally, all, except two, strontium-89 results in 1978 were <2.4 pCI/l, in agreement with 1976 and 1977 measurements.

Two of the strontium-89 results were above the LLD. They were detected in samples collected from the Olson Farm (M-18) on 10 January and 14 February, 1978. Cesium-137 levels in the same milk samples were also slightly higher than the average for the year indicating fallout origin of these isotopes.

Because the half-life of strontium-89 is 51 days, the September 1977 atmospheric test was a probable source for its presence in these samples. A sizeable increase in strontium-89 levels unaccompanied by any significant increase in strontium-90 levels is understandable on the basis of yield curves for nuclear weapons. Ten days after explosion of a nuclear weapon strontium-89 activity exceeds strontium-90 activity by a factor of more than 100. Strontium-89 activity continues to exceed strontium-90 activity until nearly a year has passed (Eisenbud, 1963).

No significant changes were seen in cesium-137, except for slight increases in July, August and September milk samples collected at control location M-10, and in strontium-90.

This absense of an effect is consistent with the low initial production of these isotopes in nuclear explosions (Eisenbud, 1963). Also, no zirconium or cerium-144 were detected in any milk samples despite their presence in some of the vegetation samples. This is consistent with the finding of the National Center of Radiological Health that most radiocontaminants in feed do not find their way into milk due to the selective metabolism of the cow. The common exceptions are radioisotopes of potassium, cesium, strontium, barium, and iodine (National Center for Radiological Health, 1968).

In summary, the milk data for 1978 show no effects of the plant, but do exhibit very slight increase in iodine-131 and strontium-89 levels attributable to fallout from recent atmospheric nuclear tests.

5. Well Water

Tritium levels ranged from <120 to 340 pCi/l. There were no statistically significant differences between the indicator wells and the control well. All of the gamma scan results were below detection limits. There was no indication of a plant effect on the results.

6. Crops

Corn and potatoes were collected in August and September and analyzed for gamma-emitting isotopes. Cabbages were also collected in September and analyzed for iodine-131. All results except for potassium-40 were below detection limits. There was no indication of a plant effect.

7. Small Game Animals

Rabbits were collected in February and September. All results for liver were below detection limits. Zirconium-95 and cerium-144 were below detection limits in all flesh samples. Low levels of cesium-137, averaging 0.07 pCi/g wet weight, were detected in two out of four flesh samples and were nearly identical to the level observed in 1977. Potassium-40 results were similar at control and indicator locations. There was no indication of a plant effect.

8. River Water and Drinking Water

Tritium averaged 280 pCi/l upstream of the plant, 320 pCi/l just downstream of the plant and 260 pCi/l in Minneapolis drinking water. The differences are not statistically significant since the typical measuring error is about 100 pCi/l. Strontium-89 was below detection limit of 1.2 pCi/l in all drinking water samples. Strontium-90 was detected in only one of four drinking water samples (0.95 pCi/l). Gross beta in Minneapolis drinking water averaged 3.8 pCi/l and was similar to the average level in 1977 (3.4 pCI/l). Comparison with gross beta and strontium-90 data reported by EPA for Minneapolis drinking water samples collected in 1975, 1976, 1977 and 1978 indicates that their concentrations are remaining fairly constant and are in the range of drinking water levels in other parts of the country (U. S. Environmental Protection Administration, 1975, 1976, 1977, 1978). Potassium-40, zirconium-95, cesium-137, and cerium-144 levels were below detection limits in all surface water samples. There was no indication of a plant effect.

9. Fish

Fish samples were collected in June and October. Whole fish were gamma scanned. Zirconium-95 and cerium-137 were below detection limits. Cerium-144 was detected in one fish sample caught upstream. Potassium-40 results were nearly identical in upstream and downstream samples. Thus, there was no indication of a plant effect.

10. Algae and Periphyton

The samples were collected in June and October and analyzed for strontium-89, -90, and gamma-emitting isotopes. Most of the isotopes were below detection limits. There was no statistical difference between control and indicator results. No plant effect was indicated.

11. Aquatic Vegetation

Aquatic vegetation was collected in May and September and analyzed for gamma-emitting isotopes. Zirconium-95 and cerium-144 results were below detection limits in all samples. Cesium-137 was detected in three out of four samples but the levels were identical for control and indicator locations. No plant effect was indicated.

12. Bottom and Shoreline Sediments

Bottom and shoreline sediment collections were made in May and October, and analyzed for gamma-emitting isotopes. Zirconium-95 results were below detection limits in all samples. Cerium-144 results were below detection limit in all bottom sediment samples, but was observed in shoreline sediments, reflecting

deposition on the beach. Cesium-137 level in bottom sediments was higher downstream of the plant but was about the same as for shoreline sediments, indicating influence of fallout deposition. No plant effect was indicated.

13. Natural Vegetation

Results for natural vegetation reflected the fallout effects observed in the airborne particulate data from the nuclear test on 14 March 1978. Iodine-131 results were below detection limits, as expected, since over seven half-lives passed between the test and collection dates. The May collection yielded cerium-144 levels in the range of 4.5 to 10.3 pCi/g wet weight, with cesium-137 and zirconium-95 averaging about 10 times lower.

The September samples had zirconium-95 levels below the detection limit. Cesium-137 and cerium-144 were detected in some of the samples but at much lower levels. Cesium-137 and cerium-144 were higher at the control location. Thus, no plant effect was indicated.

V. Tables

Table 1. Sample collection and analysis program, 1978. Monticello

Medium	Locations No.	Locations Codes (and Type)[a]	Collection Type and Frequency[b]	Analysis Type (and Frequency)[c]
TLD's	7	M-1(C), M-2(C), M-3 to M-7	C/Q	Ambient gamma dose
Airborne particulates	7	M-1(C), M-2(C), M-3 to M-7	C/W	GB, GS (MC of all locations)
Airborne iodine	3	M-1(C), M-5, M-7	C/W	I-131
Milk	3	M-24 to M-26	G/M	I-131
	2	M-10(C), M-18	G/M	I-131, Sr-89, Sr-90, GS
River water	2	M-8(C), M-9	G/W	GS(MC), H-3(QC)
Drinking water	1	M-14	G/W	GB, GS(MC), H-3 (QC), Sr-89(QC, Sr-90(QC)
Well water	4	M-10(C), M-11 to M-13	G/Q	H-3, GS
Edible cultivated crops - cabbage	2	M-10(C), M-27	G/A	I-131
Edible cultivated crops - corn	2	M-10(C), M-18	G/A	GS
Edible cultivated crops - potatoes	2	M-10(C), M-21	G/A	GS
Small game animals (Liver and Flesh)	2	M-16, M-17(C)	G/SA	GS

Table 1. (continued)

Monticello

Medium	Locations No.	Locations Codes (and Types)[a]	Collection Type and Frequency[b]	Analysis Type (and Frequency)[c]
Natural Vegetation	3	M-10(C), M-18,	G/SA	I-131, GS
Fish (two species, flesh and bones)	2	M-8(C), M-9	G/SA	GS
Algae or Aquatic Insects	2	M-8(C), M-9	G/SA	Sr-89, Sr-90 GS
Aquatic Vegetation	2	M-8(C), M-9	G/SA	GS
Bottom Sediment	2	M-8(C), M-9	G/SA	GS
Shoreline Sediment	1	M-15	G/SA	GS
Topsoil	12	M-1(C), M-2 to M-7, M-18 to M-21, M-26	G/ETY	Gs, Sr-90

[a] Location codes are defined in Table 2. Control stations are indicated by (C). All other stations are indicators.

[b] Collection type is coded as follows: C/ = continuous, G/ = grab. Collection frequency is coded as follows: W = weekly, M = monthly, Q = quarterly, SA = semi-annually, A = annually, ETY = every three years.

[c] Analysis type is coded as follows: GB = gross beta, GS = gamma spectroscopy, H-3 = tritium, Sr-89 = strontium-89, Sr-90 = strontium-90, I-131 = iodine-131. Analysis frequency is coded as follows: MC = monthly composite, QC = quarterly composite.

Table 2. Sampling locations. Monticello

Code	Type[a]	Name	Location
M-1	C	Station M-1	11.1 mi @ 306°/NW
M-2	C	Station M-2	8.8 mi @ 39°/NE
M-3		Station M-3	0.7 mi @ 353°/N
M-4		Station M-4	0.8 mi @ 23°/NNE
M-5		Station M-5	0.5 mi @ 181°/S
M-6		Station M-6	0.9 mi @ 150°/SSE
M-7		Station M-7	2.7 mi @ 136°/SE
M-8	C	Upstream of Plant (1,000 ft.)	0.2 mi @ 285°/WNW
M-9		Downstream of Plant (1,000 ft.)	0.4 mi @ 62°/ENE
M-10	C	Kirchenbauer Farm	11.5 mi @ 323°/NW
M-11		City of Monticello	3.2 mi @ 128°/SE
M-12		Plant Well #1 (on-site)	0.2 mi @ 267°/W
M-13		Trunnel Farm	0.3 mi @ 214°/SW
M-14		City of Minneapolis	36 mi @ 128°/SE
M-15		Montisippi Park	1.6 mi @ 117°/ESE
M-16		Plant Site (on-site)	On-site
M-17	C	Heberling Farm	12 mi @ 258°/WSW
M-18		Olson Farm	2.5 mi @ 24°/NNE
M-19		Plant Site Area	1.0 mi @ 323°/NW
M-20		Gillespie Residence	1.2 mi @ 134°/SE
M-21		Ewing Farm	4.9 mi @ 115°/ESE
M-22		Dechene Farm	4.7 mi @ 118°/ESE
M-23		Bohanon Farm	1.2 mi @ 156°/SSE
M-24		Nelson Farm	2.4 mi @ 269°/W
M-25		Shovelain Farm	3.0 mi @ 250°/WSW
M-26		Peterson Farm	2.3 mi @ 111°/ESE
M-27		Hageman Farm	1.4 mi @ 131°/SE

[a] "C" denotes control location. All other locations are indicators.

Table 3. Missed collections and analyses, 1978. Monticello

Sample	Analysis	Location	Coll. Date or Period	Comments
Air particulates and airbrone iodine	Gross beta	M-1 & M-6	12-05 to 12-12-78	Results not calculated due to unknown sample volume.
	Iodine-131	M-1		
Fish	Gamma scan	M-8 & M-9	1st & 2nd half year	Due to laboratory error, flesh and bones were combined rather than analyzed as separate flesh and bone samples.

Table 4. Environmental Radiological Monitoring Program Summary.
Name of facility Monticello Nuclear Generating Plant Docket No. 50-263
Location of facility Wright, Minnesota (County, state) Reporting period January - December 1978

Sample Type (Units)	Type and Number of Analyses[a]	LLD[b]	Indicator Locations Mean (F)[c] Range[c]	Location with Highest Annual Mean: Location[d]	Location with Highest Annual Mean: Mean (F) Range	Control Locations Mean (F) Range	Number of non-routine Results[e]
TLD (mrem/91 days)	Gamma 28	3.0	14.4 (20/20) (12.1-16.4)	M-1 Station 11.1 mi @ 306° NW	18.7 (4/4) (14.1-21.9)	16.1 (8/8) (12.6-21.9)	0
Air Particulates (pCi/m^3)	GB 361[f]	0.001	0.094 (259/259) (0.016-0.804)	Station M-1 11.1 mi @ 306° NW	0.101 (50/50) (0.020-0.603)	0.097 (102/102) (0.013-0.775)	0
Airborne Iodine (pCi/m^3)	I-131 151[g]	0.02	<LLD	Station M-1 11.1 mi @ 306° NW	0.04 (1/47) -	0.04 (1/47)	0
Air Particulates Monthly composite of all locations (pCi/m^3)	γ scan 12						
	K-40	0.012	<LLD	-	-	None	0
	Zr-95	0.003	0.006 (3/12) (0.004-0.007)	-	-	None	0
	Cs-137	0.0005	0.0035 (8/12) (0.0017-0.0053)	-	-	None	0
	Ce-144	0.002	0.027 (9/12) (0.006-0.044)	-	-	None	0
Milk (pCi/l)	I-131 60	0.25	0.53 (5/60) (0.28-0.95)	M-25 Shovelain 3.0 mi 250° WSW	0.95 (1/12) -	0.69 (1/12) -	0
	Sr-89 24	2.4	8.6 (2/12) (4.1-13.0)	M-18 Olson 2.5 mi@ 24° NNE	8.6 (2/12) (4.1-13.0)	<LLD	0

Table 4. (continued)
Name of facility Monticello Nuclear Generating Plant

Sample Type (Units)	Type and Number of Analyses[a]	LLD[b]	Indicator Locations Mean(f) Range	Location with Highest Annual Mean		Control Locations Mean(f) Range	Number of non-routine Results
				Location	Mean(f) Range		
Milk (continued)	Sr-90 24		6.2 (12/12) (2.9-8.3)	M-10 Kirchenbauer 11.5 mi @ 323° NW	8.8 (12/12) (4.1-13.2)	8.8 (12/12) (4.1-13.2)	0
	γ scan 24						0
	K-40		1360 (12/12) (1230-1440)	M-18 Olson 2.5 mi@ 24° NNE	1360 (12/12) (1230-1440)	1330 (12/12) (1200-1450)	0
	Zr-95	10	<LLD	-	-	<LLD	0
	Cs-137		6.3 (12/12) (4.5-8.7)	M-10 Kirchenbauer 11.5 mi @ 323° NW	8.8 (12/12) (4.0-16.2)	8.8 (12/12) (4.0-16.2)	0
	Ce-144	30	<LLD	-	-	<LLD	0
River Water (pCi/l)	H-3 8	180	330 (4/4) (260-380)	M-9 Downstream 1000 ft. 0.4 mi @ 62° ENE	330 (4/4) (260-380)	260 (3.4) (160-350)	0
	γ scan 24						
	K-40	60	<LLD	-	-	<LLD	0
	Zr-95	10	<LLD	-	-	<LLD	0
	Cs-137	2.5	<LLD	-	-	<LLD	0
	Ce-144	30	<LLD	-	-	<LLD	0

Table 4. (continued)
Name of facility Monticello Nuclear Generating Plant

Sample Type (Units)	Type and Number of Analyses[a]	LLD[b]	Indicator Locations Mean(f) Range	Location with Highest Annual Mean		Control Locations Mean(f) Range	Number of non-routine Results
				Location	Mean(f) Range		
Drinking Water (pCi/l)	GB 12		3.8 (12/12) (2.9-5.8)	M-14 Minneapolis 36 mi @ 128° SE	3.8 (12/12) (2.9-5.8)	None	0
	H-3 4		260 (4/4) (150-350)	M-14 Minneapolis 36 mi @ 128° SE	200 (4/4) (150-350)	None	0
	Sr-89 4	1.2	<LLD	-	-	None	0
	Sr-90 4	0.7	0.95 (1/4) -	M-14 Minneapolis 36 mi @ 128° SE	0.95 (1/4) -	None	0
	γ scan 12						
	K-40	60	<LLD	-	-	None	0
	Zr-95	10	<LLD	-	-	None	0
	Cs-137	2.5	<LLD	-	-	None	0
	Ce-144	30	<LLD	-	-	None	0
Well Water (pCi/l)	H-3 16	180	270 (8/12) (210-320)	M-12 Plant Well #1 0.2 mi @ 267° W	280 (4/4) (210-320)	330 (4/4) (310-340)	0
	γ scan 16						
	K-40	60	<LLD	-	-	<LLD	0
	Zr-95	10	<LLD	-	-	<LLD	0
	Cs-137	2.5	<LLD	-	-	<LLD	0
	Ce-144	30	<LLD	-	-	<LLD	0

Table 4. (continued)
Name of facility Monticello Nuclear Generating Plant

Sample Type (Units)	Type and Number of Analyses[a]	LLD[b]	Indicator Locations Mean(f) Range	Location with Highest Annual Mean		Control Locations Mean(f) Range	Number of non-routine Results
				Location	Mean(f) Range		
Crops - cabbage (pCi/g wet)	I-131 2	0.02	<LLD	-	-	<LLD	0
Crops - corn (pCi/g wet)	γ scan 2						
	K-40		2.5 (1/1) -	M-18 Olson 2.5 mi @ 24° NNE	2.5 (1/1) -	2.1 (1/1) -	0
	Zr-95	0.009	<LLD	-	-	<LLD	0
	Cs-137	0.008	<LLD	-	-	<LLD	0
	Ce-144	0.06	<LLD	-	-	<LLD	0
Crops - potatoes (pCi/g wet)	γ scan 2						
	K-40		3.1 (1/1)	M-10 Kirchenbauer 11.5 mi @ 323° NW	4.3 (1/1) -	4.3 (1/1) -	0
	Zr-95	0.02	<LLD	-	-	<LLD	0
	Cs-137	0.01	<LLD	-	-	<LLD	0
	Ce-144	0.07	<LLD	-	-	<LLD	0
Small Game Animals-Flesh (pCi/g wet)	γ scan 4						
	K-40		2.5 (2/2) (2.2-2.7)	M-16 Plant Site On site	2.5 (2/2) (2.2-2.7)	2.4 (2/2) (2.3-2.4)	0
	Zr-95	0.08	<LLD	-	-	<LLD	0

Table 4. (continued)
Name of facility Monticello Nuclear Generating Plant

Sample Type (Units)	Type and Number of Analyses[a]	LLD[b]	Indicator Locations Mean(f) Range	Location with Highest Annual Mean		Control Locations Mean(f) Range	Number of non-routine Results
				Location	Mean(f) Range		
Small Game Animals-Flesh (continued)	Cs-137	0.02	0.09 (1/2)	M-16 Plant Site On site	0.09 (1/2)	0.05 (1/2)	0
	Ce-144	0.1	<LLD	-	-	<LLD	0
Small Game Animals-Liver	γ scan 4						
	K-40	2.6	<LLD	-	-	<LLD	0
	Zr-95	0.9	<LLD	-	-	<LLD	0
	Cs-137	0.1	<LLD	-	-	<LLD	0
	Ce-144	0.7	<LLD	-	-	<LLD	0
Natural Vegetation (pCi/g wet)	γ scan 6						
	K-40		5.4 (4/4) (3.7-7.5)	M-18 Olson 2.5 mi @ 24° NNE	6.4 (2/2) (5.2-7.5)	4.1 (2/2) (3.1-5.1)	0
	Zr-95	0.04	0.78 (2/4) (0.44-1.12)	M-16 Plant Site On site	1.12 (1/2) -	0.56 (1/2) -	0
	I-131	0.07	<LLD	-	-	<LLD	0
	Cs-137	0.04	0.55 (3/4) (0.18-1.01)	M-16 Plant Site On site	0.60 (2/2) (0.18-1.01)	0.40 (2/2) (0.24-0.55)	0
	Ce-144	0.2	5.2 (3/4) (0.80-10.3)	M-16 Plant Site On site	5.6 (2/2) (0.80-10.3)	3.8 (2/2) (1.8-5.8)	0

Table 4. (continued)
Name of facility Monticello Nuclear Generating Plant

Sample Type (Units)	Type and Number of Analyses[a]	LLD[b]	Indicator Locations Mean(f) Range	Location with Highest Annual Mean		Control Locations Mean(f) Range	Number of non-routine Results
				Location	Mean(f) Range		
Fish - whole (flesh and bones) (pCi/g wet)	γ scan 8						
	K-40		2.1 (4/4) (1.7-2.8)	M-8 Upstream 1000' 0.2 mi @ 285° WNW	2.2 (4/4) (1.9-2.6)	2.2 (4/4) (1/9-2.6)	0
	Zr-95	0.08	<LLD	-	-	<LLD	0
	Cs-137	0.07	<LLD	-	-	<LLD	0
	Ce-144	0.1	<LLD	M-8 Upstream 1000' 0.2 mi @ 285° WNW	0.25 (1/4) -	0.25 (1/4) -	0
Algae (pCi/g wet)	Sr-89 2	0.05	<LLD	-	-	<LLD	0
	Sr-90 2		0.29 (1/1) -	M-9 Downstream 1000' 0.4 mi @ 62° ENE	0.29 (1/1) -	0.09 (1/1) -	0
	γ Scan 2						
	K-40	2.0	<LLD	-	-	<LLD	0
	Zr-95	0.1	<LLD	-	-	<LLD	0
	Cs-137	0.09	<LLD	-	-	<LLD	0
	Ce-144	0.5	1.0 (1/1) -	M-9 Downstream 1000' 0.4 mi @ 62° ENE	1.0 (1/1) -	<LLD	0

Table 4. (continued)
Name of facility Monticello Nuclear Generating Plant

Sample Type (Units)	Type and Number of Analyses[a]	LLD[b]	Indicator Locations Mean(f) Range	Location with Highest Annual Mean		Control Locations Mean(f) Range	Number of non-routine Results
				Location	Mean(f) Range		
Periphyton (pCi/g wet)	Sr-89 2	0.4	<LLD	-	-	<LLD	0
	Sr-90 2		0.05 (1/1) -	M-8 Upstream 1000' 0.2 mi @ 285° WNW	0.14 (1/1) -	0.14 (1/1) -	0
	γ scan 2						
	K-40	4.3	<LLD	-	-	<LLD	0
	Zr-95	0.4	<LLD	-	-	<LLD	0
	Cs-137	0.3	0.22 (1/1) -	M-9 Downstream 1000' 0.4 mi @ 62° ENE	0.22 (1/1) -	<LLD	0
	Ce-144	1.0	<LLD	-	-	<LLD	0
Aquatic Vegetation (pCi/g wet)	γ scan 4						
	K-40		1.8 (2/2) (1.12-2.47)	M-8 Upstream 1000' 0.2 mi @ 285° WNW	2.6 (2/2) (2.60-2.63)	2.6 (2/2) (2.60-2.63)	0
	Zr-95	0.02	<LLD	-	-	<LLD	0
	Cs-137	0.01	0.03 (2/2) (0.029-0.03)	M-8 Upstream 1000' 0.2 mi @ 285° WNW	0.03 (1/2) -	0.03 (1/2) -	0
	Ce-144	0.07	<LLD	-	-	<LLD	0

Table 4. (continued)
Name of facility Monticello Nuclear Generating Plant

Sample Type (Units)	Type and Number of Analyses[a]	LLD[b]	Indicator Locations Mean(f) Range	Location with Highest Annual Mean		Control Locations Mean(f) Range	Number of non-routine Results
				Location	Mean(f) Range		
Bottom or Shoreline Sediment (pCi/g dry)	γ scan 6						
	K-40		15.6 (4/4) (14.6-16.7)	M-9 Downstream 1000' 0.4 mi @ 62° ENE	16.7 (2/2) (16.6-16.7)	14.5 (2/2) (14.2-14.7)	0
	Zr-95	0.07	<LLD	-	-	<LLD	0
	Cs-137		0.28 (4/4) (0.19-0.34)	M-15 Montisippi R. 1.6 mi @ 117° ESE	0.30 (2/2) (0.29-0.31)	0.07 (2/2) -	0
	Ce-144	0.14	0.57 (2/4) (0.51-0.62)	M-15 Montisippi R. 1.6 mi @ 117° ESE	0.57 (2/2) (0.51-0.62)	<LLD	0

a GB = gross beta.
b LLD = nominal lower limit of detection based on 3 sigma error for background sample.
c Mean and range based upon detectable measurements only. Fraction of detectable measurements at specified locations is indicated in parentheses (F).
d Locations are specified (1) by name and code (Table 2) and (2) distance, direction, and sector relative to reactor site.
e Nonroutine results are those which exceed ten times the control station value. If no control station value is available, the result is considered nonroutine if it exceeds ten times the preoperational value for the location.
f Gross beta in particulate LLD excludes one result (<0.002 pCi/m^3) obtained following pump malfunction.
g Airborne iodine-131 LLD excludes four elevated values ranging from <0.05 to <0.3 which were due to low sample volumes.

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Appendix A

Crosscheck Program Results

Appendix A

Crosscheck Program Results

The Nuclear Sciences Section of Hazleton Environmental Sciences Corporation has participated in interlaboratory comparison (cross-check) programs since the formulation of its quality control program in December 1971. These programs are operated by agencies which supply environmental-type samples (e.g., milk or water) containing concentrations of radionuclides known to the issuing agency but not to participant laboratories. Participant laboratories measure the concentrations of specified radionuclides and report them to the issuing agency. Several months later, the agency reports the known values to the participant laboratories and specifies control limits. The purpose of participation in the program is to provide an independent check on the laboratory's analytical procedures and to alert it to any possible problems. Results consistently higher or lower than the known values or outside the control limits indicate a need to check the instruments or procedures used.

The results in Table A-1 were obtained for milk and water samples during the period 1975-8 through participation in the environmental sample crosscheck program conducted by the U. S. Environmental Protection Agency as specified in Footnote a. The results in Table A-2 were obtained for thermoluminescent dosimeters (TLD's) during the period 1976-7 through participation in programs under the sponsorships listed in Footnotes b and c.

Table A-1. Crosscheck program results, milk and water samples, 1975-8.[a]

Lab Code	Sample Type	Date Coll.	Analysis	pCi/l or mg/l[b] Lab Result ±2σ[c]	EPA Known Value	EPA Control Limits (3σ, n=1
STM-40	Milk	Jan. 1975	Sr-89	<2	0	±15
			Sr-90	73±2.5	75	±11.4
			I-131	99±4.2	101	±15.3
			Cs-137	76±0.0	75	±15
			Ba-140	<3.7	0	±15.0
			K(mg/l)	1470±5.6	1510	±228
STW-45	Water	April 1975	Cr-51	<14	0	-
			Co-60	421±6	425	±63.9
			Zn-65	487±6	497	±74.7
			Ru-106	505±16	497	±74.7
			Cs-134	385±3	400	±60.0
			Cs-137	468±3	450	±67.5
STW-47	Water	April 1975	H-3	1459±144	1499	±1002
STW-48	Water	June 1975	H-3	2404±34	2204	±1044
STW-49	Water	June 1975	Cr-51	<14	0	-
			Co-60	344±1	350	±53
			Zn-65	330±5	327	±49
			Ru-106	315±7	325	±49
			Cs-134	291±1	304	±46
			Cs-137	387±2	378	±57
STW-53	Water	Aug. 1975	H-3	3117±64	3200	±1083
STW-54	Water	Aug. 1975	Cr-51	233±11	255	±38
			Co-60	305±1	307	±46
			Zn-65	289±3	281	±42
			Ru-106	346±5	379	±57
			Cs-134	238±1	256	±38
			Cs-137	292±2	307	±46

Table A-1. (continued)

Lab Code	Sample Type	Date Coll.	Analysis	pCi/l or mg/l[b] Lab Result ±2σ[c]	EPA Known Value	EPA Control Limits (3σ, n=1)
STW-58	Water	Oct. 1975	H-3	1283±80	1203	±988
STM-61	Milk	Nov. 1975	Sr-90	68.9±2.1	74.6	±11.2
			I-131	64.6±3.8	75	±15
			Cs-137	75.6±20	75	±15
			Ba-140	<3.7	0	-
			K-(mg/l)	1435±57	1549	±233
STW-63	Water	Dec. 1975	H-3	1034±39	1002	±972
STW-64	Water	Dec. 1975	Cr-51	<14	0	-
			Co-60	211±1	203	±30.5
			Zn-65	215±6	201	±30.2
			Ru-106	171±9	181	±27.2
			Cs-134	198±2	202	±30.3
			Cs-137	152±4	151	±22.7
STW-68	Water	Feb. 1976	H-3	1124±31	1080	±978
STW-78	Water	June 1976	H-3	2500±44	2502	±1056
STW-84	Water	Aug. 1976	H-3	3097±21	3100	±1080
STM-86	Milk	Sept. 1976	Sr-89	29±2.0	45	±15
			Sr-90	30±1.0	30	±4.5
			I-131	100±8.6	120	±18
			Ba-140	50±10.1	85	±15
			Cs-137	17±1.5	20	±15
			K(mg/l)	-	1540	±231
STM-91	Milk	Nov. 1976	I-131	83±0.6	85	±15
			Ba-140	<4	0	-
			Cs-137	12±1.7	11	±15
			K(mg/l)	1443±31	1510	±228

Table A-1. (continued)

Lab Code	Sample Type	Date Coll.	Analysis	pCi/l or mg/l[b] Lab Result ±2σ[c]	EPA Known Value	EPA Control Limits (3σ, n=1)
STW-93	Water	Dec. 1976	Cr-51	105±15	104	±15
			Co-60	<4	0	-
			Zn-65	97±4	102	±15
			Ru-106	87±3	99	±15
			Cs-134	85±4	93	±15
			Cs-137	103±4	101	±15
STW-94	Water	Dec. 1976	H-3	2537±15	2300	±1049
STM-97	Milk	March 1977	I-131	55±2.5	51	±15
			Ba-140	<6	0	-
			Cs-137	34±1	29	±15
			K (mg/l)	1520±35	1550	±233
STW-101	Water	April 1977	H-3	1690±62	1760	±1023
STM-103	Milk	May 1977	Sr-89	38±2.6	44	±15
			Sr-90	12±2.1	10	±4.5
			I-131	59±2.1	50	±15
			Ba-140	53±4.4	72	±15
			Cs-137	14±1.2	10	±15
			K (mg/l)	1533±21	1560	±234
STW-105	Water	June 1977	Cr-51	<14	0	-
			Co-60	29±2	29	±15
			Zn-65	74±7	74	±15
			Ru-106	64±8	62	±15
			Cs-134	41±1	44	±15
			Cs-137	35±3	33	±15
STW-107	Water	June 1977	Ra-226	4.7±0.3	5.1	±2.4

Table A-1. (continued)

Lab Code	Sample Type	Date Coll.	Analysis	pCi/l or mg/l[b] Lab Result ±2σ[c]	EPA Known Value	EPA Control Limits (3σ, n=1)
STW-113	Water	Aug. 1977	Sr-89	13±0[d]	14	±15
			Sr-90	10±2[d]	10	±4.5
STW-116	Water	Sept. 1977	Gross α	12±6	10	±15
			Gross β	32±6	30	±15
STW-118	Water	Oct. 1977	H-3	1475±29	1650	±1017
STW-119	Water	Oct. 1977	Cr-51	132±14	153	±24
			Co-60	39±2	38	±15
			Zn-65	51±5	53	±15
			Ru-106	63±6	74	±15
			Cs-134	30±3	30	±15
			Cs-137	26±1	25	±15
STW-136	Water	Feb. 1978	H-3	1690±270	1680	±1020
STW-150	Water	April 1978	H-3	2150±220	2220	±1047
STW-151	Water	April 1978	Gross α	20±1	20	±15
			Gross β	56±4	59	±15
			Sr-89	19±2	21	±15
			Sr-90	8±1	10	±4.5
			Ra-226	NA[e]	-	-
			Ra-228	NA[e]	-	-
			H-3	112±12	0	-
			Co-60	19±3	20	±15
			Cs-134	16±1	15	±15
			Cs-137	<2	0	-

Table A-1. (continued)

Lab Code	Sample Type	Date Coll.	Analysis	pCi/l or mg/l[b] Lab Result ±2σ[c]	EPA Known Value	EPA Control Limits (3σ, n=1)
Stm-152	Milk	April 1978	Sr-89	85±4	101	±15
			Sr-90	8±1	9	±4.5
			I-131	78±1	82	±15
			Cs-137	29±3	23	±15
			Ba-140	<11	0	-
			K	1503±90	1500	±225
STW-154[f]	Water	May 1978	Gross α	12±1	13	±15
			Gross β	21±4	18	±15

[a] Results obtained by the Nuclear Sciences Section of Hazleton Environmental Sciences Corporation as a participant in the environmental sample crosscheck program operated by the Intercomparison and Calibration Section, Quality Assurance Branch, Environmental Monitoring and Support Laboratory, U. S. Environmental Protection Agency, (EPA), Las Vegas, Nevada.

[b] All results are in pCi/l except for elemental potassium (K) data which are in mg/l.

[c] Unless otherwise indicated, Lab result given is mean ± 2 standard deviations for three determinations.

[d] Mean ± 2 standard deviations of two determinations.

[e] NA. Not analyzed.

[f] Analyzed but not reported to EPA.

Table A-2. Crosscheck program results, thermoluminescent dosimeters (TLD's).

Lab Code	TLD Type	Measurement	mR		
			Lab Result ±2σ[a]	Known Value	Average (all participants)
115-2[b]	CaF_2:Mn Bulb	Gamma-Field	17.0±1.9	17.1[c]	16.4±7.7[d]
		Gamma-Lab	20.8±4.1	21.3[c]	18.8±7.6[d]
115-3[e]	CaF_2:Mn Bulb	Gamma-Field	30.7±3.2	34.9±4.8[f]	31.5±3.0[d]
		Gamma-Lab	89.6±6.4	91.7±14.6[f]	86.2±24.0[d]

[a] Lab result given is the mean ± 2 standard deviations of three determinations.

[b] Second International Intercomparison of Environmental Dosimeters conducted in April of 1976 by the Health and Safety Laboratory (HASL), New York, New York, and the School of Public Health of the University of Texas, Houston, Texas.

[c] Value determined by sponsor of the intercomparison.

[d] Mean ± 2 standard deviations of results obtained by all laboratories participating in program.

[e] Third International Intercomparison of Environmental Dosimeters conducted in summer of 1977 by Oak Ridge National Laboratory and the School of Public Health of the University of Texas, Houston, Texas.

[f] Value ± 2 standard deviations as determined by sponsor of the intercomparison.

Appendix B

Statistical Notations

Statistical Notations

1. Single Measurement

Each single measurement is reported as $x \pm s$

where x = value of the measurement

$s = 2\sigma$ counting uncertainty (corresponding to the 95% confidence level).

In cases where the activity is found to be below the lower limit of detection it is reported as

$$<L$$

where L = lower limit of detection based on a 3σ counting uncertainty for a background sample.

2. Computation of Means and Standard Deviations

A. The mean, $\bar{x}$, and standard deviation, s, of a set of n numbers, x, . x_1, ...x_n are defined as follows:

$$\bar{x} = \frac{1}{n} \Sigma x$$

$$s = \sqrt{\frac{\Sigma (x-\bar{x})^2}{n-1}}$$

B. Monthly and quarterly means are calculated using all detectable results.

C. Annual means and standard deviations are calculated using only those results which are above the highest lower limit of detection (LLD).

D. If all but one of the values are less than the highest LLD, the single value, x, and the associated two sigma error are reported.

E. If the standard deviation is zero, the mean value, $\bar{x}$, and the largest two sigma error are reported.

F. If all values are less than the highest LLD, no value is reported.

G. All numbers are rounded upwards if the last digit is five or greater.

Appendix C

Maximum Permissible Concentrations of Radioactivity in Air and Water

Table C-1. Maximum permissible concentrations of radioactivity in air and water above natural background in unrestricted areas.[a]

Air			Water	
Gross alpha	3	pCi/m^3	Strontium-89	3,000 pCi/l
Gross beta	100	pCi/m^3	Strontium-90	300 pCi/l
Iodine-131[b]	0.14	pCi/m^3	Cesium-137	20,000 pCi/l
			Barium-140	20,000 pCi/l
			Iodine-131	300 pCi/l
			Potassium-40[c]	3,000 pCi/l
			Gross alpha	30 pCi/l
			Gross beta	100 pCi/l
			Tritium	$3x10^6$ pCi/l

[a] Taken from Code of Federal Regulations Title 10, Part 20, Table II and appropriate footnotes. Concentrations may be averaged over a period not greater than one year.

[b] From 10 CFR 20 but adjusted by a factor of 700 to reduce the dose resulting from the air-grass-cow-milk-child pathway.

[c] A natural radionuclide.